

Grand Rapids Climate Resiliency Report

An initial report on Grand Rapids
climate resiliency and preparedness



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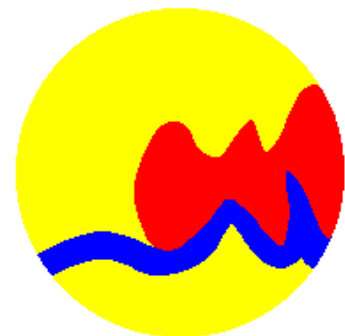
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West Michigan Environmental Action Council (WMEAC) has been West Michigan’s preeminent resource for environmental education and advocacy since 1968. Founded by a diverse group of concerned citizens and organizational stakeholders, WMEAC is a nonprofit, 501(c)(3) organization uniquely positioned to respond to emerging issues and new threats to West Michigan’s natural and human ecologies, strategically focused on building sustainable communities and protecting water resources. Since the earliest days of the environmental movement, WMEAC has provided West Michigan citizens a means to take action on behalf of the environment.

Grand Rapids Office of Energy and Sustainability focuses on three major efforts: sustainability outcomes, strategic energy management, and climate resiliency planning.



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EXECUTIVE SUMMARY

In 2012, City of Grand Rapids mayor George Heartwell was recognized by the [U.S. Conference of Mayors](#) for the City's efforts in confronting global climate change. Along with the Climate Protection Award, the City received a \$25,000 grant for use in further developing climate change protection programming. The funds were divided between Friends of Grand Rapids Parks and the West Michigan Environmental Action Council (WMEAC). WMEAC, in partnership with the Grand Rapids Office of Energy and Sustainability, embarked on a mission to investigate climate change resiliency at the local level using a triple bottom line (TBL) framework. The outcome of the investigation was the identification of key impacts across community sectors and recommendations for confronting them.

The Grand Rapids Climate Resiliency Report (the Report) builds local expertise on top of climate science, research, and analysis. Twenty-five expert interviews were conducted with contributions from a broad range of community sectors. Interviewees represented the following fields: insurance, academia, regional planning, transportation, food systems, emergency preparedness, sustainability, environmental services, community infrastructure, forestry, finance, low-impact development, built environment, community essential needs, fisheries, engineering, and energy.

The modeling software MAGICC/SCENGEN (Model for the Assessment of Greenhouse-gas Induced Climate Change with the Regional SCENario GENERator) v. 5.2.3 was used for an analysis run for coordinates marking the City of Grand Rapids and projected to a square area of 2.5 degrees by 2.5 degrees (175 miles by 175 miles). The climate change variables of temperature and precipitation were projected through the years 2022 and 2042, roughly coinciding with the City of Grand Rapids's 20-year Master Planning process. Annual seasonal projections were made for temperature and precipitation. Those projections were compared to baseline data from 1961 to 1990.

Forecasting Climate for Grand Rapids

- Average temperature and precipitation will increase by 1.1 °C and 2.6%, respectively, by 2022, and further increase by 2.2 °C and 8.5%, respectively, by 2042.
- The largest increases in temperature are projected to occur during the winter.
- The largest percentage increase in precipitation is likely to occur in the winter and spring months. The smallest temperature rise will occur during the summer.
- By 2022, the spring months will show the biggest increase in precipitation, followed closely by winter. By 2042, winter will show the greatest increase, with spring close behind.

- Summer is the only season that is projected to become drier.

The Great Lakes region can expect more variable and volatile weather from year to year and from season to season. This trend could lead to more extreme weather events, such as storms that produce more than one inch of rain in 24 hours, increased frequency of consecutive days above 90 °F and 90% humidity, and more freeze-thaw cycles in winter and spring.¹

Climate change impacts were assessed in terms of how they would affect residents' quality of life and the ability of key sectors to provide services and benefits.

Climate change impacts each sector in isolation, but it also affects the interaction of each sector with the others as well as the function of the system as a whole. Therefore, understanding the needs of the community, major relationships between sectors, and the ability of the sectors to provide those needs in a changing climate is key to building resiliency. This is not an easy task.

This report is organized through an economic, social, and environmental lens—despite the fact that every issue affects (or is affected by) all three areas.

The Report defines climate resiliency as the ability of a community to simultaneously balance ecological, economic, and social systems to maintain or increase quality of life in an uncertain, dynamic climate future.

A resilient community can mitigate both its contribution to climate change and the disruption of local climate impacts. It is agile in the face of uncertainty. Resilient cities are also better positioned to capitalize on opportunities that arise in an uncertain future.

The following are prioritized recommendations, the implementation of which the City of Grand Rapids can lead or support. Additional recommendations for building a more resilient Grand Rapids can be found in the Conclusion of the Report. **Major recommendations for municipal action are as follows:**

Process

- Grand Rapids needs a climate-resiliency champion—an individual(s) or organization(s) to own the issue in the community and focus on the implementation and financing of projects and programs.
- City resiliency efforts going forward should focus on the selection, financing, and implementation of projects, as current planning documents identify existing best practices.

- Underserved, low-income, and minority population areas will be disproportionately affected by climate change. Resiliency efforts in all aspects of community planning should recognize this reality.

Social

- Parks, pools, splash pads, and natural and green recreation areas should be considered by City decision makers as critical resiliency infrastructure that enhances quality of life.
- Preserve and grow mixed-use and dense development neighborhoods, making essential services and businesses accessible through multimodal means of transportation.

Economic

- Support policy proposals to increase energy efficiency and clean energy at the state level. Simultaneously, move to identify and adopt a community-wide energy efficiency target.
- Explore legal, policy, and economic frameworks that enable the City of Grand Rapids to build a more autonomous and resilient energy system. The City needs a system that allows greater energy sovereignty and enables the pursuit of goals related to pricing, distributed energy systems, efficiency, and renewable energy.
- Study and implement new methods of street maintenance and construction, particularly relating to materials and the construction of physical infrastructure resilient to climate change impacts.²
- Change the transportation culture in Grand Rapids to one that is built around multimodal, vital streets and that provides equal access for all social levels with diverse transportation requirements.³
- Municipal insurance, capital projects, and asset-management planning should include assessments for exposure to drought, temperature change, flooding, storms, and climate mitigation.

Environment

- Capture the “first flush” precipitation of the 90th–95th percentile wet-weather event near where it falls. Grand Rapids should utilize critical climate infrastructure such as low-impact development and green infrastructure to wholly implement the paradigm shift in stormwater-management best practices: “slow it down, spread it out, and soak it in.”
- Water efficiency efforts should be strengthened in Grand Rapids through a variety of technological, policy, pricing, and programming means.
- Improve the quality of the Grand River and its tributaries by restoring it to a more natural state. This should involve improving riparian buffers, daylighting tributary streams, and continuing the development of greenways, softening channels, and more.⁴
- Adopt a strong urban tree canopy goal—at least 40%—and implement a forestry program that addresses heat island, air quality, and other resiliency values delivered by a diverse, healthy urban tree canopy.

The primary goal of the Report is to spur a community conversation leading to processes that will enable Grand Rapids to build a more climate-resilient city. The secondary goal is to spur many specific, short- and near-term projects, policies, programs, and planning actions that enable Grand Rapids to mitigate the effects of climate change, adapt to its impacts, and harness emerging opportunities.

Grand Rapids needs resources, champions, and a directive to build a more climate-resilient community.

REPORT METHODOLOGY

The Report combines **local** expert opinion with climate science, research, and analysis. It uses localized climate data prepared by Elena Lioubimtseva, associate professor of geography and planning in Grand Valley State University's environmental studies program. The Report leans heavily on local, regional, state, and national climate documents, with a preference for local information.

WMEAC conducted 25 climate resiliency interviews with individuals representing multiple disciplines; these professionals have expertise in core city and regional functions and services. The interviews included experts from the following sectors: insurance, academia, regional planning, multimodal transportation, food networks, emergency preparedness, sustainability, environmental services, community infrastructure, finance, low-impact development, green building, community essential needs, and energy. (See Community Resiliency Interview list at the beginning of the report for a full list of those interviewed.)

The Report seeks to identify the largest and most likely impacts of climate change on core city functions and services. It details a series of climate mitigation and adaptation responses, innovations, and best-practice solutions for Grand Rapids to both adapt to a changing climate and do its part in mitigation and prevention.

The Report was conceived by Haris Alibašić of the Grand Rapids's Office of Energy and Sustainability and strongly supported by the Mayor. Funding for the project came in the form of a grant that the City received from the 2012 Mayors' Climate Protection Awards, which were sponsored by the U.S. Conference of Mayors and Wal-Mart. The \$25,000 award was split equally between WMEAC and the urban forestry initiative of Friends of Grand Rapids Parks.

PRESERVING OUR FREEDOM TO THRIVE

West Michigan Environmental Action Council has long held that environmental protection is good for people, business, and the planet. For more than 45 years, WMEAC has been a consistent voice for best practices in environmental policy and sustainability. One of our most important roles in the community is to shape dialogue on emerging trends in environmental protection in West Michigan. The City of Grand Rapids has long been our partner in cutting-edge environmental progress. We know that we can position our residents, government, and natural resources to be resilient in the face of climate change.

We've waited patiently for political debates and public opinion to catch up with decades of science. Municipal climate resiliency marks the end of this wait and moves our communities beyond tired debates. Resiliency focuses on what we can do together to build a stronger community in an uncertain, dynamic climate future. WMEAC is thrilled to have the opportunity to begin an inclusive dialogue about climate change and climate resiliency with the publication of this report.

Defining, describing, and understanding climate resiliency and its unique impacts on the Great Lakes region, West Michigan, and the City of Grand Rapids has been no small undertaking. We are thankful for the many experts and community leaders who contributed to this report. They helped us explore—and attempt to unravel—the complicated knot of interdependent dynamics that make up climate change's impacts on our community. We are thankful for the diligent research and writing of our team of contributing authors who puzzled over systems connections for hours at a time. Haris Alibašić, director of Grand Rapids's Office of Energy and Sustainability, was a key guide in our journey. Finally, special thanks go to Mayor George Heartwell for his leadership. The mayor's vision for a resilient community makes us proud to serve in partnership with the City of Grand Rapids; his investment made this report possible.

Through this process I have been struck by a few driving themes:

- We are a blessed to live in the Great Lakes region, where our incredible natural and human resources position us comparatively well to manage a dynamic climate future.
- Environmental practices that WMEAC and our partners have been educating people about for many years—such as energy efficiency, smart growth, low-impact development, local economies, and food systems—are no longer optional if we are to maintain our quality of life.
- Protecting our water resources is paramount to economic success and quality of life.

- Becoming climate-resilient is our responsibility and a unique privilege.

By designing for resiliency, we will ensure the futures of our children and their children. Along the way we will innovate, discover opportunities for economic growth, and deliver green and blue jobs that help sustain our quality of life. Through resiliency we will deepen our connections to our farmers, local businesses, and this place, which is rich in natural beauty and biodiversity.

With great hope and faith in our future,

A handwritten signature in black ink that reads "Rachel Hood". The script is fluid and cursive, with the first letters of each word being capitalized and larger than the rest of the letters.

Rachel Hood

Executive Director, West Michigan Environmental Action Council

PREFACE

A changing natural world impacts everything within that world, and those impacts reverberate and interact with each other in an infinitely complex way. Even climate change “solutions” are affected by climate change. For example, higher summer temperatures result in increased demand for air conditioning and electricity. But the production of electricity is a significant climate change contributor, creating a negative feedback loop.

Similarly, an increase in extreme precipitation events increases the likelihood of flooding. This, in turn, increases the need for more green infrastructure to manage floods. But many types of green infrastructure, including wetlands and the urban tree canopy, are themselves impacted by climate change. Such complex interactions are typical of climate change studies. Thus, this report has been purposefully limited in its breadth, depth, and scope. Climate change is full of positive, negative, and ambiguous feedback loops, making the issue quite complex. As such, it is impossible to address climate change in an exhaustive manner.

From the municipal perspective, several questions are crucial. Which issue is the root issue? Which is foundational or most important? Which issues are subservient? Where do we start and what follows? Take the flooding example. A severe flood can have profound economic and social consequences, so perhaps flooding should be the top-line issue. Better stormwater management would certainly help prevent floods and the economic damage they bring. Stormwater management also protects lakes, rivers, and wetlands from environmental pollution, which makes them more resilient to the impacts of climate change. Given that stormwater is a flooding and pollution-prevention consideration, perhaps stormwater management is the top-line issue. However, such an approach would also be problematic, as it would be to treat the concerns as equals. It is impossible to systematically unwind the climate knot without consciously adopting a framework or perspective.

With this in mind, the authors examined the issue according to the framework currently used by many sustainability initiatives in the Grand Rapids area, including those of the City of Grand Rapids itself. The triple bottom line advocates for a balancing of economic, social, and environmental concerns. The weight given to any particular issue should reflect its relative value to the triple bottom line, as should the practices employed to achieve climate resiliency. Additional priority should be given to strategic considerations and approaches that generate social, economic, and environmental benefits. Regardless of whether climate change predictions actually come true, this approach facilitates a no-regrets sustainability initiative through the lens of climate resiliency.

1 INTRODUCTION

The Grand Rapids Climate Resiliency Report (the Report) seeks to identify the largest and most likely impacts of climate change on core city functions and services. It discusses current and potential responses, innovations, and best-practice solutions for climate change adaptation and mitigation.

Climate change is a global problem with uniquely local impacts. Across the United States, communities are becoming aware of their vulnerabilities to climate change, and leaders are being challenged to identify and plan for potential climate change impacts.

In 2012, the U.S. Conference of Mayors recognized Grand Rapids Mayor George Heartwell with the Climate Protection Award for Large Cities for the City's efforts to address climate change according to the mandates set forth by the [U.S. Conference of Mayors Climate Protection Agreement](#). The honor included a \$25,000 grant for climate change protection programming, which was split evenly between Friends of Grand Rapids Parks and WMEAC. With its portion of the grant, WMEAC was asked to investigate local climate change resiliency in partnership with the [Grand Rapids Office of Energy and Sustainability](#).

This is the first attempt to comprehensively understand vulnerabilities to climate change within our community's environmental, social, and economic systems. Over a 10-month period, WMEAC interviewed more than 25 experts from a diverse range of fields, including insurance, academia, regional planning, transportation, food systems, emergency preparedness, sustainability, environmental services, community infrastructure, forestry, finance, low-impact development, built environment, community essential needs, fisheries, engineering, and energy.

In addition to subject-specific questions, all contributors were asked to provide their perspective on the meaning of climate resiliency. Based on these discussions and existing definitions used by other communities and research organizations, this report defines climate resiliency as the ability of a community to simultaneously balance ecosystem and human functions in an uncertain and dynamic climate future.

This report integrates local expert opinion with climate science, research, and analysis to create an initial report for Grand Rapids climate resiliency. It is intended neither as a stand-alone planning document nor a definitive examination of the topic; it has not had the benefit of an integrated community planning process. Instead, it is intended to spur a larger community conversation about how Grand Rapids can become a more climate-resilient city. It seeks to bring awareness to potential policy, planning, and

programming actions that would enable Grand Rapids to mitigate its contributions to climate change, adapt to its impacts, and harness emerging opportunities.

A resilient community can mitigate its contribution to climate change. It is flexible and poised to adapt. Resilient cities are better positioned to capitalize on opportunities that arise in an uncertain future. We intend for citizens, municipal officials, businesses, and community leaders to use this document as a framework to consider how climate change might impact their areas of influence. The Report is a tool for community planners, providing insights into the complexities of climate change in relation to the existing economic, environmental, and social conditions of the community.

1.1 Grand Rapids: Sustainability Leadership

Grand Rapids is located in west central Michigan, roughly 30 miles east of Lake Michigan. It is nearly equidistant from Chicago and Detroit and measures approximately 45 square miles. The Grand River, a major state waterway, runs through the center of the City (see Figure 1). The second largest city in Michigan has a population of 190,411, with more than 1.3 million in the metropolitan area, according to 2012 census estimates. It is the seat of Kent County, which boasts a population of over 614,462 in its 856 square miles.

Grand Rapids has a history of leadership, creativity, and entrepreneurship. In 1881, one of the country's first hydroelectric plants was installed on the City's west side. In 1945, Grand Rapids became the first city in the United States to add fluoride to its drinking water. Grand Rapids lays claim to the nation's first scheduled air service (to Detroit) and its first publicly funded art installation, *La Grande Vitesse* by Alexander Calder. Historically known as Furniture City for its legacy of nineteenth- and early twentieth-century furniture manufacturers, Grand Rapids is best known today for its bustling urban redevelopment, the world's largest art competition (ArtPrize), and its many sustainability initiatives and accomplishments.

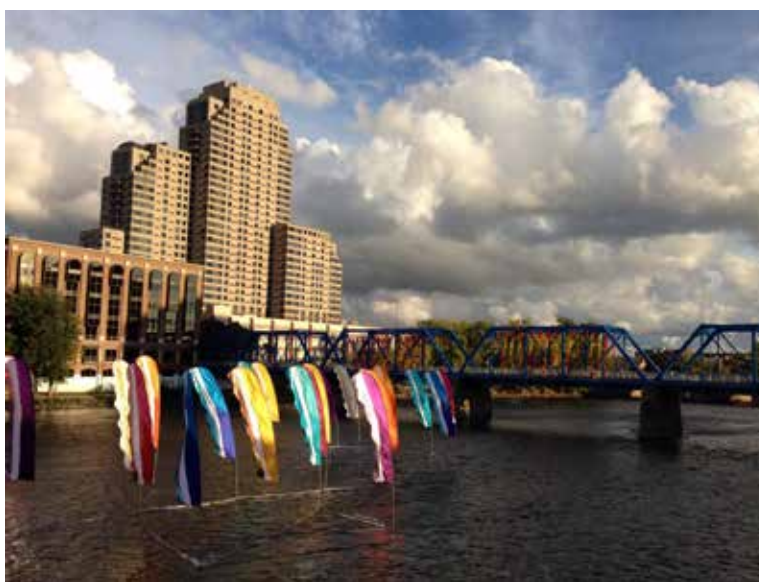


Figure 1. The Grand River runs through the center of city life.
Photo: Nicholas Occhipinti



Figure 2. The Green Grand Rapids Master Plan Update. *Click image to download.*

Grand Rapids boasts the highest per capita number of buildings with Leadership in Energy and Environmental Design (LEED) certification in the United States. It was the first city in the country to be recognized by the United Nations University as a Regional Centre of Expertise for Education on Sustainable Development. The metropolitan region is home to several of the nation’s most respected sustainable business innovators.

The City of Grand Rapids has been recognized nationally and internationally for its sustainability initiatives and use of the triple bottom line decision-making framework in its key planning documents and processes. The National League of Cities recently lauded Grand Rapids for “its recent successes in green building development and ambitious community-wide sustainability initiatives to entice new development and new businesses.”⁵

Sustainability was a key focus of the 2011 update of the [Grand Rapids Master Plan](#), the result of the multiyear [Green Grand Rapids](#) community planning initiative (see Figure 2). The City of Grand Rapids’s [Sustainability Plan](#) institutionalized the use of the triple bottom line in municipal decision making, setting goals and objectives specific to each area and requiring planners to go through a “plan-do-check-act” process to ensure that all projects meet those goals (see Figure 3).

While never before as prominent as during the tenure of Mayor Heartwell, sustainability has been a key factor in the City’s planning efforts for some time. During the 1980s city leaders addressed critical deficiencies in stormwater and wastewater treatment systems through prudent planning, design, and assessment of spending and infrastructure. The City responded to the realities of a declining economy with its 2011 [Transformation Investment Plan](#). Among other things, it ensured that citizens would get the level of service that they expect while decreasing costs and increasing transparency through a dashboard of accomplishments and expenditures. As new problems have arisen, city leaders are expanding this portfolio of plans, forming a blueprint for a sustainable future. The Grand Rapids Climate Resiliency Report is the latest addition.



Figure 3. Grand Rapids sustainability progress report. *Click image to download.*

1.2 Community Partnerships

The City of Grand Rapids has also been effective in utilizing community partnerships to advance economic, social, and environmental initiatives. Key partnerships include a waste-minimization and recycling promotion that supports local businesses with [Local First](#); regional transportation planning with the [Grand Valley Metro Council](#); a residential home energy program through [WMEAC](#); urban tree canopy analysis and planning with Friends of Grand Rapids Parks; and neighborhood development with [Seeds of Promise](#). The [Grand Rapids Community Sustainability Partnership](#) is a city-sponsored program that has 225 members from the business, public, and educational sectors. It is a true testament to community-wide support for triple bottom line efforts.

In general, a culture of sustainability is alive and well in Grand Rapids. It has been adopted by the local government, businesses, nonprofits, foundations, and neighborhood organizations. However, there are practical reasons for looking into the impact of climate change on local community. In the article entitled “Local Governments Must Take Charge of Building Resilient Communities,” Haris Alibašić argues that “climate change presents a whole new set of challenges when it comes to emergency planning and preparedness for municipalities” and concludes that “both the planning and investments in infrastructure made by the City were put to the test with the recent flood and the extreme heat waves in the summers of 2012 and 2013.”⁶

Climate resiliency represents a new paradigm for local sustainability. It acknowledges that there are existing policies, practices, and programs related to core city functions and services that make Grand Rapids more climate-resilient. Still, there are also ways in which Grand Rapids must evolve with a changing climate to ensure a sustainable and thriving community. Finally, resiliency recognizes the existence of opportunities on which to capitalize in a dynamic climate future.

1.3 Understanding Climate Change

The average global temperature has risen by approximately 1.4° Fahrenheit (F), or 0.8° Celsius (C), over the previous century.⁷ This has affected communities worldwide in diverse and often dramatic ways.

The most well documented examples involve ice and water deposition. Ice covered approximately 50% of the summertime Arctic Ocean when satellite tracking began in 1970; it covered only 24% in 2012. Snow pack melt is accelerating at an even faster rate: 18% loss per decade compared to 11% for sea ice cover, exceeding the predictions of previous climate change models.⁸ In some areas this has an adverse effect on ground and surface water replenishment and retention, vital processes for agriculture, drinking

water, sanitation, and many other primary functions for modern society. Other acute impacts include the severe droughts in Africa and Asia, which have created an estimated 42 million “environmental migrants.” This figure could increase by one billion worldwide if conditions persist.⁹

There is scientific consensus that climate change is the result of an increased proportion of greenhouse gases in the Earth’s atmosphere. Under normal conditions, short-wave solar energy penetrates the atmosphere and is absorbed on the Earth’s surface through vegetation, soil, water, and manmade materials, and converted into long-wave, infrared energy. Greenhouse gases capture too much of this energy as it is released from the surface and prevent it from escaping the planet—increasing global temperatures.

Scientists posit that the increased level of greenhouse gases can be attributed to an increase in anthropogenic (human-caused) activities that release greenhouse gases, predominantly carbon dioxide (CO₂). Since 1958, data on CO₂ levels has been collected at the Mauna Loa Observatory in Hawaii, the longest such direct study of CO₂ levels in the world. CO₂ increased from [317 parts per million \(ppm\) in 1958 to 397 ppm in 2013](#) (see Figure 4).¹⁰ Based on ice core samples and geologic studies, scientists have determined that CO₂ levels remained steady at around 280 ppm during the previous 2,000 years. Moreover, evidence suggests that they have never been at or above 400 ppm in the last 15 million years.¹¹

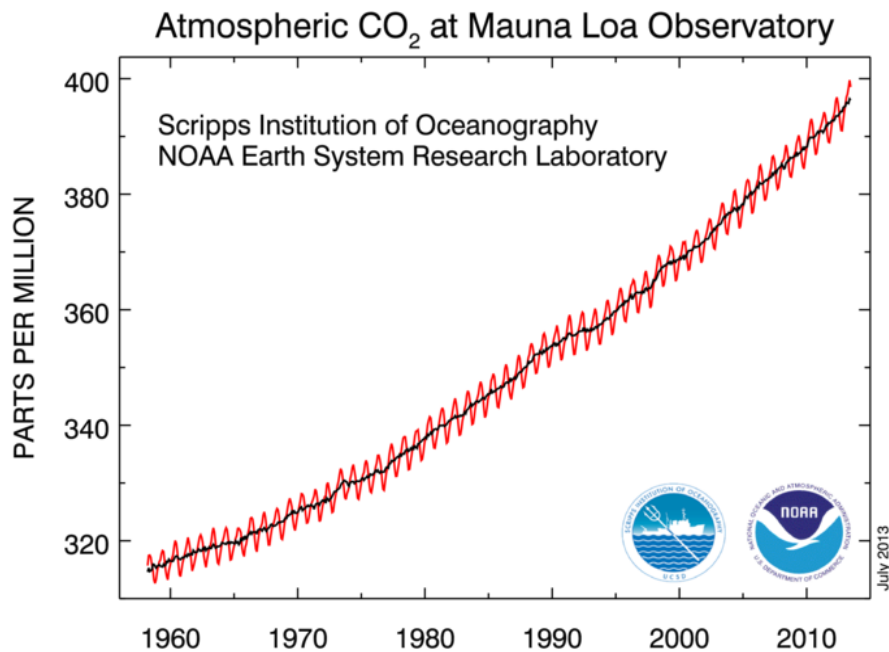


Figure 4. Carbon dioxide (CO₂) concentrations measured in the atmosphere since the late 1950s.

CO₂ is neither the only greenhouse gas nor the most potent one. However, it is the dominant metric used for quantifying greenhouse gas emissions.

Understanding climate change requires the observation of patterns and long-term trends, which must be separated from isolated or short-term weather oscillations.

Land and ocean temperature data from the beginning of the twentieth century through the first decade of the twenty-first

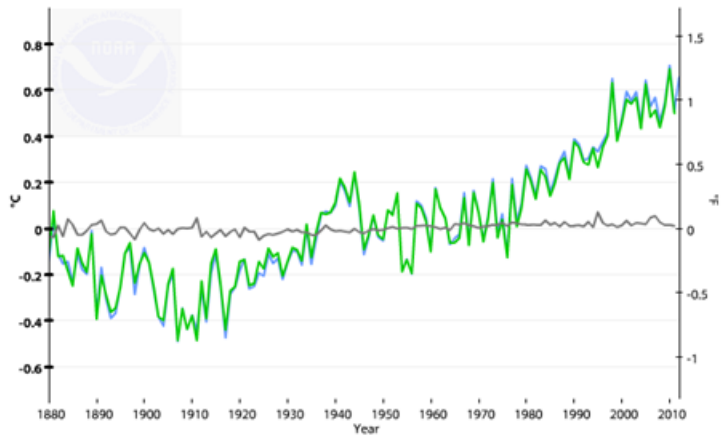


Figure 5. Comparison of historic and current temperatures to the period average. Black line: period average; green/blue line: annual temperature averages.

century indicates an increase in annual average temperatures as compared to the overall average temperature during that time period (see Figure 5).¹² These revelations have increased interest in mitigation efforts that reduce greenhouse gases. However, these gases can persist in the atmosphere or other parts of the environment for extended periods of time. Even if all anthropogenic greenhouse gas production ceased, a significant warming period could still follow. This concept is known as the climate commitment; complex atmospheric physics have prevented a definitive scientific consensus on the extent of that commitment.¹³

A 2 °C rise is a “line in the sand”

As part of the Kyoto Protocol, an international agreement between 141 countries to address climate change, the scientific community identified a specific global temperature gain over preindustrial levels at which damage to the Earth’s systems will have extreme consequences for humanity. A 2 °C temperature gain (3.6 °F) has been labeled a proverbial “line in the sand.”¹⁴ That temperature gain has an approximate corresponding safety line for greenhouse gas emissions: 350 ppm is deemed an acceptable worldwide level of CO₂ in our atmosphere; 450 ppm is generally correlated to the 2 °C rise. Currently, CO₂ levels in the atmosphere are at approximately 400 ppm.

In 2011, it was estimated that the United States was responsible for the equivalent of 5.4 billion tons of CO₂ emissions. This is roughly 16.2% of the global total of 33.4 billion tons.¹⁵ Figure 6 depicts the national trend of carbon emissions in the United States.¹⁶ These total emissions have been decreasing since 2007. An updated report by the Natural Resources Defense Council states that national CO₂ emissions have fallen by 9% since 2005, and this happened even as the economy grew.¹⁷ However, while national CO₂ emissions may be trending downward, global emissions are not. The rapid growth of

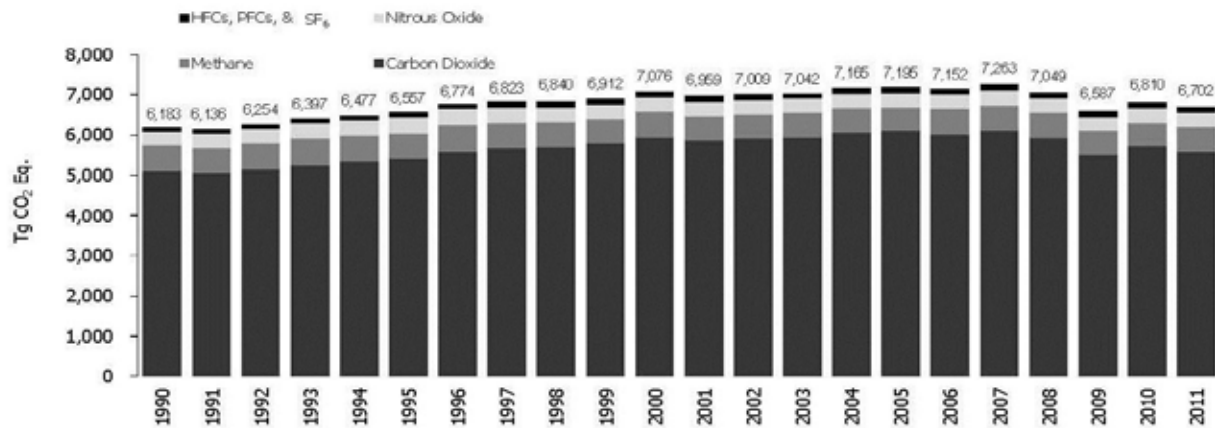


Figure 6. Total U.S. greenhouse gas emissions by gas. (From [Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2011](#))

developing countries such as China and India is significantly increasing emissions. Megacity industrial hubs like Shanghai and Beijing are contributing a massive amount of CO₂ to the atmosphere.¹⁸

1.4 Climate Change in the Midwest

Recent studies have documented noticeable climate changes occurring throughout the U.S. Midwest. These changes have already begun to affect communities and people, from farmers to urban residents. Shrinking ice coverage is a highly visible symptom of climate change and has an impact on Great Lakes ecosystems and on industries such as fishing and shipping. Since 1973, the Great Lakes have been monitored for changing ice coverage. Data shows that [winter ice coverage on the lakes decreased by 71% between 1973 and 2011](#).¹⁹ (Ice reflects solar energy, another example of a negative climate feedback loop). Winter air temperatures increased by 2.7 °F during that period. The combination of increased air temperature and reduced ice coverage has caused water temperatures in Lakes Superior, Michigan, and Huron to increase by 4.5, 3.3, and 4.3 °F, respectively.²⁰ While rising annual temperatures are considered a major contributor to reduced ice coverage, researchers have found that four-to-eight-year natural El Niño/La Niña air current oscillations also have an impact. In the summer of 1995, Chicago experienced an unprecedented seven consecutive days of temperatures in excess of 90° F and 90% humidity. Some 1,000 hospital visits, 3,000 emergency department visits, and 500 deaths were attributed to the heat wave.²¹ Chicago saw an increased frequency of extreme heat events and prompted comprehensive changes to city planning and [emergency preparedness](#).

1.5 Climate Change in Grand Rapids

With the support of Grand Valley State University’s Elena Lioubimtseva, this project employed the Model for the Assessment of Greenhouse-gas Induced Climate Change and Regional Scenario

Generator (MAGICC/SCENGEN), developed by the National Center for Atmospheric Research.²² While MAGICC/SCENGEN has been accepted and used by the Intergovernmental Panel on Climate Change (IPCC) and other agencies to model climate change, its ability to emulate real-world trends is limited. In addition to the inherent uncertainty of climate modeling, MAGICC/SCENGEN has a significant limitation in that it deals in seasonal averages and is not capable of forecasting extreme weather trends.

Climate Narrative: Hurricane Sandy Impacts Michigan

Climate change is often perceived as a faraway issue affecting other people in distant countries. Perhaps this perception has been fueled by years of media reports featuring images of polar bears, melting ice sheets and glaciers, drought, and tropical storms. Impacts will be felt asymmetrically and disproportionately around the planet, but they will be felt everywhere. Indeed, global climate change will be felt on the local level.

Hurricanes are usually associated with tropical and subtropical coastal regions, but the impact of Hurricane Sandy was felt throughout the Midwest and Great Lakes. Intense winds from Sandy created huge waves and led to damage across the Great Lakes system (see Figure 7). The storm deposited sediment in harbors and channels and caused structural damage on the shoreline. Some West Michigan harbor towns were impacted enough to elicit a federal response. Holland received \$200,000 to dredge shoaling at the harbor mouth and Saugatuck received \$370,000. Another \$19 million in Hurricane Sandy federal recovery funding will be available to repair the storm's damage to Great Lakes harbors.²³ A National Hurricane Center report estimated the costs of Sandy at \$50 billion. It's not yet possible to blame individual weather events on climate change, but scientists believe that climate change exacerbates their magnitude and frequency.



Figure 7. A man rides his bike along Lake Michigan in Chicago as waves from Hurricane Sandy winds pound Lake Shore Drive.

Photo: Chris Bentley, via [Flickr Creative Commons](#)

Table 1. Projected Changes in Temperature and Precipitation for Grand Rapids Area in 2022 and 2042

	1961–1990	2022	2042
	Monthly Average (Baseline)	Change from Baseline	Change from Baseline
Temperature	°C	°C	°C
Annual Change	8.5	1.1	2.2
Winter (Dec–Jan–Feb)	–4.3	1.4	3.3
Spring (Mar–Apr–May)	7.7	0.9	1.9
Summer (Jun–Jul–Aug)	20.7	0.9	2
Fall (Sep–Oct–Nov)	9.7	1	2.2
Precipitation	centimeters	% change	% change
Annual Change	7.6	2.6	8.5
Winter (Dec–Jan–Feb)	5.1	5.6	15.6
Spring (Mar–Apr–May)	7.7	6.5	10.4
Summer (Jun–Jul–Aug)	8.8	–1.1	–2.2
Fall (Sep–Oct–Nov)	8.9	2.5	5.3

Results produced for coordinates relating to the City of Grand Rapids and projected to an area of 2.5° by 2.5° using MAGICC/SCENGEN, a coupled gas-cycle and atmosphere-ocean general circulation database climate change model with an assumed A1B scenario as developed in the IPCC’s Special Report on Emissions Scenarios.

Historic data: World Climatological Organization, 2013

Modeling: Dr. Elena Lioubimtseva, Grand Valley State University, Department of Geography and Planning, 2013²⁴

This report’s MAGICC/SCENGEN climate-change analysis was modeled to align with the Grand Rapids Master Planning process, which is developed and adopted for 20-year intervals and updated periodically.

The MAGICC/SCENGEN model forecasts annual and seasonal temperature and precipitation changes for the years coinciding with the next two Grand Rapids planning cycles of 2022 and 2042, from the average of baseline years 1961–1990. To gain an understanding of seasonal variability from climate change, the analysis produced results for each season within the respective years.

As shown in Table 1, Grand Rapids can expect both warmer temperatures and increased precipitation from 2013 through 2042 on an annual basis. By 2022, annual average temperature is predicted to rise from a baseline of 8.5°C (47.3°F) to 9.6°C (49.28°F), then to 10.7°C (51.26°F) by 2042. Precipitation is expected to increase from a baseline annual average of 7.6 cm to 7.8 cm and 8.3 cm by 2022 and 2042, respectively.²⁵

Though only projecting through the middle of the century, the trend shown through this analysis is in accordance with the National Climate Assessment and Union of Concerned Scientists' climate change projections for Michigan through the end of the twenty-first century. According to these models and others with a focus on the Midwest, Michigan's average annual temperature is projected to increase by between 3 and 7 °C, with an increase in precipitation of between 20% and 70% by the turn of the century.²⁶

The impacts most likely to test resiliency are due to seasonal variability and the possibility of extreme swings in temperature and precipitation from year to year and from season to season.²⁷ The MAGICC/SCENGEN results indicate there is a strong likelihood of variance in temperature and precipitation change patterns within each year, such that some seasons are likely to get warmer and incur more precipitation while the opposite may occur in others.²⁸

For example, the largest increases in temperature are predicted during the coldest season, winter. The months with the least amount of predicted temperature rise are during the summer. The increases during the winter period are the cause of a predicted increase in average annual temperature. This trend could drastically alter seasonal patterns in Michigan and have implications on flora and fauna as well as on energy needs and water cycles.²⁹

The largest increase in precipitation, according to the model, is likely to occur during the winter and spring months. In 2022, the spring months show the largest increase in precipitation, with winter close behind. By 2042, that trend is expected to reverse, though both seasons show relatively similar increases and remain well ahead of the other seasons. While the autumns of 2022 and 2042 show a minimal amount of precipitation increase, each is still projected to be wetter than current and past falls. Summer, however, while not increasing in average monthly temperatures as much as the others, is the only season projected to become drier.³⁰

Grand Rapids CO₂ Emissions and Climate Agreements

The 2009 [Grand Rapids Office of Energy and Sustainability](#) Energy Efficiency and Conservation Strategy Report found that Grand Rapids emits 2,015,648 metric tons of CO₂ annually. Grand Rapids municipal operations accounted for 98,900 metric tons of CO₂.³¹ The benchmark 2 °C rise, or roughly 450 ppm, corresponds with 37 million metric tons of CO₂ equivalent emissions globally. Using a proportional, back-of-the-envelope calculation based on current emission levels, Grand Rapids's "share" of the worldwide limit is about 2,267,921 metric tons.

Emissions data for Grand Rapids has not yet been updated through 2013. However, the City of Grand Rapids Office of Energy and Sustainability is currently compiling the latest data, and the report should be completed in 2013 or 2014.³²

The City's greenhouse gas (GHG) emissions report is a unique tool, providing specific and detailed accounting of emissions that can be used to strategically target reductions. It has limitations, however. For example, the U.S. Conference of Mayors recommends using 1990 as the baseline year, but due to a lack of data, the City of Grand Rapids instead used 2008 as its baseline year. This makes it difficult to track progress made in the last decade. Additionally, when data was not available, energy usages were inferred based on 2009 usages. Another limitation of the report is that the data for the transportation sector for FY2008 was not available. (This happens to be the sector with the most emissions.) However, a complete data set from 2007 and emissions were used to extrapolate 2008 data.

The [U. S. Conference of Mayors Climate Protection Agreement](#) is a national call for the reduction of carbon emissions throughout the United States. It is based on the 2005 Kyoto Protocol. Grand Rapids joined the agreement; one of its significant commitments is a 7% reduction in emissions from 1990 levels by 2012.

Recently, Mayor George Heartwell joined other mayors in signing the [Resilient Communities Agreement Letter](#). It pledged to lead the “creation of more resilient cities, towns, and counties, built to overcome our nation’s extreme weather, energy, and economic challenges.”³³

2 ECONOMIC ISSUES

2.1 Energy

The economic impacts of a changing climate will be far-reaching, interconnected, and difficult to precisely anticipate. The goal of this report is to focus on the most likely and pronounced impacts with the intent of planning for a more resilient community. In economic terms, one of the most profound impacts will be on energy. Supply, demand, and energy infrastructure are all key areas of focus.

According to the U.S. Environmental Protection Agency (US EPA), “changes in temperature, precipitation, sea level, and the frequency and severity of extreme events will likely affect how much energy is produced, delivered, and consumed in the United States.”³⁴

The US EPA identifies the following likely major impacts:

- Demand for cooling energy will increase and demand for heating will decrease.
- Americans will use more electricity for air conditioning and less natural gas, oil, and wood for heating.
- Warming is likely to increase summer peak electricity demand.
- Increased evaporation will impact energy-consuming water processes.
- Decreasing flows in rivers will lead to decreased production of hydroelectric power.

The Michigan Public Service Commission (MPSC) is the regulatory agency tasked with anticipating changes in the energy sector. While the MPSC hasn't directly addressed climate change in a dedicated report, it is currently researching the issue from an emergency preparedness perspective. Moreover, the MPSC does not ignore climate data. The MPSC's Energy Appraisal utilizes 21 separate time series and econometric models, including data from the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service Climate Prediction and Data Center. The MPSC releases two [energy appraisals](#) every year that project short-term energy supply and demand.

Climate Change Will Impact Energy Supply and Demand in Michigan

Climate change will impact both energy supply and demand. In the long term, forecasts suggest that heating costs will decline while cooling costs will increase. The MPSC recently noted that Michigan experienced a mild winter season followed by a summer of intense heat, 45% and 68% above normal



Figure 8. Storm events can bring flooding and high winds, which threaten the reliable delivery of liquid fuels. Also, gasoline pumps generally require electricity to function. *Photo: Cody Austin*

in June and July 2012, respectively. In fact, summer 2012 brought an all-time high peak demand for Consumers Energy on July 17, 2012, exceeding its previous high of 8,930 megawatts (MW) set in 2011.³⁵ Summer 2012 temperatures in Grand Rapids align with long-term climate forecasts, but it cannot yet be proven that the weather experienced in any given season is due to climate change.

On the supply side, the most anticipated impacts of climate change are related to energy infrastructure. Increasingly volatile weather events and extended periods of peak demand may stress vulnerable energy infrastructure. Peak loads associated with extremely hot summers coupled with a predicted increase in the number and intensity of storm events (see Figure 8) have the potential to create more supply disruptions, including outages and damaged energy infrastructure.³⁶

According to Nancy Popa, manager of long-term strategy for Consumers Energy, “extreme temperatures and high humidity could challenge our systems to deliver the energy needed to cool people’s homes.” This is particularly true for heat events of extended duration—annual system planning models account for changing weather patterns and demand to assure that the energy supply system is robust and able to respond to changing conditions.³⁷ Additionally, she says that system transmission becomes less efficient during high-heat, high-humidity events because of reduced grid conductivity. Put another way, the hotter it gets, the more energy is wasted in transmission.

Extreme storm events can also bring flooding and high winds, which can impact the reliable delivery of liquid fuels. [Michigan’s energy supply](#) is largely fossil and mostly imported. All of Michigan’s coal is imported, as well as the vast majority of its natural gas and liquid fuels.³⁸ This dependence increases climate change vulnerabilities. For instance, railroads that are used to transport coal and other fossil fuels can be affected by flooding and delayed by fire. Additionally, low water levels and extreme weather events can impact water-based energy suppliers and shipping. The Gulf of Mexico’s offshore drilling platforms have been consistently impacted by extreme weather, including Hurricane Ivan, which damaged 24 platforms in 2004, and Hurricanes Katrina and Rita in 2005, which damaged more than 100 platforms.³⁹ Michigan, like many states, is dependent on areas prone to tropical systems.

Energy Sector as Contributor to Climate Change

The use of fossil fuels in the energy sector is one of the [leading contributors of CO₂](#) in the atmosphere. The accumulation of these emissions continues to push global temperatures toward the [2 °C temperature increase from preindustrial levels](#), which scientists and policymakers around the world agreed should not be exceeded.

Locally, resiliency demands that communities not only brace themselves against impacts, but also do their part in understanding and mitigating their own contributions to climate change (see Figure 9). A resilient energy system would be composed of a diverse

portfolio of energy sources that have little or no CO₂ emissions. It would transport energy through an efficient, hardened electric infrastructure that is scale-diverse, geographically distributed, redundant, and smartly interconnected.



Figure 9. Creating a resilient city will require changes from consumers as well as producers.

Photo: eutrophication&hypoxia

2.2 Energy/Water Nexus

Climate change will highlight the connection of energy and water in the modern world. According to the US EPA, current power-generating facilities can require up to 25 gallons of water to generate 1 kWh of electricity, using approximately 3.3 billion gallons per day.⁴⁰ Water filtration systems use energy to draw and move water, and electric facilities use water to produce energy. On the hottest days both are operating at peak capacity, the one to provide water and the other to provide the electricity for cooling.

In addition to its use for shipping fuels and energy equipment, water plays a role in the production and distribution of energy. For example, Consumers Energy and other energy providers use water to cool major energy plants.⁴¹ The intake pipes for these plants are currently designed for the 100-year-low water level. The drought in 2012 brought with it some near-record low water levels, specifically in the Michigan-Huron system, reaching an average of 175.9 meters.⁴² While lake levels have not dropped to the 100-year low yet, there is growing concern that if the trend continues, energy producers may need to modify their facilities and infrastructure to increase resiliency against fluctuating lake levels.⁴³ Increasingly dry conditions, and increased evaporation during winter due to a lack of ice, could force utilities to move intake structures farther out into the water.

While a decline in lake levels is a concern, a rise in water temperature could prove a bigger problem.

When water used for cooling is warmer, a greater quantity is required. This would result in a decrease in plant efficiency.⁴⁴ Additional impacts could manifest in water exiting the plant. Water used for cooling is discharged into the water system at warmer temperatures than would occur naturally. If the plants are forced to draw in water that is already at increased temperatures, discharge water temperatures would be even warmer than they are now. Consequently, plants may have problems complying with permits from state environmental agencies, which generally have seasonal temperature limits to protect fish and other organisms living near water discharge points. However, there would likely need to be “a drastic change” before the plant would be unable to operate or would face safety and compliance problems.⁴⁵

On the opposite end of the spectrum, spikes in precipitation can lead to increased electricity demand from water treatment facilities to keep up with the influx of water from rain. This is exacerbated by the fact that planning documents for water treatment facilities are based on old hydrological forecasts.⁴⁶ Both the quantity and quality of water are affected when water temperatures are elevated. Changing water temperatures can also release pollutants from lake and stream beds, which could require more extensive processing at water treatment facilities that draw from these sources.⁴⁷ Warmer water temperatures also increase the amount of materials that must be filtered in water processing plants as certain flora and fauna rapidly reproduce. Likewise, aquatic organisms used in wastewater treatment are stressed by decreased oxygen and higher temperatures, making the facilities less efficient.⁴⁸

According to a 2013 report from the Department of Energy called “U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather,” a unit at American Electric Power’s D.C. Cook Nuclear Plant was shut down in 2006 because high temperatures both in containment and in Lake Michigan were



Figure 10. The D.C. Cook Nuclear Power Plant was shut down in July 2006 because of extreme heat.

too high for cooling (see Figure 10). The plant was returned to full production five days later when the heat subsided.⁴⁹

Water- and energy-planning models will have to be updated and deployed within Grand Rapids and surrounding regions to prepare for expected increased weather variability.⁵⁰ The Natural Resources Defense Council offers an accounting of favored resiliency approaches to protect the health of water systems. These recommendations include:⁵¹

- Implement water use efficiency.
- Use “climate smart” water-management tools such as groundwater banking and water recycling.
- Factor energy use into each component of water use, including transport and treatment.
- Factor climate change into feasibility analyses and project design—particularly with storage and surface facilities.

Michigan Energy Planning

In early 2013, Governor Rick Snyder’s administration enlisted the MPSC and the Michigan Economic Development Corporation to lead a series of seven public forums across the state. The goal was to gather input from various citizens, businesses, and other organizations to help create a [statewide energy plan](#). Two of the forums were held in West Michigan, one in Grand Rapids, the other in Kalamazoo. Scheduled for release in late 2013, the plan will focus on reliability, affordability, and the environment. It is a step toward understanding community needs and the weaknesses and opportunities that exist on both the supply and demand sides of the energy system.

In 2008, Michigan enacted Public Acts (P.A.) 295 and 286 as the foundation of its statewide energy policy. From a climate and environmental perspective, the state renewable portfolio standards and energy optimization standards enshrined in those laws represent progress. The MPSC believes that the standards have also kept Michigan competitive with outside energy markets while benefiting businesses and citizens.⁵² P.A. 295 featured a statewide renewable electric standard of 10% renewable energy by 2015, an electric efficiency standard that ramped up to 1% annually, and a gas efficiency standard of 0.75%.

Michigan electric and thermal energy producers are on pace to meet the deadline for the 10% renewable energy standard (Figure 11),⁵³ though once that standard is met the mandate loses its effectiveness. On the efficiency side, the 1% annual target will remain in effect as long as providers meet it “cost-effectively” and [the law](#) remains unchanged (see Figure 12).⁵⁴ Twenty-seven states have efficiency resource standards, with certain Midwest states boasting annual efficiency targets of 2%. In all, 30 other states have higher renewable energy and energy efficiency goals than Michigan ([Department of Energy Database of State Renewable and Energy Efficiency Standards](#), August 2013).⁵⁵

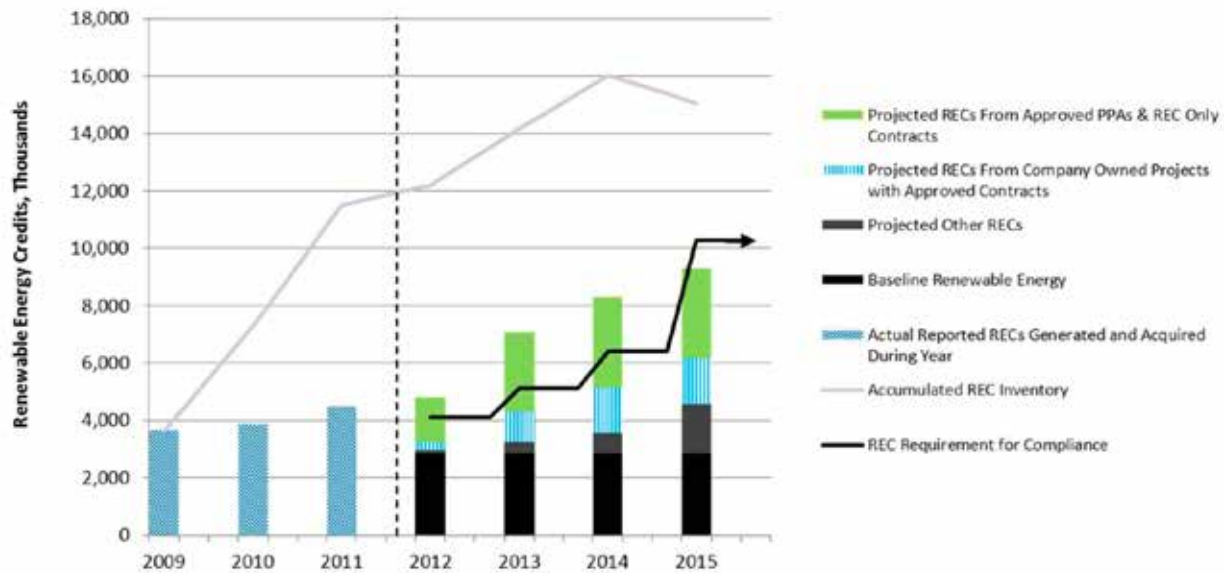


Figure 11. Michigan energy providers have met state renewable energy goals.

According to Haris Alibašić, director of the City of Grand Rapids Office of Energy and Sustainability, energy efficiency could be the factor that provides the greatest contribution to the community from a triple bottom line perspective. He explains that “if you address [energy efficiency] properly...It’s a simple financial proposition.”⁵⁶ The benefits of energy efficiency have attracted attention from the highest levels of government and business. In his [2013 State of the Union address](#), President Barack Obama set a new goal for America to “cut in half the energy wasted by our homes and businesses over the next 20 years.”⁵⁷

In 2009, leading global consulting firm McKinsey and Company found that the U.S. economy has the potential to reduce annual non-transportation energy consumption by 23% by 2020. This would save \$1.2 trillion at a cost of \$520 billion, not including program costs, and would decrease greenhouse gas emissions by 1.1 gigatons annually, the equivalent of taking the entire U.S. fleet of passenger vehicles and light trucks off the roads.⁵⁸

The U.S. government has already made a significant investment in homes and businesses to cut energy waste. As part of the American Recovery and Reinvestment Act’s energy efficiency programs, a federally funded collaboration

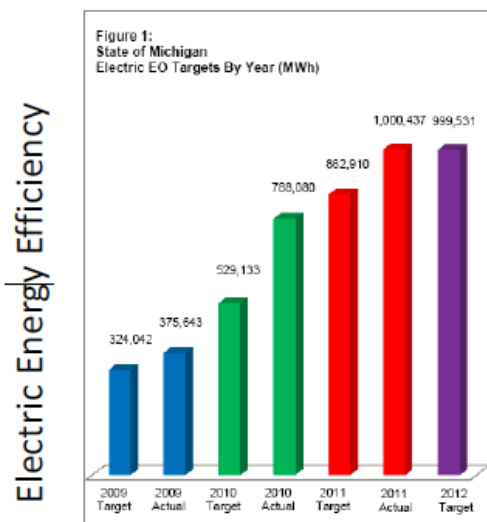


Figure 12. Michigan electric providers have met state energy efficiency goals.



Figure 13. Better Buildings for Michigan brought the City of Grand Rapids together with local contractors to retrofit almost 2,000 homes in the Grand Rapids area.

bringing together WMEAC, the City of Grand Rapids, and a handful of public and private sector partners, the Better Buildings for Michigan program was responsible for the audit and retrofit of more than 1,900 homes in greater Grand Rapids (see Figure 13). The program will save Grand Rapidsians approximately 148,444 therms, 297,667 kilowatt-hours, and 998 metric tons of CO₂.⁵⁹

Why the excitement about energy efficiency? Its low cost is the primary driver.

Energy efficiency involves accomplishing the same, or more, with less energy. It's not about sacrifice—an important distinction between energy efficiency and energy conservation.

Businesses, utilities, regulators, and many other stakeholders are experiencing and documenting the benefits of energy efficiency. In Michigan, it is the cheapest source of new energy: the [MPSC's 2013 report to the state legislature](#) found that energy efficiency cost Michiganders \$20/MWh (megawatt-hour), compared to renewable energy at \$82.5/MWh and new coal at \$107/MWh.⁶⁰

In addition, thousands of homes have been weatherized by local social service providers including the Salvation Army, ACSET (Area Community Services Employment and Training Council), Community Action Agency, Home Repair Services, and others. Improvements targeted at lower-income households have the added advantage of saving taxpayer and ratepayer dollars by decreasing low-income heating assistance payments. Energy efficiency frees up cash in tight monthly budgets and makes for more stable families and communities, as it returns dollars spent on energy to residents' wallets and the local economy. Energy efficiency also increases home values and decreases the cost of renting or owning a home.

Local Story: Holland Home Energy Retrofit Plan

Holland has assembled a number of energy task forces to pilot and innovate community-wide energy efficiency improvements as called for in its [Community Energy Plan](#).

In 2013, the Holland Home Energy Retrofits Task Force, the Community Energy Advisory Group (CEAG), local organizations, and municipal staff approved a [home retrofit program](#) plan to be considered by the Holland City Council. The comprehensive, city-wide energy retrofit plan aims to assess ways in which Holland residents can improve their home's energy efficiency and integrate energy-saving measures in their houses.

If approved by the city council, the voluntary program will aim to bring all participating homes up to Department of Energy Level 7 efficiency standards—which will place participating homes in the top 30% for home energy efficiency nationwide. Over 200 Holland households have already expressed an interest. Retrofits will range anywhere from simple fixes such as the installation of low-flow shower heads to more complex, deep-energy retrofits such as insulation, major appliances, and improved heating and cooling systems.

Task force members expect to invest between \$15,000 and \$25,000 in each participating home. Current plans call for the establishment of a revolving-fund energy trust, a joint public and private trust that would be used to fully finance home modifications suggested by audits. In what will be a significant innovation, “on-bill financing” will allow homeowners to repay their monthly energy savings from the retrofits back into the fund for a period of 10 to 12 years in order to offset the upfront costs of the renovations. Organizers hope to finalize funding options and begin home efficiency audits in 2014.

2.3 The Built Environment

The way in which our civilization, community, and individual buildings are built is a large contributor to climate change. The built environment is defined as the physical structures and organization patterns of buildings, blocks, neighborhoods, villages, towns, cities, and regions, plus their essential supporting systems, including physical infrastructure, resources, and operations.⁶¹ The definition varies by industry, and is understood by some to include community infrastructure and development patterns, and to others the architectural and operational elements of residential and commercial buildings.

In general, the built environment represents an important component of the climate resiliency discussion, and to a certain extent encapsulates the issue as a whole. Some of this is simply common

sense: Siting buildings adjacent to the Grand River, for instance, puts these properties at higher risk for flooding damage. Other points of the discussion are less obvious, particularly those related to what has been called a resilient/low-carbon community. In his action plan for community resiliency, Stephen Coyle makes a distinction between a conventional/high-carbon built environment and a resilient/low-carbon built environment. In his model, there are two goals for the creation of a sustainable, resilient community:⁶²

1. Ensure that future patterns of growth and regrowth are efficient, resource-conserving, ecologically benign, and socioeconomically vibrant.
2. Create an economy that reflects and reinforces the economic value of these efficiencies.

Even at the individual building level, the importance of the built environment cannot be understated. Americans spend 90% their time inside buildings.⁶³ These are generally the largest operational expense and most significant asset for both organizations and individuals. They fulfill a universal basic need. They are also a large contributor to climate change in the United States. According to the U.S. Energy Information Administration, residential and commercial buildings account for approximately 37% of greenhouse gas emissions.⁶⁴ As such, the built environment offers a great opportunity for climate change resiliency. If designed appropriately, a resilient building is able to absorb the impacts of climate change and provide meaningful reductions toward it. As local green building expert Keith Winn states, “We have to build buildings like our lives depend on it.”⁶⁵

LEED and Other Challenge Platforms Build Climate Resiliency

The most widely adopted model for designing sustainable built environments has been the Leadership in Energy and Environmental Design (LEED) Green Building Rating System from the U.S. Green Building Council (see Figure 14). However, LEED is not the only building design platform that increases sustainability and contributes to a more climate-resilient city. The Living Building

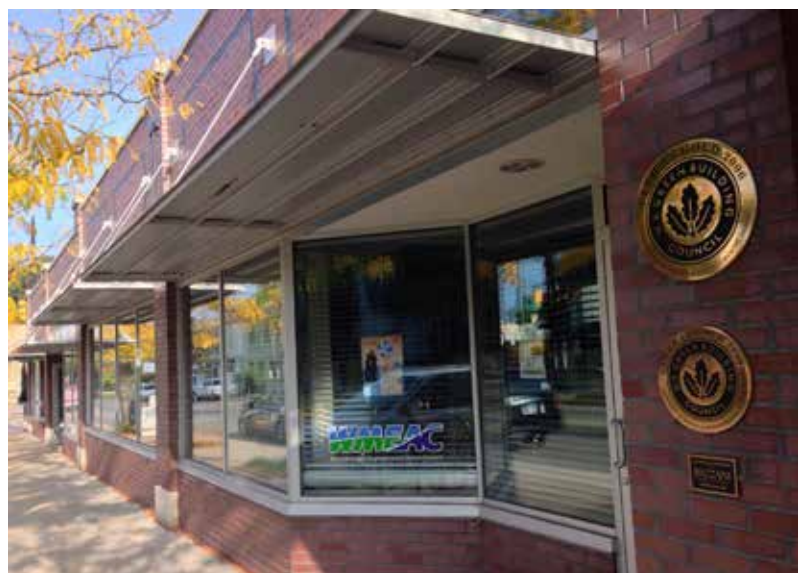


Figure 14. WMEAC offices on 1007 Lake Dr. are Double Gold LEED-certified. Photo: Nicholas Occhipinti

Challenge, Energy Star, and the 2030 Challenge are additional third-party means to define and measure “green buildings.”

LEED attempts to define and measure “green building” by providing a scorecard of benchmarks and best practices proven to improve building performance in energy savings, water efficiency, emission reductions, improved indoor environmental quality, stewardship of resources, and sensitivity to environmental impacts. Many LEED standards serve to directly reduce climate emissions while building resiliency for the building occupant. Sometimes these design standards extend into the surrounding community.

LEED credit categories include:

- Strategies that minimize the impact on ecosystems and water resources, including green infrastructure.
- Smarter use of water, inside and out, to reduce potable water consumption.
- Energy and atmosphere credits that promote better building energy performance.
- Sustainable building materials and waste standards.
- Indoor environmental quality benchmarks including air quality and access to daylight and views.
- Walkable, mixed-use neighborhoods with efficient transportation and good connections to open space.
- Awareness and education credits encourage home builders and real estate professionals to provide homeowners, tenants, and building managers with the education and tools they need to understand and make the most of the green building features of their home.

The City of Grand Rapids has recognized LEED as a valuable tool to meet its sustainability goals. In January 2006, the city commission approved a resolution directing city personnel to implement the principles of LEED and the corresponding Energy Star and Green Lights protocols, including a specific requirement that all municipal construction and renovation projects larger than 10,000 square feet and with a cost greater than \$1 million receive LEED certification. Additionally, the City’s zoning ordinance was aligned with pilot LEED-ND principles, which allow a developer who carefully follows the zoning ordinance to earn LEED-Neighborhood Development (ND) certification.

LEED has also become a critical component in how the City markets itself on the national stage, and for good reason. Grand Rapids has more buildings with LEED certification per capita than any mid-size U.S. city, and is fifth among all U.S. cities. It also currently has one of the world's highest LEED-rated buildings, Catalyst Partners/M Retail Solutions. It is also home to the first structures with LEED certification in many categories, including the first LEED Gold art museum (Grand Rapids Art Museum), the first LEED YMCA (the David D. Hunting YMCA), the first transit station (Rapid Central Bus Station), the first school (Goodwillie Environmental), the first Habitat for Humanity chapter to commit to build all LEED-certified housing, the first residence (St. Anthony of Padua rectory), the first church (Keystone Community Church), the first healthcare project (Lacks Cancer Center), and the first Double Gold building (East Hills Center of the Universe).⁶⁶

Keith Winn is the president of Catalyst Partners, a Grand Rapids-based business engaged in the development and implementation of green building design, development, construction, and LEED certification. A founder of the United States Green Building Council (USGBC), Winn was a project manager for the world's first LEED building, the Herman Miller Greenhouse in Holland, which served as the pilot project for the rating system in 1995.

Winn reports that early commitment to green building was driven by customer demand as much as by an interest in improved efficiency and productivity. The architecture and design community is intensely competitive, with sustainability a battleground issue.⁶⁷

The industry is already moving beyond the basic principles of LEED. (LEED status itself is a moving target, as the system raises the bar for its standards every three to five years.) Leading examples of this include Architecture 2030's challenge to make buildings carbon-neutral by 2030 and the Living Building Challenge, which has recently become visible in Grand Rapids thanks to its inclusion in a crowd-funded, affordable housing project to transform the Baxter neighborhood into a LEED Neighborhood Development area.

The Living Building Challenge is one of the world's most aggressive green building standards, encouraging developments to generate their own energy and process their own waste. It encourages a collaborative model in which multiple projects or buildings share in infrastructure investments.

The "Petals" of the [Living Building Challenge Standard 2.1](#) include:⁶⁸

- Site: Limits to Growth/Urban Agriculture/Habitat Exchange/Car-Free Living
- Water: Net Zero Water/Ecological Water Flow

- Energy: Net Zero Energy
- Health: Civilized Environment/Healthy Air/Biophilia
- Materials: Red List/Embodied Carbon Footprint/Responsible Industry/Appropriate Sourcing/Conservation + Reuse
- Equity: Human Scale + Humane Places/Democracy + Social Justice/Rights to Nature
- Beauty: Beauty + Spirit/Inspiration + Education

The Unique Role of the City of Grand Rapids in the Built Environment

Ultimately, climate change mitigation and resiliency improvements to the built environment are driven by cost and performance. Many private developers prioritize deadlines and budget over climate resiliency and environment. The success of “greening” the built environment will be determined by the extent to which project managers are able to demonstrate a return on investment or the mitigation of risk.

The value of potential gains in efficiency and productivity over the life of the investment—plus the secondary benefits found through marketing claims, talent attraction, and risk mitigation—is significant. There is also emerging evidence that green buildings command higher property values, while resilient buildings command lower insurance premiums.⁷⁰ However, due to the relatively low cost of energy, it is difficult to make a business case for some of the most innovative and furthest-reaching green building investments.

There is a secondary driver in green building and sustainability: leadership. Through its public commitment to green building, the City of Grand Rapids is demonstrating the value of best practices while forcing vendors to adopt practices they may have not otherwise considered. This phenomenon is well documented locally through nonprofits that seek capital campaign funds from the Wege Foundation, which requires LEED certification. In a similar fashion, the Michigan State Housing Development Authority is pushing developers of affordable housing toward sustainable practices through its green building incentives.⁷¹

Limitations of Green Building in Climate Resiliency

Until recently, green building practitioners have focused efforts on lessening the built environment’s contribution to climate change, primarily through emissions reduction. The most recent iteration of the USGBC standard available, LEED 3.0 in 2009, allocated more than 25% of its available points for reducing greenhouse gas emissions associated with building systems, transportation, water, waste, and

construction materials. A 2011 addendum on climate change resiliency created in partnership with the University of Michigan was careful to highlight that, although greenhouse gas emission reductions by definition mitigate climate change, practitioners should include both mitigation and adaptation strategies so that they may “shape the built environment in a way that is both responsive and resilient to future climate extremes.”⁷²

Adaptation is not part of LEED certification. However, through climate change resiliency guidelines USGBC has provided strong guidance on regionally specific design, construction, and operation strategies to make properties more climate-resilient. The core concept within the USGBC approach is that climate change has made the future inconveniently unpredictable. It can no longer be assumed that the future will be similar to the past, which creates a significant degree of problems for codes, standards, and practices. Adaptation strategies are necessary to ensure that the environments we design, build, and manage today will be suitable for a range of uncertain futures.⁷³ (For more specifics on how climate change informs decisions in the built environment, see “[Green Building and Climate Resilience: Understanding Impacts and Preparing for Changing Conditions](#)” by Larsen, L., et al.)

Incorporating Climate Adaptation into Existing Buildings⁷⁴

Green building and adaptation strategies must be applied to existing buildings as well as new building projects. Borrowing from the International Council for Local Environmental Initiatives (ICLEI) process, the steps below describe how a project team can integrate adaptation strategies to existing building sites:

1. *Understand regional impacts:* Identify climate impacts for the building’s region.
2. *Evaluate current operations and maintenance targets:* Understand the maintenance and operations to perform under current peak climate conditions.
3. *Conduct scenario analysis:* Analyze how the building will respond to projected climate change impacts, modeling different system options under a variety of climatic conditions.
4. *Implement adaptation strategies:* Install adaptation strategies that provide passive use of efficient responses to more extreme climate events in order to maintain occupant comfort while preventing increased energy use.

At all levels, the impacts of climate change on the built environment will depend on sensitivity and adaptability. As the MAGIC/SCENGEN model suggests, weather trends are relatively easy to project in

a general sense, but it is virtually impossible to forecast the myriad impacts with certainty. Adaptability is a function of flexibility and accuracy of the impact forecasts. By understanding probable impacts, design teams can set modified performance goals, diving deeper into project-specific changes at the building or neighborhood level, and select strategies to increase resiliency and adaptive capacity. Priority should be given to “no-regrets” strategies, those that will generate social or economic benefits whether or not climate change occurs.⁷⁵

2.4. Transportation

Transportation systems are community economic and quality-of-life assets that will be affected by climate change.⁷⁶ Transportation is considered one of the largest contributors to climate change. The IPCC estimates that transportation is responsible for 23% of global energy-related greenhouse gas emissions, with about three quarters coming from road vehicles.⁷⁷

It is estimated that transportation infrastructure in Grand Rapids currently requires \$33 million a year to maintain.⁷⁸ The 2013 Grand Rapids Sustainable Streets Task Force estimates that it costs \$22 million per year to keep 70% of Grand Rapids streets and sidewalks in good or fair condition.⁷⁹ Funding has not kept pace, and streets have experienced annual decline. In 2002, 40% of Grand Rapids streets were in poor condition. Approximately 60% of the City’s 588 miles of streets are in poor condition today. Almost 250 miles of those in poor condition are local or neighborhood streets.⁸⁰ As climate conditions shift, portions of this infrastructure will increasingly be subject to climate-driven stresses and require increased resources even to maintain status quo conditions.

The climate changes predicted by MAGICC/SCENGEN will directly impact transportation infrastructure and will indirectly impact the system through changes in resource allocation, planning methodology, transit modes, and settlement and patterns.⁸¹

Transportation Infrastructure

Traditionally constructed roads, sidewalks, and other transportation infrastructure in Grand Rapids will be affected by climate change, presenting new challenges for civil engineers and decision makers engaged in planning and maintaining the City’s roads. Road infrastructure was designed to withstand local weather and climate based on historical weather data and records of extreme storms. However, the EPA warns that “historical climate is no longer a reliable predictor of future impacts.”⁸²

Increased precipitation softens and erodes underlying base layers of roads, which results in damaged, warped, and cracked road surfaces. Inadequate drainage exacerbates these problems. During periods of



Figure 15. Periods of high temperatures soften and expand roadway materials, creating ruts, which are exacerbated by vehicles to create potholes. *Photo:* Nicholas Occhipinti

extended high temperatures, the roadway material softens and expands, creating ruts that are then aggravated by vehicles to create potholes (see Figure 15). Such failures will become more common if intense heat events continue to occur.⁸³

Abed Itani, transportation director with the Grand Valley Metropolitan Council, has increasingly observed the failure of temporary and insufficient patches on roads and sidewalks when subjected to temperature and weather extremes. Consequences include automobile and bicycle damage, safety risks, and traffic disruptions. Heat waves can also limit construction to repair damage on a timely basis, particularly during times of high humidity.⁸⁴

Itani believes the impact of these disruptions needs to be accounted for through the integration of better data sets, placing the frequency and severity of repairs in context of weather events.⁸⁵

During the spring months, faster stream flows from more frequent and intense rainfall, coupled with rapid snowmelt, could increase the likelihood of damage to bridges and drainage infrastructure such as culverts. High water levels may also impede travel routes and cause backups and delays. In April 2013, a surging Grand River caused the closure of Fulton Street Bridge (see Figure 16), a major artery in downtown Grand Rapids.⁸⁶ During the winter months, increased freeze-thaw events may occur within a single season, causing pavement to contract and expand while becoming more susceptible to water infiltration and further damage.⁸⁷

According to Itani, long-range transportation plans incorporate environmental mitigation strategies to minimize the impact of road construction and maintenance on environmentally sensitive areas. Under current “no net loss” policies, if destruction of wetlands cannot be avoided, additional wetlands must be established or enlarged to make up for the destruction.⁸⁸ Ensuring no net loss of



Figure 16. Flooding in Spring 2013 closed the Sixth Street and Fulton Street Bridges as well as others spanning the Grand River. *Photo:* Nicholas Occhipinti



Figure 17. Plainfield Avenue bioswales are designed for stormwater infiltration, neighborhood beautification, and multimodal transportation safety.

Photo: Grand Rapids Environmental Services Department

wetlands preserves natural green spaces and provides for natural stormwater absorption and drainage that does not rely on the City’s traditional “grey infrastructure” for treatment.

The Grand Valley Metro Council has maintained a policy of no new roads in the greater Grand Rapids area for the past 10 years, since the completion of M-6/South Beltline in 2004.⁸⁹ The focus on maintaining existing infrastructure encourages denser development and redevelopment of existing properties and space. Dense, multimodal, mixed-use development reduces the number and length of automobile trips. It also reduces climate emissions from fossil fuels and preserves climate-friendly green space.

Much of the reduced road construction is a result of limited state funding.⁹⁰ However, a lack of funds also prevents new developments that could improve Grand Rapids’s climate-resiliency infrastructure. The 2011 Green Grand Rapids report recommends “coordinated transportation and land-use decisions” that will establish new walking and bicycle trails throughout the City. It also recommends reducing the number of travel lanes on four-lane roads and increasing green space on medians to provide more green space and

bicycle lanes.⁹¹ The report encourages the deployment of “green streets” to manage stormwater where it falls with permeable pavement and rain-collecting landscaped areas around roads.⁹² Even in small increments, properly designed green space provides additional stormwater management. Such efforts are already in place on several roads in Grand Rapids. Roundabouts on Wealthy Street near downtown feature planted gardens in their centers, and a number of road medians in the City, including those on Fulton Street between Dwight and Eastern, are planted with greenery. Perhaps the best examples are the bioswales on Plainfield Avenue (see Figure 17). The project brought together the Michigan Department of Transportation, the City, local foundations, Meijer, and Creston Neighborhood business owners and leaders to beautify the district with greenery.

[Complete, vital, and green streets](#) encourage alternative, active transportation, reducing the wear and tear on existing roads (see Figure 18). Building these streets is an urban best practice recommended in both the 2002 Grand Rapids Master Plan and the Green Grand Rapids master plan update. The City Commission adopted a [Complete Streets Resolution](#) on March 22, 2011. Selected complete-street

layouts are already in design with further developments in progress.⁹³

Extensive implementation of these developments is difficult without proper funding. In particular, rebuilding streets to complete street standards can increase construction costs, often making these projects prohibitive in current financial climates.⁹⁴ Funding mechanisms have been identified at both the state and local level, but a solution has not yet been found.



Figure 18. Complete and vital streets decrease CO₂ emissions while diversifying Grand Rapids’s transportation portfolio, building resiliency into the system. *Photo:* Neil Jennings (FC)

While climate impacts will generally cause greater expense for transportation planners, there may also be cost savings. The increased variability of weather patterns, for example, may also lead to milder winters, requiring less road salting and fewer repairs.⁹⁵

Climate Impacts to Transportation Systems

The transportation system is built and maintained to serve “all people of our community” for various purposes.⁹⁶ Eighty-eight percent of Grand Rapids commuters use personal vehicles as their primary mode of transportation. Alternatives include walking, at 2.9%; public transportation, at 2.8%; other options, at 2.0%; and the rest work from home.⁹⁷ Planning initiatives at the city and regional level have focused primarily on maintaining the current state of the transportation system while incrementally introducing and improving alternatives—for example, bike lanes where they can be easily added (usually painted) and an upgrade of the City’s bus system (the Rapid) in the new Bus Rapid Transit program (BRT).⁹⁸

However, more community leaders are now speaking about a process of “changing the culture” downtown, preferring access to sustainable, multimodal forms of transportation. The City of Grand Rapids and the Downtown Development Authority recently announced a plan to increase parking meter rates and shift revenue from Parking Services to the Downtown Development Authority to fund a new position focused on transportation demand management. In addition to diversifying access and reducing emissions, the idea could free up land within the City for more fruitful uses than parking.



Figure 19. The Rapid's Transit Master Plan Final Report (*click image to view*). Collaborative planning fostered community buy-in.

The Rapid has expanded bus services to new areas, increasing routes, frequency, and the number of buses. It has also begun construction of Michigan's first bus rapid transit line (see Figure 19). The line is intended to begin operating in August 2014 and service is expected to be 40% faster than traditional routes. System and operational improvements have been noticed by the American Public Transportation Association, which named the Rapid an [Outstanding Public Transportation System](#) for a mid-size city.

In three years, Grand Rapids has gone from zero miles of on-street bike facilities to 35 miles as of October 2013. The region's first cycletrack, a two-way bike facility separated from vehicular traffic, will be constructed in Spring 2014. In addition, the Lyon Street Bikeway, proposed for construction in 2015, would connect Plymouth Avenue to Division Avenue. The bikeway would include a cycletrack and the region's first bicycle signal system.⁹⁹

People will experience transportation climate impacts in different ways. The most drastic impacts are likely to be felt by underrepresented and vulnerable populations, such as minorities, the elderly, the sick, and the poor. For many in Grand Rapids, basic needs such as fresh food, medical care, and employment are not easily accessible.¹⁰⁰ These populations disproportionately rely on less-sheltered forms of transportation—public, biking, walking, and other modes.¹⁰¹ Improving multimodal access will benefit these populations, but care will be required to minimize the impact of extreme temperatures, precipitation, and poor air quality. (See the [Air Quality section](#).)

Through much research and planning, Grand Rapids has successfully laid the intellectual foundation to build a more climate-resilient transportation system. The Sustainable Streets Task Force builds upon previous planning initiatives such as the 21st Century Infrastructure Task Force. The Green Grand Rapids Master Plan calls for low-impact development, complete streets, and bike lanes. The City's Sustainability Plan lays out related goals and benchmarks. The [Michigan Street Corridor Plan](#), a 2011 U.S. Department of Housing and Urban Development Sustainable Communities Challenge grant recipient, is a corridor-specific improvement project that details the relationship between commerce, residential needs, transportation, economic development, and the environment. Implementation projects have begun across the City, but resources are needed to implement the plans.

A multimodal transportation allows a broad spectrum of citizens to obtain basic needs. This in turn reduces the burden on the rest of the community to provide these services. Although there are financial, institutional, and structural challenges to overcome, Grand Rapids has developed robust strategies for building transportation resiliency.

2.5 Agriculture

Kent County has 170,117 acres of farmland. Its 1,193 farms produce a market value of crop and livestock sales of nearly \$195 million, fifth highest of any county in the state. Grand Rapids is dependent on a healthy local farm economy and the fresh food it produces.

While climate change can be modeled to make predictions, it is difficult to understand the interactions between atmospheric and terrestrial systems.¹⁰² Due to this limitation, we do not fully understand how climate change will affect Michigan crops. However, we can expect that there will be impacts—and a discussion of potential climate impacts allows stakeholders to be prepared for multiple future scenarios.

Extreme weather events may also occur in relative rapid succession, which makes planning difficult. For agriculture in particular, climate change also affects plant growth, the spread of pests and diseases, and water availability in both positive and negative ways.¹⁰³

The agricultural sector will also face known and unknown feedback loops. For example, while greater rainfall and a longer growing season can enhance crop growth, they can also lead to more plant disease and different and perhaps more virulent pests. Furthermore, if the greatest precipitation occurs in winter rather than summer, then the longer growing season will not necessarily enhance rain-fed yields and may delay the springtime drying of soil. On the other hand, if greater precipitation occurs in summer but in fewer yet more intense storms, the benefit may be offset by nitrogen loss, erosion, and other fertility problems.¹⁰⁴ Precipitation is one of many climate changes that illustrate the complex interactions between terrestrial, anthropogenic, and climate variables.

An additional consideration in the agricultural sector is increased levels of carbon dioxide in the atmosphere. Carbon fertilization refers to the idea that increased CO₂ concentrations in the atmosphere will increase crop yields.¹⁰⁵ In fact, tests in controlled environments show this to be true, and could be possible in real-world situations so long as other factors such as water availability do not limit their growth. Yet some researchers have indicated that estimates of increased yield from elevated CO₂ may be overestimated, as most experiments were conducted in enclosures that do not replicate interacting factors such as weeds, nutrients, soil moisture, and decreased air quality.¹⁰⁶

The general warming trend of the region as indicated by the modeling can also be viewed positively and negatively. Some view the trend as an opportunity for varieties of crops typically planted in more southern climates to be planted farther north.¹⁰⁷ While this may be true, there is an optimum temperature for reproductive growth. Once that maximum is exceeded, plant and seed growth is diminished, reducing yields.¹⁰⁸ Additionally, water availability may be limited as higher temperatures increase plant water use and transpiration.¹⁰⁹ Many climate models indicate an overall warming trend but also show seasonal temperatures becoming more volatile and variable. This would cause extreme swings in temperature during all seasons but especially during spring and summer.¹¹⁰

Spring and Summer 2012

Much of the concern over climate change for the agricultural industry, however, comes from the uncertainty caused not by long-term warming trends or precipitation patterns but by volatile and variable weather patterns. These patterns may be from year to year or even from season to season. For West Michigan growers, this concern was fully realized during the spring and summer of 2012.

On March 14, temperatures soared to record highs in the mid- to upper 80s and lasted for seven consecutive days (or longer in some areas).¹¹¹ The prolonged hot temperatures caused fruit trees to blossom early, leaving them exposed and vulnerable when the weather returned to normal. In mid-April, just weeks after record temperatures, there were several consecutive nights when temperatures went below 27 °F, causing a deep frost. Most farmers had little time or resources to prepare for such an event, though some deployed large fans at the ends of rows to circulate air, and others used irrigation systems to keep the soil moist and allow more warm air to be held in the soil under the plants. However, the events were so sudden, severe, and widespread that 80% to 95% of fruit crops in the region were killed, including apples, grapes, cherries, blueberries, and peaches. These unusual weather events resulted in severe economic losses for Michigan growers, particularly in West Michigan, where 65% of the state's apple growers are located.

The estimated loss across the state totaled almost \$210 million, with an estimated economic impact of \$503 million (see Table 2).¹¹²

Table 2. 2012 Michigan Weather-Related Crop Loss

Crop	Percentage Loss	Value of Loss
Apple	90%	\$108 million
Tart cherry	90%	\$38 million
Blueberry	15%	\$20 million
Juice grape	85%	\$17 million
Peach	95%	\$12 million
Sweet cherry	80%	\$12 million
Total		\$207 million

Growers of field crops faced a crisis that summer, as a severe drought struck the entire country from mid-June through mid-August. Eighty percent of agricultural land experienced drought conditions; it was the most extensive drought since 1950.¹¹³ In Michigan, 80% of the state was in some stage of drought, with 51% of the corn crop and 35% of soybeans rated poor.¹¹⁴

It is impossible to know if the weather events of 2012 were caused specifically by climate change. However, they represent the types of events and patterns that MAGICC/SCENGEN and other climate models predict could become more frequent.

Assessing Agricultural Risk

It is important for the agricultural sector to understand its vulnerabilities and prepare for multiple future climate scenarios. The first step to decreasing vulnerability is to assess the risk that a particular operation has when considering the predicted climate changes and impacts. Governmental agencies such as the [Michigan Department of Environmental Quality](#) (MDEQ), the [Michigan Department of Agriculture and Rural Development](#) (MDARD), and the [U.S. Department of Agriculture](#) (USDA) can provide advice for farmers and growers, as they have industry-specific resources and expertise regarding climate change. Academic and nonprofit institutions such as [Michigan State University's Extension Program](#) and [The Nature Conservancy](#) can also provide assistance.

Agriculture can also look to the insurance industry for guidance. Insurers have long had to collect data on climate and weather patterns in order to better inform their programs and services. Insurers can also provide coverage for lost crops due to climate-related events.

Climate-Resiliency Strategies for the Agricultural Industry

The agricultural industry can develop and implement resiliency goals and practices (see Figure 20 for an example).¹¹⁵ Although the techniques used by farmers and growers to adapt to the 2012 spring and summer conditions may have seemed ineffective, they did prevent even greater loss. A best-practice example is the use of proper irrigation systems that adequately and efficiently water soil immediately surrounding plants. To do this effectively, practitioners must understand the sites' specific soil characteristics and water availability, including predicted precipitation amounts and patterns, nearby surface water resources, soil moisture needs for the crops, and groundwater levels during times of drought and saturation. In emergencies, farmers have deployed large fans to ensure air movement or helicopters to circulate warmer air onto crops.

Some of these techniques are expensive and may seem unrealistic for a smaller farmer to pursue. However, farm co-ops already pool resources for harvesting and marketing. This same co-operative idea could be used to collect knowledge regarding impacts from climate change and the proper equipment to mitigate or adapt to its impacts. In Grand Rapids, the Fulton Street Farmers Market already hopes that its venue and planning initiatives will spur conversation about best practices and the opportunities and challenges that the agriculture system faces.


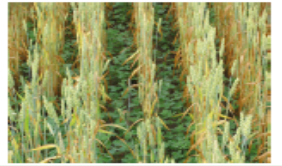


Goal	Practice	Additional benefit to farmers	
Reduce fossil fuel consumption	Renewable energy sources, improved efficiency equipment, biofuel crop substitution	Saves money, potential new biofuel crops and markets.	
Restore (sequester) soil carbon: increase carbon inputs to soil	Crop diversity through cover crops and rotations; increase crop residue quantity in no-till; manure and compost additions	Improves soil and water quality. Reduces erosion.	
Restore (sequester) soil carbon: reduce carbon loss from soil	Permanent no-till, retain crop residue, perennial crops	Improves soil, water, and air quality. Reduces soil erosion and fuel use.	
Reduce nitrous oxide emissions	Better manage nitrogen fertilizer use	Improves water quality. Saves expenses, time, and labor.	

Figure 20. Climate resiliency goals for the agriculture industry.¹¹⁶

Not only will West Michigan agricultural systems be impacted by climate change, but they can also play a role in diminishing or exacerbating climate change emissions and impacts. For instance, agricultural practices both emit and remove two of the most important greenhouse gases, CO₂ and nitrous oxide. Through photosynthesis, crops remove CO₂ from the atmosphere and use it to build plant tissue. Some of this carbon can be stored in the soil as organic matter. However, when the soil is tilled, microbes are stimulated to move quickly to convert organic carbon to CO₂, which escapes into the atmosphere. In most farmed soils, tillage has caused the release of 40% to 60% of original soil carbon.¹¹⁷

2.6 Insurance and Risk Management

In December 2011 the World Bank published “[The Sendai Report: Managing Disaster Risks for a Resilient Future](#).” The report warns that crossing the 2 °C temperature increase threshold would have “major implications on global ecosystems, agriculture and water supply, sea level rise and storm surges.”¹¹⁸

The Sendai Report also references the IPCC 2012 “[Special Report on Extreme Events](#),” which details the latest scientific consensus on the likely impact of climate change on natural disasters: “a changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events, and can result in unprecedented extreme weather and climate events.” Among other things, the report predicts that once-in-20-years storms are likely to become 1-in-5 or 1-in-15 events in many regions by the end of the twenty-first century. This has vast implications for some of the world’s largest companies and the insurers responsible for covering those companies. A report from global consulting firm Mercer estimated the climate change risk implicit in traditional asset-management strategies to be as high as 10% of portfolio value.¹¹⁹

Insurance companies, and reinsurance companies in particular, are taking action on climate change. They are working it into their business models, quantitatively programming it into their rates, and advocating for climate action at the United Nations (UN) and to world governments. Reinsurers are the last fiscal stop on the economic damage train. Climate change becomes harder to ignore when it consistently and fundamentally impacts the bottom line.

According to Marsh, a global risk management firm:

“The climate is changing and no company is immune from the consequences. ... Measured changes in the climate have already affected the way that a number of businesses manage risks and [climate change] is set to have even more profound consequences on the way that many other companies will operate in the future. For example, the costs of the floods in the UK in 2007 were estimated to have

been around 3 billion British pounds, while in 25 years' time it is predicted that flood damage will cost the UK economy around GBP10 billion every year. [This] indicates a rising trend, the largest level of insured losses in any one year will probably be much higher."¹²⁰

According to Marsh, "climate change should be amongst the top considerations companies will need to take into account when making long-term capital investment decisions."¹²¹ Marsh notes that projects exposed to rising sea levels, extreme drought, flooding, or severe storms are the most vulnerable. It recommends that such endeavors be environmentally friendly and "climate proof."¹²² Another leading global reinsurer, [Munich RE](#), has advocated for a climate plan aiming to develop renewable energy sources that can compete financially with fossil energy sources in the medium term.¹²³

Local Risk Management Insights

Jon Job, a field engineer for FM Global Insurance Company, a company that has held policies for Grand Rapids and Kent County in the past, provided local insurance insights for this report.¹²⁴ Some of his top climate-related insurance concerns are:

- Flooding of basements, particularly in institutions such as hospitals and universities. Hospitals often store expensive equipment in basements, and when these are located near the bottom of a hill in a floodplain or in bowl areas they are prone to flooding.
- Wind damage, particularly during extreme weather events. Anecdotally, tornados seem to be causing more economic damage nationally. (Climate scientists have not been able to find strong data linking tornadic activity to climate change.)
- Snow drifts and the weight load added to structures during snow events.
- Power loss is a particular concern in freezing temperatures, threatening pipes, plumbing, and electrical infrastructure.

FM Global employs a strategy of "loss prevention" to protect clients and its own bottom line from climate change, utilizing national flood maps and elevation data from the Federal Emergency Management Agency's website, the latest rainfall data from the National Weather Service, and official airport rain gauges and [The Weather Underground](#) website. The Weather Underground uses private stormwater conveyance data and rain gauges to build a more robust data set. FM Global asks its clients to provide stormwater drainage/barriers on their sites to keep stormwater from entering buildings, basements, and tunnels, a recommendation based on damage from actual recent heavy rainstorms.¹²⁵

Job notes that the occurrence of a storm event in proximity to a client site goes a long way in convincing the client of the need to make improvements, adding that regulations may be needed to convince some companies to do the right thing. He recommends a number of on-site, preventative actions to decrease exposure to weather and climate-related damage:

- Design simple flood barriers into buildings to prevent water from entering.
- Review site drainage plan to ensure enough green space and storage capacity.
- On-site stormwater containment to slow water infiltration and mitigate effects of localized flooding.
- Design landscaping to move water away from buildings.
- Hydrologic forcing—ensuring consistent groundwater pressure is not an easy task. Buildings are particularly vulnerable at floors and wall joints. Buildings below the water table should be designed accordingly.

According to Job, there will at times be a conflict between climate adaptation and mitigation strategies. For example, power companies cut down trees and branches near electrical lines, but these trees might have been providing shade to a building structure, road, or sidewalk. The World Bank offers some guidance, suggesting a preference for activities that “help manage disaster risk now and offer near-term development benefits, while reducing vulnerability over the longer term.”¹²⁶

2.7 Climate Change’s Emerging Economic Opportunities

“Uncertainty around climate policy is a significant source of portfolio risk for institutional investors to manage over the next 20 years. The economic cost of climate policy for the market to absorb is estimated to amount to as much as approximately \$8 trillion cumulatively, by 2030.”¹²⁷

This passage from Mercer’s [“Climate Change Scenarios—A Report for Strategic Asset Allocation”](#) illustrates several important concepts. The first is that climate change has economic implications across economic sectors. Second, climate change will bring with it risk and cost.

However, one firm’s costs may well be another firm’s revenue. For example, when New York City builds higher sea walls to adapt to climate change, the firms designing and building the walls will receive a new revenue stream, which they will then use to pay employees, contractors, and taxes. Some industries will lose and others will gain. The Mercer report lays out some of the likely winners and losers of climate change: Infrastructure, private equity, and real estate are anticipated to be highly sensitive to climate change, while sustainable assets could act as a hedge.

Good Stewardship Reflects Good Management

Brian Salerno, vice president and senior investment portfolio manager for Huntington Bank in Grand Rapids, has thought about sustainable assets for some time. Salerno was integral to the creation of Huntington Bank's EcoLogical Strategy Exchange-Traded Fund (New York Stock Exchange symbol: HECO). He developed the fund to align financial investment with macro societal trends and his belief that human habits, capital, and regulations favor a global environmental movement.



Figure 21. Horizontal Engineering Company works with the Minnesota Army National Guard to repair a levee. Photo: Sgt. First Class Daniel Ewer, U.S. Army

Salerno bases this belief on several recent studies suggesting that “large companies that have been good stewards of the environment have also been better stewards of capital for investors.”¹²⁸ In the *Financial Analysts Journal*, Derwall, Guenster, Bauer, and Koedijk compared the performance of two equity portfolios. The more “eco-efficient” portfolio had “substantially higher average returns than its low-ranked counterpart over the 1995–2003 period. This performance differential could not be explained by differences in market sensitivity, investment style, or industry-specific factors. Moreover, the results remained significant for all levels of transaction costs, suggesting that the incremental benefits of socially responsible investing can be substantial.”¹²⁹

Salerno reasons that superior ecological practices are a good indicator of high-quality management. He believes that companies that take steps to reduce pollution, energy usage, waste, and overall environmental footprint are run by folks who are “just a little bit smarter.” These companies have aggressively pursued low-hanging fruit and then some. They recycle, encourage employees to carpool, and have installed energy-efficient lighting. Some of the organizations have “longer-term” energy agreements—locking costs in over 20 years—possibly even paying more in the short term to do so. “It’s good for business, reputation, and it’s really good for risk management.”

Huntington Bank's EcoLogical Strategy fund is based on two types of companies: producers of eco-friendly goods and services and those that use eco-friendly goods. The fund includes only public companies with a track record of profitability. Salerno notes that with sustainability becoming more prominent in business schools and business practices, he is seeing a “greater number of companies that make environmentally sound products reach profitability.”¹³⁰ Huntington Bank's EcoLogical Strategy fund has largely kept pace with the Standard & Poor's 500 Index since its inception.

Natural Capital: Valuing Ecosystem Services and Monetizing Externalities

Most economic systems acknowledge, but fail to value, the capital provided by natural resources. **Natural capital can be defined as the raw materials, benefits, and services provided by nature that fuel the basic economic productivity necessary for human survival.** Rainfall to irrigate crops, clean water, and clean air, as well as liquid, solid, and organic raw materials are just a few examples.

Natural capital is not easy to identify in a relatively depleted and largely built urban landscape, but it is still omnipresent. For example, what is the value of the Grand River as a viable fishery, as municipal receiving water, and as an economic development tool? What boost do riverfront property values get from proximity to a relatively clean, odor-free river? (See Figure 22.)

It may seem impossible to put a value on such important, traditionally invaluable resources, but it's not. Using an assortment of economic valuation tools and a robust, triple bottom line econometric cost-benefit analysis that includes major externalities, economists are able to develop reasonable estimates. As will be discussed in [a later chapter](#), the Grand Rapids Urban Forestry Project has estimated the portion of the City's natural capital provided by the urban tree canopy: If all of the trees in



Figure 22. Natural capital: What percentage of the price of every drink sold at the JW Marriott's six.one.six bar can be directly attributed to the river view? Photo: Steven Depolo

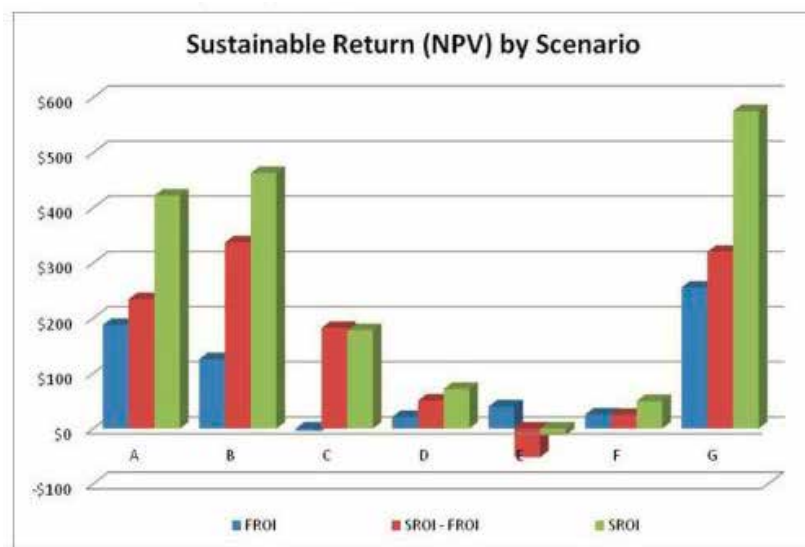


Figure 23. Holland Board of Public Works, energy-generation scenarios A–G. (Holland Board of Public Works, 2012)

Grand Rapids disappeared, the City would need to construct an additional 67 million cubic feet of stormwater storage. This benefit alone is worth an estimated \$32 million annually.¹³¹

Economic valuation of natural capital and environmental services is increasingly common at most levels of government and decision making. One of its more common forms is the valuation of externalities. The City of Holland recently employed

such a valuation when it calculated the [sustainable return on investment](#) of seven different municipal utility energy-generation scenarios (see Figure 23).¹³² Economists were hired to work with community members to value natural capital and monetize externalities, including CO₂ emissions, particulate matter, mercury, impact on harbor dredging, lakefront property values, and more. This analysis more robustly captured the predicted economic impact. Figure 23 displays the direct fiscal return (blue) for the limited stakeholders involved in the direct financial transactions associated with the scenarios. More interesting is the net social benefit (green) that would accrue to the community at large.

3 ENVIRONMENTAL ISSUES

A changing climate will impact the environment globally in both the long and short term. Grand Rapids, as a mid-size urban (density greater than 1,000 people per square mile) city in the Midwest, is not exempt from these effects. Certainly, climate change's impact on the environment will be of a different nature and different scale depending on many factors, including but not limited to the location, type, endowment, and health of local ecosystems. A short list of Grand Rapids's critical natural systems includes the Grand River and its watershed, the urban tree canopy, soils, hydrology, air, biota (the combined flora and fauna), and biogeochemistry ([chemical](#), [physical](#), [geological](#), and [biological](#) processes and reactions that govern the composition of the natural environment). Because urban spaces are highly developed, they often have less pristine "environments" to be impacted but are still wholly integrated and reliant on natural systems.

3.1 Stormwater Management

Increased precipitation and more intense wet-weather events will strain the stormwater system. MAGICC/SCENGEN and national climate modeling predicts Grand Rapids can expect increased precipitation.¹³³ The Grand River and the Great Lakes are vital to our community's quality of life. In fact, Grand Rapids has historically been connected by and to the Grand River. It was what initially attracted settlers to the region and was the force behind the City's first century of industrial investment. Today it remains the central geographic and topographic feature in our community, a critical part of civic life and downtown revitalization.

Development has drastically altered the West Michigan landscape. Native vegetation has been cleared, rivers buried, floodplains built upon, and large swaths of the ground paved. Unable to soak naturally back into the ground, rainwater instead runs over impervious surfaces and into the sewer system or local waterways as stormwater runoff. Ultimately, the stormwater system conveys it to streams, rivers, and lakes, impacting river hydraulics and temperature and carrying with it a variety of pollutants.

Controlling stormwater and protecting water quality benefit the environment and improve quality of life. Maintaining high water quality is a basic requirement for successful recreation programs and is also a major contributor to public health and safety. Stormwater management is the front line of water pollution prevention in West Michigan and the protection of the region's water resources.

Building on Recent Success

Over the past two decades Grand Rapids has spent hundreds of millions of dollars separating its sanitary and stormwater systems—all but eliminating sewage overflows into the Grand River. This has improved the water quality of both the Grand River and Lake Michigan (see Figure 24).¹³⁴

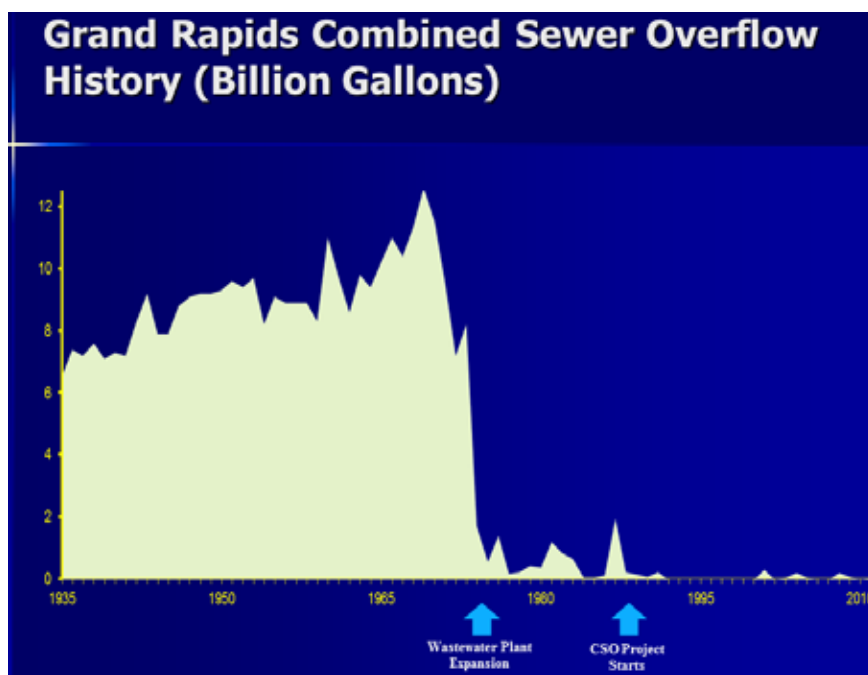


Figure 24. City of Grand Rapids combined sewer overflows.

However, water pollution is still a problem in Grand Rapids and West Michigan. The Grand River and Plaster Creek remain listed as impaired waterways under the Clean Water Act. Plaster Creek is contaminated to the point that human body contact restrictions have been put in place.

Mike Lunn, manager of the City of Grand Rapids Environmental Services Department, is responsible for overseeing the City’s stormwater and wastewater systems. According to Lunn, rain and snow lead to problems and costs for municipal storm and wastewater systems. Significant wet-weather events put increased volumes, velocities, and pressures on the city infrastructure. Significant and dynamic flows cause outfalls to collapse, ditches to erode, pipes to burst, and streets and basements to flood. This has always been true, but climate change will exacerbate these effects.¹³⁵

Grand Rapids Moves Stormwater Management Forward

Stormwater management is vital to long-term economic growth and stability in Grand Rapids. It protects infrastructure and private and public property; it also contributes to the attraction and retention of talent and capital.

“All of our infrastructure is designed for where we live,” says Lunn. “If we lived in Florida, [we would] design for that heat. You don’t have to look far to see that things are made to be here. In 2050, if you have a palm tree out front, things will have changed significantly.”¹³⁶

The City has been examining its stormwater management plans and processes for decades, making improvements whenever practical. The City's stormwater ordinance was filled with best practices and was considered a model for other communities. The ordinance encourages 100% stormwater retention on new development sites using an incentive-based program that allows developers to obtain "greenspace" credits: Green roofs, green walls, planters, and other green infrastructure techniques reduce the amount of stormwater.

Recently, in partnership with WMEAC, the Community-Based Stormwater Planning Initiative completed a two-year stakeholder engagement and research project with a [report](#) and recommendations to the Grand Rapids City Commission. The City acted on one of the stakeholder group's core recommendations in 2012 when it commissioned a [Stormwater Asset Management Plan complete with Capital Improvement Plan](#), a [Stormwater Master Plan](#), and a [technical reference manual](#).¹³⁷

The Stormwater Asset Management Plan inventoried the entire stormwater infrastructure system, including pipes, culverts, catch basins, gravity mains, pumps, green infrastructure, etc. The inventory was programmed into customizable asset-management optimization software. The software provides organized, updatable, project- and system-wide development-planning capabilities. It calculates business risk exposure using probability of failure and consequence of failure to prioritize maintenance and replacement needs. The tool can be run to identify a prioritized capital improvement project list and system-wide costs based on level of service.

The Stormwater Master Plan is an update of the 1994 Plan that established standards with respect to the use and operation of the City's stormwater system. It discusses the legal and regulatory framework of stormwater management, details existing projects and local watershed plans, and lists recommendations for the future.

The Technical Reference Manual lays out stormwater standards, technical criteria, and methods for how projects are to be implemented in the City. The Technical Reference Manual is based in large part on requirements in the City's stormwater ordinance, but enables staff to update technical standards as they become available. An excellent example of this is NOAA's recently released Atlas 14 hydro-meteorological rainfall data. This is the most up-to-date rainfall data available and should replace the Huff and Angel 1992 report that is currently used in Grand Rapids. This data is important because it is used to design and retrofit stormwater and wastewater infrastructure features such as conveyance and overflow capacity. It will become even more important over time as it works its way into state and national regulatory policy.¹³⁸

Green Infrastructure and Low-Impact Development

One of the most important outcomes of the asset-management process was the articulation and documentation of a “paradigm shift in how we think about managing runoff.” According to the 2013 Stormwater Master Plan:

“The character of stormwater management has [changed] and continues to change. Originally, stormwater systems were built just for conveyance, with a mindset of ‘get it out quick.’ Now, stormwater management is a component of a comprehensive integrated urban water resource. The new mantra is ‘slow it down, spread it out, and soak it in.’ Contemporary stormwater management includes quantity and quality considerations, multiple-use facilities, riparian corridors, recreation, wetland preservation, and groundwater recharge. The new approaches require a paradigm shift on how we think about managing runoff...”¹³⁹

Green infrastructure and low-impact development are stormwater management techniques that mimic predevelopment natural systems and hydraulics, the way that West Michigan land looked before settlers began to clear away vegetation for farming, housing, and urban development. These are generally considered stormwater management best practices because they address both water quantity and quality issues. Some common examples include trees, rain gardens, rain barrels, infiltration basins (see Figure 25), and pervious pavement.

The practice is often more cost-effective than conventional stormwater infrastructure and may reduce the need for road construction as critical underground infrastructure is replaced with surface features.

The economic benefits become most distinct when a new stormwater system or improvement is considered. Early adopters have found that green stormwater infrastructure is generally cheaper



Figure 25. The City has installed a number of infiltration basins around town to capture stormwater near where it falls to help it slowly seep back into the ground. Photo: Grand Rapids Environmental Services Department

to build and maintain than the corresponding “grey” infrastructure. Significant savings can be realized due to the reduced costs for site grading and preparation, paving, and landscaping.

In a review of 17 case studies, a [US EPA report](#) identified total capital cost savings ranging from 15% to 80% when low-impact development methods were used, with a few exceptions.¹⁴⁰ A 2012 study of 479 projects from 43 states and Canada found a multitude of projects that were less costly than grey infrastructure: 44% demonstrated likely cost reduction, 24.5% had increased costs, and 31.4% did not influence cost.¹⁴¹

Green infrastructure isn't a silver bullet; there are constraints on its use. It generally works better in sandy soils and above water tables. Clay-filled soils and low-lying areas present difficulties. Integrating green infrastructure into built, dense neighborhoods can also be challenging. However, in such areas rooftops, tree canopies, parking space, and right-of-ways can be used.

Generally, stormwater practitioners and environmental engineers consider green infrastructure on a site-by-site basis. The downside of this approach is that more thought and custom design have to go into each project. The upside is that project managers have flexibility to conform to a site's "best fit" criteria. In close proximity to residences and businesses, this flexibility could be a tremendous asset.

Lunn confirms that the City is integrating this approach into departmental decision making: "We're moving gradually from [its being] a nice add-on to [its being] a first-line decision on green infrastructure. That process is happening. That will enable us to be more resilient."¹⁴²

Grand Rapids is not the only community that will have to move in this direction. In fact, the new paradigm will be reflected in the proposed US EPA Stormwater Rules.¹⁴³

3.2 Flooding

Evidence suggests that the frequency of downpours is increasing: Heavy downpours are now twice as frequent as they were a century ago. Both summer and winter precipitation has been above-average for the last three decades, the wettest period in a century. The Midwest has experienced two record-breaking floods in the past 15 years.¹⁴⁴

The Union of Concerned Scientists expects this trend to continue, estimating that the frequency of heavy rainstorms, both 24-hour and multi-day, will continue to increase during the next century and may double by 2100.¹⁴⁵ Wet-weather events can stress the existing storm and waste water infrastructure. When natural or built infrastructure becomes overwhelmed, flooding results.

Flooding negatively impacts the built environment and the human populace, causing damage to homes, commercial property, and infrastructure. Less obvious is flooding's impact on the environment and ecosystem.

Flooding is a natural, cyclical part of the environment, an integral process that makes many ecological and human systems possible. In "Confronting Climate Change in the Great Lakes Region," the Union of Concerned Scientists summarizes the consequences of flooding on natural systems:

"Floods exert their greatest physical influence by reshaping river channels and inundating floodplains, and by moving large wood and sediments. Intense floods can scour the channel, resulting in mass

mortality to algal, invertebrate, and vertebrate species. Under high flow regimes, water quality is often degraded when untreated human, commercial, or agricultural wastes overflow from treatment facilities or when soils are eroded from agricultural fields treated with pesticides and fertilizers (US EPA 1993; Adams et al. 1999). High water flow also diminishes the capacity of the stream to recycle nutrients and sequester suspended or dissolved organic matter because of reduced water contact with the stream bank and substrate (Mulholland et al. 1985; D'Angelo et al. 1991) and reduced retention structures such as wood dams (Munn and Meyer 1990; Wallace et al. 1995). Channelized urban and agricultural streams have very low water-retention capabilities, and the anticipated increases in spring runoff by the end of the century are expected to result in increased height of spring floods and lower nutrient and sediment retention in these streams.¹⁴⁶

Flooding impacts ecosystems and alters the hydrology of water bodies such as the Grand River. Changes in the timing and severity of flood pulses are likely to reduce safe breeding sites, especially for amphibians, migratory shorebirds, and waterfowl, and may cause many northern migratory species such as Canadian geese to winter further north.¹⁴⁷

Three Types of Urban Flooding

According to Lunn, there are significant differences between various flood events in Grand Rapids, which has been a point of confusion for residents.¹⁴⁸

1. Localized, temporary flooding often occurs during and after storms and is considered a normal part of the stormwater system. The gutter, street, and catch basins are designed to carry water during major wet-weather events.
2. Floods can be caused by equipment malfunction or infrastructure failure, such as a clogged catch basin. This type of flooding can be avoided by proactive maintenance of the system.
3. The most serious type of flood is one that occurs when all infrastructure is overwhelmed by a major wet-weather event. This type of flood cannot be prevented but can be mitigated through widespread adoption of green infrastructure. The Grand River Flood of 2013 is a prime example of this.

Grand River Flood of 2013

April 2013 was the third wettest month on record in Grand Rapids, causing serious flooding that illustrates the potential impact of increased downpours. On April 22, the Grand River crested at 21.85 feet, breaking a 30-year record by more than two feet (see Figure 26). Mayor Heartwell declared a state of emergency as the City incurred damages of approximately \$5 million. An additional \$10.6 million in damage was estimated for Kent County. During this time, the City of Grand Rapids released some 429 million gallons of partially



Figure 26. On April 22, 2013, the Grand River crested at 21.85 feet.
 Photo: Nicholas Occhipinti

as California that have well delineated wet and dry seasons. In Grand Rapids it refers to the first few moments of a significant wet-weather event, when a much higher portion of pollutants is carried to bodies of surface water relative to later during that same storm.

Research preceding regulatory changes in the 1990s documented the first flush,¹⁵⁰ though specific delineation through empirical quantification is difficult. It may also be useful to distinguish between mass-based first flush and concentration-based first flush. The concentration first flush, the more common of the two, refers to the proportion of pollutant load in the runoff, whereas the mass first flush is flow-dependent (flow multiplied by concentration).¹⁵¹

Understanding the concept is quite important for designing the most efficient and effective stormwater controls. According to Mike Lunn, the City is most concerned with capturing the 90th- or 95th-percentile rain event, or rain events of one inch or less. This aligns with US EPA recommendations. “If we can capture that first flush, that first inch of rain, and keep it out of the river, we’ll keep a lot of trash, sediment, *E. coli*, oil, and grease out of our waterway.”¹⁵² (See Figures 27 and 28.) Green infrastructure, retention areas, and the urban

treated sewage into the Grand River. National Weather Service hydrologist Mark Walton estimates that three or four more inches of rain would have brought floodwaters onto bridges and the tops of flood walls.¹⁴⁹

Capture the First Flush

The term “first flush” refers to the initial moments of a wet-weather event that are the most environmentally damaging. The concept is both seasonal—the first rain ending the dry season—and event-specific. The seasonal first flush is more associated with states such



Figure 27. During the Great Flood of 2013 the Grand River plume extended much further into Lake Michigan than is typical, depositing flood detritus along miles of shoreline.
 Photo: Marge Beaver



Figure 28. The Great Flood of 2013 deposited piles of natural debris and trash on Lake Michigan beaches.

Photo: Carol Cooper, Carol Cooper Photography

tree canopy are important tools in capturing the first flush. According to the “[Banking on Green](#)” report, there are economic reasons for capturing the first flush:

“The potential for damages caused by smaller storms is one incentive for employing management strategies like green infrastructure....In fact, the Federal Emergency Management Agency estimates that up to 25% of economic losses resulting from flooding occur in areas not designated as being in a ‘floodplain,’ but as a consequence of urban drainage. Since 1978, the National Flood Insurance Program has paid over \$2.8 billion in claims, related to localized flooding.”¹⁵³

Market Avenue Retention Basin (MARB)

The MARB is an important wet-weather tool for Grand Rapids. MARB backs up the City’s wastewater treatment plant, which can treat a maximum of 90 million gallons per day. In the event of a major storm, sewer and stormwater flows can exceed the wastewater treatment plant’s capacity. To prevent a direct discharge of untreated wastewater into the Grand River, MARB can store an additional 30 million gallons of wastewater and partially treat up to one billion gallons per day.^{154,155} MARB provides for some settling, floatable removal, disinfection, and dechlorination.¹⁵⁶

MARB has been an important addition to the City’s water infrastructure and has already made Grand Rapids more resilient (see Figure 29). However, climate change may undermine investments like MARB. The treatment plant and MARB are more effective with a predictable distribution of smaller storm events. More extreme wet-weather events will challenge the capacity of wastewater infrastructure, causing combined sewer overflows (CSOs) such as those that occurred during the floods of 2013.



Figure 29. MARB prevents almost all direct discharge of untreated wastewater into the Grand River. MARB can store and partially treat 30 million gallons of wastewater per day.

Grand Rapids has been working to eliminate CSOs over the past two decades. As of 2013, only four combined sewers of the original 59 remain. With the elimination of these combined sewers, less stormwater runoff will enter the sewer and wastewater systems, and fewer overflows will occur. The result is that less sewage ends up in the surrounding rivers and lakes.

3.3 Great Lakes Water Levels

In early 2013 the Lake Michigan-Huron system approached record-low water levels.¹⁵⁷ Even with the Flood of 2013, the Army Corps Detroit District office reported that all of the Great Lakes were below long-term (1918–2012) average water levels in June, except for Lake Ontario. Lakes Superior and Michigan-Huron continued a 14-year stretch of below-average water levels, the longest in each of their recorded histories.¹⁵⁸

It is well documented that the Great Lakes cycle between high and low water levels. In addition, there are many manmade and natural system inflows and outflows, so it would be neither possible nor accurate to definitively and solely implicate climate change in Great Lakes water levels at any given moment in time—even during record lows. Indeed, shortly after the record lows recorded in February, intense rains and the [Grand Rapids Flood of 2013](#) quickly brought lake levels up. However, NOAA climate models demonstrate that lower lake levels are a projected impact of high CO₂ emissions (see Figure 30).¹⁵⁹

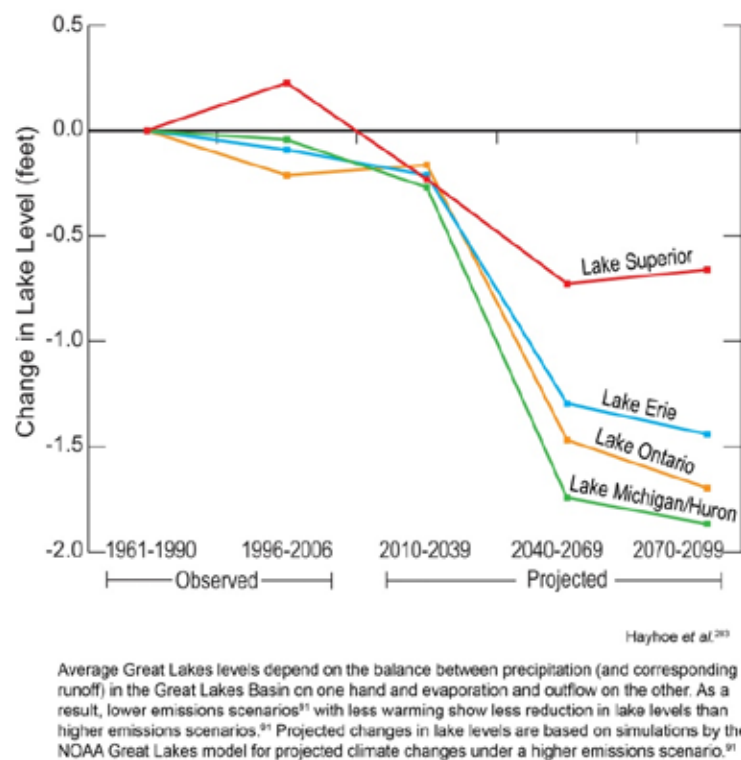


Figure 30. Projected changes in Great Lakes levels under higher emissions scenario.



Figure 31. Exposed docks in Traverse City. Low water levels in Lake Michigan have an effect on commerce, recreation, and the environment. Lake levels are naturally cyclical, but scientists suspect climate change will have an overall downward impact. *Photo: Michigan Sea Grant*

Because of the cyclical nature of low lake levels, the common impacts are already well understood (see Figure 31). Lower lake levels mean that shippers must carry less, groundings become more common, and some harbors may be forced to close. According to the Corps, every foot of lost depth requires a 1,000-foot vessel to load 3,200 tons less; at 1.5 feet below baseline, vessels lose 8% to 10% of their carrying capacity.¹⁶⁰

According to the Lake Carriers' Association, a shipping industry group out of Rocky River, Ohio, "In the high waters of the late 1990s, the largest coal-carrying vessel to pass through the Soo Locks was able to navigate while laden with 71,000 tons of cargo, but as of December 2012, that capacity was reduced to 62,000 tons."¹⁶¹

In St. Joseph, the commercial harbor is normally dredged to a depth of 23 feet, but the channel was just [16 feet deep in the spring of 2013](#).¹⁶² This low depth in the St. Joseph channel threatens the viability of a port that sees up to 400,000 tons of freight each year, forcing shippers to find alternative routes and incur additional expense. As the Great Lakes comprise an interconnected port system, problems in one part of the system will negatively impact ports in another. Impacts in Huron-Michigan will also affect ports on Lakes Erie and Ontario.¹⁶³

3.4 Drinking Water Supply and Ground Water

The Great Lakes account for some 20% of all fresh surface water on the planet. Lake Michigan is also the primary source of drinking water in Grand Rapids and several neighboring communities. The Grand Rapids Water Filtration Plant in West Olive, near Grand Haven, cleans, filters, and sterilizes water before piping it to Kent County (see Figure 32).

The Association of Metropolitan Water Agencies has issued guidance on how water systems could be affected by climate change:¹⁶⁴

- Warmer and shorter winters with more rain and runoff will alter the manner in which surface and ground water aquifers will replenish.

- In warmer and drier summers, vegetative growth may decrease the quality of surface waters that will eventually reach treatment systems.
- Water temperatures impact filtration systems by increasing eutrophication and the sediment that must be removed from fresh water, which alters the necessary treatment requirements.
- Increased rainfall can stir up sediment and buried toxins.
- Drought periods will increase demand for water.¹⁶⁵



Figure 32. Massive pumps move treated, potable water from the water filtration plant in West Olive to Grand Rapids. The energy/water nexus goes both ways; saving water saves energy.

Some obvious potential local impacts involve the effect of climate change on filtration plants' water intake. Lower lake levels could mean that intake pipes would need to stretch farther out into the lake to bring in water. Stormwater runoff could alter levels of sedimentation, temperature, and the variety of pollutants in intake water by creating a larger and dirtier plume at the mouth of the Grand River. Further discussion of these impacts can be found in the [Energy/Water Nexus section](#).

According to the Association of Metropolitan Water Agencies:

“If programs such as those intended to control sewage overflows and waste load allocations are undermined by changes in hydrology, there may still be room to maneuver within the altered hydrologic system and attain good outcomes, if regulatory constraints are flexible. The bottom line in water supply planning has always been a matter of coping with variability. With the coming changes in climate, there will be a heightened need to respond to increased variability. The net effect of the direct impacts of global warming [...] will be to change the variability of key parameters affecting the quantity and quality of water that would normally be expected to be available at any specific time and place. In addition, the capability to store water in various forms and the demand for water will be changed.”¹⁶⁶

Groundwater

In general, [climate change will stress surface water supplies](#) and will likely lead to increased groundwater withdrawals, which may lead to “significant groundwater depletion and contamination...”¹⁶⁷ The [Ottawa County Water Resources Study](#) conducted by Michigan State University (MSU) shows falling water levels over the last decade in the Marshall Formation glacial aquifer, which the authors

of the study state is “the only productive bedrock aquifer beneath Ottawa County.”¹⁶⁸ It has fallen three meters in the last decade, according to Ottawa County Planning and Performance Improvements Director Mark Knudsen. He notes that withdrawals for agricultural, industrial, and domestic use are draining the aquifer faster than it can be recharged, a situation exacerbated by recent drought and snowfall reductions.¹⁶⁹ The MSU study also [provided documentation](#) that the remaining water within the aquifer has become more saline as the aquifer is tapped to deeper depths.¹⁷⁰ The report cites similar problems across the state.¹⁷¹

3.5 Water Efficiency

Water efficiency will become a key tool for building resiliency as a changing climate distributes precipitation less predictably and with increased variability (see Figure 33). Although climate change may create a wetter Grand Rapids in winter and spring months, summer will likely experience decreased precipitation.¹⁷² This will be more pronounced in other parts of the country where there is not a reliable supply of fresh water. Climate change will likely lead to increased withdrawals for local use and increased potential for withdrawals for use by other regions.

The City of Grand Rapids Sustainability Plan includes a now-obsolete target to reduce the annual customer consumption of water provided by the municipal water system by at least 3%. This goal was met prior to its 2013 deadline.¹⁷³ The City has also signed the Great Lakes and St. Lawrence Cities Initiative Water Conservation Framework, a voluntary commitment to reduce total water usage by 15% from 2000 water consumption levels by 2015. As of 2009, Grand Rapids had conserved 8.5 billion gallons of water since 2000, nearly meeting the goals of the framework six years early.¹⁷⁴



Figure 33. Water efficiency saves money, energy, and a myriad of materials used in its processing, such as ferric chloride, alum, lime, carbon, fluoride, polymers, and phosphate blends.

Among other tactics, municipal efforts to reduce water use include public education, fixing leaks in large transmission lines, and the reuse of treated wastewater at the wastewater treatment plant for irrigation and system cooling.¹⁷⁵

One of the more powerful potential tools is pricing water in a way that encourages conservation. Water systems typically have a fixed cost—which is the cost of operating and maintaining the system infrastructure—and variable costs, which increase and decrease

according to the quantity of water consumed. Water rates should include fixed costs as the foundation, but then increase or decrease on the marginal unit of water consumed. The more closely consumers associate increased water use with increased costs, the more they will be interested in conserving.

California's [20x2020 Water Conservation Plan](#) hopes to achieve a 20% reduction by 2020 in daily per capita water use in California. The plan describes three conservation rate structures:

- Volumetric pricing: increases the price per unit volume as usage increases.
- Seasonal pricing: can be used during periods of low precipitation or high water use.
- Allocation pricing: generally includes increasing costs after a base quantity is exceeded.¹⁷⁶

3.6 Wetlands

Wetlands are crucial to both climate change mitigation and adaptation yet are themselves threatened by climate change. This is a classic example of a negative climate feedback loop. The destruction of a wetland releases CO₂ that has been stored for centuries in layers of muck, while also eliminating the future possibility of carbon storage. Plant life in wetlands conducts high levels of photosynthesis, a process that consumes CO₂; as plants die and become part of the mud and muck, the CO₂ is stored in perpetuity. In fact, a recent [U.S. Geological Survey greenhouse gas emission ecosystem assessment](#) concluded that wetlands have the highest carbon capture rate of all ecosystems.¹⁷⁷

In addition to carbon sequestration, wetlands also offer ecosystem benefits to West Michigan, including flood control, water filtration, and wildlife habitat. This has made wetlands preservation and restoration a key concern for local and national hunting and fishing organizations. The local chapter of Trout Unlimited is particularly interested in protecting wetlands for the purpose of managing stormwater. Increased wetlands acreage at the headwaters of the Rogue River would act as storage for stormwater, slowing the stormwater's infiltration into the Rogue. The subsequent reduction in flooding and water pollution would enhance habitats in the Rogue River, an important fishery.¹⁷⁸

In November 2007, Grand Rapids adopted regulations pertaining to wetlands, urban forest canopy, and steep slopes (erosion) in the zoning ordinance. The ordinance's provisions address wetlands in addition to those regulated by the Michigan Department of Environmental Quality (MDEQ) and seek to mitigate the impacts of urban development on the environment.¹⁷⁹

Michigan Wetlands Policy in Flux

Recent changes in state policy could impact protection of wetlands. In July 2013, the State of Michigan amended its wetland law ([P.A. 98 of 2013](#)). The new law alters the MDEQ's wetland program responsibilities under the federal Clean Water Act. Environmental groups argue that the new law expands regulatory exemptions and will weaken wetland protections. Others are worried that program changes will result in Michigan's losing its authority to regulate the federal wetland program or allow the program to revert to the Army Corps of Engineers.

3.7 Fisheries and the Grand River

In 2006, *Field and Stream* designated Grand Rapids the nation's sixth best urban fishery, particularly noting the quality of steelhead fishing in the Grand River at the Sixth Street Bridge (see Figure 34).¹⁸⁰ Coldwater fish, such as steelhead and other trout species, are particularly vulnerable to climate change, according to Nichol De Mol, project manager for Trout Unlimited's Rogue River Home Rivers Initiative. De Mol said that anglers are already noticing a change in spawning habits of trout in streams across West Michigan as spring arrives earlier. Anglers and the Michigan Department of Natural Resources (MDNR) are finding fish spawning runs that are more variable than in the past. The impact of milder spring temperatures on trout reproduction is not immediately clear, but Trout Unlimited is concerned about the sustainability of the species as spawning cycles fluctuate.¹⁸¹

Fishing is an asset to Grand Rapids and an economic necessity for the state. With increased storm events and warmer temperatures, the integrity of local fisheries and portions of economies are at risk, threatening the \$9 to \$155 per day each fisherman spends in the local community.¹⁸²

De Mol and Trout Unlimited have focused their attention on one of the Grand River's major tributaries, the Rogue River, where fishing brings an estimated \$485,000 annually to nearby communities. Data collected by the MDNR shows that weather events leading to stormwater runoff have increased in the Rogue River



Figure 34. Improvements in Grand River water quality have led to better fishing. In 2006, *Field and Stream* designated Grand Rapids the nation's sixth best urban fishery.

watershed.¹⁸³ According to De Mol, stormwater has a “compounding” negative effect on trout. Runoff can cause warmer and inconsistent water temperatures that create particularly stressful living conditions for trout. It washes sediment into the river, burying the rocky ecosystems that trout prefer and causing the Rogue River to become shallower. This in turn causes water temperatures to increase even more.¹⁸⁴

The Union of Concerned Scientists expresses similar concern for the health of fish in the broader Great Lakes region, estimating that climate change will affect nearly 10 million anglers in the region. Warming lake waters not only redistribute current Great Lakes fish species, but also offer opportunity for invasive species to migrate into the ecosystem where conditions had previously created barriers to entry.¹⁸⁵ In its report, the Union of Concerned Scientists cites the striped bass as a potentially invasive species that could capitalize on the warm water and expand its range eastward. Meanwhile, current invasive species, such as the zebra mussel, could expand their range northward in warming waters. Warm lake water also forms a layer above cold water throughout the summer. If the layer of warm water becomes too large, it begins to deplete the cold water of oxygen, which is absorbed by sediment in a phenomenon called anoxia. Increased instances of anoxia can release mercury from sediment, causing health issues for both fish and the public.

Overall, says De Mol, many threats facing trout are a result of or are exacerbated by climate change. They could fundamentally change the ecosystem, potentially eradicating some cold-water species. The impacts witnessed in the Rogue River are likely to occur or are currently being felt in larger local waterways such as the Grand and Muskegon Rivers. De Mol notes that the Muskegon River is experiencing even more dramatic increases in stormwater flow than the Rogue River.¹⁸⁶

Combined, hunting and fishing licenses account for nearly 25% of revenue for the Department of Natural Resources. In 2011, Michigan anglers spent an estimated \$2.46 billion on fishing equipment and apparel.¹⁸⁷

3.8 Grand River Restoration and Habitat Improvements

Restoring the Grand River to a more natural state will increase its value as a habitat and make it more resilient to a changing climate. Additionally, it will increase the ecosystem services provided to the City, making the community more resilient.

Like most rivers that run through urban spaces, the Grand River has been greatly altered from its natural state. The river has been corralled and channeled, harnessed for productive use, and has served as a sewer for human waste.

The floodwalls lining the river in downtown Grand Rapids protect the City from flooding, but also contribute to downstream sediment issues. According to the MDNR's 2011 Draft Grand River Assessment, "they do not allow sediments to be deposited in the floodplain" or other low-speed areas naturally occurring along a riverbank. Instead, sediments settle inside the channel or get pushed downstream.¹⁸⁸

Additionally, dams have submerged "a geologically unique, expansive (historic spawning) reef of exposed bedrock found between the Sixth Street Dam and Ann Street" that had provided the City's namesake rapids. Dam removal and restoration would allow better flow of sediment, fish, and invertebrates downriver. The series of four low-head beautification dams between the Sixth Street Dam and the Pearl Street Bridge provide only aesthetic functions and likely represent a barrier to native fish species during low-flow conditions. Removal of these four dams would increase the amount of habitat available to native fish species, substantially improving conditions for sturgeon.¹⁸⁹

Grand Rapids Whitewater Working to Restore the Rapids

A burgeoning effort to restore the Grand River's historic rapids offers an opportunity to improve habitat for fish and bolster one of the nation's best urban fisheries. Restoring the Grand River to its natural state entered the public discourse in conjunction with Green Grand Rapids. Since then, [Grand Rapids Whitewater Association](#) has championed the River Restoration project.

In May 2013, the Grand Rapids Downtown Development Authority approved a \$100,000 grant to continue studying the potential of this extensive project. Grand Rapids Whitewater asserts that the improved habitat and dam removal will improve walleye and bass populations and provide a safer fishing experience for anglers. Restoration of the rapids would include the addition of rocks and boulders originally found throughout the river that provide habitat and improve oxygenation. In addition, the project proposes to add more than 100 more fishable acres upstream from the rapids.¹⁹⁰

Removal or offset of the floodwalls in accordance with plans outlined by River Restoration will increase habitat for a variety of organisms. The MDNR's assessment notes that floodwalls prevent fish from accessing seasonally flooded areas that are important for spawning and feeding. In addition, they eliminate shallow water areas and naturally diverse edge habitat that can be important to macro-invertebrates and block animal access to and from streams.¹⁹¹

Removal of the Sixth Street Dam will have a positive influence on regional fish populations in Lake Michigan as well as in the Grand River. The dam presents a barrier to multiple species of lake-dwelling

fish that ascend the river to spawn. The current fish ladder, built to assist fish to bypass the dams, is only partially effective.¹⁹² Some migratory species such as lake sturgeon and walleye are unable to successfully climb the ladder, and only a portion of adult salmon and steelhead successfully traverse the ladder to spawning areas upstream of the dam. Failure to reach their upstream spawning habitats currently limits the productivity of several fish species. The MDNR reports that lake sturgeon rehabilitation efforts face a “major obstacle” due to inaccessible upstream spawning habitats.¹⁹³

The report “[Grand Rapids Restoration: Opportunities and Constraints](#)” lists several quantifiable habitat improvements in addition to increased upstream fish passage that current restoration plans can achieve:

- 500% increase in habitat diversity
- 500% increase in fish-holding habitat
- 850% increase in lake sturgeon spawning habitat
- 1,700% increase in stream health as measured by hyporheic exchange
- Four additional acres of native riparian forest habitat
- Propagation of 100,000 mussels¹⁹⁴

While the ecological benefits of dam removal to the fish population are established, there are also downsides. For example, the Sixth Street Dam currently serves as an important barrier to [sea lamprey](#), preventing their migration upstream. Invasive lampreys have seriously impacted trout and other native species, and they continue to affect the restoration of fish communities. The [snuffbox mussel](#) was found in the project area and was added to the federal endangered species list in 2012. The mussels might have to be found and relocated.

Additionally, local fishermen have grown to cherish the Sixth Street Dam as an ideal place to fish. The dam tends to corral fish in the area and the cement floodwall on the river’s east side offers easy access for the young, old, and handicapped. River Restoration stakeholders have noted river accessibility (including handicapped access) as a priority feature to maintain.

A phase II [environmental site assessment \(ESA\)](#) was conducted in October 2011 by NTH Consultants, Ltd. on behalf of the Grand Rapids Whitewater Association. NTH Consultants took 45 sediment cores from the 1.5-mile section of the Grand River immediately north of the Sixth Street Dam. Polynuclear

aromatic hydrocarbons were detected in three samples, but their levels did not exceed Michigan's Natural Resources Environmental Protection Act Part 201 Generic Residential Cleanup Criteria. Polychlorinated biphenyls were not detected in any of the samples. Samples were tested for a variety of metals: sample SS-15 contained levels of arsenic that exceed criteria for direct contact by 1.3%; no other excessive concentrations were detected.¹⁹⁵

Grand Rapids Whitewater believes that the restoration of the rapids and the construction of whitewater recreational facilities will bring more than \$5 million in annual economic benefits to Grand Rapids. The restoration would offer recreational opportunities for kayaking, canoeing, and competitive rowing. The plan includes beautification of the shoreline, educational signage, and the addition of four acres of riparian forest. Grand Rapids Whitewater acknowledges the key barriers as sea lamprey control, lands and easements, project cost, and flood conveyance.¹⁹⁶ Climate change threatens West Michigan's already compromised fisheries, but restoring the Grand River rapids may offer a resilient opportunity that provides a triple bottom line benefit to the City.

In May 2013, the Urban Waters Federal Partnership added the Grand River as one of 11 new locations for its program. The Partnership aims to improve coordination among federal agencies and encourage collaboration among stakeholders to foster a community-led revitalization of selected urban waterways.¹⁹⁷ It recognizes that "reconnecting people with urban waterways results in economic, environmental, and social benefits to communities."¹⁹⁸

The federal endorsement will help facilitate additional evaluation of restoration options, expansion of stakeholder engagement and outreach, and ultimately, the reconstruction of the rapids, slated for completion in 2016.

3.9 Land Use

Land development in Kent County grew at a rate three times faster than population growth (14.7%) from 1960 to 1990.¹⁹⁹ Vacant properties are scattered in and around Grand Rapids and new housing developments are being built.²⁰⁰ Thoughtful land management encourages smart development, preserves natural assets, and maintains infrastructure. It also builds climate-resilient communities.

Land Use Management Policy Structure

State and federal policies affect local and regional land-management decisions. For example, the state establishes guidelines for the preservation of wetland areas that can mitigate flooding and collect and filter stormwater naturally. Policies such as the amended 1956 Michigan Drain Code (P.A. 40)

establish guidelines for local drainage infrastructure. The 1994 Natural Resources and Environmental Protection Act (P.A. 451) includes provisions that govern pollution levels in stormwater runoff and controls that maintain natural areas across the state.

However, many decisions regarding land use and management are left to local governments, in accordance with Michigan's long-standing tradition of home rule. The responsibility of ensuring stable infrastructure, developing effective zoning ordinances and community development plans, and establishing effective land-use plans falls upon local units. Deferring these responsibilities to local communities often creates redundant or conflicting land-use management strategies across regions of the state.

Kent County is no exception. Land-management policies and infrastructure systems overlap between many of the county's different communities, sometimes with significant differences. Planning decisions are left to other county departments, the Grand Valley Metro Council, and other more local community departments. Most communities in Kent County have up-to-date plans and active planning commissions that undertake many of the responsibilities that a county planning commission would normally have.

However, regional organizations such as the Grand Valley Metropolitan Council, United Growth for Kent County, and the West Michigan Regional Planning Commission promote county-wide collaboration on issues that affect Grand Rapids. This regional approach can help to promote sustainable and resilient land policy throughout the interconnected communities that make up the Grand Rapids metropolitan area.

Notable among regional projects is the [Grand Valley Metropolitan Council's Blueprint II](#) report, which outlines a set of goals for crafting sustainable, resilient communities. Among them are:

- Promote regional settlement patterns in the Grand Rapids metropolitan area to better integrate development with existing urbanized areas and to cultivate the unique qualities of community places and neighborhoods.
- Involve regional planning entities or cooperative, coordinating municipal associations in decision making about significant land uses affecting broad settlement patterns.
- Promote land-use patterns that most efficiently use existing public infrastructure and community resources without diminishing the social, economic, and cultural values of existing residential settlements and neighborhoods.

- Promote development patterns that help maintain the viable long-term use of working open lands, such as agriculture and forestry.
- Identify and protect those natural areas in our metropolitan region, which enhance the quality of our air, water, and habitat for wildlife.
- Establish a metro-wide system of environmental corridors, greenways, or landscapes, which establish convenient, nondestructive public use of our natural environment, including bikeways, recreation areas, nature walks, and scenic preserves.
- Promote the cleanup and reuse of vacant and underutilized buildings and sites served with public utilities.
- Plan and develop timely, orderly, and efficient arrangements of public facilities and services that reinforce local land-use plans developed within a regional framework or perspective.
- Promote a single regional sewer, water, and stormwater authority charged with integrating and equitably paying for the provision of these services within regionally adopted patterns of land use.²⁰¹

While some goals, such as the creation of county-wide drain authorities, are difficult to initiate in Grand Rapids and surrounding areas, other goals, such as those dealing with preserving the nature of local neighborhoods and promoting the use of current properties and infrastructure, are already supported by programs such as the Kent County Land Bank and Kent County Purchase Development Rights (PDR), explained below.

Grand Rapids’s Master Plan supports county-wide goals for intelligent land management within cities. If the principles outlined in the Master Plan and the Green Grand Rapids report are actively applied to new development within the City, Grand Rapids will be more resilient to rapid climate change—and quality of life for Grand Rapidians will also increase.

Zoning and Land Management Policy in Grand Rapids

Grand Rapids has been engaged in land-use planning for more than 150 years. With the development of different forms of transportation—from the horse and cart to the streetcar and, later, the automobile—land-use patterns and land-management strategies have changed drastically. The result of these varied development strategies is a uniquely diverse and sometimes inconsistent city design. Each different land-use pattern presents unique challenges for zoning and development in resilient and sustainable ways.

The Master Plan identifies two main categories of development patterns, which are subdivided into four different eras of development within the City. The first category encompasses pre-World War II developments, built between 1850 and the 1950s. This category is divided into turn-of-the-century neighborhoods between 1850 and 1900 and early-twentieth-century neighborhoods that were built up around streetcar lines that ran across the City. Today, these neighborhoods compose the dense development of downtown and many of the commercial strips within city neighborhoods. Because they were built before the advent of the automobile, they are designed for easy pedestrian access from local residential areas and feature lots of mixed-use buildings, often with shops on the ground floor and residential space on the stories above.²⁰²

Conversely, postwar development patterns were designed with the automobile in mind. In these neighborhoods, land-use patterns are similar to what exists around 28th Street today. Larger, multilane artery roads are fed by “feeder” streets that channel automobile traffic to the larger thoroughfares. In these areas, residential spaces are usually separated from businesses by longer distances and are very inconvenient to walk or bike to. Developments built after 1970 are even more dispersed and disconnected. Huge tracts of land set up as campuses and “superblocks” of land—very large, isolated sections of development that are only accessible from the main artery roads—dominate business districts with gargantuan parking lots that support automobile traffic and long swaths of roadways. Residential areas are often cut off as well, located away from businesses and developments.²⁰³ The high concentration of surface parking creates large heat-retaining surfaces that warm up during the day and release the heat at night—the “urban heat island” effect. With climate change models suggesting more hot days during Grand Rapids summers, the urban heat island is a concern.

For these different styles of land use within the City, the current Grand Rapids Master Plan encourages different approaches and changes, many of which are already oriented toward resiliency and sustainability. For pre-World War II neighborhoods, the Plan recommends preservation and revitalization as strategies for action, rather than a complete redevelopment of neighborhoods. The Plan also supports converting postwar developments in areas zoned for commercial use, such as strip malls and shopping centers, into effective, walkable mixed-use centers, to achieve many of the positive benefits that the older neighborhoods have.²⁰⁴

In general, preserving mixed-use and dense development is environmentally beneficial.²⁰⁵ By allowing Grand Rapidsians to have essential services and businesses within walking distance of their homes, fewer automobile trips need to be made, reducing carbon emissions (see Figure 35). Road infrastructure is also preserved. Promoting use of these areas also allows the City of Grand Rapids to utilize existing



Figure 35. Build a Better Block Grand Rapids reimagines a vacant alley. Renewal of dense, mixed-use areas within walking or biking distance of residences reduces carbon emissions and increases local self-sufficiency.

infrastructure instead of developing new spaces that put additional burdens on infrastructure. This is in line with the goals of the Grand Valley Metro Council's Blueprint report. Finally, concentrating population in a denser urban environment reduces automobile dependence and the need for additional land.²⁰⁶

While these goals are active in the City and promote resilient and sustainable communities, there are challenges to incorporating them into existing developments.

Traditional neighborhood-style areas within cities are most easily achieved when they start on empty land. Working to renew existing, automobile-centric areas proves difficult due to existing structures.²⁰⁷ However, the city zoning ordinance contains a Transit-Oriented Development district, which encourages sidewalks, bike facilities, and well-designed urban structures. It also seeks to advance tree canopy and stormwater goals. If a project meets all of the ordinance requirements, then it can be administratively approved, without the need to go to the City Commission, Planning Commission, or Board of Zoning Appeals for approval.²⁰⁸

Many dense, mixed-use areas were originally established along public transportation routes and flourished because of them. Increased traffic from concentrated groups that hopped off streetcars provided businesses with a diverse group of consumers in one area. Because this style of land use developed before the automobile, there was no need for parking. Today's situation is quite different. These places are also facing difficulty because the traffic is down, and neighborhood residents cannot sustain them on their own.²⁰⁹

To generate traffic, these areas need to provide parking for automobiles, something that was not originally included in the plans for these areas. Otherwise, effective public transportation to these areas is needed. Both are difficult. New parking results in loss of usable real estate, promotes increased

automobile use, and creates large swaths of impermeable pavement—all things that traditional business districts are supposed to avoid in their design.²¹⁰

Increasing public transportation is also difficult. Though most bus routes run between these business districts, it can be time-consuming to reach a distant destination due to bus route locations and schedules. Additionally, areas outside the city center are often underserved by public transportation; stops are often too far from homes to encourage ridership. Experienced planners have found that riders are most likely to use public transportation if it is located within five minutes' walk of their home.²¹¹

Challenges remain in establishing and supporting more resilient, sustainable, and dense land-use patterns. However, the Grand Rapids Master Plan, the Green Grand Rapids report, and current zoning rules promote such land use. With careful investment, more concentrated neighborhood environments will become the norm in Grand Rapids.

Regional Land Use Management Programs

On a county-wide level, land banks and other active land-management programs can be effective tools in shaping development of communities and promoting smart, resilient land-use methods.

Land banks are organizations that gain ownership of foreclosed properties in a community in order to restore them and revitalize the community through increased property values and new real estate developments.²¹²

Kent County's Land Bank Authority has its origins in Michigan's Land Bank Fast Track Act, which "authorized land banks to strengthen and revitalize the economy by assembling and using public property to promote economic growth and to clear titles in an expedited manner."²¹³ Since 2012, it has obtained properties in Kent County through several channels. Some are privately donated to the land bank by owners or by banks that have foreclosed on them. Other properties are foreclosed on by the government after property owners fail to pay property taxes for three years. These are purchased by the land bank for the price of the taxes after other government entities decide not to purchase them.²¹⁴

After the properties are acquired by the Kent County Land Bank, some are restored or repaired and placed back on the public market through the Land Bank's own Multiple Listing Service. Anyone is allowed to purchase the restored properties. However, the Land Bank requires buyers to submit construction specifications, proof of adequate financial support to complete development, and proof of ability to complete any renovations to the property.²¹⁵ This prevents Land Bank-restored areas from repeatedly falling into disrepair.

Most of the properties claimed by the Kent County Land Bank are residential homes that ended up in foreclosure due to the recent housing crisis, with a number of commercial sites included in the mix. Restoring both types of properties has various positive social, economic, and long-term environmental effects on communities.

Once they are restored, these properties provide affordable, attractive housing for people in Grand Rapids and Kent County. Blight, which drops property values and encourages flight away from city centers and into suburban communities, is also avoided. Preserving dense, old neighborhoods is also beneficial from an environmental standpoint. These mixed-use neighborhoods, such as Eastown and Heritage Hill in Grand Rapids, often provide their residents with services and recreation opportunities—such as grocery stores, doctors’ offices, restaurants, and other businesses—near their homes. The need for automobile trips in these neighborhoods is reduced because so much is within walking and biking distance.²¹⁶

Case Study: The Cuyahoga Land Bank

Other communities in the Midwest, such as Cuyahoga County, Ohio, have used land banks in innovative ways that more directly address climate resiliency. After the housing market crashed in 2007, Cuyahoga County was mired in the housing foreclosure crisis. With unsellable properties accruing in Cleveland and other cities in the area, local academics and public officials decided to set up a land bank in the county in order to manage the glut of abandoned and deteriorating properties.²¹⁷

The Cuyahoga County land bank program was established as a nonprofit corporation, separate from the county government. The nongovernmental structure of the Cuyahoga Land Bank allowed the land bank to more easily adapt to communities’ needs and cut through government boundaries to create interesting and innovative projects that went beyond refreshing and reselling property.

By the end of 2010, the Cuyahoga Land Bank had acquired 495 properties, utilizing funding from both private and public sources. Notably, the land bank established a partnership with Fannie Mae to pick up foreclosed properties in Cuyahoga County for a nominal fee, often \$1. Fannie Mae also agreed to commit \$3,500 to each property that needed to be demolished.²¹⁸ This allowed the land bank to take apart a large number of useless and derelict buildings, creating new green spaces in urban communities. For developers and community organizers, these green spaces became blank canvases for new and innovative ideas. While some of the new empty lots were simply annexed to current properties, many became locations for new community-focused public developments that also doubled as units of green infrastructure:

- The City of Berea teamed up with the Cuyahoga Land Bank to redevelop the northern section of the city. While certain newly demolished properties were scheduled to be construction sites for new homes, the land bank's plans for lots included a public rain garden, which will reduce stormwater runoff in a sustainable way and function as a public green space in a residential community.²¹⁹
- East Cleveland is working with the land bank to demolish a number of shuttered apartment buildings. While the properties could be sold to developers, [the land bank is planning to convert the empty lots to open green space](#).²²⁰ This should boost property values while providing natural benefits of green space, including natural stormwater drainage and reduced heat island effect.

The Cuyahoga Land Bank does not have the Kent County Land Bank's rapid turnover time (on average, after renovation, Kent County Land Bank properties are on the market for only about two weeks before they are sold). However, Cuyahoga's diverse uses for reclaimed land are a good example of smart land use promoted on a regional level.

The Cuyahoga Land Bank is also promoting green infrastructure and community-building public spaces across the county. Because the Land Bank is promoting these resilient land-use projects in multiple cities in the region, its impact is greater than that of any single municipal organization on its own.

Purchase of Development Rights (PDR)

Kent County's PDR program is another example of a regional policy program that supports more resilient land use. The PDR program pays farm landowners within the target areas the difference between the current value of the land and the value of the land if it were developed (see Figure 36).²²¹ In return, the landowner hands off development rights to the county, ensuring that the farmland will be preserved for its current agricultural use.²²² These rights are sold in perpetuity. Effectively, the county holds these rights forever, unless a court decides that the land needs to be developed. As of February 2013, 2,285 acres of land have been preserved through the program.²²³

The conservation regulations are comprehensive. No new roads can be constructed on these properties once development rights are sold to the county. The farm properties cannot be subdivided, and new utilities cannot be connected unless they directly serve the farm.²²⁴

While the landowners receive an immediate financial benefit from the sale of development rights, Grand Rapids benefits from preserving open-space farmland. According to United Growth for Kent County,

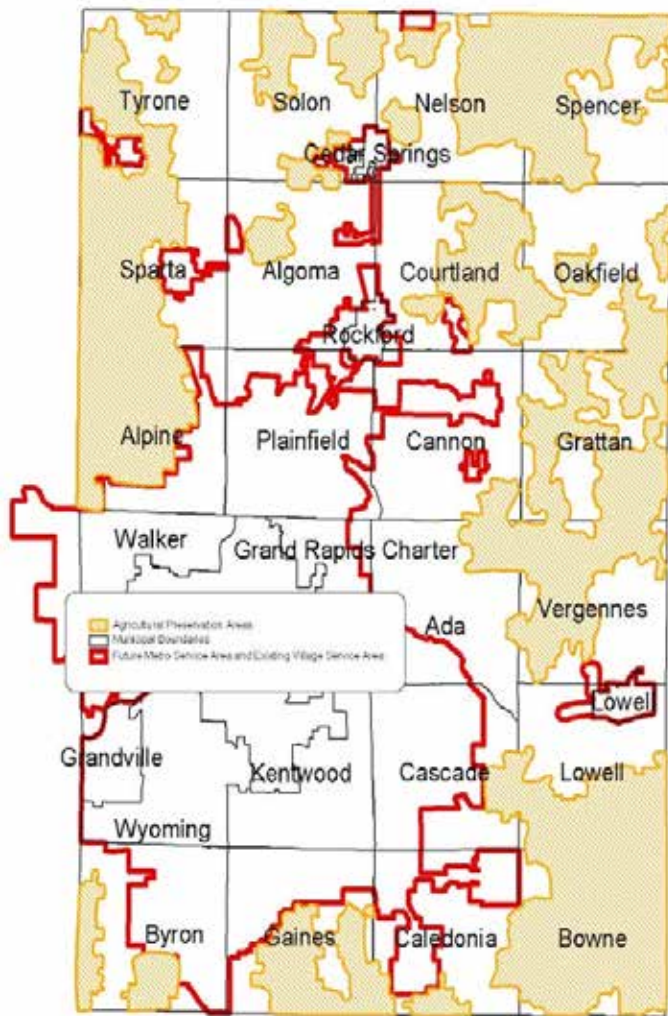


Figure 36. Map of targeted Kent County PDR areas.

a successful PDR program helps to limit the movement outward of housing, people, and the tax base that sustains our communities, away from current urban centers and established communities. It helps to prevent low-density sprawl, and strengthens urban communities that are already supported by current infrastructure investments.²²⁵ In short, it promotes the sort of dense, mixed-use urban landscape that supports climate resiliency in Grand Rapids—the kind of land use that is also supported by the Kent County Land Bank’s efforts to reinvest in existing properties and communities.

The preserved farms also function as effective, low-cost green space. Parks and other public spaces require lots of funding from local governments to establish and maintain.²²⁶ As mentioned before, this green space provides many benefits to our community, such as effective stormwater drainage and control and natural habitats for wildlife.

United Growth for Kent County found that for every dollar of tax revenue from agricultural land, service costs for infrastructure and other needs only totaled \$0.62. By contrast, low-density residential properties, the kind that would most likely be placed on the farmland, cost \$1.40 for every dollar of taxes generated.²²⁷

While none of the preserved farms is located in Grand Rapids, the ecological benefits of having a large amount of green space in the surrounding area help support climate resiliency in Grand Rapids and align with the goals of the Grand Valley Metro Council’s Blueprint II goals. The PDR program reduces sprawl, conserves green space, and limits unplanned and unsustainable land use around Grand Rapids. It is an example of smart regional land-use management and shows how regional cooperation can benefit the City of Grand Rapids and the metropolitan area.

Transportation Infrastructure and Land Use

Further discussion of this issue can be found in the [Transportation section](#).

3.10 Urban Forest

The City of Grand Rapids recognizes the triple bottom line value of its urban tree canopy. Trees decrease and mitigate the urban heat island effect. They lower cooling costs and shade residents. Trees sequester carbon, manage stormwater, and remove pollutants from the air. They improve aesthetic qualities, increase pavement life, and have been shown to relieve stress. The benefits of a robust urban tree canopy are extensive, and almost invaluable.

Tree cover in the City is both a public service and a private responsibility. Some 95% of Grand Rapids trees are privately owned. The City owns only approximately 82,000 trees (62,000 along streets and 20,000 in parks) of an estimated 1.5 million (see Figure 37). Trees are particularly important for vulnerable populations and in low-income neighborhoods, where residents are less likely to have air conditioning, as they provide cooling on hot days.

Trees provide tangible, monetary benefits to the City. According to the [Grand Rapids Urban Forestry Committee's 2012 annual report](#), trees' annual benefit to the City totals \$6.5 million dollars. These benefits come from pollution removal, stormwater interception, lower energy costs, carbon emission reductions, carbon sequestration, aesthetic appeal, and increased property values. The total asset value of Grand Rapids's tree infrastructure is at least \$71 million.²²⁸

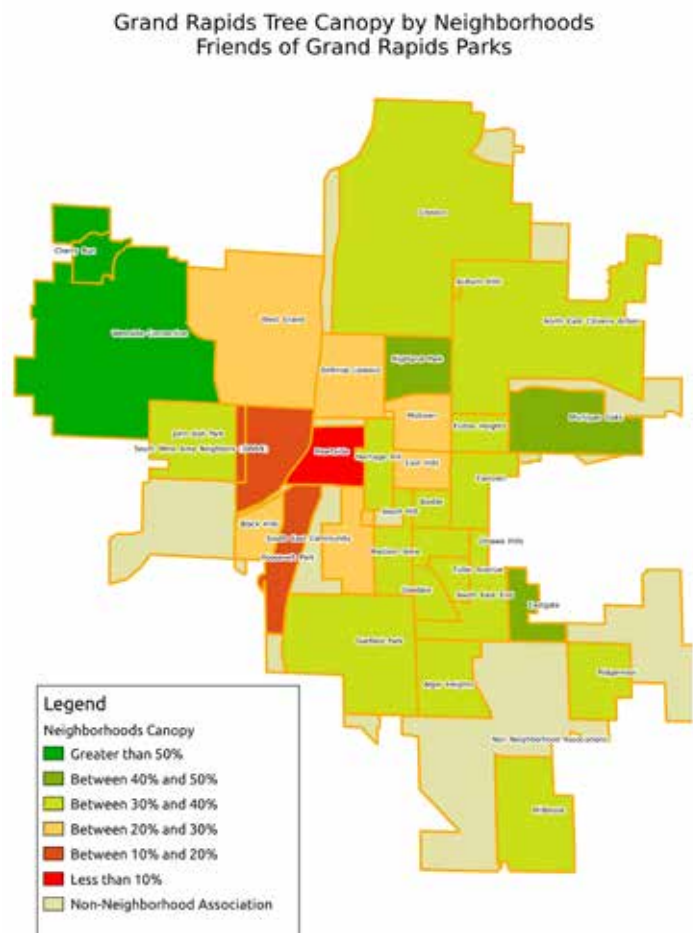


Figure 37. Urban canopy by neighborhood. Friends of Grand Rapids Parks, 2012 GR Urban Forestry Committee Annual Report. The City's urban canopy provides an estimated \$32 million in stormwater benefits and \$1.7 million in clean-air benefits every year.

An earlier study by the Annis Water Resources Institute (AWRI) revealed the substantial benefits that the current urban tree canopy provides to Grand Rapids. In terms of climate change mitigation, the City's trees have stored 438,494 metric tons of carbon, while adding only 3,414 metric tons annually. The urban tree canopy is also critically important to stormwater management. If all of the City's trees were eliminated, an additional 67 million cubic feet of stormwater storage would need to be constructed. The AWRI study calculates that this service alone is worth over \$32 million annually to Grand Rapids.²²⁹

In 2009, the City produced an [Urban Forestry Plan](#) to outline goals for the management of this asset. A culmination of several events—the onset of the invasive emerald ash borer, the Green Grand Rapids initiative, and the City's renewed membership in the Arbor Day Foundation's Tree City USA program—sparked interest in the management of its urban forest. In a study commissioned by the Green Grand Rapids initiative, AWRI found 34.6% tree canopy distributed unevenly throughout the City. The City has a goal of planting and maintaining a 40% canopy across the City. The current public planting regime has been detailed through 2018 and is prioritized by those areas with the least tree cover.²³⁰

10–20–30 Rule

Grand Rapids is changing its management of the urban canopy in part due to a changing climate and its impacts. Primarily, the City is adjusting its tree species selection strategy. Currently, 54% of the City's trees are maples. A single invasive pest, disease, or temperature flux could have a devastating impact on a homogenous urban canopy, as seen with elm trees and ash trees (ravaged by Dutch Elm disease and the emerald ash borer, respectively).²³¹ Cities have traditionally invested in a narrow list of species due to aesthetic reasons, maintenance, and other non–climate-related issues.

A diverse portfolio of trees will be inherently more resilient to climate changes. City Forester Tyler Stevenson cited a dearth of literature on urban tree canopy design, but he has decided to diversify tree species at the street level to limit the damage that a pest or disease might provoke.²³²

In 2012, the City planted 40 different species of trees—the most diverse palette of trees planted in Grand Rapids history. Future plantings will be guided by a 10–20–30 rule:

- No single species should make up more than 10% of a city's tree population.
- No single genus should make up more than 20% of a city's tree population.
- No single family should make up more than 30% of a city's tree population.

Stevenson said the early onset of spring 2012 was followed by a harsh frost that made it very difficult for newly planted trees. The extreme fluctuations in 2012 motivated him to change the City's main planting season to the fall.

Climate change may also create additional and sometimes unanticipated maintenance concerns for trees. Drier summers are also generating more demand for tree watering, a service limited by funding and staff. Trees planted by the City are watered for two to three years, after which trees are considered established. In addition, the canopy is vulnerable to increased severe storms. A regular, five- to seven-year pruning routine improves a tree's capacity for withstanding high winds. Not all trees are suitable for every location, but larger-canopy trees provide the most benefits and shade.²³³

Citizen Involvement and Private Property

Citizen involvement is essential to advancing urban forestry goals. In order to achieve the City's canopy cover goals, most new trees will need to be planted on private property and cared for by private individuals and interests. Stevenson asserts that it is important that qualified companies perform difficult tree care and that citizens choose companies with certified arborists.²³⁴ An example of proactive citizen involvement is the NeighborWoods program. Every October, the [Grand Rapids Urban Forestry Project](#) partners with local organizations to draw attention to the value of trees in our community. NeighborWoods projects include tree plantings, tours, inventory parties, and tree care projects.

Growing Seasons

Climate change will alter growing conditions in the region for all plant life. Impacts will be felt by agricultural crops, landscaped green spaces, native plants, and trees. Warmer temperatures may stress vegetation and introduce new pests and diseases into the area. Additionally, drought may reduce water available for use on cultivated plants.

In January 2012, the USDA updated its hardiness zone map (see Figure 38), a ubiquitously used guide for determining which plant species thrive in a given area's climate. Hardiness zones are based on the average annual extreme minimum temperature for the area. In the 1990 version of the map, the southern lower peninsula of Michigan was almost exclusively listed as zone 5b, where the average annual extreme minimum temperature ranged from -10°F to -15°F . The 2012 updated map demonstrates a northward shift for the hardiness zones across the United States and puts several areas of the Lower Peninsula, including most of Grand Rapids, into zone 6a, where the annual extreme minimum temperature ranges from -5°F to -10°F .

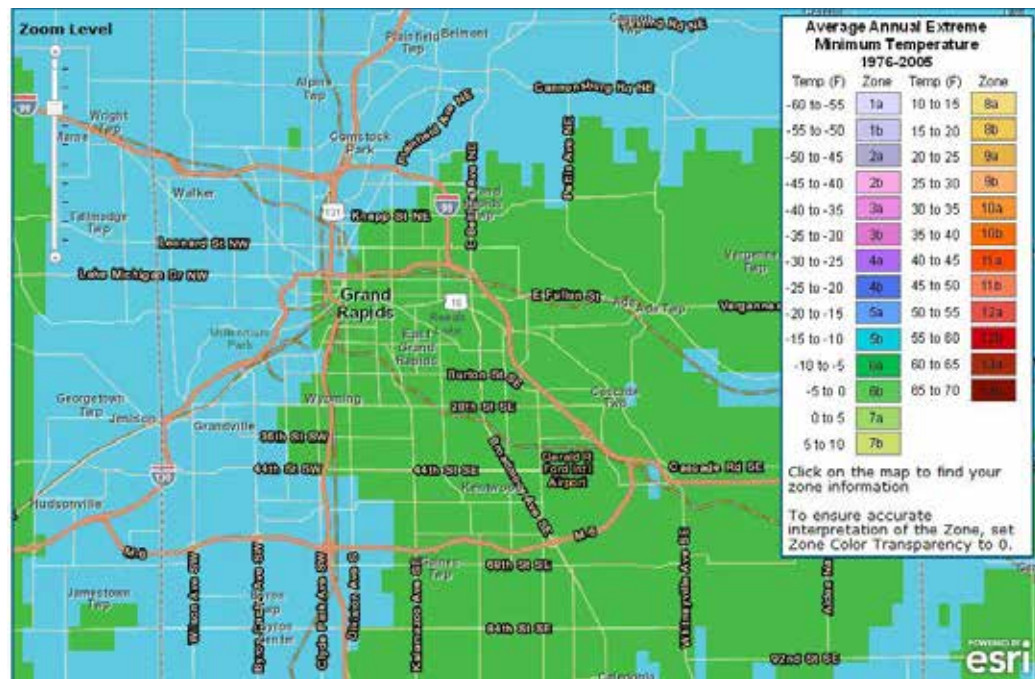


Figure 38. In 2012 the USDA published a new hardiness zone map that shows a warming shift in Grand Rapids’s temperature-based hardiness zones.

According to the US EPA, the length of the growing season is increasing throughout the United States and has seen the steadiest increases during the last 30 years. The most dramatic increase in the growing season has occurred in the western U.S. Nationally, the first frost of fall is occurring on average about two days later in the year than it did in 1980, while the last frost of spring is occurring about four days earlier.²³⁵

In total, the eastern U.S. has seen its growing season extend approximately eight days since the late 1980s. While a longer growing season may benefit a region like West Michigan, the US EPA warns that a longer growing season “could also limit the types of crops grown, encourage invasive species or weed growth, or increase demand for irrigation. A longer growing season could also disrupt the function and structure of a region’s ecosystems and could, for example, alter the range and types of animal species in the area.”²³⁶

3.11 Parks

City of Grand Rapids parks offer important adaptation and mitigation opportunities in the face of anticipated climate changes (see Figure 39). Parks, pools, splash pads, and natural recreation areas can all be viewed as potent climate-resiliency features that enhance quality of life and make Grand Rapids more resilient.

Parks are also key assets in preserving ecological areas/corridors in three priority categories:

- Core habitat preservation
- Buffer and connection areas
- Restoration and enhancement opportunity areas²³⁷

Certain park projects, such as splash pads, have both climate mitigation and adaptation elements. According to Jay Steffen, former director of the Parks and Recreation Department and currently assistant city planner: “On any given hot summer day, all through the summer, there are 30 to 50 kids and their families [...] out there cooling down, because many of the neighbors in that neighborhood don’t have air conditioning. [...] It’s been a real asset to the neighborhood.”²³⁸ These assets are helpful in building climate resiliency, as they have proven important during extended periods of high heat.

Similarly, new and renovated parking lots, community gardens, and other landscaping features can be designed to accommodate stormwater flows for on-site infiltration, decrease solar gain and heat island impacts, and advance other goals for park design.²³⁹

Grand Rapids has policy and plans in place to add new parks, interconnect existing parks, and improve access to underserved neighborhoods.²⁴⁰ Availability and access to city parkland is relatively low, compared to national and regional standards (see Figure 40). A [2011 audit for the Parks and Recreation Department](#) found that park acreage, including Grand Rapids Public Schools, is 7.88 acres per 1,000 residents. This is in comparison to a range for other typical Midwestern cities of around 12 to 15 acres per 1,000 residents.²⁴¹ The City has responded with a goal of having parkland available within a quarter mile of all residents.

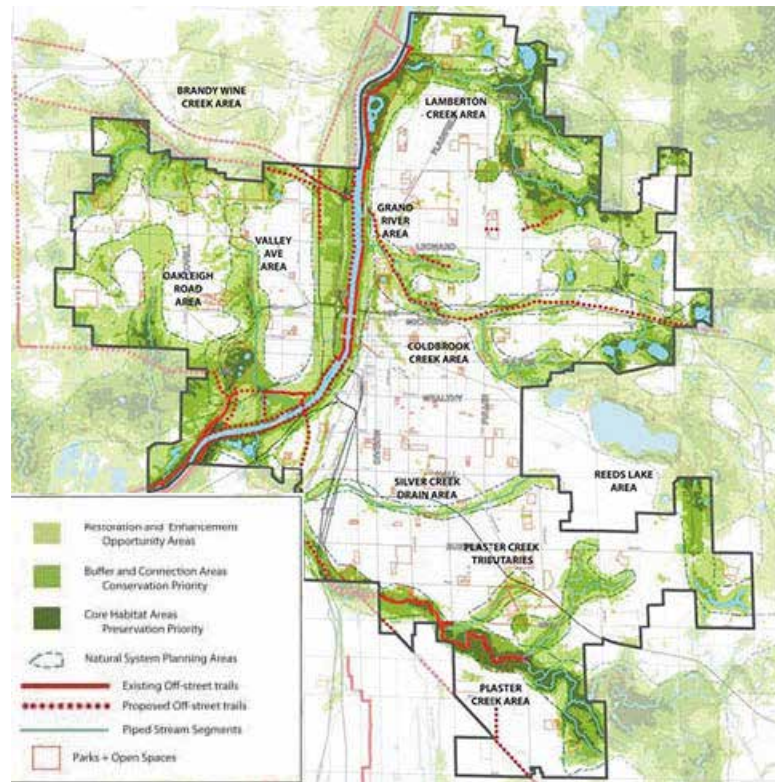


Figure 39. Parks are the primary tool for conservation in Grand Rapids, preserving our most important ecological features and natural corridors, and they offer the best opportunity for restoration.

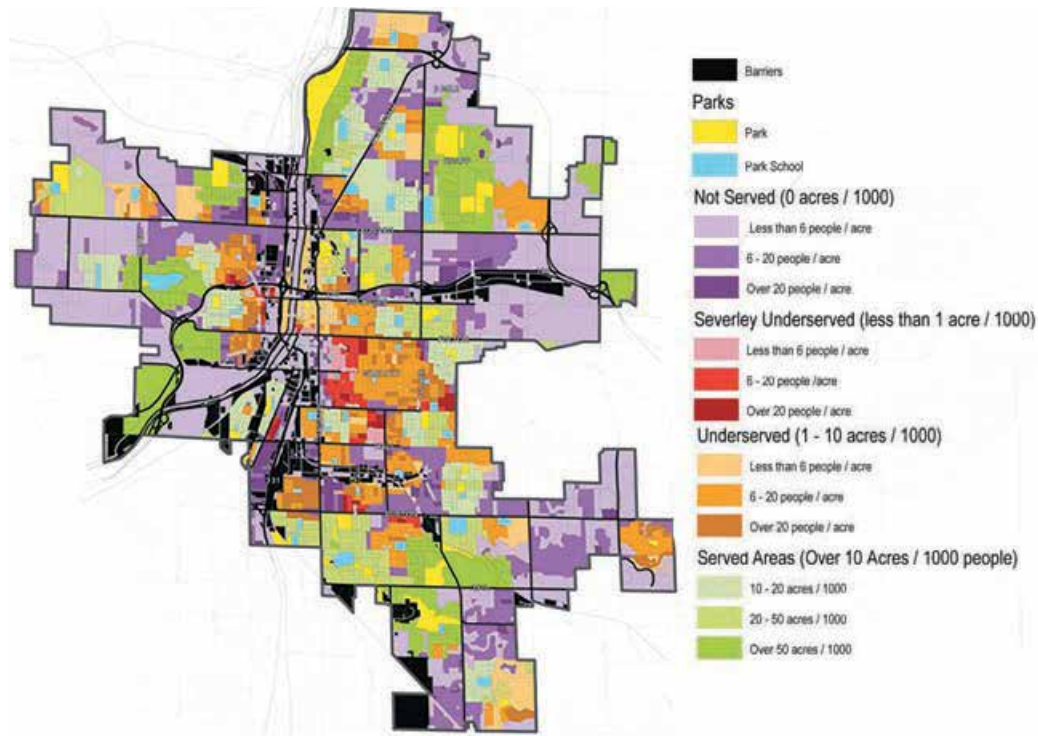


Figure 40. Park accessibility. The City’s quarter-mile accessibility goal reduces the need for driving, increases green space, and improves community health.

City funding of the Parks Department fell steeply between 2002 and 2011. Park maintenance budgets were down by 40% and staffing was down 68%. Citizen groups, including the Neighbors for Parks, Pools, and Playgrounds, recently proposed a millage to increase funding. The City Commission supported a seven-year .98 millage Parks, Pools, and Playgrounds proposal that will bring in approximately \$4 million per year.²⁴² The millage passed with 60% voter approval.

City park plans and the proposed millage do not broadly address questions of climate change, but they address specific elements. For example, Joe Taylor Park includes pervious pavement, rain gardens, energy-efficient lights, and underground on-site stormwater infiltration tanks designed to hold and infiltrate 270,00 gallons of stormwater runoff from 40 acres.²⁴³

Other park adaptation strategies address the microenvironment of the parks themselves. As mentioned, the USDA Plant Hardiness Zone Map has recently been updated, placing Grand Rapids in Zone 6a, a warmer zone than the previously occupied Zone 5b.²⁴⁴ This change means that a slightly different portfolio of trees and landscape plantings is now ideal in park and streetscape environments. Similarly, changes in the climate entail changes in plant watering and maintenance needs as well as in pest and invasive species populations and activity. Tree selection and landscape design should adapt to these changes.²⁴⁵

4 SOCIAL IMPACTS

In Grand Rapids the potential exists for climate change to highlight and exacerbate social inequity, disproportionately affecting vulnerable populations with limited resources and mobility. Vulnerable populations include the very young and elderly, the poor, the infirm, and the historically marginalized, such as minority populations.²⁴⁶

Impacts that are more likely to affect these groups can be more generally categorized under food insecurity, housing, economic uncertainty, physical displacement, and health. This report is not intended to quantify these impacts, but rather to draw key actors' attention to these areas in order to facilitate further dialogue and future development.

4.1 Emergency Preparedness

“The practice of disaster risk management is a defining characteristic of resilient societies, and should therefore be integrated into all aspects of development.”²⁴⁷

A key piece in building community resiliency is the ability of communities to respond to disasters. When it comes to emergency planning and preparedness, climate change does not present a whole new set of challenges. Instead, it serves to increase, exacerbate, and extend existing impacts. In the past few years many parts of the country, including Grand Rapids, have experienced the impact of extended heat events, drought, heavy rain, and flooding.

Emergency preparedness and climate resiliency are interrelated, as they are associated with the impact of foreseen or unforeseen events on the environment and property, both public and private. Preparing for such events makes it easier to respond and return the environment and property to their previous, stable state. By adopting preventative measures, damage will be mitigated, and assessing the damage at a later date is much more achievable and effective.

Local risk-management experts have highlighted the need for community preparation. A community-wide emergency plan should focus on the areas most likely to be impacted, comprehensively cataloging community resources, where they are, and how to deploy them quickly.²⁴⁸

The City's Emergency Action Guidelines have been amended to include additional considerations and planning procedures directly related to climate change. Resiliency planning takes into consideration similar approaches used for zoning, planning, design, emergency preparedness, food, health, and safety, and incorporates them into a single plan.

The following steps were added to Grand Rapids’s Checklist of Considerations: Public Health Services to better prepare the City for a climate-related event:

- Coordinate with the American Red Cross and other agencies to establish cooling shelters.
- Issue public statements informing residents of ways to avoid heat-related illness/injury, encouraging them to check on vulnerable neighbors and family members and providing them with information regarding shelter locations.
- Issue public statement to encourage lowering emissions during prolonged heat events to improve air quality.
- Coordinate with utility companies to ensure timely response in the case of power outages during severe weather events.
- Ensure Heat Wave Safety Checklist and other important information is integrated into Public Health Services Emergency response and shared with appropriate parties.

Beyond these amendments to the document, additional steps have been taken to ensure that the City is better prepared to handle extended heat events in the future, such as the establishment of the flow chart in Figure 41, which can be used during a protracted heat event.

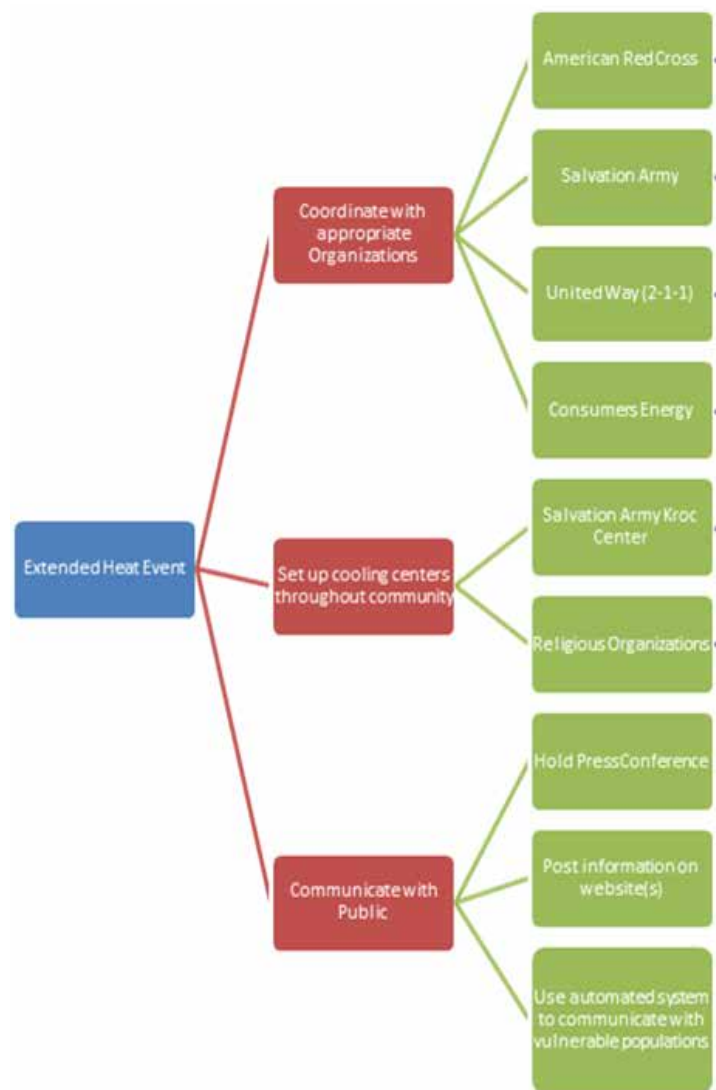


Figure 41. Extended Heat Event Response Chart.

4.2 Human Health

Extreme Temperatures

Anticipated increases in the frequency, occurrence, and duration of heat waves will disproportionately affect the very young, the elderly, and those with certain chronic diseases such as diabetes. The

urban heat island effect will intensify heat waves' impact on Grand Rapids. More information on the heat island effect can be found below. Heat-related illnesses include heat exhaustion, kidney stones, and in the most extreme cases, death from heat stroke or dehydration.

An increasing number of hot, high-humidity days will increase the occurrence and concentration of ground-level ozone. Smog exposure hampers lung function and causes particular problems for people with asthma or other lung diseases. In elderly populations, this pollution makes chronic cardiovascular and pulmonary diseases worse. Exposure may also encourage the development of asthma in children. Low-income communities are more susceptible as they are more likely to have older cars and be nearer to industrial activities with higher emission outputs.²⁴⁹

When considering human health, attention should be given to areas with the least access to essential needs and emergency services. These areas will be disproportionately impacted when climate-related impacts cause sudden injuries and adverse health events. Unfortunately, these areas tend to be markedly populated with low-income and minority populations.

Heat Island

Urban heat island is a phenomenon in which the built environment traps, reflects, and absorbs more heat than natural areas. Cities with over one million people can warm 1.8 °F to 5.4 °F (1 °C to 3 °C) more than the surrounding area. At night, roofs, streets, and other impermeable surfaces slowly release heat, causing some areas to be as much as 22 °F (12 °C) warmer than the surrounding area (see Figure 42).²⁵⁰

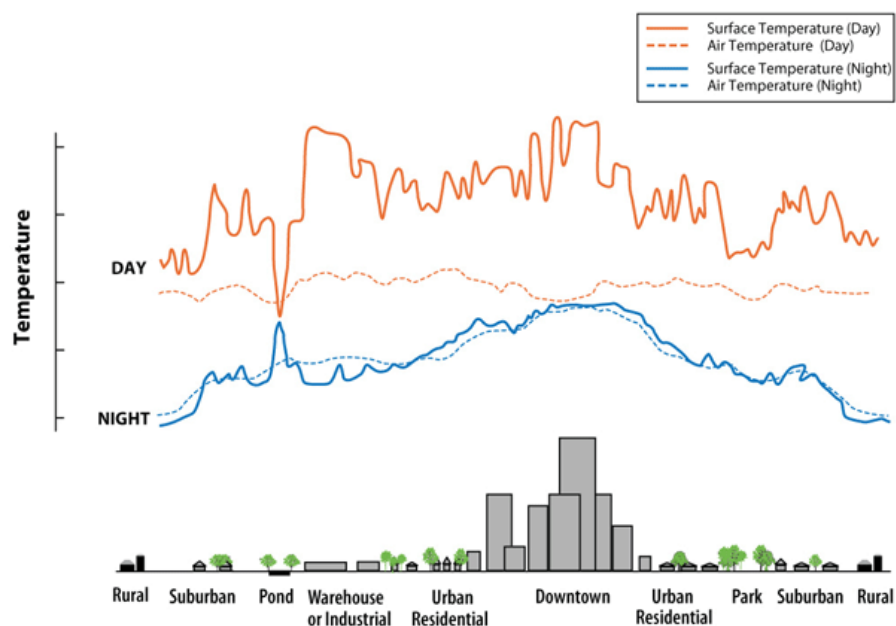


Figure 42. The urban heat island effect.

The urban heat island has numerous impacts on a city. It increases demand for cooling, thus increasing electricity demand. It can impair human health by causing “general discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and heat-related mortality.”²⁵¹

During wet-weather events, the urban heat island can warm stormwater as it travels through the urban watershed to its destination. Aquatic species are sensitive to water temperatures; warm water can have a particularly damaging influence on the metabolism, reproduction, and mortality of these species. These impacts are discussed in greater detail in the [Fisheries section](#).

Pestilence

Climate change is predicted to bring an increase in pestilence. MAGICC/SCENGEN and other climate models predict an increase in rainfall and changes in temperature that could influence the strength and resistance of disease-carrying insects.²⁵² According to the U.S. Forest Service, climate change and drought have already worsened the impact of the emerald ash borer, the bark beetle, the gypsy moth, and the engraver beetle, leading to a threefold increase in forest mortality between 2003 and 2007.²⁵³

The emerald ash borer is currently infesting the Grand Rapids area (see Figure 43). The City has been actively treating infected trees, but many have perished. In 2011 it was reported that the population of infected public trees numbered 5,300, including 4,000 along city streets. At that time the City had already spent \$600,000 removing infected trees according to a tree removal and treatment plan that continues today.²⁵⁴



Figure 43. Emerald ash borer. *Photo: USDA*

Mosquitoes are also of concern with an increase in temperature, both globally and locally. While it is entirely normal for mosquitoes to hatch in spring with the first few downpours, 2013 began with a substantially worse season due to extreme flooding. According to Michael Kaufman, a professor of entomology at Michigan State University, this increased activity is not entirely uncommon for mosquitoes. Put simply, mosquitoes flock to places with an abundance of water. According to Professor Kaufman, “This year we got a huge rain, so we not only picked up the regular groups that would come out in a normal year, but the water levels were high enough to flood the eggs that had been there for many years.”²⁵⁵



Figure 44. Asian Tiger mosquito.

Photo: Sean McCann

Kaufman believes that a warming climate is allowing different species of mosquitoes to migrate north into Michigan. One particularly aggressive species that could be on its way is the Asian Tiger (see Figure 44). A rare day-biter, this mosquito can carry a number of diseases. It is currently prevalent in the eastern United States and is moving toward Michigan. Normally, Michigan's extreme winters and below-freezing temperatures would slow or stop the spread of mosquito populations, but milder winters could allow them to proliferate.²⁵⁶

An increase in pestilence can also harm crops and livestock. Invasive weeds and insects that attack large-scale crops benefit from higher CO₂ levels and increased temperatures. Herbicides are also less effective with higher CO₂ levels.²⁵⁷ As such, more time and money will likely be spent on pest control.

Air Quality

Climate change is expected to have detrimental effects on air quality, particularly ozone and particulate matter (PM) levels, according to a study conducted by Harvard University and US EPA personnel. The report states that climate change will increase PM concentrations by 0.1–1.0 micrograms per cubic meter over the coming decades. It also states that climate change will directly increase summertime ground-level ozone in polluted regions by 1–10 parts per billion (ppb) over the same time frame, with the largest effects in urban areas.²⁵⁸

The study posits a “strong correlation” between elevated temperatures and elevated ozone concentrations, and demonstrates that temperatures above 80 °F correlate with a dramatically increased probability of excessive ozone levels.²⁵⁹

Ozone formation increases with elevated temperatures. High temperatures increase the emission rate of volatile organic compounds (VOCs) from building materials, furnishings, carpeting, personal care products, and cleaning products. VOCs and nitrogen oxides are precursors to the formation of ozone in the presence of bright sunlight and high temperatures; they are emitted by both natural and anthropogenic sources such as automotive emissions.²⁶⁰

MDEQ's Air Quality Division enforces compliance with state air quality regulations and federal US EPA air quality regulations originating from the Clean Air Act. The US EPA provides coordination and support for anti-pollution activities conducted by state and local governments through its regional

offices in Chicago. Title I of the 1990 Clean Air Act Amendments requires states with “nonattainment areas” that do not meet National Ambient Air Quality Standards (NAAQS) to make mandatory emission reductions that include deadlines. Title I places much of the responsibility of protecting air resources and solving pollution problems on the states, generally via a State Implementation Plan.

Michigan’s State Implementation Plan contains legally enforceable requirements to control pollution emissions. It is made up of federal and state air quality regulations, permits, enforcement orders, and agreements that have been approved by the US EPA. P.A. 451 of 1994, which is part of the Natural Resources and Environmental Act, is the state law that addresses air quality in Michigan.

Grand Rapids’s Environmental Services Department provides air quality oversight in multiple ways: It is responsible for enforcement of the City’s Air Pollution Control ordinance (Code of Ordinances, Chapter 151, Article 4); it provides analytical services for the state and City related to air quality; and it operates the seven air monitoring devices on the west side of Michigan through a contract with the state.²⁶¹

Grand Rapids was classified as a nonattainment maintenance area by the US EPA in 2007; in the past the City persistently exceeded NAAQS for eight-hour ozone concentrations, but currently meets all NAAQS standards.²⁶² In all of 2008, Kent County had one day in which ozone concentrations exceeded NAAQS (0.075 ppm).²⁶³

Based on the Centers for Disease Control’s most recent data on airborne particulate matter, Kent County’s annual average concentration of PM_{2.5} is 9.6 micrograms per cubic meter (µg/m³), the highest measured level in Michigan outside of the greater Detroit area, but under the NAAQS limit of 12 µg/m³.²⁶⁴

In 2012, the MDEQ declared 25 air quality action days (see Figure 45), the most in 18 years and a sharp increase from previous years.²⁶⁵ Air quality action days are declared when an area’s Air Quality Index reaches unhealthy levels, signified by an Air Quality Index value of 151 or above. Unhealthy Air Quality Index level triggers include eight-hour ozone levels in excess of 95 ppb, one-hour ozone concentrations of 165 ppb or higher, or PM_{2.5} concentrations of 55.5 µg/m³ or higher.²⁶⁶ There have been two action days in 2013.²⁶⁷

Grand Rapids	2012	25	5/24, 5/27, 6/9, 6/10, 6/15, 6/16, 6/19, 6/20, 6/28, 6/29, 7/2, 7/3, 7/4, 7/5, 7/6, 7/7, 7/13, 7/15, 7/16, 7/17, 8/4, 8/24, 8/25, 8/30, 8/31
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Figure 45. The incredible heat of 2012 brought with it a high number of MDEQ air quality action days. On these poor-air quality days people should reduce air emissions. Those at risk include the elderly, children, and people with asthma or heart disease. People who work or exercise strenuously outdoors can protect their health by reducing exertion.

The American Lung Association’s 2013 “State of the Air” report recognizes that significant improvements have occurred in Kent County’s air quality in the last decade. The average annual measured particle concentration, 9.7 $\mu\text{g}/\text{m}^3$, earned a passing grade. Kent County earned a “B” for its 0.3 particle pollution days, down from 10 a decade ago, and a “C” for ozone days.²⁶⁸

According to Jacqui Patterson, director of climate impacts for the National Association for the Advancement of Colored People (NAACP), there is a higher incidence of people with special health located in poorer communities, making them more vulnerable.²⁶⁹ Dave Schroeder, a consultant for the Kent County Emergency Needs Task Force, has similar concerns. He noted that people with fewer financial resources often have vehicles that are less efficient and pollute more, leading to higher localized concentrations of ozone, carbon monoxide, CO_2 , and other airborne pollutants.²⁷⁰

Increased probabilities of ambient air pollutants combined with a more vulnerable population means negative health impacts are more likely in underserved areas. Special attention to these areas should be a part of climate resiliency efforts undertaken by the City, because they are likely to be disproportionately affected as climate change exacerbates existing air quality challenges.

Emissions on Ozone Action Days

The main contributors to air pollution in most urban settings are gaseous and particulate emissions from vehicular traffic.²⁷¹ Automotive emissions contain VOCs, carbon monoxide, CO_2 , PM, and nitrogen oxides (NO_x)—all recognized pollutants. Many of these contribute to climate change or are precursors to ozone, a short-lived but highly potent greenhouse gas with deleterious health effects when the concentration is elevated at the surface of the earth.

The Rapid bus program offers free rides on clean air action days. Decreasing vehicular miles traveled reduces the emission of ozone precursors and fine particulate matter. Expanded routes and service hours are likely to increase utilization of public transportation.

Indoor Air Quality Affected by Climate Change

Indoor air quality is likely to be affected by climate change. Extended periods of warm temperatures during spring and fall will increase the incidence of open windows, especially among lower-income residents who lack air conditioning, allowing increased exchange with outdoor air and greater equalization with outdoor air quality conditions.²⁷² Hot and humid days tend to have the poorest air quality.

As temperatures rise, VOC emission rates will increase, meaning that consumer product material choices will have an increased effect on indoor air quality. Low- or no-VOC materials should be prioritized over materials with high-VOC emission rates as lower VOC concentrations are correlated with less ozone formation.²⁷³

Climate and Allergies

Climate change is likely to enhance the production of pollen, leading to increased incidence of symptoms among citizens with allergies. Warmer temperatures have been observed to coincide with earlier and extended pollen seasons; higher temperatures and CO₂ availability have been observed to trigger “substantial increases in pollen production” in ragweed; and the pollen of trees grown at increased temperatures has displayed “significantly stronger allergenicity.”²⁷⁴

Ambient pollutants such as ozone and particulate matter can interact with pollen to increase a person’s vulnerability to allergens. Pollen grains can bind with particulate air pollutants, which then act as pollen carriers. Airways damaged by air pollutants “may facilitate the access of inhaled allergens to the cells of the immune system.”²⁷⁵

4.3 Resilient Food Systems

Most urban residents purchase their food rather than grow or otherwise manufacture it. The path from rural producer to urban consumer is complex, and each stage in the process is susceptible to climate change disruption. According to Cynthia Price of the Greater Grand Rapids Food Systems Council, any disruption to production, processing, or transportation—near or far—could increase food prices due to the interconnectedness of these systems. This would place a greater burden on family budgets and decrease access to nutritious food.²⁷⁶

Food Desert

A food desert is defined as a district lacking access to a grocery store with healthy and nutritious food options. In food desert areas, existing establishments sell unhealthy and processed foods with limited selection. Fast food chains and convenience marts are often more accessible than grocery stores with healthy selections. Residents in these areas are less likely to have reliable transportation and more likely to walk to the nearest food vendor. Although public transportation is available in some areas, it can be difficult to use due to the large amount of products that needs to be transported.

The Michigan Department of Agriculture and the U.S. Census Bureau have identified populations of low- and moderate-income individuals with travel limitations in every county in Michigan; 59% of all Michiganders live in a limited-access area.²⁷⁷ The proximity of produce locations to inner-city residents is a crucial factor in the health of residents across the nation, as the best produce and lowest prices have moved to the suburbs.²⁷⁸ This is especially a concern for individuals who struggle to find transportation, including the elderly, children, people with disabilities, and low-income individuals.²⁷⁹

Marie Roper writes that low-income residents in Grand Rapids neighborhoods such as Heartside and Baxter have minimal convenient access to healthy food. A number of organizations working to address the problem include the [Inner City Christian Federation](#), Wealthy Market, and the potential for a 30,000-foot grocery store at the corner of Wealthy Street and Jefferson Avenue.²⁸⁰

Urban Agriculture and Relocalizing Food Systems

Urban agriculture (UA) is that which takes place in urban or near-urban settings. Practices address a variety of food-security issues—such as food deserts, unstable supply chains, and distribution difficulties—by locating food production closer to the people who will consume the food. It also increases consumer involvement in and awareness of food systems. Urban agriculture can be applied on a wide range of scales, from container gardens at the household level to commercial operations occupying rooftop greenhouses or dedicated facilities.

The Greater Grand Rapids Food Systems Council's Price believes that the effects of climate change on agriculture will be very serious. She says that building a more resilient community will require greater local control over our food supply than is currently possible. The reason is that our reliance on highly interconnected worldwide food systems may be vulnerable to shortages and disruptions originating hundreds or thousands of miles away. Price sees relocalization of our food systems as a key factor in increasing the climate resiliency of the Grand Rapids area.²⁸¹

Food miles are a measure of the distance that food travels between producer and plate. Price believes these should be minimized. Increasing food miles increases both our food-related carbon footprint and our vulnerability to non-local disruptions and shortages. “The main thing is to get the infrastructure in place so that transportation isn’t necessary,” says Price, who sees farmers markets, direct markets, and community-supported agriculture (CSAs) as obvious ways to work toward short transportation distances and supply chains. In 2011, the Greater Grand Rapids Food Systems Council published its fifth [West Michigan Fresh: Guide to Local Food](#) report with comprehensive listings of local, fresh, and nutritious farms, markets, and other food sources.

According to Price, a key first step would be an analysis of what food crops can be grown locally, what crops can be grown locally in artificial environments, and how our community can harness longer growing seasons. She noted that West Michigan residents start seeing the inefficiencies of the status quo when apples from Washington State are more available than those from Michigan's bountiful Fruit Ridge agricultural area. She wants people to start growing their own food in their backyards. To help, the Food Systems Council will have a technical advisor this year offering on-site assistance to less-experienced people who may not feel qualified to grow their own food, starting with lower-income individuals.²⁸²

Certain farmers at the Fulton Street Farmers Market are now using hoop houses, high-wind tunnels, and hydroponic growing technologies to extend their growing seasons to a three-quarters or year-round operation.²⁸³ Recently, federal grant money has been available for extending growing seasons in Michigan.

Food hubs are being promoted by the USDA to facilitate the aggregation, marketing, and distribution of local food.²⁸⁴ A local example is the West Michigan Co-Op, which promotes online sales of food produced within 50 miles. The model borrows ideas from mainstream food systems. According to Price, this is why food hubs have been so readily accepted. She suggests copying existing models in which food moves quickly through storage and transportation hubs to reduce spoilage and keep costs down. She sees food hubs as a way to integrate local food into existing distribution structures.

Food Preservation

Eating according to the seasons and using home-based food preservation techniques, such as canning and smoking, have been somewhat neglected in our current age of convenient food. However, they could prove helpful in building more self-reliance and resiliency into our local food system. For example, Kent County's [Michigan State University Extension](#) delivers food-preservation education. The program features a certification that teaches about storing temperatures, freezing and dehydrating food, and canning. Local nonprofits such as Baxter Community Center and [Access of West Michigan](#)'s Food Pantry system have trained low-income families on food preservation while providing them with food and canning supplies.

Container and Community Gardens

Gardens and other small-scale food production methods have the potential to allow Grand Rapids residents to become more self-sufficient. Operations such as Our Fresh Local demonstrate the possibilities of neighborhood-scale food production to address the problems of distribution and food

deserts. The “green grocer garden” model allows residents within walking distance to harvest produce as they need it and be billed electronically for the food they take.²⁸⁵

There are valuable lessons to be learned from the citizens of Cuba, who learned many of the key concepts from UA when the collapse of the Soviet Union left them without fuel, fertilizers, pesticides, agricultural machinery, and spare parts.²⁸⁶ With the support of a framework of government programs, Cuban citizens were producing one kilogram of produce per capita per day by 2006 by making heavy use of large-scale container gardens. The typical growing environment, or *organopónico*, is a collection of several 30-meter-by-1-meter container gardens cast from concrete featuring raised planting beds.²⁸⁷

Future plans for the garden could include small-scale artificial environments such as a greenhouse, which would moderate the effects of extreme and/or variable weather on produce and extend the growing season.

Local Story: [Congress Elementary School](#)

Grand Rapids Public Schools recently constructed the Cornelius Kos Community/School Garden on the grounds of Congress Elementary School in community partnership with the East Hills Council of Neighbors. A variety of produce was planted in the dozen raised garden plots, allocated between students and their families, educational projects, and East Hills neighbors.

The garden was constructed in May after the school was approached by the East Hills Council of Neighbors and given a \$5,000 grant from the Kos family. Bridget Cheney, principal at Congress, is looking to turn the garden and the school grounds into a community hub that promotes awareness of sustainability. Cheney said that children who learn lessons of sustainability are able to influence the wider community: “Kids are really, really good at reminding, being persistent, and are just very observant and aware. If you tell them how this is good, and how the sustainability movement enriches our community, they’re more apt to say that to more than just one or two people.”

Food in the garden is grown organically, without petroleum-based chemical inputs, and has a significantly lower transportation footprint than the produce it replaces. Cheney said that just one of the 12 plots is projected to provide enough food to distribute to 100 people.

Farmers Markets

For nearly a century, the Fulton Street Farmers Market has been a fixture on the northeast side of Grand Rapids, making local food available to citizens. While the market does not prescribe a maximum radius that qualifies as local, vendors naturally self-select based on practical driving distances. According to

Melissa Harrington, executive director of the Fulton Street Farmers Market, farmers markets build community climate resiliency because the farmers who supply the markets operate at small scales. These small scales allow them to adapt to changing circumstances. Although smaller vendors tend to be more economically vulnerable than larger agricultural operations, farmers markets allow them to sell directly to consumers, which can increase their margin by eliminating middlemen. Harrington believes that small-scale farmers are naturally inclined to diversify their crops to protect against crop failure and that small-scale farming uses more human labor. Small-scale farmers also tend to use lesser quantities of fossil fuels and pesticides—saving money and reducing chemical inputs.²⁸⁸

Food justice is an important part of Harrington’s mission. Fulton Street Farmers Market has partnered with the Department of Human Services and the [Fair Food Network](#) for “Double Up Food Bucks,” a matching-funds program that allows food-assistance recipients to double their food dollars to buy fresh food grown in Michigan during the market’s peak summer months. [The Grand Rapids Community Foundation](#) was a major local donor. Harrington notes that an unexpected bonus of the program is that wholesale vendors who might otherwise source product from out of state are instead sourcing food from within Michigan to qualify for the program.

In a related initiative, market vendors are taking part in a pilot program to test mobile point-of-sale devices that enable electronic transactions, including Bridge cards. Harrington believes adoption of this technology is an important step toward making local food more accessible to underserved community members. She views the market as an inclusive social space where all people can have access to healthy, affordable food. This includes being able to accept SNAP (the federal Supplemental Nutrition Access Program) and working with incentive programs such as Double Up Food Bucks. These programs have proven beneficial for customers and farmers alike and keep money circulating in the local economy.

Harrington is also planning for the future and trying to facilitate the succession of a younger generation of farmers as many current vendors approach retirement age. Harrington encourages communication between the older generation and future farmers by proposing mentorships as a means to pass on the wealth of knowledge that current farmers possess.

One can search for a local farmer’s market online at the [Michigan Farmers Market Association website](#). [The Greater Grand Rapids Food Systems Council](#) keeps a [list of Grand Rapids farmers markets](#), such as the Fulton Street Farmers Market, Maple Creek Farmers Market, Plainfield Township Farmers Market, South East Area Farmers Market, Wealthy Street Farmers Market, West Side Farmers Market, and the recently opened [Downtown Market](#) (see Figure 46).



Figure 46. The 130,000-square-foot Downtown Market provides space for local vendors. The market is expected to attract 500,000 visitors annually, increasing demand for fresh, local food.²⁸⁹

Photo: John Eisenschenk

Urban agriculture’s potential is not limited to produce. New York City, for example, permits several varieties of livestock (chicken, rabbits, cattle, swine, sheep, and goats) to be raised by city residents, contingent on space and other requirements. Chickens in particular have small space requirements, lay eggs every 36 hours, and provide protein, fat, and other nutrients without the hassle, health concerns, or ethical issues that animal slaughter entails.

Urban Aquaculture

Urban aquaculture, defined as fish farming in or near an urban area, is another source of sustainable nutrition. Recirculating aquaculture systems can breed a wide range of species for local consumption, including tilapia, walleye, flounder, clams, and oysters. Farming is done under environmentally controlled conditions, with minimal water use or effluent output and highly scalable indoor tanks. Brooklyn College biology professor Martin Schreibman has grown tilapia by the thousands in a cellar at the college, using bacteria to break down produced effluent, in a process that has already seen commercial success and is projected by Schreibman to have economic potential of \$1.5 billion in New York.²⁹⁰

4.4 Climate Change and Crime

One of the most difficult aspects of developing a triple bottom line view of climate change impacts is understanding the relationship between climate impacts and societal needs. Within that framework is

an even more overlooked aspect of climate change: social conflict.²⁹¹ For some time, law enforcement agencies and criminal justice researchers have gathered data that links certain weather events such as heat waves and major storms to increases in crime in urban communities.

The Grand Rapids Police Department knows that when temperatures rise, certain crimes tend to go up. This happens for several reasons. When the weather is nice more people tend to be outside, which creates more chances for interactions between people and therefore greater chances for hostile interactions.²⁹² Warmer weather also means people leave windows and doors open during the day and at night, which facilitates potential instances of breaking and entering.²⁹³ Interestingly, there is anecdotal evidence that extreme heat events can have the opposite effect, keeping people inside and causing those with air conditioning to close windows and doors.²⁹⁴ An additional common belief held by the criminal justice community is that ambient temperatures can affect aggression and self-control. Therefore, as the weather warms some people become more agitated and are more likely to commit aggressive acts.

Some theories that explain criminal behavior directly link climate change to behavioral change. Other theories consider how existing social standards (underserved populations, areas of concentrated poverty, lack of education, discrimination, etc.) may lead to increased crime rates due to climate change. These theories view existing social injustices as a foundation for criminal activity that is exacerbated by climate change. Conversely, more affluent individuals may be impacted by climate events as they may be more likely to feel a threat to their livelihood, which could lead to acts of desperation to support themselves and their families.²⁹⁵

In some communities, low-income populations occupy housing that is within flooding areas, industrial zones, and older, blighted neighborhoods. These situations can exacerbate feelings of unfair practices by decision-makers. While climate change is not responsible for these situations, its impacts can compound an already unstable situation and expose the insufficient resiliency that exists in these areas.²⁹⁶

Although City of Grand Rapids census data shows that the greatest number of minority households and households with the lowest median incomes do indeed reside nearest the Grand River (see Figures 47 and 48),²⁹⁷ Grand Rapids police chief Kevin Belk is unaware of data suggesting that crime increased during the flood in April 2013 or other emergency events within the City.²⁹⁸

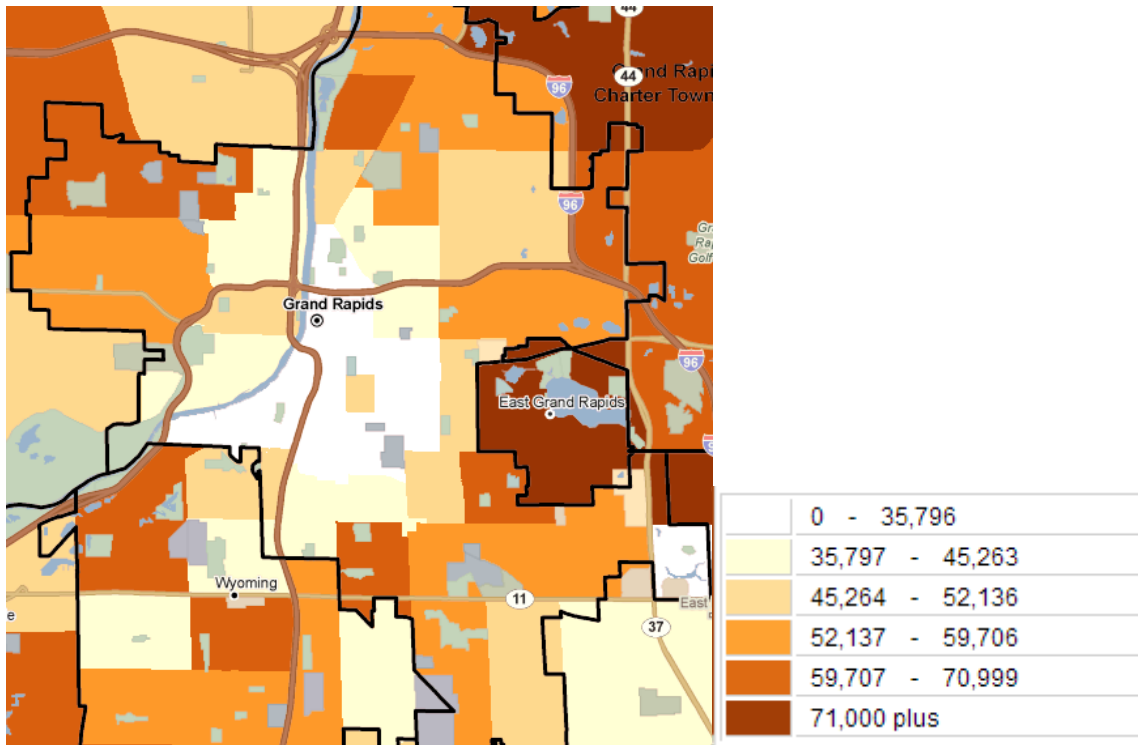


Figure 47. Median income (U.S. dollars) in Grand Rapids.

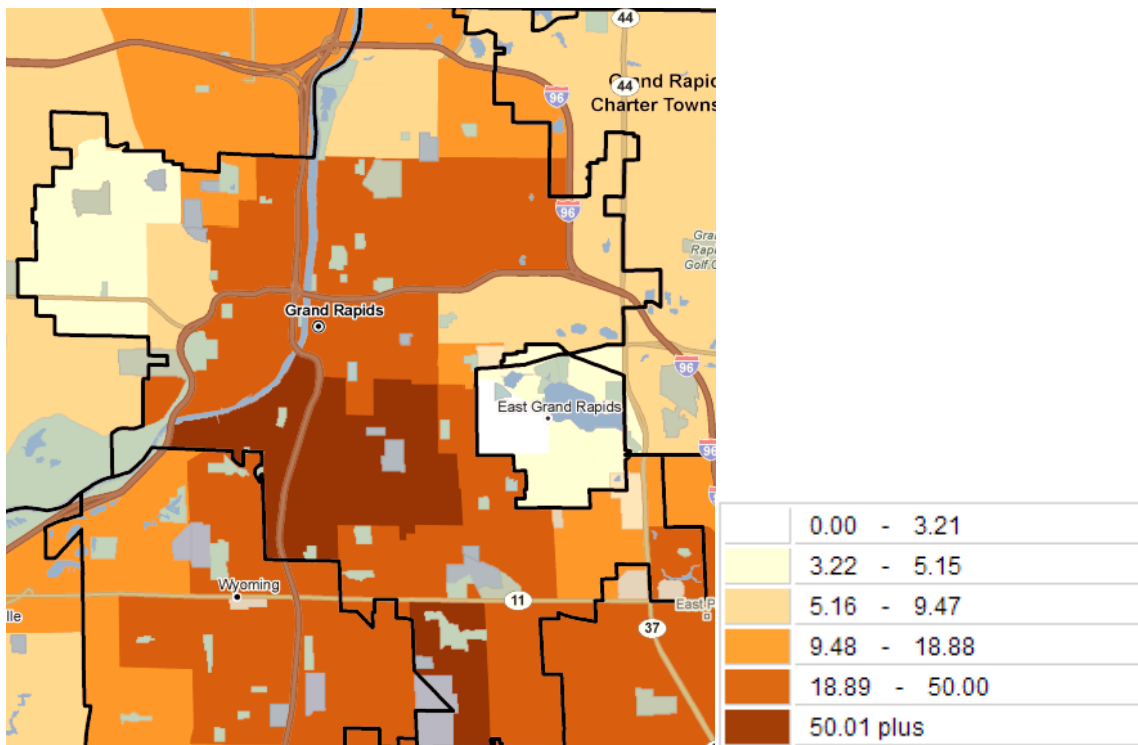


Figure 48. Percentage of non-white homeowners in Grand Rapids.

There are several additional factors in the link between climate change and crime in a community:

- Increased strain placed on families or individuals as they have to support others who have been impacted by an extreme event or are vulnerable to new climatic conditions due to age or illness.
- Reduced social control during times when resources are focused on combating or recovering from an extreme event such as a flood or storm-related power outage.
- Weakening social supports that are initially strong immediately following a disaster but lessen over time as the recovery prolongs in areas that are less able to rebound from the event.
- Fostering beliefs and values favorable to crime if the person or group feels that the community as a whole or organizations meant to help during disasters are not providing the proper services.
- People resorting to crime as a coping mechanism for a bad situation that was made worse by an extreme or disastrous event.²⁹⁹

Further study is needed to test these theories, many of which were created to explain criminal activity changes in developing nations. These countries are among the most vulnerable to climate change impacts and often have less capacity to provide social services that might deter criminal activity.

The Grand Rapids Police Department is taking steps toward increasing resiliency to extreme weather events in this area, including institutional policies and partnerships to provide the best service with available resources. One example is the You Are Not Alone program, an effort to promote a “neighborly atmosphere” by asking citizens to check on neighbors and friends, especially the elderly or sick. With 280 police officers and 190,000 citizens, there is a need for citizen assistance to fill in the gap, as limited resources have made existing services vulnerable.³⁰⁰ In addition, Chief Belk stresses the importance of early childhood programs in helping the community adapt to future impacts from climate change or other emergency events.

Other programs meant to reduce the City’s vulnerability to crime include crime prevention through environmental design of parks and public spaces, opening lines of communication with community organizations to help monitor neighborhoods, and providing support to prisoner reintegration programs.³⁰¹

5 CONCLUSION

Climate change resiliency planning is a wicked problem. It has complex roots and no definitive end. It is part of an open system, is the symptom of other problems, and leaves little room for mistakes by decision makers.³⁰²

According to the MAGICC/SCENGEN model used in this analysis, and other climate research conducted for the Midwest and the State of Michigan, Grand Rapids will be impacted by climate change. This community is fortunate to be buffered against its most extreme impacts, such as coastal flooding tied to increasingly strong storms or the extreme drought and heat experienced in more arid regions.

Grand Rapids can expect both warmer temperatures and increased precipitation. Annual average temperature is predicted to rise from a baseline of 47.3 °F to 49.28 °F by 2022, then to 51.26 °F by 2042. Precipitation is expected to increase from a baseline annual average of 7.6 cm to 7.8 cm and 8.3 cm in 2022 and 2042, respectively.

These increases may seem insignificant, but research shows that such annual changes to temperature and precipitation averages can have major effects on hydrologic cycles, vegetation growth patterns, seasonal weather patterns, and air quality. Importantly, they may cause an increase in the occurrence of extreme-weather events (such as days above 90 °F and 90% humidity), storms producing one inch of rain within 24 hours, and more freeze-thaw cycles within a year.

However, the true nature of the problem that climate change poses to the resiliency of the community becomes clear when we consider that the predicted climate changes will likely impact each sector of the Grand Rapids community to a certain extent. Grand Rapids represents a complex system in which each of the subsystems does not function in isolation, but rather has unique relationships to the others and to the residents who rely upon them. Decisions made regarding the transportation system have implications for several other subsystems, such as food and healthcare, by inhibiting or enhancing access to certain locations. Understanding that interdependent characteristic of the community system is vital for any planning effort.

Resiliency for Grand Rapids means the ability to simultaneously balance ecosystem and human functions in an uncertain and dynamic climate future. Grand Rapids must continue to mitigate its contribution to climate change while also preparing to adapt to the predicted impacts in a way that enhances residents' freedom to flourish.

Grand Rapids needs resources, champions, and a directive to build a more resilient community.

5.1 Recommendations: Process and High-Level

The recommendations provided in this section were developed with an understanding that Grand Rapids represents a complex system with differing perspectives, resources, goals, and processes. Each sector possesses unique and valuable knowledge and direction, which will be needed to understand and solve the wicked problem that increasing resiliency to climate change represents.

1. Grand Rapids needs an individual(s) or organization(s) to own and champion the responsibility of building climate resiliency in our community.
2. The champion(s) need a directive and resources to engage the community across sectors. Existing local community climate-resiliency narratives and leaders should be highlighted.
3. Champion(s) should utilize resiliency concepts, issues, and strategies identified in this report to evaluate existing plans (Green Grand Rapids, Sustainability Plan, etc.) to inform priority implementation.
4. City resiliency efforts going forward should focus on the selection, financing, and implementation of projects, as current planning documents identify existing best practices.
5. Underserved low-income and minority populations will be disproportionately impacted by climate change. Resiliency efforts in all aspects of community planning should recognize this.
6. Organizations should use economic valuation tools and comprehensive, triple bottom line impact analyses when considering major project spending.

5.2 Recommendations: Environmental Issues

Grand Rapids is in a unique position as an urban center that has aspects of a natural ecosystem within its boundaries and immediate surroundings. As such, it is important when planning for climate resiliency to consider not only solutions for the ecosystem components themselves but also those that will preserve communities' ability to interact with these resources.

7. Grand Rapids should strive to reduce GHG emissions through City operations and in the community as stated in the City of Grand Rapids Sustainability Plan and the U.S.

Conference of Mayors Climate Protection Agreement (Grand Rapids Sustainability Plan).

8. Capture the “first-flush” precipitation of the 90th–95th percentile wet-weather event near where it falls.
9. Study the impact of climate change on the Grand Rapids water filtration plant.
10. Promote best practice regional settlement patterns in the Grand Rapids metropolitan area. Better integrate development with existing infrastructure (GVMC).
11. Increase watershed-level cooperation among sewer, water, and stormwater authorities.
12. Establish a metro-wide system of environmental corridors, greenways, or landscapes, which create convenient, non-destructive public use of our natural environment, including bikeways, recreation areas, nature walks, and scenic preserves (GVMC).
13. Preserve and grow mixed-use and dense development neighborhoods, making essential services and businesses accessible through multimodal means of transportation (Green Grand Rapids).
14. Continue the Grand Rapids Metro Council’s policy of “no new road construction in Grand Rapids,” focusing instead on maintenance and “vital streets” improvement of existing roads where appropriate (GVMC).
15. Continue monitoring Great Lakes and aquifer water levels to more precisely understand the multiple causes and effects of fluctuations.
16. Water efficiency efforts should be strengthened in Grand Rapids through a variety of technological, policy, pricing, and programming means (Grand Rapids Sustainability Plan).
17. P.A. 98 of 2013 alters Michigan’s wetland program. The City of Grand Rapids should advocate to the state and federal government for a robust wetlands program that at a minimum equals the previous standard.
18. Improve the quality of the Grand River and its tributaries by restoring it to a more natural state. This should involve the improvement of riparian buffers, daylighting

tributary streams, continuing the development of greenways, and softening channels (Green Grand Rapids).

19. Reconnect residents and visitors to Grand Rapids urban waterways to increase citizen awareness of our fundamentally important water resources, build a sense of place, and maximize opportunities to create economic and social capital (Grand Rapids Whitewater).
20. Adopt a stronger urban canopy goal—at least 40%—and implement a program that reflects heat island, air quality, and other documented resiliency values delivered by a diverse, healthy urban tree canopy (Grand Rapids Urban Forestry Plan).
21. Engage citizens and private property owners in characterizing, managing, and growing the urban canopy through innovative programs and tools such as the GR Tree Map app (Friends of Grand Rapids Parks).
22. Parks, pools, splash pads, and natural and green recreation areas should be considered by City decision makers as critical climate infrastructure that enhances quality of life and makes Grand Rapids more resilient.
23. Use critical climate infrastructure such as low-impact development and green infrastructure to wholly implement the paradigm shift in stormwater management best practices (Green Grand Rapids; Green Infrastructure Portfolio Standard Projects).

5.3 Recommendations: Social

A unique impact of climate change is the exacerbation of existing social inequities, which disproportionately affects vulnerable populations with limited resources and mobility. Collaborative efforts and resources should be pooled to understand impacts and solutions concerning food insecurity, housing, economic uncertainty, physical displacement, and health.

24. Citizens should develop a disaster-preparedness plan of their own by using resources such as the American Red Cross.
25. Grand Rapids should expand on existing strategies to improve long-term air quality efforts by researching and forwarding more powerful policy tools, locally and statewide, such as incentives to reduce vehicle miles traveled.

26. Grand Rapids and its partners (i.e., American Red Cross, Essential Needs Task Force, Kent County Emergency Preparedness, etc.) should analyze the effectiveness of resources used by citizens during extreme heat events, such as cooling centers and ozone action alerts, in order to continue providing the most useful and efficient responses.
27. Consider mitigating the production and exposure to low-level ozone and the urban heat island when planning and developing new infrastructure.
28. Continue to improve access to food sources by developing local food infrastructure.
29. Evaluate data-driven, flexible police staffing program for correlation with seasonal and daily temperature modulations.

5.4 Recommendations: Economic

The economic impacts of a changing climate will be far-reaching, interconnected, and difficult to precisely anticipate. Grand Rapids is fortunate to have organizations and leaders who already collaborate to resolve market-based problems and increase the sustainability of businesses and organizations wherever possible. However, climate change will likely require new levels of analysis using the triple bottom line principle to consider solutions that address climate change impacts and allow the organizations, businesses, and individuals of the community to thrive.

30. Support policy proposals to increase energy efficiency at the state level, such as the energy efficiency resource standard in P.A. 295. Simultaneously move to identify and adopt a triple bottom line, balanced, community-wide efficiency target (Grand Rapids Sustainability Plan).
31. Explore legal, policy, and economic frameworks that enable the City of Grand Rapids to build a more autonomous and resilient energy system. Such a system would enable Grand Rapids to pursue ambitious goals around pricing, decentralized energy systems, efficiency, and renewable energy.
32. Request that the MI Public Service Commission or another appropriate institution study climate change impacts on the energy sector, including supply, demand, infrastructure, and the energy/water resource nexus.
33. Research and implement climate-resilient street maintenance and construction practices, particularly for materials and physical infrastructure (Sustainable Streets Task Force; Green Grand Rapids).

34. Change the transportation culture in Grand Rapids to one built around multimodal, vital streets, providing equal access for all social levels with diverse transportation requirements (Green Grand Rapids).
35. Municipal insurance, capital projects, and asset-management planning should include assessments for exposure to drought, temperature change, flooding, storms, and climate mitigation.
36. Increase the number of commercial, residential, redevelopment, and remodeling building projects certified to be sustainable (i.e., LEED, Green Built, Green Star, etc.) beyond the existing 2015 goal. Study and recommend policy tools to reduce barriers and expand use beyond early adopters (Grand Rapids Sustainability Plan; City of Grand Rapids Zoning Ordinance).
37. Retain green building leadership by encouraging the construction of best-in-class green building projects (i.e., Living Building Challenge, 2030, Netzero, LEED V.4 Platinum).
38. Prepare the agricultural industry for future climate scenarios by encouraging the use of existing decision-making resources, and where possible, host resiliency informational forums.

ACRONYMS

ACSET	Area Community Services Employment & Training
AWRI	Annis Water Resources Institute
BRT	Bus Rapid Transit
C	Celsius
CEAG	Community Energy Advisory Group
CO ₂	carbon dioxide
CSA	community supported agriculture
CSO	combined sewer overflow
ESA	environmental site assessment
F	Fahrenheit
FY	fiscal year
GHG	greenhouse gas
GVMC	Grand Valley Metropolitan Council
ICLEI	International Council for Local Environmental Initiatives
IPCC	Intergovernmental Panel on Climate Change
LEED	Leadership in Energy and Environmental Design
MAGICC	Model for the Assessment of Greenhouse-gas Induced Climate Change
MARB	Market Avenue Retention Basin
MDARD	Michigan Department of Agriculture and Rural Development
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
MPSC	Michigan Public Service Commission
MSU	Michigan State University

MW	megawatt
MWh	megawatt-hour
NAACP	National Association for the Advancement of Colored People
NAAQS	National Ambient Air Quality Standards
ND	Neighborhood Development
NOAA	National Oceanic and Atmospheric Administration
NO _x	nitrogen oxides
P.A.	Public Act
PDR	Purchase Development Rights
PM	particulate matter
ppb	parts per billion
ppm	parts per million
SCENGEN	Regional Scenario Generator
TBL	triple bottom line
µg/m ³	micrograms per cubic meter
UA	urban agriculture
UN	United Nations
U.S.	United States
USDA	United States Department of Agriculture
US EPA	United States Environmental Protection Agency
USGBC	United States Green Building Council
VOC	volatile organic compound
WMEAC	West Michigan Environmental Action Council

GLOSSARY

City of Grand Rapids vs. Grand Rapids

Grand Rapids is the second largest city in Michigan, a vibrant, exciting, and diverse place. The City of Grand Rapids refers to the municipal government of Grand Rapids, Michigan.

Climate change adaptation

Any responses, actions, or tools employed in reaction to climate change impacts that serve to sustain quality of life as the climate changes rather than decrease the occurrence of climate change itself.

Climate change impacts

The effects of a changing climate on the human and ecological world.

Climate change innovations

Leading, exemplary, or best-practice responses, actions, or tools employed in reaction to climate change impacts that serve to mitigate and/or adapt to those impacts.

Climate change mitigation

Any response, proactive step, or tool employed to reduce or prevent climate change from occurring. Mitigation is usually expressed in the sequestration of greenhouse gases from the atmosphere.

Climate resiliency

The ability of a community to simultaneously balance ecological, economic, and social systems to maintain or increase quality of life in an uncertain, dynamic climate future.

Sustainability

Development that meets the needs of current generations without compromising the ability of future generations to meet their own needs.

Triple bottom line

The triple bottom line (TBL) is a framework for dynamic systems and decision making employed by individuals, groups, or organizations that accounts for economic, social, and environmental issues associated with that system.

Two-degree Celsius threshold

As part of the Kyoto Protocol, scientists have identified a 2 °C rise (3.6 °F) as the specific global temperature gain at which damage to the earth system will have extreme consequences for humanity.

ENDNOTES

- ¹ Kling, G., Zak, D., & Wilson, M. (2003) Confronting climate change in the great lakes region: Impacts on Michigan ecosystems and communities. Retrieved from www.ucsusa.org/greatlakes and Winkler, J. A., Arritt, R. W., & Pryor, S. C. (2012) Climate projections for the Midwest: Availability, interpretation, and synthesis. Retrieved from http://glisa.msu.edu/docs/NCA/MTIT_Future.pdf and Liobimtseva, E. (2013) Unpublished MAGICC/SCENGEN climate change modeling for Grand Rapids, MI.
- ² City of Grand Rapids Planning Department, Green Grand Rapids Committee (2011) Green Grand Rapids. Retrieved from http://grcity.us/design-and-development-services/Planning-Department/Documents/Green_Grand_Rapids_Report_LowRez_2011_10_04.pdf
- ³ City of Grand Rapids Planning Department, Green Grand Rapids Committee (2011) Green Grand Rapids. Retrieved from http://grcity.us/design-and-development-services/Planning-Department/Documents/Green_Grand_Rapids_Report_LowRez_2011_10_04.pdf
- ⁴ City of Grand Rapids Planning Department, Green Grand Rapids Committee (2011) Green Grand Rapids. Retrieved from http://grcity.us/design-and-development-services/Planning-Department/Documents/Green_Grand_Rapids_Report_LowRez_2011_10_04.pdf
- ⁵ Geary, C. (2011) Sustainable Connections: Linking Sustainability and Economic Development Strategies. <http://www.nlc.org/Documents/Find%20City%20Solutions/Research%20Innovation/Sustainability/sustainable-connections-linking-sustainability-and-economic-development-strategies-cpb-jun11.pdf>
- ⁶ Alibašić, Haris. Local Governments Must Take Charge of Building Resilient Communities. TriplePundit, 2013. <http://www.triplepundit.com/2013/07/building-resilient-communities/>
- ⁷ US EPA (2013, September) Climate change: Basic information. Retrieved from <http://www.epa.gov/climatechange/basics/>
- ⁸ Karl, T. R., Melillo, J. M., & Peterson, T. C. National Science and Technology Council, U.S. Global Change Research Program (2009) Global climate change impacts in the United States. Retrieved from <http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf> and National Snow and Ice Data Center. Cooperative Institute for Research in Environmental Sciences, National Snow and Ice Data Center (2012) Press release: Arctic sea ice reaches lowest extent for the year and satellite record. Retrieved from University of Colorado http://nsidc.org/news/press/2012_seaiceminimum.html
- ⁹ Castles, S. United Nations High Commissioner for Refugees, Evaluation and Policy Analysis Unit (2002) Environmental change and forced migration: Making sense of the debate. Retrieved from United Nations http://www3.hants.gov.uk/forced_migration.pdf
- ¹⁰ NOAA Earth System Research Laboratory (2013) Trends in Carbon Dioxide. Retrieved from: <http://www.esrl.noaa.gov/gmd/ccgg/trends/>
- ¹¹ Tripathi, A. K., Roberts, C. D., & Eagle, R. A. (2009) Coupling of co2 and ice sheet stability over major climate of the last 20 million years. Science, 326(5958), 1394-1397. <http://www.sciencemag.org/content/326/5958/1394>
- ¹² National Climatic Data Center. National Oceanographic and Atmospheric Administration (2012) Global monthly state of the climate report. Retrieved from <http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CC4QFjAA&url=http://www.ncdc.noaa.gov/sotc/global/&ei=4FMUuPZO8iWyAGw8IHICw&usq=AFQjCNFGXR9cWtQReCsurJEXWd7A>

[JSR&sig2=10Z1f7l8K0KW1DOjcuI_Q&bvm=bv.53371865,d.aWc&cad=rja](#)

- ¹³ Armour, K. C., & Roe, G. H. (2011) Climate commitment in an uncertain world. *Geophysical Research Letters*, 38(1), Retrieved from <http://onlinelibrary.wiley.com/doi/10.1029/2010GL045850/abstract>
- ¹⁴ United Nations (2011) Durban: Toward full implementation of the UN Climate Change Convention. Retrieved from http://unfccc.int/key_steps/durban_outcomes/items/6825.php
- ¹⁵ European Commission, Joint Research Centre (JRC)/PBL Netherlands Environmental Assessment Agency. Emission Database for Global Atmospheric Research (EDGAR), release version 4.2. <http://edgar.jrc.ec.europa.eu/index.php>
- ¹⁶ US EPA (2013) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2011. <http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-Main-Text.pdf>
- ¹⁷ National Resources Defense Council (2012) Closer Than You Think. Retrieved from <http://www.nrdc.org/globalwarming/closer-than-you-think-IB.asp>
- ¹⁸ Lan, L. (2012, May 4) Chinese cities ‘near top’ of world carbon emissions list. *China Daily*. http://www.chinadaily.com.cn/cndy/2012-05/04/content_15204309.htm
- ¹⁹ Jia Wang, Xuezhi Bai, Haoguo Hu, Anne Clites, Marie Colton, Brent Lofgren, 2012: Temporal and Spatial Variability of Great Lakes Ice Cover, 1973–2010*. *J. Climate*, 25, 1318–1329. <http://journals.ametsoc.org/doi/abs/10.1175/2011JCLI4066.1>
- ²⁰ Andresen, J., S. Hilberg, K. Kunkel, 2012: Historical Climate and Climate Trends in the Midwestern USA. In: U.S. National Climate Assessment Midwest Technical Input Report. J. Winkler, J. Andresen, J. Hatfield, D. Bidwell, and D. Brown, coordinators. Available from the Great Lakes Integrated Sciences and Assessments (GLISA) Center, http://glisa.msu.edu/docs/NCA/MTIT_Historical.pdf.
- ²¹ Hayhoe, K., Sheridan, S., Kalkstein, L., & Greene, S. (2010) Climate change, heat waves, and mortality projections for Chicago. *Journal of Great Lakes Research*, 36(2010) Retrieved from http://www.as.miami.edu/geography/research/climatology/jgr_manuscript.pdf
- ²² Wigley, T. US EPA (2008) Magicc/scengen 5.3: User manual. Retrieved from <http://www.cgd.ucar.edu/cas/wigley/magicc/UserMan5.3.v2.pdf>
- ²³ Hayden, J. “Holland, Saugatuck harbors receiving funds for Hurricane Sandy relief.” *Holland Sentinel*. March 20, 2013. Retrieved from <http://www.hollandsentinel.com/x1959360160/Holland-Saugatuck-harbors-receiving-funds-for-Hurricane-Sandy-relief>
- ²⁴ Liobimtseva, E. (2013) Unpublished MAGICC/SCENGEN climate change modeling for Grand Rapids, MI.
- ²⁵ Liobimtseva, E. (2013) Unpublished MAGICC/SCENGEN climate change modeling for Grand Rapids, MI.
- ²⁶ Kling, G., Zak, D., & Wilson, M. (2003) Confronting climate change in the great lakes region: Impacts on Michigan ecosystems and communities. Retrieved from www.ucsusa.org/greatlakes and Winkler, J. A., Arritt, R. W., & Pryor, S. C. (2012) Climate projections for the Midwest: Availability, interpretation, and synthesis. Retrieved from http://glisa.msu.edu/docs/NCA/MTIT_Future.pdf and Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R. K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton (2007) Regional Climate Projections. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Retrieved from <http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter11.pdf> and Hayhoe, K., Sheridan, S., Kalkstein, L., & Greene, S. (2010) Climate change, heat waves, and mortality projections for Chicago. *Journal of Great Lakes Research*, 36(2010), Retrieved from

http://www.as.miami.edu/geography/research/climatology/jgr_manuscript.pdf

and Kunkel, K.E., et al. (2012) Regional Climate Trends and Scenarios for the U.S. National Climate Assessment; Part 3. Climate of the Midwest.

http://www.nesdis.noaa.gov/technical_reports/NOAA_NESDIS_Tech_Report_142-3-Climate_of_the_Midwest_U.S.pdf

- ²⁷ Kling, G., Zak, D., & Wilson, M. (2003) Confronting climate change in the great lakes region: Impacts on Michigan ecosystems and communities. Retrieved from www.ucsusa.org/greatlakes
- and Winkler, J. A., Arritt, R. W., & Pryor, S. C. (2012) Climate projections for the Midwest: Availability, interpretation, and synthesis. Retrieved from http://glisa.msu.edu/docs/NCA/MTIT_Future.pdf
- and Liobimtseva, E. (2013) Unpublished MAGICC/SCENGEN climate change modeling for Grand Rapids, MI.
- ²⁸ Liobimtseva, E. (2013) Unpublished MAGICC/SCENGEN climate change modeling for Grand Rapids, MI.
- ²⁹ Kling, G., Zak, D., & Wilson, M. (2003) Confronting climate change in the great lakes region: Impacts on Michigan ecosystems and communities. Retrieved from www.ucsusa.org/greatlakes
- ³⁰ Liobimtseva, E. (2013) Unpublished MAGICC/SCENGEN climate change modeling for Grand Rapids, MI.
- ³¹ City of Grand Rapids and Fishbeck, Thompson, Carr, and Huber (2009) City of Grand Rapids Energy Efficiency and Conservation Strategy.
- ³² Alibašić, H. (2013) Office of Energy and Sustainability Director, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- ³³ Resilient Communities for America (2013) Resilient Cities Climate Agreement Letter. www.resilientamerica.org/wp-content/uploads/2013/09/RC4A-Agreement-9.13.13-1.pdf
- ³⁴ US EPA (2013) Energy Impacts and Adaptation. <http://www.epa.gov/climatechange/impacts-adaptation/energy.html>
- ³⁵ MPSC (2012) Michigan energy appraisal: Winter 2012. Retrieved from <http://www.dleg.state.mi.us/mpsc/reports/energy/html/>
- ³⁶ Popa, N. (2013) Manger of Long Term Strategy, CMS Energy. WMEAC Climate Resiliency Interview.
- ³⁷ Popa, N. (2013) Manger of Long Term Strategy, CMS Energy. WMEAC Climate Resiliency Interview.
- ³⁸ Michigan Department of Licensing and Regulatory Affairs. MPSC (2011) Michigan energy overview. Retrieved from <http://www.dleg.state.mi.us/mpsc/reports/energy/energyoverview/> and MPSC (2012) Winter2012 Energy Appraisal. Retrieved from <http://www.dleg.state.mi.us/mpsc/reports/energy/past/12winter/index.htm>
- ³⁹ US EPA (2013) Climate Impacts on Energy. Retrieved from <http://www.epa.gov/climatechange/impacts-adaptation/energy.html>
- ⁴⁰ US EPA (2013) Energy Impacts and Adaptation: Temperature, Energy Demand, and Energy Supply. Retrieved from <http://www.epa.gov/climatechange/impacts-adaptation/energy.html> - Temperature
- ⁴¹ Popa, N. (2013) Manger of Long Term Strategy, CMS Energy. WMEAC Climate Resiliency Interview.
- ⁴² NOAA. Great Lakes Water Level Dashboard. <http://www.glerl.noaa.gov/data/now/wlevels/dbd/>
- ⁴³ Popa, N. (2013) Manger of Long Term Strategy, CMS Energy. WMEAC Climate Resiliency Interview.
- ⁴⁴ Popa, N. (2013) Manger of Long Term Strategy, CMS Energy. WMEAC Climate Resiliency Interview.
- ⁴⁵ Kowalski, K. M. (2013, August) Low great lakes levels raise concerns for Midwest power plants. Midwest Energy News,

<http://www.midwestenergynews.com/2013/07/16/low-lake-levels-raise-concerns-for-midwest-power-plants/>

- ⁴⁶ US EPA (2006) A Screening Assessment of the Potential Effects of Climate Change. Retrieved from <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=166366> Current information drawn from http://www.amwa.net/galleries/climate-change/AMWA_Climate_Change_Paper_12.13.07.pdf
- ⁴⁷ Morel, F. M. M., Kraepiel, A.M.L., Amyot, M. (1998) [The Chemical Cycle and Bioaccumulation of Mercury](#). Annual Review of Ecology and Systematics, 29, 543-566.
- ⁴⁸ North Carolina State University Cooperative Extension (2008) The NCSU water quality group newsletter. Retrieved from <http://www.bae.ncsu.edu/programs/extension/wqg/issues/notes130.pdf>
- ⁴⁹ U.S. Department of Energy (2013) “U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather.” Retrieved from <http://energy.gov/sites/prod/files/2013/07/f2/20130710-Energy-Sector-Vulnerabilities-Report.pdf>
- ⁵⁰ Existing software systems include: BASINS www.epa.gov/waterscience/basins; OASIS www.hydrologics.net/oasis.html; RIVERWARE <http://cadswes.colorado.edu/riverware/>; WEAP www.weap21.org.
- ⁵¹ National Resources Defense Council (2010) Climate Change and Water Resources Management: Adaptation Strategies for Protecting People and the Environment. <http://www.nrdc.org/water/files/waterandclimate.pdf>
- ⁵² Quackenbush, J.D., O.N. Isiogu, and G.R. White (2013) Report on the implementation of the P.A. 295 renewable energy standard and the cost effectiveness of the energy standards. Lansing, MI: MPSC. http://www.michigan.gov/documents/mpsc/Report_on_the_implementation_of_Wind_energy_resource_zones_2013_413124_7.pdf
- ⁵³ MPSC (2013) Kalamazoo Energy Forum Presentation. http://michigan.gov/documents/energy/Quackenbush_Bakkal_Intro_Slides_412406_7.pdf
- ⁵⁴ State of Michigan (2008) Public Act 295. Retrieved from www.michigan.gov/documents/mpsc/2007-SNB-0213_254495_7.pdf
- ⁵⁵ Database of State Energy Efficiency Resource Standards. <http://www.dsireusa.org/>. Accessed Online 8.5.2013. EERS PDF online at http://www.dsireusa.org/documents/summarymaps/EERS_map.pdf <http://www.dsireusa.org/>. RPS PDF online at http://www.dsireusa.org/documents/summarymaps/RPS_map.pdf
- ⁵⁶ Alibašić, H. (2013) Office of Energy and Sustainability Director, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- ⁵⁷ Obama, B. (2013) 2013 State of the Union Address. Retrieved from <http://www.whitehouse.gov/state-of-the-union-2013>.
- ⁵⁸ McKinsey & Company (2009) Unlocking Efficiency in the U.S. Economy. Retrieved from http://www.mckinsey.com/client_service/electric_power_and_natural_gas/latest_thinking/unlocking_energy_efficiency_in_the_us_economy
- ⁵⁹ Hertl, A., Kontras, A., Occhipinti, N. (2013) Better Buildings for Michigan Final Summary Presentation. Delivered July 23, 2013.
- ⁶⁰ MPSC (2013) Report on the Implementation of the P.A. 295 Renewable Energy Standard. http://www.michigan.gov/documents/mpsc/implementation_of_PA295_renewable_energy_411615_7.pdf
- ⁶¹ Coyle, S. J. (2011) Sustainable and resilient communities: A comprehensive action plan for towns, cities, and regions. Hoboken, NJ: John Wiley and Sons Inc.

<http://www.amazon.com/Sustainable-Resilient-Communities-Comprehensive-Regions/dp/0470536470>

- ⁶² Coyle, S. J. (2011) Sustainable and resilient communities: A comprehensive action plan for towns, cities, and regions. Hoboken, NJ: John Wiley and Sons Inc.
<http://www.amazon.com/Sustainable-Resilient-Communities-Comprehensive-Regions/dp/0470536470>
- ⁶³ Larsen, L., et al. (2011) Green Building and Climate Resilience: Understanding Impacts and Preparing for Changing Conditions. Retrieved from
<http://www.usgbc.org/Docs/Archive/General/Docs18496.pdf>
- ⁶⁴ Larsen, L., et al. (2011) Green Building and Climate Resilience: Understanding Impacts and Preparing for Changing Conditions. Retrieved from: <http://www.usgbc.org/Docs/Archive/General/Docs18496.pdf>
- ⁶⁵ Winn, K. (2013) President, Catalyst Partners. WMEAC Climate Resiliency Interview.
- ⁶⁶ U.S. Green Building Council. West Michigan Chapter. <http://usgbcwm.org/leed>
- ⁶⁷ Winn, K. (2013) President, Catalyst Partners. WMEAC Climate Resiliency Interview.
- ⁶⁸ International Living Future Institute (2012) Living building challenge 2.1. Retrieved from
<https://ilbi.org/lbc/LBC Documents/lbc-2.1>
- ⁶⁹ Winn, K. (2013) President, Catalyst Partners. WMEAC Climate Resiliency Interview.
- ⁷⁰ Winn, K. (2013) President, Catalyst Partners. WMEAC Climate Resiliency Interview
and Job, J. (2013) Loss Prevention Engineering Specialist, FM Global. WMEAC Climate Resiliency Interview.
- ⁷¹ Winn, K. (2013) President, Catalyst Partners. WMEAC Climate Resiliency Interview.
- ⁷² Larsen, L., et al. (2011) Green Building and Climate Resilience: Understanding Impacts and Preparing for Changing Conditions. Retrieved from
<http://www.usgbc.org/Docs/Archive/General/Docs18496.pdf>
- ⁷³ Larsen, L., et al. (2011) Green Building and Climate Resilience: Understanding Impacts and Preparing for Changing Conditions. Retrieved from
<http://www.usgbc.org/Docs/Archive/General/Docs18496.pdf>
- ⁷⁴ Larsen, L., et al. (2011) Green Building and Climate Resilience: Understanding Impacts and Preparing for Changing Conditions. Retrieved from
<http://www.usgbc.org/Docs/Archive/General/Docs18496.pdf>
- ⁷⁵ Larsen, L., et al. (2011) Green Building and Climate Resilience: Understanding Impacts and Preparing for Changing Conditions. Retrieved from: <http://www.usgbc.org/Docs/Archive/General/Docs18496.pdf>
- ⁷⁶ Tilma, T. (2013) Executive Director, Greater Grand Rapids Bicycle Coalition. WMEAC Climate Resiliency Interview
and Lunger, J. (2013) Public Policy Coordinator, Grand Rapids Area Chamber of Commerce. WMEAC Climate Resiliency Interview.
- ⁷⁷ Kahn Ribeiro, S., S. Kobayashi, M. Beuthe, J. Gasca, D. Greene, D. S. Lee, Y. Muromachi, P. J. Newton, S. Plotkin, D. Sperling, R. Wit, P. J. Zhou (2007) Transport and its infrastructure. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
http://www.ipcc.ch/publications_and_data/ar4/wg3/en/contents.html
- ⁷⁸ Itani, A. (2013) Director of Transportation, Grand Valley Metro Council. WMEAC Climate Resiliency Interview.
- ⁷⁹ Sustainable Streets Task Force (2013, June) Sustainable streets task force final report. Retrieved from

<http://grcity.us/engineering-department/DownloadFiles/SSTF%20Final%20Report%208-13-13.pdf>

- ⁸⁰ Meyer, N. (2013) Grand Rapids Sustainable Streets Task Force Report. Retrieved from <http://prezi.com/jdybkpnwksjj/grand-rapids-sustainable-streets-task-force-presentation/>
- ⁸¹ Coyle, S. J. (2011) Sustainable and resilient communities: A comprehensive action plan for towns, cities, and regions. Hoboken, NJ: John Wiley and Sons Inc. <http://www.amazon.com/Sustainable-Resilient-Communities-Comprehensive-Regions/dp/0470536470>
- ⁸² US EPA (2009) Climate impacts on transportation. Retrieved from <http://www.epa.gov/climatechange/impacts-adaptation/transportation.html>
- ⁸³ Itani, A. (2013) Director of Transportation, Grand Valley Metro Council. WMEAC Climate Resiliency Interview.
- ⁸⁴ US EPA (2009) Climate impacts on transportation. Retrieved from website: <http://www.epa.gov/climatechange/impacts-adaptation/transportation.html>
- ⁸⁵ Itani, A. (2013) Director of Transportation, Grand Valley Metro Council WMEAC Climate Resiliency Interview.
- ⁸⁶ Ellison, G. (2013) Fulton Street bridge closed 'ASAP' as crews de-energize major downtown utility cable threatened by flood. http://www.mlive.com/news/grand-rapids/index.ssf/2013/04/fulton_street_bridge_closed_as.html
- ⁸⁷ Tilma, T. (2013) Executive Director, Greater Grand Rapids Bicycle Coalition. WMEAC Climate Resiliency Interview.
- ⁸⁸ Itani, A. (2013) Director of Transportation, Grand Valley Metro Council. WMEAC Climate Resiliency Interview.
- ⁸⁹ Itani, A. (2013) Director of Transportation, Grand Valley Metro Council. WMEAC Climate Resiliency Interview.
- ⁹⁰ Itani, A. (2013) Director of Transportation, Grand Valley Metro Council. WMEAC Climate Resiliency Interview.
- ⁹¹ City of Grand Rapids Planning Department, Green Grand Rapids Committee (2011) Green Grand Rapids. Retrieved from http://grcity.us/design-and-development-services/Planning-Department/Documents/Green_Grand_Rapids_Report_LowRez_2011_10_04.pdf
- ⁹² City of Grand Rapids Planning Department, Green Grand Rapids Committee (2011) Green Grand Rapids. Retrieved from http://grcity.us/design-and-development-services/Planning-Department/Documents/Green_Grand_Rapids_Report_LowRez_2011_10_04.pdf
- ⁹³ Sustainable Streets Task Force (2013, June) Sustainable streets task force final report. Retrieved from <http://grcity.us/engineering-department/DownloadFiles/SSTF%20Final%20Report%208-13-13.pdf>
- ⁹⁴ Itani, A. (2013) Director of Transportation, Grand Valley Metro Council. WMEAC Climate Resiliency Interview.
- ⁹⁵ Coyle, S. J. (2011) Sustainable and resilient communities: A comprehensive action plan for towns, cities, and regions. Hoboken, NJ: John Wiley and Sons Inc. <http://www.amazon.com/Sustainable-Resilient-Communities-Comprehensive-Regions/dp/0470536470>
- and Kling, G., Zak, D., & Wilson, M. (2003) Confronting climate change in the great lakes region: Impacts on Michigan ecosystems and communities. Retrieved from www.ucsusa.org/greatlakes
- ⁹⁶ Patterson, J. (2013) Director of Climate Justice, NAACP. WMEAC Climate Resiliency Interview and Sustainable Streets Task Force (2013, June) Sustainable streets task force final report. Retrieved from <http://grcity.us/engineering-department/DownloadFiles/SSTF%20Final%20Report%208-13-13.pdf>
- ⁹⁷ U.S. Census Bureau (2009) City of Grand Rapids American Factfinder. Retrieved from <http://quickfacts.census.gov/qfd/states/26/2634000.html>
- ⁹⁸ Itani, A. (2013) Director of Transportation, Grand Valley Metro Council. WMEAC Climate Resiliency Interview

and Alibašić, H. (2013) Office of Energy and Sustainability Director, City of Grand Rapids. WMEAC Climate Resiliency Interview.

and DeClerq, M. (2013) City Engineer, City of Grand Rapids. WMEAC Climate Resiliency Interview.

- ⁹⁹ Schulz, S. (2013) Director, City of Grand Rapids Planning Department. Personal Communication.
- ¹⁰⁰ Schroeder, D. (2013) Management Consultant, Kent County Emergency Needs Task Force. WMEAC Climate Resiliency Interview
and Tilma, T. (2013) Executive Director, Greater Grand Rapids Bicycle Coalition. WMEAC Climate Resiliency Interview.
- ¹⁰¹ Patterson, J. (2013) Director of Climate Justice, NAACP. WMEAC Climate Resiliency Interview.
- ¹⁰² Steketee, D. (2013) Associate Professor of Sustainable Business, Aquinas College. WMEAC Climate Resiliency Interview.
- ¹⁰³ Kling, G., Zak, D., & Wilson, M. (2003) Confronting climate change in the great lakes region: Impacts on Michigan ecosystems and communities. Retrieved from www.ucsusa.org/greatlakes
and Doll, J. E., & Baranski, M. Michigan State University, Extension Program (2011) Field crop agriculture and climate change. Retrieved from
<http://lter.kbs.msu.edu/wp-content/uploads/2012/06/E3149-Climate-Change-Fact-Sheet.pdf>
- ¹⁰⁴ Doll, J. E., & Baranski, M. (2011) Field crop agriculture and climate change. Michigan State University, Extension Program. Retrieved from <http://lter.kbs.msu.edu/wp-content/uploads/2012/06/E3149-Climate-Change-Fact-Sheet.pdf>
- ¹⁰⁵ Doll, J. E., & Baranski, M. (2011) Field crop agriculture and climate change. Michigan State University, Extension Program. Retrieved from <http://lter.kbs.msu.edu/wp-content/uploads/2012/06/E3149-Climate-Change-Fact-Sheet.pdf>
and Hatfield, Tackle, Grotjahn, Holden, Izaurralde, Mader, & Marshall, USDA(2013) Climate change and agriculture in the United States. Retrieved from
[www.usda.gov/oce/climate_change/effects_2012/CC%20and%20Agriculture%20Report%20\(02-04-2013\)b.pdf&ei=iX5NUqaAL8GMiAKdyYHYAw&usg=AFQjCNEZlyqx2ZeZLBHatKMhmMxBSc-yoA&sig2=HymnthAL0cC8vRub87Epg&bvm=bv.53537100,d.cGE&cad=rja](http://www.usda.gov/oce/climate_change/effects_2012/CC%20and%20Agriculture%20Report%20(02-04-2013)b.pdf&ei=iX5NUqaAL8GMiAKdyYHYAw&usg=AFQjCNEZlyqx2ZeZLBHatKMhmMxBSc-yoA&sig2=HymnthAL0cC8vRub87Epg&bvm=bv.53537100,d.cGE&cad=rja)
and Harrington, M. (2013) Executive Director, Fulton Street Farmers Market. WMEAC Climate Resiliency Interview.
- ¹⁰⁶ Hatfield, Tackle, Grotjahn, Holden, Izaurralde, Mader, & Marshall, USDA (2013) Climate change and agriculture in the United States. Retrieved from
[www.usda.gov/oce/climate_change/effects_2012/CC%20and%20Agriculture%20Report%20\(02-04-2013\)b.pdf&ei=iX5NUqaAL8GMiAKdyYHYAw&usg=AFQjCNEZlyqx2ZeZLBHatKMhmMxBSc-yoA&sig2=HymnthAL0cC8vRub87Epg&bvm=bv.53537100,d.cGE&cad=rja](http://www.usda.gov/oce/climate_change/effects_2012/CC%20and%20Agriculture%20Report%20(02-04-2013)b.pdf&ei=iX5NUqaAL8GMiAKdyYHYAw&usg=AFQjCNEZlyqx2ZeZLBHatKMhmMxBSc-yoA&sig2=HymnthAL0cC8vRub87Epg&bvm=bv.53537100,d.cGE&cad=rja)
- ¹⁰⁷ Doll, J. E., & Baranski, M. (2011) Field crop agriculture and climate change. Michigan State University, Extension Program. Retrieved from <http://lter.kbs.msu.edu/wp-content/uploads/2012/06/E3149-Climate-Change-Fact-Sheet.pdf>
- ¹⁰⁸ Hatfield, Tackle, Grotjahn, Holden, Izaurralde, Mader, & Marshall, USDA (2013) Climate change and agriculture in the United States. Retrieved from
[www.usda.gov/oce/climate_change/effects_2012/CC%20and%20Agriculture%20Report%20\(02-04-2013\)b.pdf&ei=iX5NUqaAL8GMiAKdyYHYAw&usg=AFQjCNEZlyqx2ZeZLBHatKMhmMxBSc-yoA&sig2=HymnthAL0cC8vRub87Epg&bvm=bv.53537100,d.cGE&cad=rja](http://www.usda.gov/oce/climate_change/effects_2012/CC%20and%20Agriculture%20Report%20(02-04-2013)b.pdf&ei=iX5NUqaAL8GMiAKdyYHYAw&usg=AFQjCNEZlyqx2ZeZLBHatKMhmMxBSc-yoA&sig2=HymnthAL0cC8vRub87Epg&bvm=bv.53537100,d.cGE&cad=rja)
and Doll, J. E., & Baranski, M. (2011) Field crop agriculture and climate change. Michigan State University, Extension Program. Retrieved from

<http://lter.kbs.msu.edu/wp-content/uploads/2012/06/E3149-Climate-Change-Fact-Sheet.pdf>

- ¹⁰⁹ Doll, J. E., & Baranski, M. (2011) Field crop agriculture and climate change. Michigan State University, Extension Program. Retrieved from <http://lter.kbs.msu.edu/wp-content/uploads/2012/06/E3149-Climate-Change-Fact-Sheet.pdf>
- ¹¹⁰ Winkler, J. A., Arritt, R. W., & Pryor, S. C. (2012) Climate projections for the Midwest: Availability, interpretation, and synthesis. Retrieved from http://glisa.msu.edu/docs/NCA/MTIT_Future.pdf
- ¹¹¹ Paige, L. (2012) March historic West Michigan heat wave summary. Retrieved from <http://www.examiner.com/article/march-historic-west-michigan-heat-wave-summary>
- ¹¹² Michigan Department of Agriculture and Rural Development (2012) Agricultural Disaster Loan Origination Act of 2012. Retrieved from http://www.michigan.gov/mdard/0,4610,7-125-1568_51684-283154--,00.html
- ¹¹³ USDA (2012) U.S. Drought 2012: Farm and Food Impacts. Retrieved from <http://www.ers.usda.gov/topics/in-the-news/us-drought-2012-farm-and-food-impacts.aspx#.UfiZJW3hdB0>
- ¹¹⁴ Anders, M. (2012) Michigan's 2nd-largest cash crop at risk if drought continues. Retrieved from http://www.mlive.com/business/index.ssf/2012/07/michigans_2nd-largest_cash_cro.html
- ¹¹⁵ Doll, J. E., & Baranski, M. (2011) Field crop agriculture and climate change. Michigan State University, Extension Program. Retrieved from <http://lter.kbs.msu.edu/wp-content/uploads/2012/06/E3149-Climate-Change-Fact-Sheet.pdf>
- ¹¹⁶ Doll, J. E., & Baranski, M. (2011) Field crop agriculture and climate change. Michigan State University, Extension Program. Retrieved from <http://lter.kbs.msu.edu/wp-content/uploads/2012/06/E3149-Climate-Change-Fact-Sheet.pdf>
- ¹¹⁷ Doll, J. E., & Baranski, M. (2011) Field crop agriculture and climate change. Michigan State University, Extension Program. Retrieved from <http://lter.kbs.msu.edu/wp-content/uploads/2012/06/E3149-Climate-Change-Fact-Sheet.pdf>
- ¹¹⁸ World Bank (2012) Managing Disaster Risks for a Resilient Future: The Sendai Report.. September 21, 2012 <http://web.worldbank.org/WBSITE/EXTERNAL/DEVCOMMEXT/0,,pagePK:64000837~piPK:64001152~theSitePK:277473~contentMDK:23276768,00.html>
- ¹¹⁹ Mercer, 2011. "Climate Change Scenarios – Implications for Strategic Asset Allocation". Retrieved from www.mercer.com/attachment.dyn?idContent=1407480&filePath=/attachments/English/04028-IC_ClimateChangeAssetAllocationStudy_Report_FNL_lowres.pdf
- ¹²⁰ Marsh (2011) Sustainability – the changing climate of risk. <https://usa.marsh.com/NewsInsights/ThoughtLeadership/Articles/ID/3532/Sustainability-The-Changing-Climate-of-Risk.aspx>
- ¹²¹ Marsh (2011) Sustainability – the changing climate of risk. <https://usa.marsh.com/NewsInsights/ThoughtLeadership/Articles/ID/3532/Sustainability-The-Changing-Climate-of-Risk.aspx>
- ¹²² Marsh (2011) Sustainability – the changing climate of risk. <https://usa.marsh.com/NewsInsights/ThoughtLeadership/Articles/ID/3532/Sustainability-The-Changing-Climate-of-Risk.aspx>
- ¹²³ Munich Re (2011) Climate protection further postponed. Retrieved from http://www.munichre.com/en/group/focus/climate_change/strategy_and_policy/climate-protection-further-postponed/default.aspx
- ¹²⁴ Job, J. (2013) Loss Prevention Engineering Specialist, FM Global. WMEAC Climate Resiliency Interview.
- ¹²⁵ Job, J. (2013) Loss Prevention Engineering Specialist, FM Global. WMEAC Climate Resiliency Interview.

- ¹²⁶ World Bank (2012) Managing Disaster Risks for a Resilient Future: The Sendai Report. September 21, 2012. <http://web.worldbank.org/WBSITE/EXTERNAL/DEVCOMEXT/0,,pagePK:64000837~piPK:64001152~theSitePK:277473~contentMDK:23276768,00.html>
- ¹²⁷ Mercer (2011) Climate Change Scenarios – Implications for Strategic Asset Allocation. Retrieved from http://www.mercer.com/attachment.dyn?idContent=1407480&filePath=/attachments/English/04028-IC_ClimateChangeAssetAllocationStudy_Report_FNL_lowres.pdf
- ¹²⁸ Salerno, B. (2013) Vice President and Senior Investment Portfolio Analyst, Huntington Bank. WMEAC Climate Resiliency Interview.
- ¹²⁹ Derwall, J., Guenster, N., Bauer, R., & Koedijk, K. (2005) The Eco Efficiency Premium Puzzle. Financial Analysts Journal, 61(2), 51-63. <http://arno.unimaas.nl/show.cgi?fid=15671>
- ¹³⁰ Salerno, B. (2013) Vice President and Senior Investment Portfolio Analyst, Huntington Bank. WMEAC Climate Resiliency Interview.
- ¹³¹ Clune, Bliss, Bartley, et al. (2009) City of Grand Rapids Urban Forestry Plan. Retrieved from <http://grcity.us/public-services/Parks-Recreation-Forestry/Documents/Grand%20Rapids%20Urban%20Forest%20Plan%202009.pdf>
- ¹³² The Holland Board of Public Works (2012) Power for the 21st Century Sustainable Return on Investment Analysis Final Report. Retrieved from <http://p21decision.com/wp-content/uploads/2012/08/Holland-SROI-Report-Final.pdf>
- ¹³³ Liobimtseva, E. (2013) Unpublished MAGICC/SCENGEN climate change modeling for Grand Rapids, MI.
- ¹³⁴ City of Grand Rapids (2011) Combined Sewer Overflow. Retrieved 7.15.2013 from <http://grcity.us/enterprise-services/Environment-Services/Pages/Combined-Sewer-Overflow.aspx>
- ¹³⁵ Lunn, M. (2013) Environmental Services Department Manager, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- ¹³⁶ Lunn, M. (2013) Environmental Services Department Manager, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- ¹³⁷ City of Grand Rapids Environmental Services Website. <http://grcity.us/enterprise-services/Environment-Services/Pages/default.aspx> Accessed 7.31.2013.
- ¹³⁸ Lunn, M. (2013) Environmental Services Department Manager, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- ¹³⁹ City of Grand Rapids. Environmental Services Department (2013) Stormwater Master Plan. Retrieved from http://grcity.us/enterprise-services/Environment-Services/Stormwater/SWMP_2013-06-12.pdf
- ¹⁴⁰ US EPA (2007) Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices. EPA 841-F-07-006 http://water.epa.gov/polwaste/green/costs07_index.cfm
- ¹⁴¹ Odefey, J., Detwiler, S., Rousseau, K., & Trice, A. (2012) Banking on green: A look at how green infrastructure can save municipalities money and provide economic benefits community-wide. Retrieved from http://www.asla.org/uploadedFiles/CMS/Government_Affairs/Federal_Government_Affairs/Banking_on_Green_HighRes.pdf
- ¹⁴² Lunn, M. (2013) Environmental Services Department Manager, City of Grand Rapids. WMEAC Climate Resiliency Interview.

- 143 Stoner, N. (2013) Understanding EPA Stormwater Rules: How Will New Proposal Impact Development. Retrieved from <http://www.smartgrowthamerica.org/2013/04/25/upcoming-webinar-understanding-new-stormwater-rules/>
- 144 U.S. Global Change Research Program (2009) Regional Highlights from the Global Climate Change Impacts in the United States. Cambridge University Press. Midwest Fact Sheet. www.globalchange.gov/usimpacts
- 145 Union of Concerned Scientists (2009) Selected Findings from 'Confronting Climate Change in the Great Lakes Region'. Retrieved from http://ucsusa.org/assets/documents/global_warming/ag_factsheet-fnl.pdf
- 146 Union of Concerned Scientists (2009) Selected Findings from 'Confronting Climate Change in the Great Lakes Region'. Retrieved from http://ucsusa.org/assets/documents/global_warming/ag_factsheet-fnl.pdf
- 147 Union of Concerned Scientists (2009) Selected Findings from 'Confronting Climate Change in the Great Lakes Region'. Retrieved from http://ucsusa.org/assets/documents/global_warming/ag_factsheet-fnl.pdf
- 148 Lunn, M. (2013) Environmental Services Department Manager, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- 149 Fenton, H. (2013, April 28) How close was the Grand River to breaching city flood walls? Think 3 inches of rain, hydrologist says. Grand Rapids Press. Retrieved from http://www.mlive.com/news/grand-rapids/index.ssf/2013/04/how_close_was_the_grand_river.html
- 150 Lunn, M. (2013) Environmental Services Department Manager, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- 151 California Department of Transportation (2005) First Flush Phenomenon Characterization. Retrieved from http://www.dot.ca.gov/hq/env/stormwater/pdf/CTSW-RT-05-073-02-6_First_Flush_Final_9-30-05.pdf
- 152 Lunn, M. (2013) Environmental Services Department Manager, City of Grand Rapids. WMEAC Resiliency Interview.
- 153 A Joint Report by American Rivers, the Water Environment Federation, the American Society of Landscape Architects and ECONorthwest (2012) Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide. Retrieved from http://www.asla.org/uploadedFiles/CMS/Government_Affairs/Federal_Government_Affairs/Banking_on_Green_HighRes.pdf
- 154 City of Grand Rapids (2011) What are Combined Sewers? Retrieved from <http://grcity.us/enterprise-services/Environment-Services/Pages/Combined-Sewer-Overflow.aspx>
- 155 Lunn, M. (2013) Environmental Services Department Manager, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- 156 City of Grand Rapids Website: What are Combined Sewers? Accessed 7/16/13. <http://grcity.us/enterprise-services/Environment-Services/Pages/Combined-Sewer-Overflow.aspx>
- 157 Alexander, D. (2013) Lakes Michigan and Huron hit all-time record low water levels; no end to low-water trend in sight. http://www.mlive.com/news/muskegon/index.ssf/2013/02/lakes_michigan_and_huron_hit_a.html
- 158 U.S. Army Corps of Engineers Detroit District Office (2013) Record Low Water Levels. Retrieved 7.24.2013 <http://www.lre.usace.army.mil/Media/NewsStories/RecordLowWaterLevels.aspx>
- 159 U.S. Global Change Research Program (2009) Projected Changes in Great Lakes Levels under Higher Emissions Scenario. <http://nca2009.globalchange.gov/projected-changes-great-lakes-levels-under-higher-emissions-scenario>
- 160 U.S. Army Corps of Engineers - Detroit District Office (2013) Record Low Water Levels. Retrieved from <http://www.lre.usace.army.mil/Media/NewsStories/RecordLowWaterLevels.aspx>

- ¹⁶¹ Manes, Nick (2013) Low Water Levels Causing Problems for Great Lakes Shipping. Retrieved from <http://mibiz.com/item/20621-low-water-levels-causing-problems-for-great-lakes-shipping>
- ¹⁶² Manes, Nick (2013) Low Water Levels Causing Problems for Great Lakes Shipping. Retrieved from <http://mibiz.com/item/20621-low-water-levels-causing-problems-for-great-lakes-shipping>
- ¹⁶³ U.S. Army Corps of Engineers - Detroit District Office (2013) Record Low Water Levels. Retrieved from <http://www.lre.usace.army.mil/Media/NewsStories/RecordLowWaterLevels.aspx>
- ¹⁶⁴ AMWA (2007) Implications of Climate Change for Urban Water Utilities. Retrieved from http://www.amwa.net/galleries/climate-change/AMWA_Climate_Change_Paper_12.13.07.pdf
- ¹⁶⁵ Nelson, B., Schmitt, M., Cohen, R., Ketabi, N., & Wilkenson, R. (2007) In Hot Water: Water Management Strategies to Weather the Effects of Global Warming. Retrieved from www.nrdc.org/globalwarming/hotwater/hotwater.pdf
- ¹⁶⁶ AMWA (2007) Implications of Climate Change for Urban Water Utilities. Pages 13-14. Retrieved from http://www.amwa.net/galleries/climate-change/AMWA_Climate_Change_Paper_12.13.07.pdf
- ¹⁶⁷ Allen, D., & Thorbes, C. (2013) Groundwater fate and climate change. Informally published manuscript, Simon Fraser University, Burnaby, British Columbia. Retrieved from <http://www.sfu.ca/pamr/media-releases/2013/groundwater-fate-and-climate-change.html>
- ¹⁶⁸ Michigan State University (2012) Ottawa County Water Resources Study. Retrieved from http://www.miottawa.org/Departments/BOC/WaterQuality/pdf/2012/Ottawa_Water_Study_2012.pdf
- ¹⁶⁹ Kukla, Myron (2012) Huge glacial aquifer under Ottawa County shrinking from overuse, water study finds. Retrieved from http://www.mlive.com/news/grand-rapids/index.ssf/2012/12/huge_glacial_aquifer_under_ott.html
- ¹⁷⁰ Kukla, Myron (2012) Huge glacial aquifer under Ottawa County shrinking from overuse, water study finds. Retrieved from http://www.mlive.com/news/grand-rapids/index.ssf/2012/12/huge_glacial_aquifer_under_ott.html
- ¹⁷¹ Kukla, Myron (2012) Huge glacial aquifer under Ottawa County shrinking from overuse, water study finds. Retrieved from http://www.mlive.com/news/grand-rapids/index.ssf/2012/12/huge_glacial_aquifer_under_ott.html
- ¹⁷² Liobimtseva, E. (2013) Unpublished MAGICC/SCENGEN climate change modeling for Grand Rapids, MI.
- ¹⁷³ City of Grand Rapids (2012) Second Year Progress Report: FY2011-FY2015 Sustainability Plan. Retrieved from http://grcity.us/enterprise-services/officeofenergyandsustainability/Documents/Sustainability_Plan_Year_2_Update.pdf
- ¹⁷⁴ Great Lakes & Saint Laurence Cities Initiative (2005) Water conservation framework: Sustainable water resources agreement. Retrieved from <http://www.glsregionalbody.org/GLSLRB/Agreements.aspx>
- ¹⁷⁵ City of Grand Rapids (2009) Grand Rapids Water System Recognized For Leadership in Water Conservation. Retrieved from http://grcity.us/enterprise-services/Water-System/Documents/10793_GLSLCI%20media%20release.pdf.
- ¹⁷⁶ California Department of Water Resources et al. (2010) 20x2020 Water Conservation Plan. Retrieved from <http://www.water.ca.gov/wateruseefficiency/sb7/docs/20x2020plan.pdf>
- ¹⁷⁷ Cimitile, M. (2013, April 5) Great Lakes Wetlands May Mitigate Climate Change. Retrieved from <http://greatlakesecho.org/2013/04/05/great-lakes-wetlands-may-mitigate-climate-change/>
- ¹⁷⁸ De Mol, N. (2013) Rogue River Home Rivers Project Manager, Trout Unlimited. WMEAC Climate Resiliency Interview.

- ¹⁷⁹ Schulz, S. (2013) Director, City of Grand Rapids Planning Department. Personal Communication.
- ¹⁸⁰ Field and Stream (2006) America's Best Fishing Cities. Retrieved from <http://www.fieldandstream.com/photos/gallery/kentucky/2006/06/americas-best-fishing-cities?photo=5 - node-1000014488>
- ¹⁸¹ Marbek (2010) Assessing the economic value of protecting the great lakes: Rouge River case study for nutrient reduction and nearshore health protection. Retrieved from http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@subject/@greatlakes/documents/nativedocs/stdprod_086943.pdf
- ¹⁸² Marbek (2010) Assessing the economic value of protecting the great lakes: Rouge River case study for nutrient reduction and nearshore health protection. Retrieved from http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@subject/@greatlakes/documents/nativedocs/stdprod_086943.pdf
- ¹⁸³ Buth, M. (2002) Analysis of stormwater policy: Rogue River watershed, Kent County, Michigan. Retrieved from <http://scholarworks.gvsu.edu/cgi/viewcontent.cgi?article=1004&context=mcnair>
- ¹⁸⁴ De Mol, N. (2013) Rogue River Home Rivers Project Manager, Trout Unlimited. WMEAC Climate Resiliency Interview.
- ¹⁸⁵ Kling, G., Zak, D., & Wilson, M. (2003) Confronting climate change in the great lakes region: Impacts on Michigan ecosystems and communities. Retrieved from www.ucsusa.org/greatlakes
- ¹⁸⁶ De Mol, N. (2013) Rogue River Home Rivers Project Manager, Trout Unlimited. WMEAC Climate Resiliency Interview.
- ¹⁸⁷ Campbell, K. (2013) Hunting, fishing boost Michigan economy. Retrieved from <http://greatlakesecho.org/2013/01/22/hunting-fishing-provide-boost-to-michigan-economy/>
- ¹⁸⁸ MDNR (2011) Draft Grand River Assessment. Retrieved from http://grandrapidswhitewater.org/wp-content/uploads/2013/04/Draft_Grand_River_Assessment_10_2011_369541_7-1.pdf
- ¹⁸⁹ MDNR (2011) Draft Grand River Assessment. Retrieved from http://grandrapidswhitewater.org/wp-content/uploads/2013/04/Draft_Grand_River_Assessment_10_2011_369541_7-1.pdf
- ¹⁹⁰ Grand Rapids Whitewater (not dated) Frequently Asked Questions. Retrieved from <http://grandrapidswhitewater.org/faq/>
- ¹⁹¹ MDNR (2011) Draft Grand River Assessment. Retrieved from http://grandrapidswhitewater.org/wp-content/uploads/2013/04/Draft_Grand_River_Assessment_10_2011_369541_7-1.pdf
- ¹⁹² Grand Rapids Whitewater (not dated) <http://grandrapidswhitewater.org/documents/>
- ¹⁹³ MDNR (1997) Lake Sturgeon Rehabilitation Strategy. Retrieved from <http://www.michigan.dnr.com/PUBLICATIONS/PDFS/ifr/ifrilibra/special/reports/SR18.pdf>
- ¹⁹⁴ Grand Rapids Whitewater (2012) Grand Rapids River Restoration: Opportunities and Constraints. Retrieved from http://grandrapidswhitewater.org/wp-content/uploads/2013/04/OpportunitiesAndConstraintsEXSUMM_0812.pdf
- ¹⁹⁵ Grand Rapids Whitewater (2012) Phase 2 Environmental Site Assessment. NTH Consultants, Ltd. [environmental site assessment \(ESA\). http://grandrapidswhitewater.org/wp-content/uploads/2013/04/001-0119-ESA-P2.pdf](http://grandrapidswhitewater.org/wp-content/uploads/2013/04/001-0119-ESA-P2.pdf)
- ¹⁹⁶ NTH Consultants, Ltd. (2012) Report: Phase II Environmental Site Assessment; 1.5 mile long stretch of Grand River, Grand Rapids, Michigan. Retrieved from <http://grandrapidswhitewater.org/wp-content/uploads/2013/04/001-0119-ESA-P2.pdf>

- ¹⁹⁷ US EPA (2013) May 10, 2013 press release: Federal Agencies Expand Urban Waterway Revitalization Efforts in Communities Across the Nation. <http://www.urbanwaters.gov/pdf/May10PressRelease.pdf>
- ¹⁹⁸ Urban Waters Federal Partnership (2013) About the urban waters federal partnership. Retrieved from <http://www.urbanwaters.gov/pdf/urbanwaters-factsheet.pdf>
- ¹⁹⁹ Cleveland, J. West Michigan Strategic Alliance, Green Infrastructure Task Force (2003) The West Michigan green infrastructure strategy. Retrieved from http://wmsa.miottawa.org/documents/publications/Green_Infrastructure_Task_Force_Final_Report- Nov_2003.pdf
- ²⁰⁰ Cleveland, J. West Michigan Strategic Alliance, Green Infrastructure Task Force (2003) The West Michigan green infrastructure strategy. Retrieved from http://wmsa.miottawa.org/documents/publications/Green_Infrastructure_Task_Force_Final_Report- Nov_2003.pdf
- ²⁰¹ Grand Valley Metropolitan Council (not dated) Blueprint II Principles. Retrieved from http://www.gvmc.org/blueprint/bpII_princ.shtml
- ²⁰² City of Grand Rapids. Planning Department (2005) City of Grand Rapids master plan key concepts. Retrieved from website: http://www.grcity.us/design-and-development-services/Planning-Department/Documents/1606_Master_Plan_Summary.pdf
- ²⁰³ City of Grand Rapids. Planning Department (2005) City of Grand Rapids master plan key concepts. Retrieved from http://www.grcity.us/design-and-development-services/Planning-Department/Documents/1606_Master_Plan_Summary.pdf
- ²⁰⁴ City of Grand Rapids. Planning Department (2005) City of Grand Rapids master plan key concepts. Retrieved from http://www.grcity.us/design-and-development-services/Planning-Department/Documents/1606_Master_Plan_Summary.pdf
- ²⁰⁵ Itani, A. (2013) Director of Transportation, Grand Valley Metro Council. WMEAC Climate Resiliency Interview.
- ²⁰⁶ Duany, A., Plater-Zyberk, E., & Speck, J. (2010) Suburban nation: The rise of sprawl and the decline of the American dream. (10th ed.) New York: North Point Press.
- ²⁰⁷ Duany, A., Plater-Zyberk, E., & Speck, J. (2010) Suburban nation: The rise of sprawl and the decline of the American dream. (10th ed.) New York: North Point Press.
- ²⁰⁸ Schulz, S. (2013) Director, City of Grand Rapids Planning Department. Personal Communication.
- ²⁰⁹ City of Grand Rapids. Planning Department (2005) City of Grand Rapids master plan key concepts. Retrieved from http://www.grcity.us/design-and-development-services/Planning-Department/Documents/1606_Master_Plan_Summary.pdf
- ²¹⁰ Duany, A., Plater-Zyberk, E., & Speck, J. (2010) Suburban nation: The rise of sprawl and the decline of the American dream. (10th ed.) New York: North Point Press.
- ²¹¹ Duany, A., Plater-Zyberk, E., & Speck, J. (2010) Suburban nation: The rise of sprawl and the decline of the American dream. (10th ed.) New York: North Point Press.
- ²¹² Chicago Southland Housing and Community Development Collaborative (2013) Sustainable communities challenge grant: Land banking. Retrieved from <http://public.cshcdc.org/home/initiatives/sustainable-communities-challenge-grant-1/land-banking>
- ²¹³ Kent County Land Bank. Kent County, MI (2013) Land banking 101: Land back legislation. Retrieved from <http://kclba.org/land-bank-101/>
- ²¹⁴ Kent County Land Bank. Kent County, MI (2013) Land banking 101: Land back legislation. Retrieved from

- <http://kclba.org/land-bank-101/>
- 215 Kent County Land Bank. Kent County, MI (2013) Land banking 101: Land back legislation. Retrieved from <http://kclba.org/land-bank-101/>
- 216 Itani, A. (2013) Director of Transportation, Grand Valley Metro Council. WMEAC Climate Resiliency Interview.
- 217 Cuyahoga Land Bank. Cuyahoga Land Bank (2013) About us. Retrieved from <http://cuyahogalandbank.org/aboutUs.php>
- 218 Keating, L. Cuyahoga Land Bank (2009) The beginning, the present, and beyond. Retrieved from http://www.cuyahogalandbank.org/articles/CCLRC_2009_2011_Report.pdf
- 219 Cuyahoga Land Bank. Cuyahoga County (2013) It's happening in Berea. Retrieved from <http://blog.cuyahogalandbank.org/2013/04/its-happening-in-berea>
- 220 Byrne, Brian. Sun News. "Cleveland Heights, East Cleveland look to revive depressed North Coventry neighborhood." March 22, 2013. Updated July 10, 2013 at 11:15 PM http://www.cleveland.com/cleveland-heights/index.ssf/2013/03/cleveland_heights_east_cleavela.html
- 221 Kent County (2013) Purchase development rights. Retrieved from <http://www.accesskent.com/Departments/BOC/PDR/>
- 222 Kent County (2013) Purchase development rights. Retrieved from <http://www.accesskent.com/Departments/BOC/PDR/>
- 223 Kent County (2013) Purchase development rights. Retrieved from <http://www.accesskent.com/Departments/BOC/PDR/>
- 224 Kent County (2013) Purchase development rights. Retrieved from <http://www.accesskent.com/Departments/BOC/PDR/>
- 225 United Growth For Kent County (2004) Position paper on Kent County Board of Commissioners purchase of development rights subcommittee report. Retrieved from http://www.unitedgrowth.org/pdfs/reports/pdr_position_paper.pdf
- 226 United Growth For Kent County (2004) Position paper on Kent County Board of Commissioners purchase of development rights subcommittee report. Retrieved from http://www.unitedgrowth.org/pdfs/reports/pdr_position_paper.pdf
- 227 United Growth For Kent County (2004) Position paper on Kent County Board of Commissioners purchase of development rights subcommittee report. Retrieved from http://www.unitedgrowth.org/pdfs/reports/pdr_position_paper.pdf
- 228 Grand Rapids Urban Forestry Committee (2013) 2012 Annual Report. Retrieved from <http://www.friendsofgrparks.org/Resources/Documents/UFC%202012%20Annual%20Report.pdf>
- 229 Clune, Bliss, Bartley, et al. City of Grand Rapids Urban Forestry Plan. March 2009 <http://grcity.us/public-services/Parks-Recreation-Forestry/Documents/Grand%20Rapids%20Urban%20Forest%20Plan%202009.pdf>
- 230 Grand Rapids Urban Forestry Committee (2009) City of Grand Rapids Urban Forestry Plan. Retrieved from <http://grcity.us/public-services/Parks-Recreation-Forestry/Documents/Grand%20Rapids%20Urban%20Forest%20Plan%202009.pdf>
- 231 Stevenson, T. (2013) City Forester, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- 232 Stevenson, T. (2013) City Forester, City of Grand Rapids. WMEAC Climate Resiliency Interview.

- 233 Stevenson, T. (2013) City Forester, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- 234 Stevenson, T. (2013) City Forester, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- 235 Climate Change Indicators in the United States: Length of Growing Season. Retrieved from <http://www.epa.gov/climatechange/indicators> Updated August 2013.
- 236 US EPA (2013, September) Climate change: Basic information. Retrieved from <http://www.epa.gov/climatechange/basics/>
- 237 City of Grand Rapids (2010) City of Grand Rapids Parks and Recreation 2010 Master Plan. Page 50. Retrieved from http://grcity.us/public-services/Parks-Recreation-Forestry/Documents/14349_5_yr_Master_Plan_2010_final.pdf
- 238 Steffen, J. (2013) Assistant Planning Director, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- 239 City of Grand Rapids (2012) Michigan Street Corridor Plan: A Health Impact Assessment. Retrieved from <http://www.healthimpactproject.org/resources/document/Michigan-Street-Corridor-Plan.pdf> and Steffen, J. (2013) Assistant Planning Director, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- 240 Steffen, J. (2013) Assistant Planning Director, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- 241 City of Grand Rapids (2011) Comprehensive Audit Analysis for Parks and Recreation. Page 7. Retrieved from <http://www.friendsofgrparks.org/resources/Documents/parkaudit.pdf>
- 242 Vande Bunte, M. (2013, June 4) Parks tax proposal in Grand Rapids lists how money would get spent over 7 years. Grand Rapids Press. Retrieved from http://www.mlive.com/news/grand-rapids/index.ssf/2013/06/parks_tax_proposal_in_grand_ra.html
- 243 Steffen, J. (2013) Assistant Planning Director, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- 244 USDA (2012) USDA Plant Hardiness Zone Map. Retrieved from <http://planthardiness.ars.usda.gov/PHZMWeb/Images/72DPI/mi.jpg>
- 245 Stevenson, T. (2013) City Forester, City of Grand Rapids. WMEAC Climate Resiliency Interview and Steffen, J. (2013) Assistant Planning Director, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- 246 Patterson, J. (2013) Director of Climate Justice, NAACP. WMEAC Climate Resiliency Interview.
- 247 World Bank (2012) Managing Disaster Risks for a Resilient Future: The Sendai Report. Retrieved from <http://web.worldbank.org/WBSITE/EXTERNAL/DEVCOMEXT/0,,pagePK:64000837~piPK:64001152~theSitePK:277473~contentMDK:23276768,00.html>
- 248 Job, J. (2013) Loss Prevention Engineering Specialist, FM Global. WMEAC Climate Resiliency Interview.
- 249 Patterson, J. (2013) Director of Climate Justice, NAACP. WMEAC Climate Resiliency Interview and Schroeder, D. (2013) Management Consultant, Kent County Emergency Needs Task Force. WMEAC Climate Resiliency Interview.
- 250 US EPA (2013) What is the Urban Heat Island Effect? Retrieved from <http://www.epa.gov/heatisld/about/index.htm>
- 251 US EPA (2013, September) Heat Island Effect: Basic information. Retrieved from <http://www.epa.gov/heatisld/about/index.htm>
- 252 Kling, G., Zak, D., & Wilson, M. (2003) Confronting climate change in the great lakes region: Impacts on Michigan ecosystems and communities. Retrieved from www.uksusa.org/greatlakes
- 253 Harger, J. (2011) Grand Rapids battles the emerald ash borer, one of several marauding insects threatening our forests. Retrieved from http://www.mlive.com/news/grand-rapids/index.ssf/2011/07/grand_rapids_at_the_front_line.html

- 254 Harger, J. (2011) Grand Rapids battles the emerald ash borer, one of several marauding insects threatening our forests. Retrieved from http://www.mlive.com/news/grand-rapids/index.ssf/2011/07/grand_rapids_at_the_front_line.html
- 255 Williams, R. (2013) Spring floods bring bumper crop of mosquitoes. Retrieved from <http://www.michiganradio.org/post/spring-floods-bring-bumper-crop-mosquitoes>
- 256 Williams, R. (2013) Spring floods bring bumper crop of mosquitoes. Retrieved from <http://www.michiganradio.org/post/spring-floods-bring-bumper-crop-mosquitoes>
- 257 U.S. Global Change Research Program. (2009) Global Climate Change Impacts in the United States. Retrieved from <http://downloads.globalchange.gov/usimpacts/pdfs/20page-highlights-brochure.pdf>
- 258 Jacob, D.J., & Winner, D.A. (2009) Effect of climate change on air quality. Atmospheric Environment 43(1): 51-63. Retrieved from <http://dash.harvard.edu/handle/1/3553961>
- 259 Jacob, D.J., & Winner, D.A. (2009) Effect of climate change on air quality. Atmospheric Environment 43(1): 51-63. Retrieved from <http://dash.harvard.edu/handle/1/3553961>
- 260 D'Amato, G and Cecchi, L. (2008) Effects of climate change on environmental factors in respiratory allergic disease. Clinical Experimental Allergy. 38(8):1264-74.
- 261 Lunn, M. (2013) Environmental Services Department Manager, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- 262 US EPA (2008) Michigan area designations for the 2008 lead national ambient air quality standards. Retrieved from http://www.epa.gov/leaddesignations/2008standards/rec/letters/05_MI_EPATSD.pdf
- 263 West Michigan Clean Air Coalition (2013) History of air quality in West Michigan. Retrieved from <http://www.wmcac.org/history.html>
- 264 West Michigan Clean Air Coalition (2013) History of air quality in West Michigan. Retrieved from <http://www.wmcac.org/history.html>
- 265 MDEQ (2013) Ozone Action Days. Retrieved from <http://www.deqmiar.org/actionday.cfm>
- 266 West Michigan Clean Air Coalition (2013) History of air quality in West Michigan. Retrieved from <http://www.wmcac.org/history.html>
- 267 <http://www.deqmiar.org/actionday.cfm>
- 268 American Lung Association (2013) State of the air. Retrieved from <http://www.lung.org/associations/states/california/assets/pdfs/sota-2013/sota-2013-full-report.pdf>
- 269 Patterson, J. (2013) Director of Climate Justice, NAACP. WMEAC Climate Resiliency Interview.
- 270 Schroeder, D. (2013) Management Consultant, Kent County Emergency Needs Task Force. WMEAC Climate Resiliency Interview.
- 271 D'Amato, G and Cecchi, L. (2008) Effects of climate change on environmental factors in respiratory allergic disease. Clinical Experimental Allergy. 38(8):1264-74.
- 272 Field, William R. (2010). Climate Change and Indoor Air Quality. Contractor Report Prepared for: U.S. Environmental Protection Agency. <http://bit.ly/1hOamvL>
- 273 Field, William R. (2010). Climate Change and Indoor Air Quality. Contractor Report Prepared for: U.S. Environmental Protection Agency. <http://bit.ly/1hOamvL>
- 274 D'Amato, G and Cecchi, L. (2008) Effects of climate change on environmental factors in respiratory allergic disease.

- Clinical Experimental Allergy. 38(8):1264-74.
- ²⁷⁵ D'Amato, G and Cecchi, L. (2008) Effects of climate change on environmental factors in respiratory allergic disease. Clinical Experimental Allergy. 38(8):1264-74.
- ²⁷⁶ Price, C. (2013) Chair, Greater Grand Rapids Food Systems Council. WMEAC Climate Resiliency Interview.
- ²⁷⁷ Collier, A. and Rabaut, C. (2011) Good Food Access: Michigan Good Food Work Group Report No. 2 of 5. Retrieved from http://www.michiganfood.org/assets/goodfood/docs/Good_Food_Access_Report.pdf
- ²⁷⁸ Cameron, L., & Howard, P. (2011) Mapping food deserts. Informally published manuscript, Extension Program, Michigan State University, East Lansing, MI, Retrieved from <http://msutoday.msu.edu/news/2011/mapping-food-deserts/>
- ²⁷⁹ Litman, T.A. (2011) Economic Value of Walkability. Victoria Transport Policy Institute. Retrieved from <http://www.walkscore.com/professional/public-health-research.php>
- ²⁸⁰ Roper, M., Jackins, N., Libolt, T., Burkley, K., & Granger, A. (2012) Food Access Crisis Affects Grand Rapids. Retrieved from <http://therapidian.org/food-access-crisis>
- ²⁸¹ Price, C. (2013) Chair, Greater Grand Rapids Food Systems Council. WMEAC Climate Resiliency Interview.
- ²⁸² Price, C. (2013) Chair, Greater Grand Rapids Food Systems Council. WMEAC Climate Resiliency Interview.
- ²⁸³ Harrington, M. (2013) Executive Director, Fulton Street Farmers Market. WMEAC Climate Resiliency Interview.
- ²⁸⁴ Matson, J., & Thayer, J. (2013) The role of food hubs in food supply chains. Journal of Agriculture, Food Systems, and Community Development, 3(4), 43–47. <http://dx.doi.org/10.5304/jafscd.2013.034.004>
- ²⁸⁵ Tank, E. (2012, August) Our fresh local envisions community gardens, energy efficient housing. The Rapidian, Retrieved from <http://therapidian.org/our-fresh-local-envisions-community-gardens-sustainable-housing>
- ²⁸⁶ Koont, S. (2008) A Cuban success story: Urban agriculture. Review of Radical Political Economics, Retrieved from <http://rrp.sagepub.com/content/early/2008/06/30/0486613408320016>
- ²⁸⁷ Koont, S. (2008) A Cuban success story: Urban agriculture. Review of Radical Political Economics, Retrieved from <http://rrp.sagepub.com/content/early/2008/06/30/0486613408320016>
- ²⁸⁸ Harrington, M. (2013) Executive Director, Fulton Street Farmers Market. WMEAC Climate Resiliency Interview.
- ²⁸⁹ Schneider, Keith. "A Michigan City Bets on Food for Its Growth." The New York Times. November 13, 2013. <http://www.nytimes.com/2012/11/14/realestate/commercial/grand-rapids-mich-bets-on-a-food-market-for-growth.html?r=0>
- ²⁹⁰ Schreibman, M.P. & Zarnoch, C.B. (2005) Urban Aquaculture in Brooklyn, NY, USA. Urban Aquaculture. CABI Publishing; Cambridge, MA.
- ²⁹¹ White, R. (2012) The criminology of climate change. New York: Springer.
- ²⁹² Belk, K. (2013) Chief of Police, City of Grand Rapids. WMEAC Climate Resiliency Interview and Ranson, M. (2012) Crime, weather, and climate change. Harvard Kennedy School. Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2111377
- ²⁹³ Belk, K. (2013) Chief of Police, City of Grand Rapids. WMEAC Climate Resiliency Interview and Ranson, M. (2012) Crime, weather, and climate change. Harvard Kennedy School. Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2111377
- ²⁹⁴ Belk, K. (2013) Chief of Police, City of Grand Rapids. WMEAC Climate Resiliency Interview.

- ²⁹⁵ Agnew, R. (2011) Dire forecast: A theoretical model of the impact of climate change on crime. *Theoretical Criminology*. Retrieved from <http://tcr.sagepub.com/content/16/1/21>
- ²⁹⁶ Agnew, R. (2011) Dire forecast: A theoretical model of the impact of climate change on crime. *Theoretical Criminology*. Retrieved from <http://tcr.sagepub.com/content/16/1/21>
and Patterson, J. (2013) Director of Climate Justice, NAACP. WMEAC Climate Resiliency Interview.
- ²⁹⁷ Community Research Institute (2010) Grand Rapids Median Income. Retrieved from <http://cridata.org/Publications.aspx>
- ²⁹⁸ Belk, K. (2013) Chief of Police, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- ²⁹⁹ Belk, K. (2013) Chief of Police, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- ³⁰⁰ Belk, K. (2013) Chief of Police, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- ³⁰¹ Belk, K. (2013) Chief of Police, City of Grand Rapids. WMEAC Climate Resiliency Interview.
- ³⁰² Rittel, Horst W. J.; Melvin M. Webber (1973). Dilemmas in a General Theory of Planning. *Policy Sciences* 4: 155–169.