Climate Ready Great Lakes Cities

Capstone Thesis

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School of Natural Resources and Environment, University of Michigan

Contents

I. Executive Summary

Project goal

Rising out of the strategic alliance between the National Oceanic and Atmospheric Administration (NOAA) and the Great Lakes and St. Lawrence Cities Initiative (GLSLCI), the motivating goal of this 13-month project was to create a more resilient Great Lakes region by fostering climate adaptation planning. NOAA and GLSLCI recognize that municipalities across the Great Lakes Region will suffer economic, structural, health, and other impacts under a changing climate, and will need to engage in adaptation planning in order to mitigate and minimize these losses. The problem this project seeks to address is to surmount challenges in building adaptive capacity in a governance environment that is multi-level, cross-jurisdictional and resource-limited.

Our team focused on showcasing the ongoing efforts of Great Lakes cities to move the region towards a more resilient future, and our deliverables were designed to fill critical information gaps that may hinder robust action. We provided a suite of multimedia decision support tools that:

1) Support city officials' efforts to increase Great Lakes-specific climate literacy within their municipalities
2) Disseminate descriptive climate adaptation "best practices" among Great Lakes municipal officials

Key findings

1) **Municipal planners often have unclear ideas of what constitutes an adaptation action.** Although there is growing institutional enthusiasm around climate adaptation, throughout our interviews and literature review we found many different, sometimes conflicting concepts of what climate adaptation actually is. Interviewees would often talk about mitigation or broader sustainability goals when asked to discuss adaptation actions. There are fundamental differences between mitigation and adaptation, and it is important for municipalities to understand their nuances, especially when there are trade-offs between these actions. In this context, "mitigation" refers to efforts to reduce or stop the impacts of climate change, commonly through reducing or capturing greenhouse gas emissions. "Adaptation" or "resilience" refers to efforts that seek to lessen the degree of impact these changes have on a system. Mitigation efforts seek to slow or stop climate change by eliminating the impacts themselves, while adaptation efforts accept that not all impacts of climate change are avoidable, they are currently or will soon be felt by the system in question, and will need to be adapted to. Education – in the form of outside expertise, or even the training modules that we developed for NOAA, will help raise the level of awareness about concrete adaptation actions and thought processes, and help planners clearly identify adaptation actions from mitigation or sustainability actions.

2) **Adaptation in a municipality is decentralized.** Across our case-study cities, the entire suite of adaptation concerns and adaptation actors were never contained in just one unit or department. The same climate driver will have impacts that affect multiple sectors, and sectors that are managed by different departments and multiple-levels of governance. Cities now are using decentralized staff within various departments to develop climate adaptation plans and actions, and utilize existing knowledge and expertise from across these departments. While this decentralization requires a "knowledge broker" within the municipality to communicate information on impacts and adaptation which may hinder cohesive action

and progress, it may at the same time make it easier to aggregate resources from different sectors, and to build on insider knowledge of each department or sectors regarding key concerns and planning systems.

3) **Adaptation is still the low-hanging fruit.** Most adaptation actions identified by the case study cities included substantial co-benefits; e.g. the action has some additional mitigative or economic benefit outside of increased resilience. In Great Lakes Cities, actions taken to adapt to a certain climate impact often had additional climate mitigation co-benefits; for example, green infrastructure in a city serves the dual purpose of reducing the impact of flood events, but also absorbs carbon emissions. Another common co-benefit and potential driver of individual adaption actions are those that are also cost-saving at multiple temporal scales.

4) **The knowledge barrier to adaptation is substantial.** While the funding barrier was the most commonly cited barrier to adaptation in our case study cities, they also identified the need for accurate and easily accessible knowledge resources. Municipalities expressed difficulty finding adequate resources on climate impacts and climate adaptation for public education outreach, difficulty finding resources and tools to inform strategic plan design, and a lack of understanding of or access to descriptions of adaptation actions in practice and their relative success. Organizations such as NOAA can address this barrier through providing streamlined top-down support.

5) **The city-scale is appropriate for adaptation.** Adaptation and cities are a good fit. Adaptation is an exercise in complex problem solving. Cities as a unit are designed to tackle complex problems as uncertainties, and have experience planning for a set of scenarios, rather than a concrete future. While the concept of adaptation is new, most cities already possess the right frameworks and modes of thinking to engage in complex environmental problem solving.

6) **There is no universal adaptation action**. Adaptation actions should be unique to a locality, and there is no silver bullet. Our case studies, modules, and infographics are descriptive, rather than prescriptive because what will constitute an effective adaptation action is highly tailored to each unique set of physical, cultural, economic, and governmental systems in a locality. A “checklist” format for adaptation actions was found to be overly reductive, and did not include enough overlap between generalizability and usability to be helpful. Introducing descriptive examples of problem solving in order to foster “adaptation thinking” may be more useful for cities wanting to engage in adaptation planning.

Recommended next steps

We encourage NOAA and GLSLCI to continue promoting work and communication across jurisdictional boundaries and disciplines. Adaptation is necessarily complex, and requires buy-in and engagement from multiple sectors throughout the process. Municipalities are already equipped to work on multi-sector efforts, and this should be further incentivized. Departments should work together to make a strategic plan that demonstrates a commitment to cross-office resilience building.

We recommend that cities closely examine diversifying their infrastructure portfolio with both classical and green engineering. Adaptation to climate change requires an integrated approach to infrastructure planning. While green infrastructure is often touted for its many co-benefits, the importance of classic

"gray" infrastructure can not be overstated. Green and gray infrastructure work best when they are designed to complement one another. For example to reduce combined sewage overflows, Milwaukee built a deepwater tunnel to hold large amounts of storm water in a single place and also has funded green infrastructure to hold small amounts of water in many places. By integrating the objectives of green and gray infrastructure Milwaukee was able to maximize the adaptive capacity of their storm water management system.

Finally, we recommend that cities, NOAA, and GLSLCI leverage existing frameworks and knowledge. Existing resources increases all the time, and keep update on the new sciences and technologies is necessary.

II. Background and Scientific Basis

The scientific evidence for anthropogenic climate change and its associated impacts is compelling, and mitigative action has been slow (IPCC, 2013). Municipalities worldwide are already experiencing the impacts of climate change, and are expected to experience more as we approach a 2˚C world. In the Great Lakes region, warmer temperatures and changing climate regimes are already impacting city infrastructure, resources, and public health (Pryor *et al,* 2014). Average temperature is expected to rise by 1˚ to 3˚ C in the basin by 2050 and up to 6˚ C by 2100 (GLISA, 2014). The direction and magnitude of change of precipitation in the basin is currently unclear, but studies generally agree that a smaller proportion of precipitation will fall as snow, and there will be in increase in extreme storm events. Reduced winter snowpack may lead to an increase in summer drought, and an interesting consequence of more frequent extreme weather events is their potential to drive an increase in harmful algal blooms through increased delivery of legacy nutrients to the lakes (Paerl and Scott, 2010).

The impacts associated with these climate changes will be felt in every economic sector of Great Lakes municipalities. The economy of the Great Lakes is fully dependent, if not fully integrated, with the ecosystems of the basin. The changing phenology, temperature, and weather patterns will be felt most succinctly by regions dependent on agriculture and tourism, as well as the public sector economies. However, Great Lakes/St. Lawrence cities can mitigate many of these impacts if adaptation actions are deliberate, careful, and swift, and cities must soon begin to adapt to and prepare for unavoidable impacts.

At the municipal practitioner-level, the field of climate adaptation is nascent (Beirbaum et al 2007). The focus of this project was to create multimedia communication tools that can help advance climate literacy and understanding of climate adaptation strategies among municipal officials in the Great Lakes. Our team, composed of six masters students from the School of Natural Resources and Environment at the University of Michigan, began working on this project in March of 2014, and delivered the project outputs to our two clients in April of 2015.

Project Clients

Our project's primary purpose was to provide resources to strengthen the objectives outlined within the National Oceanic and Atmospheric Administration and the Great Lakes and St. Lawrence Cities Initiative (GLSLCI)'s strategic partnership.

National Oceanic and Atmospheric Administration (NOAA GLERL)

NOAA is a scientific agency within the United States Department of Commerce focused on the conditions of the oceans and the atmosphere. NOAA's Great Lakes Environmental Research Laboratory (GLERL) provides scientific understanding to inform the use and management of Great Lakes and coastal marine environments.

Great Lakes and St Lawrence Cities Initiative (GLSLCI)

The Great Lakes and St. Lawrence Cities Initiative is a binational coalition of U.S. and Canadian mayors and other local officials working to advance the protection and restoration of the Great Lakes and St. Lawrence River.

NOAA & GLSLCI Partnership

NOAA is working in partnership with GLSLCI to help accomplish their mutual goals of assisting Great Lakes municipalities to prepare for and adapt to climate change impacts over time.

Specifically, this partnership will support the development of an online toolbox for municipalities that provides:

1. Training materials and resources with on-the-ground examples of how cities are incorporating climate hazards and impacts into planning
2. Infographics and visualizations that will assist cities in identifying potential hazards (i.e., flooding and inundation) and how best to plan for them

5 Great Lakes municipalities

Our project's aim was to create resources that would be immediately relevant to municipal decision makers in the Great Lakes. In order to achieve this goal, we worked closely with five of GLSLCI's member cities:

- Milwaukee, WI (USA)
- Traverse City, MI (USA)
- Goderich, ON (CA)
- Evanston, IL (USA)
- Niagara Region, ON (CA)

Our team visited each of these cities throughout the course of the project. During these visits, we interviewed a range of municipal officials and community stakeholders, and toured some of the areas that are most impacted by climate change. We were able to see firsthand the adaptation strategies being implemented on the ground, and delved into informative conversations about what the biggest adaptation challenges are.

Thanks to the guidance of the five GLSLCI member cities with whom we worked, our team was able to synthesize a descriptive list of strategies that are already working well for Great Lakes cities.

Advisors

In addition to the guidance provided by NOAA and GLSLCI, our team benefited from the experience shared by academic leaders and adaptation professionals.

David Allan PhD, School of Natural Resources & Environment

Our project advisor was Dr. Allan, whose research investigates stream ecosystems and the influence of human activities on rivers and their watersheds. This includes active research into the effects of landscape and land use on stream health, assessment of variation in flow regime, and estimation of nutrient loads and budgets. Additional, collaborative activities are directed at the translation of aquatic science into useful products for management, conservation and restoration of running waters.

Dr. Allan provided important project management guidance and helped our team better understand the scientific nuances of climatic impacts on Great Lakes aquatic systems. Dr. Allan's support, advice, and knowledge were extremely helpful to our team as we synthesized complex concepts into generalized language and graphics.

Beth Gibbons, University of Michigan Climate Center & GLISA

Beth serves as both the Director of the University of Michigan Climate Center and Program Manager of NOAA's Great Lakes regional RISA, GLISA. GLISA integrates information from a wide array of scientific fields, develops collaborations between entities with similar goals, and helps inform decision makers throughout the region with sound science. In both roles, Beth's core responsibilities include fostering the transfer of information on climate change and resilience from the research community to stakeholders throughout the region.

Beth's experience transferring information between diverse stakeholders was invaluable to the team. She offered sage advice throughout the project; our team's research and interview methodology, as well as the relevance of our finalized deliverables were all strengthened thanks to Beth's contributions.

Deliverables

In order to fulfill these objectives our Master's Project team provided an accessible summary of the current knowledge about climate impacts in the Great Lakes, as well as a set of best-practices in adaptation planning tailored for different city types (eg. rural, suburban, associated basin).

These materials were delivered in the form of an online toolbox, which will be hosted on GLSLCI's online portal. The materials build upon, rather than replicate, the efforts of a 2011-2012 Master's Project Team. The final deliverables include:

- **Case Studies:** 5 descriptive case studies of Great Lakes cities engaged in adaptation activities;
- **Climate adaptation training modules:** 7 training modules delivered as webinars by GLSLCI;
- **Infographics:** 2 city-informed data visualizations on relevant threats to resilience and solutions to these threats;
- **GIS based maps:** 2 GIS based maps and associated data to identify threats and green infrastructure opportunities;

This Master's Project report dives into further detail concerning the primary needs that inspired the project, the purpose of each deliverable, and the team's project methodology.

III. Motivation

Why adapt?

While there is still a great need for mitigation efforts, the need for adaptation in tandem with mitigation efforts is increasingly recognized. "Adaptation" in a climate context describes taking actions that anticipate future impacts, and plan in ways that will help the system withstand and manage these anticipated impacts or shocks. Even if global warming is held to 2˚C (the current goal in international treaty negotiations), this will not negate certain impacts.

Domestically, many cities are already feeling the impacts of climate change. While no single event can be directly attributed to climate change, many midwestern cities have reported experiencing more extreme weather events, like storms, extreme heat, and extreme cold events. Particular catastrophic events - like Chicago's 1995 heat wave, Milwaukee's 2010 flood, and Goderich's 2010 tornado - are well remembered by planners and residents in these cities, and are held up as an example of what these cities might experience under climate change.

Nor does adaptation happen in a vacuum. Many adaptation actions at the city-level have co-benefits, or additional mitigation (or economic) benefits beyond just resiliency. For example, adding white roofs to city buildings helps cool the city in an extreme heat event (adaptation) but also reduces the gray infrastructure's overall albedo (mitigation). Many adaptation actions that cities can take involve updating outdated infrastructure to more resilient and more efficient systems; often, these updates are cost-effective even without internalizing the negative externalities of climate impacts.

Why cities?

Most aggressive action on adaptation has been done independently at the city level (Bulkeley, 2013), and this is not a coincidence. This is partly attributable to the American political landscape; climate action remains controversial in many states and localities and can still be a significany political liability, but charismatic leaders in receptive cities (like Grand Rapids, Michigan) have been able to move past such political barriers and take action. Cities are also uniquely poised to engage in adaptation -- they enjoy a degree of autonomy that allows them to develop their own plans and efforts on a relatively short timescale. Cities are already built to plan, and possess much of the expertise and networks that will need to be mobilized for adaptation efforts. Actions are also more easily implemented at the city level -- urban municipal governments can influence the built environment as well as land use and land cover change through zoning codes, building codes, and water management systems. Cities also are centers of the cultural, political and intellectual transformation that is vital to forming new frameworks and paradigms through which climate change adaptation can thrive.

Why multidimensional deliverables?

For many cities and localities, however, adaptation is still a confusing effort. It involves complex problem solving across disciplines, and access to scientific expertise. The concept of adaptation is still fuzzy, and significant informational and technical barriers as well as financial barriers still impede the process.

Tutorials are a means of addressing some informational barriers in a cost-effective, easily accessible manner. The tutorials are not meant to be the end process for adaptation learning, but instead a first step for localities and cities that may be at the beginning of the adaptation process. The tutorials, rather than outlining prescriptive, step-by-step actions, instead focus on efforts that other cities have done as a model for thinking around adaptation, and examples of adaptation actions. The webinar format allows for a greater reach to participants in the Great Lakes - Saint Lawrence region, without requiring governments to fund conference travel.

Case studies provide a format to investigate how cities and city planners have grappeled with thinking around adaptation -- they allow for a holistic discussion of specific opportunities and challenges, as well as a discussion of the process, not just the outcomes, that can help inform efforts in other cities that may be facing the same impacts, confounding political factors, or other barriers. Infographics build on both the tutorials and the case studies, easily communicating impact information to a lay audience, but also customizable to include a particular city's set of problems and solutions.

IV. Case Studies

Our team conducted a series of interviews with Great Lakes municipalities to evaluate past and current adaptation practices, and to determine how those endeavors were executed, funded and staffed. Because climate change heightens the existing risks that municipalities face - including risks to economies, infrastructure, assets and vulnerable community populations (GLISA, 2014) - our goal was to conduct a comprehensive assessment of the strongest adaptation practices in the region. From these interviews, we drafted five brief, readable case studies that highlight each city's top three adaptation successes and discuss the barriers they faced. With these case studies, we hoped to offer an accessible collection of decision-relevant information for municipal adaptation planners.

While cities are already actively engaging in planning and implementation, they nevertheless often face personnel and funding challenges as well as a lack of certainty about how to use scientific information in their planning processes (White, 2014). Similarly, it can be a challenge for cities to package that information for the public in an accessible and digestible way. Due in large part to these reasons, we elected to create city case studies to assist municipalities with this process.

We chose the case study format for several reasons. Foremost, case studies deliver salient information in a compact, concise and readable manner. We hoped to improve on this by developing a highly visual layout that incorporated bulleted lists, "callout" boxes and imagery. In comparison to a case study with standard academic formatting, these tactics make the material more inviting to the reader. Our template includes climate projections and trends for the city, resilience milestones achieved, major partners,

funding sources, challenges and key lessons learned. It also provides links to governmental and nonprofit websites that house grant information, climate visualization tools and adaptation support. With this template, our aim was to assist cities in quickly extracting the adaptation success stories from other cities that faced similar constraints.

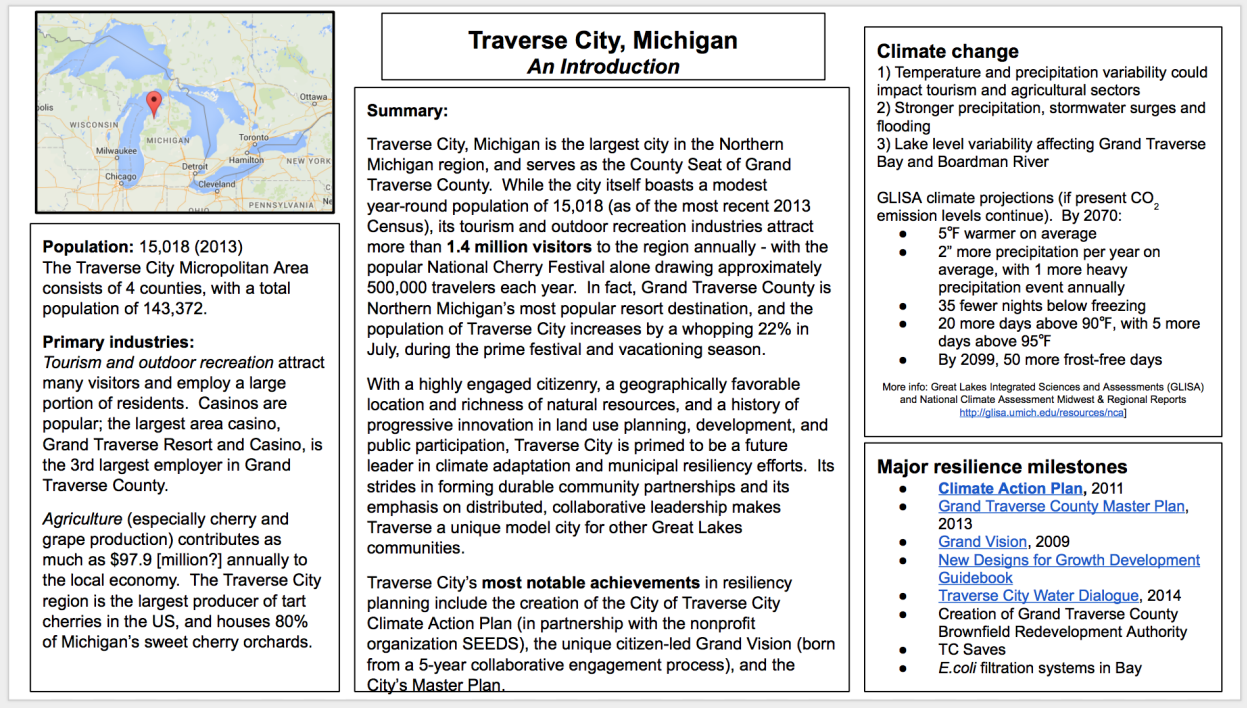

Figure 1. Template for case studies, as seen in the Traverse City case study example.

Case Study Methodology

Our clients helped us identify a diversity of Great Lakes cities, both in the US and in Canada, that were facing unique adaptation challenges. Since these cities range widely in terms of size, demographic composition, geography, governance structure and resources, we were able to examine a useful cross-section of the region's adaptation practices. In some cities, like Goderich and Milwaukee, severe weather events kick-started the conversation about adaptation and catalyzed municipal action. In other locations we visited, such as Traverse City, adaptation and resiliency planning had been discussed extensively, but personnel and resource constraints posed a significant barrier [to project completion]. The goal of the case studies was to get an overall sense of the circumstances that might allow adaptation work to progress. How did adaptation efforts differ across borders, and could we identify anything universal? We hoped to capture the innovations employed by each city so that other cities might build on those, incorporating the strongest regional lessons into their own municipal efforts.

Methodologically, our research was grounded in qualitative social research strategies, learned through our SNRE coursework. We conducted preliminary phone interviews with officials from each city. The questions we asked attempted to gauge baseline climate adaptation awareness, both among city staff as

well as the general public. An example of the preliminary interview questions is available in our Appendix section. While an effort was made to keep these questions fairly consistent across cities, we found that we frequently needed to include questions that addressed specific weather events and funding strategies that were particular to a given locale. Once the preliminary telephone interviews were completed, we traveled to each city for an in-depth team interview (please find example questions in the Appendix). In some cases, we were able to tour the city's adaptation infrastructure and meet with community partners as well. These interviews provide the foundation for our case studies.

Below, we include a short summary of each case study. See the Appendix for the full text.

Case Study: Milwaukee, WI (See Appendix F)

Milwaukee is a leader in climate change adaptation. An increase in extreme storm events have motivated the Milwaukee Metropolitan Sewerage District (sewerage district), City of Milwaukee Office of Environmental Sustainability (sustainability office), and The Water Council (water council) to build a network of programs that engage the public to build resilience to climate change. Building political capital for adaptation following various crises, these organizations have focused on shared resources to empower the private sector and community residents and to build adaptive capacity in Milwaukee.

Case Study: Traverse City, MI (See Appendix I)

Traverse City, Michigan is the largest city in the Northern Michigan region, and serves as the County Seat of Grand Traverse County. While the city itself boasts a modest year-round population of 15,018 (as of the most recent 2013 Census), its tourism and outdoor recreation industries attract more than 1.4 million visitors to the region annually - with the popular National Cherry Festival alone drawing approximately 500,000 travelers each year. In fact, Grand Traverse County is Northern Michigan's most popular resort destination, and the population of Traverse City increases by a whopping 22% in July, during the prime festival and vacationing season.

With a highly engaged citizenry, a geographically favorable location and richness of natural resources, and a history of progressive innovation in land use planning, development, and public participation, Traverse City is primed to be a future leader in climate adaptation and municipal resiliency efforts. Its strides in forming durable community partnerships and its emphasis on distributed, collaborative leadership makes Traverse a unique model city for other Great Lakes communities.

Traverse City's most notable achievements in resiliency planning include the creation of the City of Traverse City Climate Action Plan (in partnership with the nonprofit organization SEEDS), the unique citizen-led Grand Vision (born from a 5-year collaborative engagement process), and the City's Master Plan.

Case Study: Goderich, ON (See Appendix I)

In 2011, Goderich was hit by an F3 tornado. It tore through Goderich's downtown, causing the death of a salt mine worker and preliminary damage of $100 million. Within 15 minutes, 54 buildings were demolished and 283 more required repair. The entire town was left without power and over three dozen people were injured.

However, thanks to years of institutionalized resilience practices and critical infrastructure upgrades, Goderich recovered from the tornado's damage. Furthermore, the town's leaders leveraged their experience with the unexpected natural disaster as an invaluable learning experience that would strengthen their overall resilience efforts.

Herein lies a collection of the best practices that Goderich demonstrates with its dedication to disaster preparedness, community engagement, and collaborative partnerships--all critical components of a holistic resilience strategy.

Case Study: Niagara Region, ON (See Appendix G)

Niagara Region, Ontario, famous for Niagara Falls, sits on the Canada – United States border. The region has experienced severe climate change impacts and has taken steps in reacting to climate change. The region developed its first climate action plan in 2007, and joined the Partners for Climate Protection (PCP) program in 2009. A steering committee and planning team in the regional government serve as the leaders and coordinators in strategically designing and implementing the action plans. In collaboration with the nearby university, Niagara Region has received fundamental scientific support for this planning effort. The region has actively engaged multiple communities in the planning process and developed various partnerships through forums, workshop, online surveys, and collaborative meetings. Niagara Region has completed and published the government and community climate change action plan with identified action items, and is in the process of implementing the plan, with an evaluation planned for 2017

Case Study: Evanston, IL

At the time of writing, this case study was still in progress. In June of 2015 it will be housed in GLSLCI's website (http://www.glslcities.org/).

Evanston, IL prides itself as an environmental leader on multiple fronts, and was among the first US cities to take formal action on climate change. In 2006, Evanston joined the U.S. Mayor's Climate Protection Agreement, a voluntary agreement for member cities that seeks to meet or beat 2005 Kyoto targets. In 2008, Evanston released its first Climate Action Plan, with the most recent update in 2012.

Key impacts that concern Evanston are extreme heat, extreme cold, and extreme storm events. For example, extreme cold and ice events may put the city's water system at risk due to the formation of frazil ice at the water intake point (Force). Most of the anticipated impacts for Evanston are not necessarily new phenomena, but rather more frequent and intense occurrences of previous extremes.

While Evanston's robust climate mitigation actions have included many adaptation co-benefits, the city has yet to release a specific climate adaptation plan. However, the city is well poised to begin such an effort – the Office of Sustainability already acts as a knowledge and information broker across critical departments on climate change issues, and has the support and momentum of the mayor's office to take further action on climate adaptation.

IV. Training Modules & Webinars

In addition to the case studies, we created a series of 7 climate adaptation training webinars. The goal of this webinar series was to help inform municipal officials about the most pressing climate change topics by breaking down the major trends and projections for the Great Lakes Region. The webinars also showcase positive municipal responses to climate threats. Webinars are brief and more interactive than simply reading an academic report, thus our hope was that they might be more appealing to a busy municipal audience. Additionally, they provide networking and relationship-building opportunities for the participants.

The previous Climate-Ready Great Lakes Cities master's project had already compiled online webinars, but the data was no longer current and the visual design needed improvement. We updated and condensed these existing modules to cover the following topics:

- Introduction to Climate Change
- Introduction to Adaptation
- Climate Change and Vulnerable Populations
- Water Systems
- Infrastructure Networks
- Transportation
- Ports and Shoreline Management

GLSLCI presented these webinars to their member audience in Spring 2015. The average attendance was 26 participants per webinar, and most of the audience was comprised of Canadian municipal officials (statistics provided by GLSLCI). These webinars are now housed on the NOAA and GLSLCI websites, as well as online on the GLSLCI YouTube channel (https://www.youtube.com/channel/UCl_6viIUesmos6hZ7RkVahQ/videos).

Name of Module	**Date Piloted**	**YouTube Link**
Introduction to Climate Change	10/23/2014	https://www.youtube.com/watch?v=vKbqDqB2ZAM
Introduction to Adaptation	11/05/2014	https://www.youtube.com/watch?v=ROShqhv6hgo
Climate Change and Vulnerable Populations	12/03/2014	https://www.youtube.com/watch?v=4VCMUuzyb60
Water Systems	01/28/2015	https://www.youtube.com/watch?v=fIA7AIwoGdM
Infrastructure Networks	02/11/2015	https://www.youtube.com/watch?v=aFLpxdKVVKk
Ports and Shoreline Management	03/11/2015	https://www.youtube.com/watch?v=Yyb928v15hQ

Figure 2. Excerpt of title slide for Water Systems training webinar.

Module 1: Introduction to Climate Change in the Great Lakes
Module 2: Introduction to Adaptation
Module 3: Climate Change and Vulnerable Populations
Module 4: Vulnerable Populations
Module 5: Infrastructure Networks
Module 6: Transportation Systems
Module 7: Ports and Shoreline Management

V. Infographics

Two infographics were developed to be used by municipal officials to facilitate efforts in educating and engaging the public into taking climate adaptation actions. The first infographic covers general climate trends in the Great Lakes region and the relevant impacts to residents. The second infographic specifically hones in on how climate change impacts urban areas and what people can do to adapt to climate change. By providing concise and visually effective information, the two infographics can help educate a lay audience about climate change issues prevalent in where they live and empower them to take actions.

The infographics serve as a visual tool to aid public engagement by conveying information in a concise and visually appealing way. Infographics are meant to be eye-catching, easy to scan and remember, easy to disseminate, fun and engaging.

Infographic Methodology

Infographics (or information graphics) are graphic visual representation so information, data, or knowledge "intended to present complex information quickly and clearly" (Smickilas, 2012). Benefits of using infographics include eye-catching, easy-to-scan and remember presentations of information, and fun, engaging, and easy way to disseminate information.

In our project, we used infographics to convey climate change information through picture and icons, which are not only visually appealing, but attract people's attention to the information the graphic contains. These graphics can also create more effective and lasting messages for viewers, and may incentivize climate adaptation efforts.

We first laid out a landscape and the primary elements of a watershed and the landscape of an urban area. Second, we collected information on climate change impacts via sources that included NOAA and the EPA's websites. Then, we translated the information into graphs and concise texts. After that, we listed additional resources for people to reference in order to learn more. Finally, we solicited feedback from city practitioners on ways to improve the infographics' aesthetics and suggested resources.

The infographics are designed for both online and print use. The vector based infographic can be expanded without impacting on the quality. The additional resources listed are both hyperlinkable and QR code scannable so people can link to those sources easily using different mediums.

Infographic: Climate Change and the Great Lakes

Fig. 3. Climate Change and the Great Lakes Region (in draft)

Fig. 3 is an infographic with a watershed layout: forests, agriculture, urban areas, wetlands, and the lakes. The climate projections are from the GLISA fact sheet about the climate trends in the Great Lakes region and the main impacts on each sector are concluded from the GLISA fact sheets, the Freshwater Future fact sheets, and Great Lakes Coastal Wetland Communities report from Environment Canada, University of Waterloo, and Snell and Cecile.

The infographic offers a description of the major climate change projections and impacts on the Great Lakes region, including changes in average temperature and precipitation, increase in extreme weather events and decrease in lake ice coverage.

In the callout boxes, we draw out climate change trends in forests, agriculture, urban areas, wetlands, and the Great Lakes. Specifically, we call out climate impacts that are personal-relevant to our audiences, for example changes in growing seasons are affecting agricultural producers and agriculture-dependent economies, degraded air quality and increased demand on the energy grid are some of the primary concerns in urban sector, and loss of migratory habitat and reduced stormwater infiltration are how climate change impacts people through impacting the wetlands. Additional resources are provided on the side to encourage people to learn more about how climate change impact different sectors in the Great Lakes region.

Infographic: Climate Change in Evanston, Illinois

Fig 4. Climate Change and Evanston, Illinois (in draft)

Fig. 4 is an infographic focuses on encouraging resident actions on coping with climate change in the built environment, transportation, human health, and shoreline sectors. The climate change impacts on each sector and what people can do to help are based on the fact sheets from GLISA and Freshwater Future and also what we learned from the project case studies and training modules in general.

The information presented in this infographic is general climate change impacts to urban areas in generic mid-size Great Lakes cities. Given that climate change impacts in those cities are similar, the same information can then be tailored to be used in different cities. For example, the infographic shown is an infographic we designed for Evanston, one of our partner cities. We added the lighthouse in the infographic to tailor the infographic to audiences from the city of Evanston. Other mid-size Great Lakes cities who are interested in using this infographic can use the same background and information presented in this infographic and add their own landmarks to target their residents. Cities can also adapt the infographic to suit their own needs by adding in the "Learn More" section their specific resources from the city. [Please see appendix E.]

VI. GIS Maps

The GIS component of this project sought to address resource limitations that many municipalities in the Great Lakes basin face. Great Lake cities have limited resources for climate change adaptation. Effective planning and deployment of adaptive techniques requires an understanding of the locations within a particular city that are most vulnerable to climate change. By targeting resources in this way cities can "get the most bang for their buck". This end goal is the guiding framework for the GIS analyses carried out by the Climate Ready Great Lakes team. Two methods of climate change vulnerability mapping are described in this section. The first is "extreme heat and flooding" or "warm season climate change vulnerability". The second is extreme cold and winter weather infrastructure damage or "cold season climate change vulnerability. The methodology for both types of maps is similar. Final discussion will focus on how cities may customize the analysis by providing their own data and/overlaying the results with suggested layers. There is also room for improving methodology which is discussed in the methods section of the appendix.

Warm Season Climate Change Vulnerability and Green Infrastructure in Milwaukee, WI

The warm season climate vulnerability map was piloted in Milwaukee. The analysis was approached with the intention of lessening the major public health impacts of climate change in cities which is urban heat island effect (Luber et al, 2008). Furthermore, the analysis draws on the framework of co-production of science between practitioners and university researchers. Given Milwaukee's deep concern with storm water management and combined sewerage overflows the analysis used data provided by MMSD to show where residents of Milwaukee were most vulnerable to flooding impacts. This sort of collaborative

methodological design helps to downscale climate science into tangible pieces that policy makers can use to make decisions (Corburn, 2009).

Zones that are both highly vulnerable to urban heat island effect and residential flooding can be considered vulnerable to climate change writ large. In this analysis we over analyzed the placement of green infrastructure based on climate vulnerability. Milwaukee has done an adequate job of placing green infrastructure in areas that are vulnerable to urban heat island effect, but could improve placement in terms of residential flooding. This map can be used to guide future rounds of green infrastructure funding. The map and the methodology used in the analysis can be found in the Appendix.

Cold Season Climate Change Vulnerability in Evanston, IL

Winter weather vulnerability is considerably more difficult to ascertain in the context of climate change. Impacts on human health and infrastructure are more complex than temperature alone. For example damage to physical infrastructure, "snowed-in" elders, and transportation system breakdowns are more likely to occur during weather fluctuations rather than sustained cold. Additionally, one day of extreme cold can drive an average down, while sustained cold is the main factor when considering danger to children. These types of fluctuations in temperature are difficult to capture at sufficiently small enough spatial and large enough temporal scales to differentiate relative vulnerability across census block groups. Notwithstanding these methodological challenges the GIS analysis attempts to understand how extreme winter weather might affect various neighborhoods of Evanston, IL relative to each other. This decision was made in concert with the sustainability office of Evanston. The sustainability office requested the cold weather vulnerability analysis after reviewing the warm weather vulnerability map. The decision to pursue cold weather vulnerability mapping was made on a particularly blustery February day, which perhaps overstated the need for such an analysis.

The analysis drew on previous work which illustrated linkages between impacts of cold weather on families and poor nutritional outcomes; for many families a cold snap means they must answer the question "heat or eat?" (Bhattacharya et al, 2003). Input from Evanston, IL officials helped to guide the selection of social and built environment indicators that were chosen to develop the vulnerability index. Data mining of publicly available "311" information was utilized to determine where infrastructure was vulnerable to cold weather damage.

Maps and methodology are in appendix C and D

VII. Concluding Team Reflection

This project was both extremely challenging and extremely rewarding. Unlike many other available projects, the Climate Ready Great Lakes Cities project did not lend itself well to the typical research design format; rather, the project was based around crafting an evolving set of deliverables around an evolving set of issues and concerns from both the local level (our cities) and regional/federal level (our clients). Designing our deliverables and communicating with the cities was necessarily an iterative

process; for example, some case studies and infographics went through 4-5 fundamental revisions before they reached the format most useful for our clients.

We believe the project has given us a tangible skill set far beyond the actual deliverables; e.g. in the project, we had to learn to be the broker between individuals and cities in our clients at NOAA/GLSCI, and to present scientific information in a way that is both complex and comprehensive but also easily understood and followed by the lay audience through our infographics and training modules. In additional, at least two members of the group intend to seek employment in fields or institutions related to this master's project.

Perhaps the most exciting end realization for the team is that each element of this project was designed to have a life long after the masters project term ends. Rather than a report that is used once and then put on a shelf, the products themselves are designed to not only be easily re-used, but also easily reworked for each context that seeks to use them, and we are excited to follow how these deliverables will change over time and are expanded upon in future Great Lakes adaptation efforts.

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APPENDICES

To the Climate Ready Great Lakes Cities Capstone Thesis

April 21, 2015

Table of Contents:

Appendix A: Example Preliminary Interview Questions (Traverse City)

Please note: some of these questions were asked in our initial email correspondence with the city officials, and some were asked in the preliminary telephone interview.

- Where does adaptation planning occur in your city? (e.g. does it involve one or multiple offices, staff members, etc.)
- Is there a possibility that we might tour your green infrastructure and/or view your recent adaptation planning documents during our visit?
- Are there organizations in the city that work closely with you on your adaptation planning efforts, and if so, may we speak with them and/or invite them to participate in the interview?
- May we record our interview session using audio and video devices?
- What are your top planning objectives and priorities? Can you give us a sense of some of the challenges you are facing?

Appendix B: Example Case Study Interview Questions (Goderich)

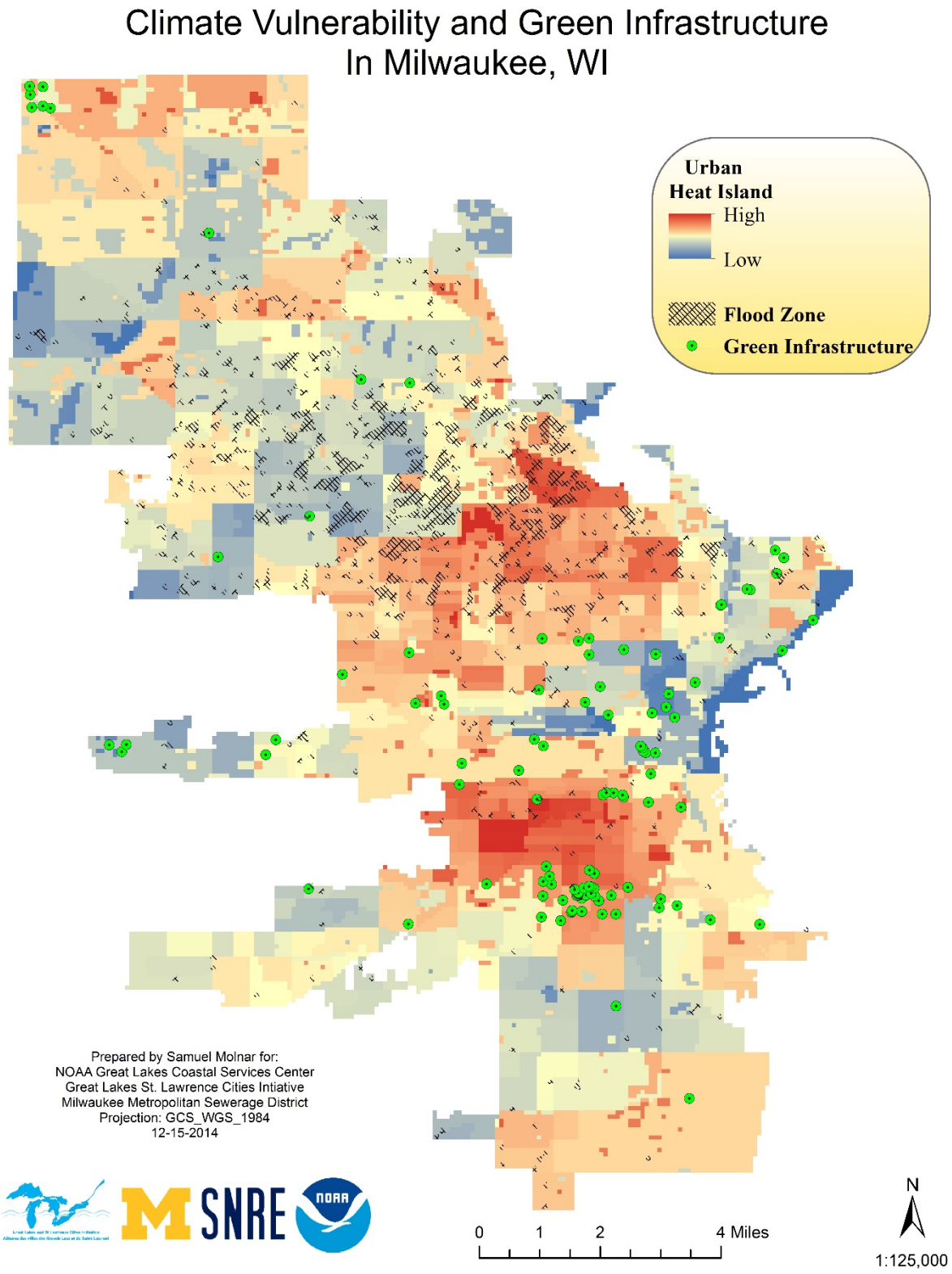
City history and climate threats

1. What are the primary climate or weather-related threats that have historically impacted Goderich? Are they similar to regional threats, or are you working in a microclimate of sorts?
2. Have these impacts been getting more frequent or severe? What sort of future climate projections are you working with?
3. Where do you get your climate data from? Do you work with Brucefield climate station southeast of Goderich much?
4. What infrastructure and economic sectors do you feel are most vulnerable to the major climate threats you're facing?
5. We heard about the major tornado that Goderich experienced in 2011. How did the City react to this event? We read an article stating that some residents viewed the tornado as an opportunity to rebuild and revitalize the community, while others viewed it as a reason to leave Goderich. Did the tornado change the City's climate planning process? If so, in what ways?

Adaptation planning and strategies

- Responding to and preparing for severe weather has been something cities have always done. What are you doing differently now that you're engaging in climate adaptation planning? Can you walk us through the events that brought you to this new form of planning?
- What kind of work has been done in Goderich related to climate change or resiliency building? (we read about combined sewer separation and lakeshore erosion prevention)
- (If they don't mention it beforehand) We read that you separated your combined sewer system. Who spearheaded that?
- What was the impetus to write the 2013 Asset Management Plan?
    a. How often will this plan be updated?
- Are there any other plans that look at the city's resilience against climate change? Is there an official adaptation plan? If so, may we receive a copy or online links for review?
- Have you used any other cities' plans or adaptation strategies as a model for your own?
    a. Are you aware of any other communities using you as a model?
- Where do you get your information about adaptation strategies? (We know you've worked with GLAA-C in the past. Do you actively use their resources or those of any other regional organizations?)

Appendix C: Example Summer Climate Change Vulnerability



Example: Summer Climate Change Vulnerability Methodology

Raw data used:

ASTER Global Emissivity Database, North America, Summer, 100 meter, HDF5 V003

1. Obtained from NASA Reverb website in HDF file format.
2. Shows average temperature of each 100 M pixel in summer months from 2000-2008.

US Census Data, obtained as polygons from SimplyMap database.

- Housing Stock---Percent of housing in census tract built in 1939 or earlier.
- Percent of block group in poverty.
- Percent of block group over 65 years old.
- Percent of block group under 5 years old.

Green Infrastructure Points (provided as a KML file from Milwaukee Metropolitan Sewerage District)

Basement flooding points (provided as a shapefile from MMSD)

Methods:

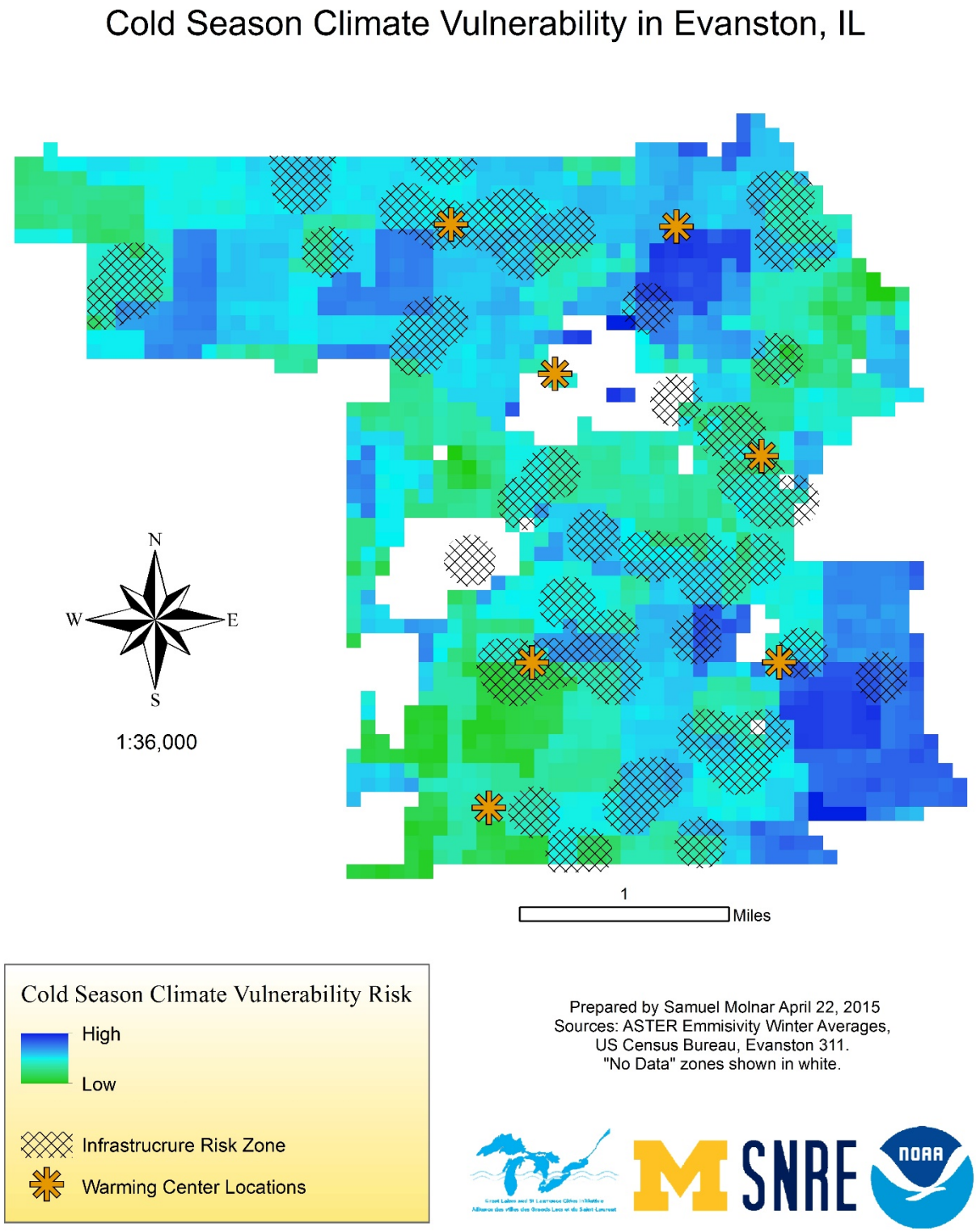
1. Convert ASTER Emissivity data into a GeoTiff using R or Python (working program deposited in archive folder).
2. Convert Census polygons to raster datasets
3. Stretch census and aster to to a standardized 0-100 relative grid.
4. Using raster calculator combine emissivity data and census data to create urban heat island effect vulnerability raster.
    a. Total UHI Vulnerability on a scale of 0-100: (TemperatureRisk * .34) + (HousingPre1939 * .165) + (poverty * .165) + (over65 * .165) + (under5*.165)
5. Place a 100 M buffer around basement flooding points to signify residential flooding zone.
6. Overlay residential flooding zone with urban heat island effect vulnerability. Intersection of high urban heat island effect vulnerability and residential flooding zone signifies overall summer season climate change vulnerability.
7. Overlay green infrastructure points onto existing map. This allows an evaluation of current green infrastructure geography, and allows planning for more targeted green infrastructure building.
8. Use Landsat 8 images to highlight hotspots down to a 30 M scale from the current 100 M scale. This allows users to pinpoint exact source of high relative temperature.
    a. Note that Landsat 8 images will not provide an average, but a snapshot in time. Use accordingly.

Suggestions for improved methodology and analysis

- Include more sociological and geographic context data in Urban Heat Island effect such as:
    - Distance to freeways.
    - Distance to major smokestacks.
    - Percentage of census tract able to walk ¼ mile without assistance.
    - Localized crime rates
    - Neighborhood stability index.

    - Percentage of census tract with asthma.
    - Percentage of census tract living alone
    - Normalized Difference Vegetation Index, tree cover.
- Overlay gray infrastructure for analysis, especially new lateral builds in the case of Milwaukee.
- Create a gentrification index by census tract neighborhood and overlay with green infrastructure points. Utilize to analyze links between green infrastructure and gentrification.

Appendix D: Example Cold Season Climate Vulnerability



Data used:

- ASTER Global Emissivity Database, North America, Winter, 100 meter, HDF5 V003
  - Obtained from NASA Reverb website in HDF file format.
  - Shows average temperature of each 100 M pixel in winter months from 2000-2008.

3. US Census Data, obtained as polygons from SimplyMap database.
   - Housing Stock---Percent of housing in block group built in 1939 or earlier.
   - Percent of block group in poverty.
   - Percent of block group over 85 years old.
   - Percent of block group under 5 years old.
   - Percent of block group using electric heat.
   - Percent of block group using oil heat.
   - Percent of block group in housing with 5-9 units.
   - Percent of block group in housing with 9-20 units
   - Percent of block group in housing with 20-50 units
   - Percent of block group in housing with 50 or more units.
4. Pothole locations, publicly available through Evanston, IL website.
5. Warming center locations.

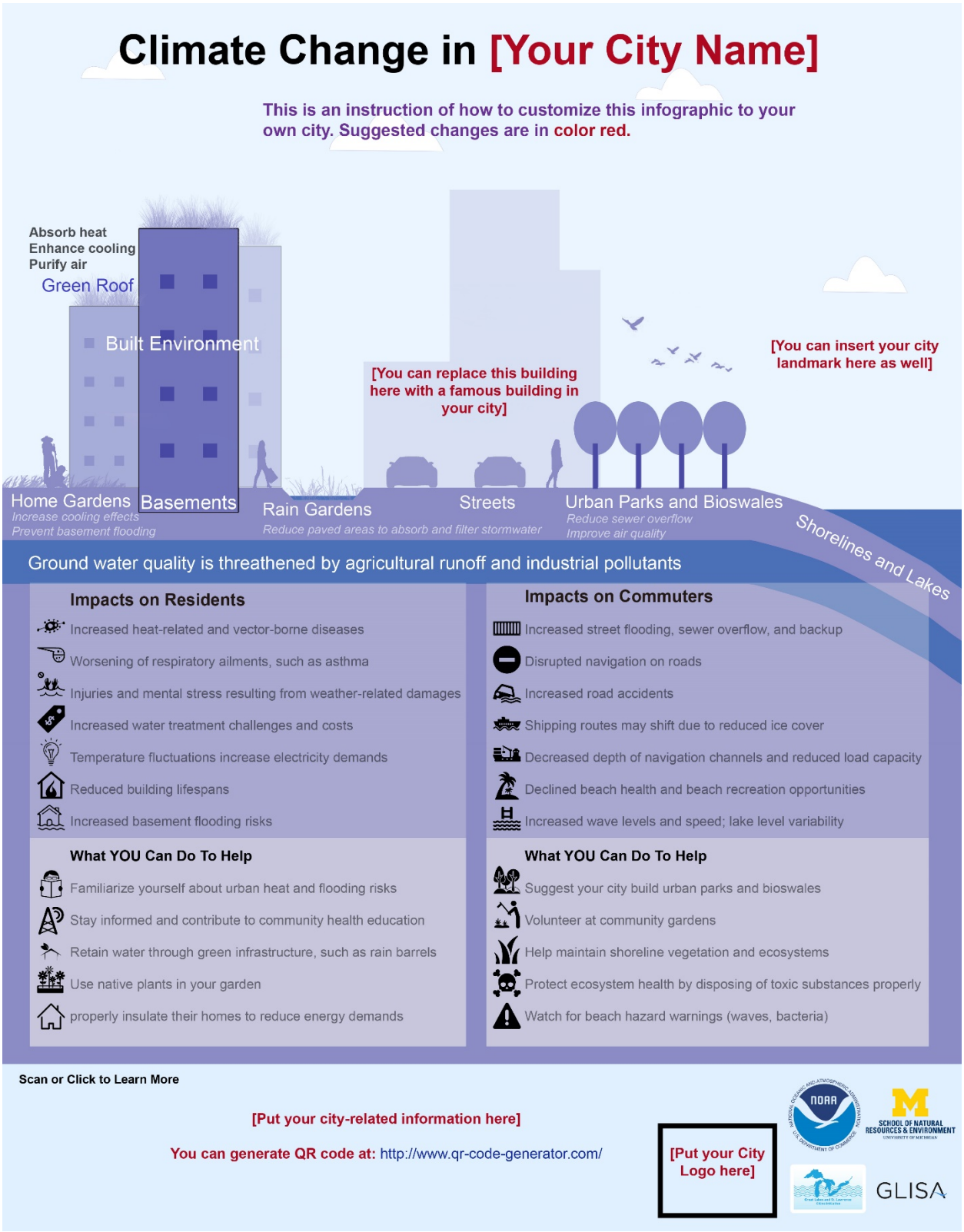
Methods:

1. Convert ASTER Emissivity data into a GeoTiff using R or Python (working program deposited in archive folder).
2. Convert Census polygons to raster datasets.
3. In raster calculator combine apartment data by calculating each of the four apartment data sets by .25.
4. Stretch census and ASTER to to a standardized 0-100 relative grid.
5. Invert ASTER by taking the absolute value of Grid-100
6. Using raster calculator combine emissivity data and census data to winter weather vulnerability index
   (Temperature Invert * .34) + (Percent Under 5 * .11) + (Pre 1939 * .05) + (Apartments * .06) + (Percent over 85 * .11) + (Poverty * .11) + (Oil Heat * .11) + (Electric Heat * .11)
7. Place a 100 M buffer around potholes to indicate winter weather infrastructure damage zones.
8. Overlay warming centers.

Suggestions for improved methodology and analysis

- Include water main locations. This was not possible in this analysis because of security concerns.
- Interpolate winter data such as snow depth from multiple weather stations around target area.
- Keep in mind the difference between “extreme cold” and “winter season vulnerability”. Extreme cold is somewhat easier to map, but vulnerability of infrastructure to extreme winter weather may be more useful, albeit harder to understand on a small spatial scale.

Appendix E: Instruction on how cities can customize the infographic



Climate Adaptation in the Great Lakes Region

A Case Study of Milwaukee, Wisconsin

Milwaukee's Lake Michigan Skyline, by Mike Fisk

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Dr. David Allan, University of Michigan Professor of Natural Resources and Environment
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With grateful thanks to:
The Milwaukee Metropolitan Sewerage District, The Milwaukee Water Center, and the Milwaukee Office of Sustainability
School of Natural Resources and Environment, University of Michigan

Fast Facts

Location: Wisconsin

Population: 594,000

Primary industries: Trade, transportation, manufacturing, education, health services.

Unique features: Located at confluence of three rivers.

Major resilience milestones:

- Reduced combined sewerage overflows through watershed scale management
- Built a diversified portfolio of green and grey infrastructure
- Incentivized homeowners to replace and lateral connections to sewer system

Executive Summary

Milwaukee is a leader in climate change adaptation. An increase in extreme storm events have motivated the Milwaukee Metropolitan Sewerage District (sewerage district), City of Milwaukee Office of Environmental Sustainability (sustainability office), and The Water Council (water council) to build a network of programs that engage the public to build resilience to climate change. Building political capital for adaptation following various crises, these organizations have focused on shared resources to empower the private sector and community residents and to build adaptive capacity in Milwaukee.

Milwaukee is an indigenous word for "gathering place by the water."[1] The largest city in the state of Wisconsin, Milwaukee sits along Lake Michigan at the confluence of three rivers: the Menomonee, the Kinnickinnic, and the Milwaukee. The City of Milwaukee is the largest of 28 communities in the Milwaukee metropolitan area, with a population of around 600,000 and a total area of 96.80 square miles, of which, 0.68 square miles are water.[2] Milwaukee's access to water is a great opportunity, but it presents challenges for stormwater and wastewater management as well as beach quality.

Projected Climate Impacts

Climate change is predicted to increase storm frequency and intensity in the U.S. Midwest region.[3] The number, duration, and volume of combined sewerage overflows (CSOs) are expected to increase as well. Milwaukee is predicted to experience a 25- to 37-percent increase in the frequency of storm events by 2050. According to the Wisconsin Initiative on Climate Change Impacts, by the middle of the century annual average temperatures will warm by two to seven degrees Fahrenheit, and large storms during fall and winter will become more frequent. Secondary impacts will include decreases in the quantity and quality of water resources and natural habitats, increases in soil erosion, and changes in agriculture, human health, and infrastructure.

Milwaukee is already experiencing impacts. In May 2004 Milwaukee experienced 8.9 inches of rain, the most in 110 years.[4] This storm caused a 1.565-billion-gallon CSO. In June 2008, Milwaukee observed 12.27 inches of rain, setting a new maximum-rainfall record for any month.[5] On July 22, 2010, seven inches of rain fell, causing flash flooding that closed the airport, created giant sinkholes, and flooded basements.[6] Over two billion gallons of untreated water were discharged into the Milwaukee River and Lake Michigan watersheds in a CSO event. With estimated damage of $30 million, this was the most expensive weather event in Milwaukee's history.[7]

Milwaukee Metropolitan Sewerage District

This regional government agency provides water reclamation and quality protection services to 28 communities with a population of 1.1 million, which enables it to facilitate regional communication and collaboration. [8]

MMSD's "whole watershed" approach allows for water quality management at multiple points, from rural upstream to urban to discharge. Its use of green infrastructure and partnerships with the private sector help stop or slow stormwater before it enters the system, reducing CSO risks. Partnerships with rural municipalities help the agricultural sector reduce nutrient loading into the watershed. As a nexus among different jurisdictions, the agency has pushed conversations toward climate action and adaptation strategies.

MMSD has been able to deploy its cross jurisdictional organizational structure to adapt to climate change at the watershed scale.

Milwaukee's preparation for climate change has been integrated into their sustainability vision, planning, and projects. Their success can be seen in a number of projects around sustainability—green infrastructure, energy efficiency, and overall social and economic resilience. Documented here are the main lessons learned along with examples of the projects executed in Milwaukee.

Turning Crisis into Momentum for Action

Major storm events and the foreclosure crisis are two examples in which Milwaukee catalyzed crisis moments into climate action. The city and the sewerage district used the 2010 storms crisis to build the political capital necessary for addressing climate change in two areas: the funding of green infrastructure; and financing enabling homeowner to rebuild the lateral pipe structures that connect pipes in houses to the storm system.

Between 2008 and 2010, almost 16,000 properties in Milwaukee went into foreclosure.[11] A new city plan identifies financing that allows qualified home buyers to purchase and rehabilitate existing, vacant homes with energy-efficient measures. Vacant housing that is reoccupied instead of demolished contributes to the sustainability of neighborhoods.[12]

"You have this foreclosure crisis and it's terrible," says Erick Shambarger, the deputy director for the sustainability office. "But on the flip side, it is freeing up lands for something else."

Sharing Resources to Build Consensus

Momentum and consensus for climate action have been built by focusing the attention of political leadership, the grassroots, and the private sector on shared resources and the shared watershed—the Lake Michigan coastal area where Greater Milwaukee is situated.

The result is a culture of regional collaboration. For example, non-profit organizations have taken up the sustainability office's framework of job development and neighborhood health and safety improvements. The Water Council's help in forming academic-private partnerships is moving Milwaukee forward as a world water hub, with research, education, technology development, and industry sectors coming together under one roof. In addition, the "ReFresh Milwaukee" campaign, developed by the sustainability office, is growing Milwaukee's "cluster of energy-efficient and clean tech companies to create local jobs and exports."[13]

The sewerage district is collaborating with municipalities, nonprofits, and the public to increase access to funds that can help protect water resources. [14] "We helped the region understand that in order to either save money or protect our watershed, we all needed to work together," says Kevin Shafer, executive director of the sewerage district. Its plan identifies the facilities, programs, operational improvements, and policies required by the year 2020 to meet the existing regulatory framework and permitting requirements.[15]

City of Milwaukee Office of Environmental Sustainability

This office was created by Mayor Tom Barrett in 2006.[9] It has streamlined sustainability work by integrating various Department of Public Health, Department of Neighborhood, and Area Healthcare Alliance projects.

The mayor-appointed Milwaukee Green Team organized the mission of the sustainability office around four key adaptation issues: stormwater; smart energy policies; green jobs and the green economy; and an implementation strategy across issues and sectors.

Green Infrastructure in the 30th St. Corridor supported by MMSD (Photo: 1000 Friends of Wisconsin)

The sewerage district also partners on innovative approaches and projects such as watershed-based permits, river restorations, and green infrastructure. Their partners include the Southeast Wisconsin Watershed Trust and the Southeastern Wisconsin Regional Planning Commission. As far back as 2003, the Best Management Practices Partnership Program was created by the district to provide matching funds for green infrastructure projects. This funding cuts across sectors to implement green infrastructure quickly that benefits the watershed and builds climate resilience.

Community and Private-Sector Empowerment

Milwaukee engages the public in planning and implementing efforts for adaptation. For instance, the "ReFresh Milwaukee" plan has been a call to action around a community-endorsed and collaborative set of goals and strategies. This bottom-up, community-centered approach empowered area residents to provide direction and set priorities toward making their neighborhoods better places. In 2012, the Green Team surveyed 1,011 residents and gathered input on issues and priorities (the survey can be found in the *ReFresh Milwaukee* report appendix). The team then reached out to an additional 435 residents by hosting five formal town halls and more than 30 focus groups. The team chair also received 85 business comments through partnerships with trade groups and area businesses.

In order to give property owners the incentive to maintain the lateral structures that feed into sewers, the sewerage district uses a combination of approaches. One approach, the "basement connection," informs people on how pipes work, how to prevent flooding, and how people can maintain or replace home pipes.[16] The office of environmental sustainability is also working with private property owners to maintain private lateral structures.[17]

The office sought to increase participation in green roof implementation by stressing the importance of project density and making residents aware of their neighbors' participation. At the conclusion of the laterals project, the office increased participation from 60 percent to 90 percent by facilitating conversations between neighbors.

Green infrastructure has been used as a main strategy to help protect basements, sewers, and area water quality during rain events through the collection and filtration of stormwater. On a city scale, the sewerage district has promoted bioswales along city streets and has used porous pavers in parking lots, driveways, and sidewalks. (Porous pavers help reduce overflow by increasing the permeability of land surface.) To encourage public participation in using green infrastructure, the district partnered with the Fresh Coast 740 program to offer technical assistance and financing to small-scale green infrastructure projects. This mosaic of projects created the collective impact benefitting Milwaukee today.[18]

The Water Council

This council was established in 2008 to harness the strength of Milwaukee as one of the major hubs for water research and industry around the world. [10] It attracts companies from around the world to address water issues by developing business models for companies to locate in Milwaukee. With a membership of more than 150 water technology companies as well as partnerships with local schools, it has accelerated communication among business and academia, facilitated economic development, and attracted expertise in adaptation planning.

Messaging is framed around themes of "environmental friendliness" and "cost-effectiveness" to trigger both extrinsic and intrinsic motivation. The sustainability office has formed its vision for sustainability on base condition outcomes. [19] For example, when introducing green buildings, the message was framed around how implementation would create job opportunities, support education, and promote human health. Most essential in messaging is focusing on the benefits that people can experience directly. The sewerage district's messaging strategy echoes this direct-benefit focus. Their climate action work is framed around reduced costs to ratepayers.

Conclusion

Milwaukee's extensive climate adaptation efforts are due in large part to its ability to collaborate across municipal boundaries and agencies. The "whole watershed" approach and shared messaging has allowed the sewerage district, sustainability office, and water council to parlay various crises into opportunities for public collaboration and action. A shared consensus among community members and the private sector, and a mosaic of climate adaptation efforts, have created a Milwaukee more resilient to climate change that is ultimately a better place to live. According to Kevin Shafer of the sewerage district, "When the city wins, we win. When the suburbs win, we win. And when all of us win, the climate wins."

[1] Darrell Brown, "Water Technology: An Interview with Dean Amhaus, President and Chief Executive Officer, The Water Council," *Leaders Online*, April/May/June 2014, www.leadersmag.com/issues/2014.2_Apr/Wisconsin/LEADERS-Dean-Amhaus-The-Water-Council.html.
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[12] Ibid.
[13] *ReFresh Milwaukee: A Vision for Community Sustainability*, City of Milwaukee Sustainability Plan 2013 – 2023, page 23, www.city.milwaukee.gov/ReFreshMKE_PlanFinal_Web.pdf?.
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[15] "2020 Water Quality Initiative," Milwaukee Metropolitan Sewerage District, www.mmsd.com/waterquality/2020-water-quality-initiative.
[16] *Refresh Milwaukee: A Vision for Community Sustainability*, City of Milwaukee Sustainability Plan 2013-2023.
[17] *Refresh Milwaukee: A Vision for Community Sustainability*, City of Milwaukee Sustainability Plan 2013-2023.
[18] Fresh Coast 740, www.freshcoast740.com.
[19] *Refresh Milwaukee: A Vision for Community Sustainability*, City of Milwaukee Sustainability Plan 2013-2023, image, page 14.

Climate Adaptation in the Great Lakes Region

A Case Study of Niagara Region, Ontario

Niagara Region at a glance in the sky. Source: http://www.travelblat.com/wp-content/uploads/2012/01/Niagara.jpg

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Acknowledgements
Dr. David Allan, University of Michigan Professor of Natural Resources and Environment
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Brent Schleck, Coastal Storms Outreach Coordinator of Minnesota Sea Grant
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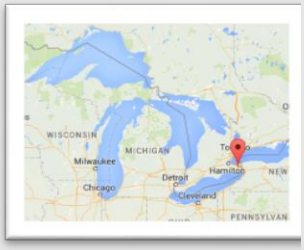
With grateful thanks to:
The Regional Municipality of Niagara
School of Natural Resources and Environment, University of Michigan

Fast Facts



Jurisdictions: 12 local municipalities with one metropolitan planning organization

Land area: 1,852 square kilometers comprising 12 local municipalities

Shoreline: 117km along Lakes Erie and Ontario
Population: 431,346 (2011), averaging 232.9 people per square kilometer

Economic Sectors: Agriculture, manufacturing, and tourism

Unique features:
The Niagara Escarpment begins in Niagara-on-the-Lake and travels east-west through the region
Niagara's eastern border is an international border
Niagara Falls is a popular tourist attraction and large producer of hydroelectricity
The Welland Canal shipping route is constructed to bypass Niagara Falls

Summary

Federal funds served as an incentive for municipalities to initiate a national program and include climate change in regional planning.

The steering committee and planning team led and coordinated implementation of actions.

Academic research provided scientific support.

Extensive community and partnership engagement took place through forums, collaborative meetings, a workshop, and an online survey.

Climate Impacts

Increased water treatment and stormwater management cost because of increased runoff and combined sewage overflows from intense rainfall.

Longer tourism and outdoor activities season beginning earlier in spring as well as a warmer summer season lasting later into the fall.

Reduced productivity and quality of "cool climate" grape varietals.

More "hot crop" production from longer and warmer growing season.

Decline in wetlands because of lower water levels, with impacts on wetland plants, marsh-nesting birds, amphibians, and fish.

A shift in the transfer and distribution of electricity from the increase in the frequency and intensity of extreme weather.

Reduced lifecycle of building materials and structures.

Lessons Learned

Leadership and dedication

Fact: A Corporate Climate Change Steering Committee was established to provide the corporate management team and regional council with strategic leadership. This committee identifies ways to both respond to climate change and reduce the corporate ecological footprint. The committee works on the corporate climate action plan and is made up of staff members from across regional departments and agencies.

Major Adaptation Milestones:

- 2007 Climate change mitigation and adaptation planning team created
- 2008 Climate Change Action Work Plan completed
- 2009 Niagara Region joined Partners for Climate Protection program
- 2010 Corporate* and community 2006 greenhouse gas emissions inventory completed
- 2011 the Niagara Climate Change Network (NCCN) was formed; the City of St. Catharines identified climate change as one of six major challenges in sustainability strategy
- 2013 Corporate and community climate action plans completed

Major Partners:

- The Federation of Canadian Municipalities (FCM)
- The International Council for Local Environmental Initiatives (ICLEI)
- Niagara Research and Planning Council (Organizational Support)
- Climate Action Niagara
- Niagara Federation of Agriculture (North and South)
- School boards
- Walker Industries
- Rankin
- Wineries
- Brock University and Niagara College

Fact: The Engagement and Outreach Action Planning Team takes the lead in working on the community climate action plan, and it leads council and community communication through meetings, workshops, media outreach, and surveys. Through these efforts, the team builds the Niagara Climate Change section of the Niagara Knowledge Exchange, creates a connection to climate change on the Living in Niagara website, identifies a source of funding, and applies for the financial support needed to appoint a knowledge broker and create an outreach and education strategy.

Takeaway: A team with a focus on climate action strengthens corporate commitment to adaptation because it involves staff members from various departments and facilitates efficient communication and collaboration among these departments.

Collaboration

Fact: Under the guiding work of the Corporate Climate Change Steering Committee and the Engagement and Outreach Action Planning Team, various departments within the corporation as well as partners from communities, nongovernmental organizations, and universities have been actively engaged in the action planning process—for instance, by providing academic and scientific support and taking the lead on various action items.

Takeaway: Actions are better implemented when a specific department or partner is designated as the lead.

Focus Areas

Fact: The Niagara region focuses adaptation action in various fields within the municipal corporation, including buildings, the public, transportation, water and wastewater, and waste reduction. Community adaptation efforts can target many areas: the built environment, such as green roofs; accessible local food; energy and transportation; community engagement and outreach; and industrial, commercial, and institutional engagement. For example, In one example, several regional companies installed drinking fountains so workers can fill their water bottles at regional headquarters rather than buying bottled water.

Takeaway: Municipalities beginning adaptation efforts could start with the same fields noted above. Some fields are more general in their applications—for, example, the built environment, transportation, waste, and energy—while others are more target-specific, such as employee and community outreach.

Funding strategies/sources:

- Green Municipal Fund (financed by the Government of Canada and administered by the Federation of Canadian Municipalities)
- Regional Funds
- Grants
- Donations

Motivation

Fact: The Niagara region created Climate Change Champions, which is a corporate recognition program, to motivate people involved in climate action. A number of individuals and groups were part of the Climate Change Champions recognition because of their role in sustaining and protecting the Niagara environment since 2000. These included team and staff members representing social assistance and employment opportunities as well as team members representing social, wellness, education, and environmental efforts. A project that uses sugar beet juice to reduce road salt was also a champion. Another champion was a green-building design. A comprehensive study, Adapting to Climate Change: Challenges for Niagara, serves as a valuable resource for many organizations and individuals working together to address climate actions. (The study authors collaborated with Brock University, and some faculty members and students helped conduct the study.)

Takeaway: Recognition programs and awards provide a good motivation for all area residents to be creative and energetic about climate change adaptation. A comprehensive academic study provides valuable fundamentals for actions to build on. Seeking graduate students from local academic institutions to conduct such a study is possible.

Good practice example

Fact: The Niagara region is using a sugar beet juice compound to reduce the amount of salt on the roads by as much as 30 percent, from 85 kilograms to 78 kilograms per lane kilometer. By applying the beet juice to the road first, before the road salt, the amount of "bounce and scatter" is reduced while still achieving the same results. This de-icing alternative is less toxic and reduces impacts to the natural environment. The region will see a cost savings of almost two dollars per lane kilometer.

Takeaway: Replacing some of the salt with sugar beet juice has become popular in many other areas, and it is one good practice to apply in areas with similar icy road conditions.

Additional Resources:

- Niagara Region Community Climate Action Plan
- Niagara Region Corporate Climate Action Plan
- Adapting to Climate Change: Challenges for Niagara
- Liquid Assets: Assessing Water's Contribution to Niagara

Concluding thoughts from the team

Impressive: The sustainable developing way the region has been thinking, the ambitious greenhouse gas reduction target and the detailed actionable items identified for the past decade, the diverse components of the climate action team to engage almost all departments in the corporate, and great support from multiple communities.

Strengthening: The climate action team, a comprehensive evaluation system on the implementation of the action items, and the emission reduction report on time. Broader funding resources and public outreach programs. Continuing adopting new actions incorporating the lessons learned from past experiences.

Funding and leadership are two core essentials for climate actions. Communication and collaboration are significant parts of the action plan. Climate actions are long-lasting programs and municipalities should have the patience to keep working on the issue for decades.

1. Niagara Region map: http://www.jkinspectionservices.ca/wp-content/uploads/2014/08/niagararegion2.jpg
2. Niagara Region logo: https://encrypted-tbn3.gstatic.com/images?q=tbn:ANd9GcSqMXnFSM1iGj6zHO-hiYcrvvHgDNbA1z1rzZARTLd6nCGQtPwP
3. Niagara Region Community Climate Change Action Plan
4. Niagara Region Corporate Climate Change Action Plan
5. Liquid Assets: Assessing Water's Contribution to Niagra
6. Adapting to Climate Change: Challenges for Niagara
7. "Niagara Regional Municipality census profile". 2011 Census of Population. Statistics Canada. Retrieved 2015-03-27.

Climate Adaptation in the Great Lakes Region

A Case Study of Traverse City, Michigan

Image Source: Vineyard Bay Estates

Lead Author: Lauren White
Co-Authors: Alexandra Brewer, Andrea Kraus, Samuel Molnar, Wufan Jia, Pearl Zhu Zeng

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Brent Schleck, Coastal Storms Outreach Coordinator of Minnesota Sea Grant
Elizabeth Gibbons, Director of the University of Michigan's Climate Center

With grateful thanks to:
The Traverse City Department of Planning, Northwestern Michigan College, and SEEDS
School of Natural Resources and Environment, University of Michigan

Fast Facts

Population: 15,018
Primary industries:

- Tourism and outdoor recreation, attract many visitors and employ a large portion of residents.
- Agriculture (especially cherry and grape production) contributes as much as $97.9 million annually to the local economy. The Traverse City region is the largest producer of tart cherries in the US, and houses 80% of Michigan's sweet cherry orchards.

Major resilience milestones:

- Climate Action Plan, 2011
- Grand Traverse County Master Plan, 2013
- Grand Vision, 2009
- New Designs for Growth Development Guidebook
- Traverse City Water Dialogue, 2014
- Creation of Grand Traverse County Brownfield Redevelopment Authority
- TC Saves
- The Boardman River Plan
- E.coli filtration systems in Bay

Summary

Traverse City, Michigan is the largest city in the Northern Michigan region, and serves as the County Seat of Grand Traverse County. While the city itself boasts a year-round population of 15,018 (as of the most recent 2013 Census), its tourism and outdoor recreation industries attract more than 1.4 million visitors to the region annually - with the popular National Cherry Festival alone drawing approximately 500,000 travelers each year. In fact, Grand Traverse County is Northern Michigan's most popular resort destination, and the population of Traverse City increases by 22% in July, during the prime festival and vacationing season.

With a highly engaged citizenry, a geographically favorable location and richness of natural resources, and a history of progressive innovation in land use planning, development, and public participation, Traverse City is primed to be a future leader in climate adaptation and municipal resiliency efforts. Its strides in forming durable community partnerships and its emphasis on distributed, collaborative leadership makes Traverse a unique model city for other Great Lakes communities.

Traverse City's most notable achievements in resiliency planning include the creation of the City of Traverse City Climate Action Plan (in partnership with the nonprofit organization SEEDS), the unique citizen-led Grand Vision (born from a 5-year collaborative engagement process), and the City's Master Plan.

Climate Change Projections

Temperature and precipitation variability could impact the tourism and agricultural sectors. Stronger storms, stormwater surges and flooding are more likely to occur, and lake level variability may negatively affect Grand Traverse Bay and the Boardman River. GLISA's climate projections (to occur by 2070 if present CO2 emission levels continue) include the following:

- 5°F warmer on average
- 2" more precipitation per year on average, with 1 more heavy precipitation event annually
- 35 fewer nights below freezing
- 20 more days above 90°F, with 5 more days above 95°F
- By 2099, 50 more frost-free days

More info: Great Lakes Integrated Sciences and Assessments (GLISA) and National Climate Assessment Midwest & Regional Reports
http://glisa.umich.edu/resources/nca]

Major Partners

SEEDS and other local nonprofit organizations
SEEDS has been an instrumental force in enabling Traverse City to reach key resilience milestones. With their partnership, the Climate Action Plan was completed in 2011. SEEDS also conducted a Greenhouse Gas Inventory for the area, also in 2011.

Northwestern Michigan College and its Great Lakes Water Studies Institute offers academic and research expertise. It hosts a monthly "Freshwater Roundtable" where NGOs and others assemble to discuss local issues including critical infrastructure redesign and replacement. Because local monitoring data on climate, invasives and regional hydrology is still patchy, NMC attempts to correct this with the creation of additional scientific stations and the involvement of partner organizations.

Grand Traverse County, comprised of 13 townships and 2 villages, seeks to maintain the high quality of life and tourism appeal of the area (including nature recreation and agriculture), whilst encouraging smart development.

The Grand Traverse Regional Land Conservancy is a 20+ year old local nonprofit whose mission is to "protect natural, scenic and farm lands and advance stewardship, now and for future generations." The GTRLC serves 5 counties, and has preserved over 38,000 acres of land to date. The organization also monitors over 200 conservation easements and maintains 34 nature preserves.

Key Lessons Learned

Build Collaborative Partnerships

Traverse City has formed strong relationships with local nonprofits, academic institutions, and private sector businesses (refer to side boxes for a list of major partners). Additionally, as part of Grand Traverse County, Traverse City has maintained open dialogue with neighboring municipalities, working synergistically on regional initiatives. These strategies have enabled Traverse City to build an extensive and impressive network of partners, both within the city limits and beyond. These partners can and have provided everything from climate adaptation education, data collection/monitoring assistance and capacity-building, to project management support and funding.

Takeaways for other cities: Reach out to area colleges, local nonprofit organizations, business leaders and officials in adjacent municipalities. Projects undertaken collaboratively are often able to accomplish broader goals, receive more funding and more attention, and may garner citizen support more readily.

Analyze and Assess

Traverse City already has quite a comprehensive compilation of planning, development and resiliency materials (see Climate Action Plan and Master Plan especially, as well as New Designs for Smart Growth Handbook). In tandem with key partners, Traverse City has extensively inventoried their natural and human resources, and has conducted several "town hall"-style collaborative meetings, which involved multiple stakeholders and broad-scale input. Next steps and best practices have, on the whole, largely been identified already. Similarly, Traverse City has also already created detailed maps of redevelopment, growth and investment areas. It would be fairly straightforward to build on these existing maps by overlaying climate vulnerability maps, thereby helping prioritize the most critical projects. Redevelopment projects that increase climate resilience, while simultaneously reinforcing, repairing or replacing existing infrastructure, have been the City's primary target.

Takeaways for other cities: Take every opportunity to gather key stakeholders and prioritize highest goals for the future. Evaluate infrastructural vulnerability frequently (wastewater and stormwater management, energy efficiency upgrades).

Additional Partners

- The Conservation Resource Alliance
- The Watershed Center
- Traverse City Light and Power
- The Traverse City Chamber of Commerce
- Michigan Sea Grant
- Northwest Michigan Council of Governments
- Traverse Area Association of Realtors
- Northern Michigan Chapter of Citizen's Climate Lobby

Past & Present Funding Strategies

The Master Plan was funded by the US Dept of Housing and Urban Development's Community Challenge Planning Grant program (through the Partnership for Sustainable Communities). Additional project funding has been provided in the past by Rotary Charities of Traverse City and Traverse City Light and Power.

Michigan Sea Grant has also funded hydrology research in Traverse City.

Future Funding

EPA stormwater grants

NOAA Office for Coastal Management offers grant opportunities

Identify Core Community Values to Bridge Differences

In the Master Plan, emphasis was placed on what factors unified the communities in Grand Traverse County. All communities prioritized high quality of life, proximity to unspoiled nature, preservation of local character & unique identity, and maintenance of diversity among communities. Placemaking and walkability were also a priority. This sense of unity, shared fate, and recognition of common goals is a positive force for change and provides an ideal starting point for collaborative work. "People want to live in denser communities with better transit and more green space," explained Sarna Salzman, Executive Director of SEEDS, during our interview. "They want 'viewsheds'." Traverse City has employed considerable innovation in zoning, and ascribes to the notion that zoning ordinances are one of the best ways to incorporate resiliency and/or sustainability initiatives into the city agenda, especially when these topics might otherwise be overlooked.

Takeaways for other cities: By focusing on what unifies a regional vision, and identifying key interim goals toward achieving that vision, it may become easier to align priorities in a way that supports neighboring communities. Rather than having siloed efforts all aimed at achieving the same ends, resources can be pooled and a "divide and conquer" approach can be implemented. Along the way, successes can be recognized and celebrated.

Innovate, Take Risks and Trailblaze

Traverse City has already been a pioneer in several environmental projects, including the removal of one dam from the Boardman River, with two more to follow soon. This is the largest dam removal project in Michigan history. In a similar vein, Traverse City was one of first communities to engage in brownfield redevelopment. They have redeveloped the old Traverse City Ironworks, and have created the Grand Traverse County Brownfield Redevelopment Authority. The Planning Commission has discussed incentivizing LEED building projects and retrofits. All of these endeavors strongly indicate that Traverse City has taken a proactive rather than reactive approach to building community resilience.

Takeaways for other cities: Having the resiliency discussions early, before there is an acute need, can help with the allocation of monies and labor toward these projects before they become critical. Small investments now may prevent excessive cleanup and triage costs in the future. Additionally, getting climate readiness onto the collective "radar" can help ease the discomfort of some of these discussions, as well as gently diffuse resistance to the topic.

Future Directions: Stormwater Utility

Traverse City has received a $2 million SAW Grant (Stormwater, Asset Management and Wastewater Grant) through the Michigan Department of Environmental Quality (DEQ) to help develop Asset Management Plans and assist with the formation of a stormwater utility.

Stormwater utilities are fees separate from property taxes that residents pay, based on the amount of runoff they generate. Per the SAW Package press release, "This grant will allow the city to explore new funding sources for its stormwater infrastructure..providing a mechanism for the City to address its backlog of projects intended to reduce flooding risk, improve stormwater quality, and enhance public safety." The city will conduct GIS mapping of waste and stormwater drainage and collection systems, as well as examine maintenance and capital needs

Challenges

Personnel

City Planning Director Russell Soyring mentioned in our interview that the City only had 2.5 dedicated staff members in the Planning Department. These staff are charged with all planning, zoning and project review matters before they are able to work on other issues relating broadly to "sustainability" - which would encompass adaptation and resiliency planning.

Be Action-Oriented and Responsive

After two severe, 100-year storm events occurred in the same month and led to flooding and E.coli issues in the Bay, Traverse City installed special filtration systems and also designed "bay-friendly streets" that generate less stormwater, reduce snow-plowing needs and are narrower. In the interview, the City officials mentioned that stormwater management is also an opportunity to help complete street development projects, revitalize the economy, and work synergistically with other groups and City departments.

Takeaways for other cities: Climate disasters, while quite challenging on all levels, provide an opportunity to build in enhanced resiliency measures during reconstruction. Similarly, as infrastructure ages and needs replacement, it too could be upgraded. For example, aging culverts can be replaced with wider ones that could better accommodate higher projected stormwater flows. Initial investments in technology and infrastructure upgrades may be slightly higher, but if systems are in need of updating anyway, it makes sense to replace them with more resilient models.

Engage the Public: Residents are a Resource

Traverse City has a very engaged citizenry. Boasting an unusually high percentage of well-educated and liberal-minded residents, there is no shortage of passionate activism among community members. The citizen-led regional land use, transportation, economic development and environmental stewardship endeavor, called the Grand Vision, drew more than 15,000 participants - 12,000 of whom voted on future visioning and how to best prioritize the City's resources. Recognizing that sustainable growth is possible, and that development can enhance rather than hinder quality of life, the Grand Vision prospects what citizens and government envision for 2060, then uses participatory backcasting to determine which present projects and priorities will help realize those goals.

Takeaways for other cities: Residents are a valuable asset and barometer for what is working and what is not. Host a series of community meetings and scenario planning workshops, and seek citizen leaders; this is one way to provide additional manpower to City departments that may otherwise be understaffed or lack key resources. Survey the public to identify top local concerns, help envision the future and inform highest priority development and/or adaptation work. With more involvement in the planning process, participants are likely to be more invested in the outcome.

Challenges (continued)

Funding

Past adaptation efforts have only been possible with the influx of grants and and other awards. Oftentimes, there are no dedicated State or local funding sources for these types of projects.

Siloed Efforts

Many separate resiliency initiatives and interested organizations exist, and there is much energy on this front, but efforts are still largely disconnected rather than unified.

Future directions

- Energy Savings Account (as identified in the Climate Action Plan)
- Traverse City BumpOut Project (with matching grant, up to $5k)
- Low lake levels create friction between those who wish to groom beaches and those who own marinas/docks and are negatively impacted

Additional Funding Resources

The Michigan Department of Natural Resources (DNR) offers **grants for coastal managers**, to assist with everything from aquatic invasive species control to dam removal to targeted runoff management.

Concluding Thoughts from the Team

Our project team was quite impressed with Traverse City's distributed leadership, and it's valuation of ongoing dialog with the public. Traverse City is a true pioneer in the realm of collaboration and partnership. We were heartened by the mycelial, interconnected network of nonprofits, private sector and academic support spheres that Traverse has carefully cultivated. We hope other Great Lakes municipalities might benefit from Traverse's trailblazing efforts in this regard.

Suggested Focal Points

We identified several possible areas of foci for Traverse City, going forward. Since staffing constraints have proven to be a barrier for the city in the past, we recommend investigating the possibility of reconvening the City and/or County Green Teams. These teams could report to the Planning Commission and could, in part, be tasked with carrying out some of the more minor climate adaptation planning and coordination responsibilities (infrastructure and habitat monitoring, public education, researching adaptation grants / grantwriting, etc.). Alternatively, Traverse could capitalize on the already-invigorated citizenry and existing Neighborhood Associations, and create a citizen task force for adaptation. Another possible strategy would be to divide climate adaptation and funding outreach efforts among the next City Councilmembers. Perhaps new hires to positions with the City could be entrusted with small but meaningful responsibilities that pertain to climate resiliency, or a part-time or volunteer Grants Coordinator could be funded through a nonprofit or business sector city partner.

Because much of the city's needed research about highest priority development and infrastructure upgrades is already in place, and there is a strong vision for moving forward, Traverse City is well-equipped to take the next step toward adaptation and resiliency work in earnest. It seems to merely be a matter of having enough sustained funding and an allocated labor pool to bring Traverse's clearly delineated goals to fruition.

Additional Funding Resources (continued)

The EPA's Great Lakes Restoration Initiative also offers funding.
The Association of Marina Industries offers boating access grants for public construction projects and Clean Vessel Act grants for marina sewage/pumpout stations
Useful Links
White House U.S. Resilience Climate Toolkit, compiled by U.S. Climate Resilience Task Force, contains visualization tools, case studies, videos and more: www.toolkit.climate.gov
GLISA resources for marinas: http://glisa.msu.edu/media/files/projectreports/14-728%20Increase%20Resilience%20at%20Marinas%20and%20Harbors.pdf

Team's project description

We are a team of seven University of Michigan graduate students, based out of UM's School of Natural Resources and Environment. Our Master's Project focuses on climate adaptation and resiliency planning for Great Lakes municipalities. We work for NOAA's Great Lakes Regional Collaboration Team, in partnership with the Great Lakes and St. Lawrence Cities Initiative (GLSLCI). Our goal is to develop a useful online toolbox of climate adaptation resources, including online webinars, case studies and infographics.

Our city case studies stem from municipal interviews conducted during the summer and fall of 2014. They aim to both capture Great Lakes regional best practices in climate resilience, and also to assess common barriers that Great Lakes communities face in enhancing their climate change adaptation efforts. On June 23, 2014, we spoke with Traverse City Planning Director Russell Soyring, Mayor Michael Estes, former City Manager Jered Ottenwess, Executive Director of SEEDS, Sarna Salzman, and Director of the Great Lakes Water Study Institute at Northwestern Michigan College, Hans van Sumeren. We are very grateful to them for sharing their time and insights with us!

1. "Climate-Ready Great Lakes Cities Master's Project Team, Interview with Traverse City Michigan." Personal interview. 23 June 2014.
2. Ottenwess, J. Soyring, R. vanSumeren, H. Salzman, S. Estes, M. Personal interview. June 23, 2014.
3. A Master Plan for Grand Traverse County. http://www.traversecitymi.gov/downloads/gtc_mp_document_final_27_nov_2013.pdf
4. Traverse City Climate Action Plan: http://www.traversecitymi.gov/downloads/climateactionplanfeb2011.pdf
5. The Grand Vision www.grandvision.org
6. Grand Traverse County Emergency Management facebook page: "Do 1 Thing" https://www.facebook.com/GTCemergency
7. Traverse City Water Dialog: Session Report http://www.kbsincorporated.com/wp-content/uploads/2013/12/2014-04-04-Traverse-City-Water-Dialogue-Session-Report-FINAL.pdf
8. Wikipedia
9. City of LaCrosse, Wisconsin: Is A Stormwater Utility Right for LaCrosse? http://www.cityoflacrosse.org/DocumentCenter/Home/View/3739
10. http://www.cityoflacrosse.org/index.aspx?nid=1898
11. City of Madison, Wisconsin - stormwater utility information http://www.cityofmadison.com/engineering/sewerUtility.cfm
12. City of Champaign, Illinois - stormwater utility now in effect http://ci.champaign.il.us/departments/public-works/residents/stormwater-management/stormwater-utility-fee/
13. Grand Traverse Regional Land Conservancy https://www.gtrlc.org/about/
14. Grand Traverse County http://www.co.grand-traverse.mi.us/Welcome/Community.htm
15. Traverse City Bumpout Project http://www.newdesignsforgrowth.com/events.php?news_id=461
16. SAW grant http://www.traversecitymi.gov/downloads/20131105_traverse_city_saw_package.pdf
17. Great American Adaptation Road Trip http://adaptationstories.com/2013/05/29/ann-arbors-climate-smart-stormwater-utility/
18. http://energy.gov/eere/better-buildings-neighborhood-program/michigan-sweeps-neighborhoods-energy-upgrades
19. http://www.tcsaves.com/content/about

Climate Adaptation in the Great Lakes Region

A Case Study of Goderich, Ontario

Goderich Harbor in Expansion Mode (2014), Dredgingtoday.com

Lead Author: Andrea Kraus
Co-Authors: Alexandra Brewer, Wufan Jia, Samuel Molnar, Lauren White, Pearl Zhu Zeng

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Brent Schleck, Coastal Storms Outreach Coordinator of Minnesota Sea Grant
Elizabeth Gibbons, Director of the University of Michigan's Climate Center

With grateful thanks to:
Goderich City
School of Natural Resources and Environment, University of Michigan

Fast Facts

Population: 7,251
Province: Ontario
County seat of Huron County.

Primary industries:

- Agriculture: Huron County is the most agriculturally productive county in Ontario.
- Salt mining and transporting: The largest industry in Goderich is the Sifto Salt Mine, located at the Goderich harbour. The salt mine extends for many kilometres beneath Lake Huron.
- Tourism: Goderich's waterfront, surrounding forests, rivers, and outdoor festivals draw thousands of tourists each year.

Major resilience milestones:

- 30+ year effort to reduce raw sewage overflow into Lake Huron culminated with completion of CSO separation 2007
- Goderich's harbor was dredged at several points throughout its history, thus helping decrease impact of declining lake levels
- Lakefront green infrastructure measures to coutneract erosion
- Tabletop and live emergency management drills

Summary

Canada's "prettiest small town" is also one of its most resilient.

In 2011, Goderich was hit by an F3 tornado. It tore through Goderich's downtown, causing the death of a salt mine worker and preliminary damage of $100 million. Within 15 minutes, 54 buildings were demolished and 283 more required repair. The entire town was left without power and over three dozen people were injured.

However, thanks to years of institutionalized resilience practices and critical infrastructure upgrades, Goderich recovered from the tornado's damage. Furthermore, the town's leaders leveraged their experience with the unexpected natural disaster as an invaluable learning experience that would strengthen their overall resilience efforts.

Herein lies a collection of the best practices that Goderich demonstrates with its dedication to disaster preparedness, community engagement, and collaborative partnerships--all critical components of a holistic resilience strategy.

Climate Change Impacts

1) Wind
2) Freeze/thaw cycles
3) Strong precipitation

GLISA climate projections (if present CO2 emissions continue). By 2070:

- 5°F warmer on average
- 2" more precipitation per year on average, with 1 more heavy precipitation event annually
- 35 fewer nights below freezing
- 20 more days above 90°F, with 5 more days above 95°F
- By 2099, 50 more frost-free days

Personal insight:

"*Those mock exercises we do, that's what really helped us, because we'd all been through a mock, whether it was a 'table top' exercise or a little more involved*.

Everyone knew their role from the moment things happened. *What needed to be done. That's something that should be encouraged in any municipality—make sure to do those exercises*."

- Jennette Walker, Environmental Services Technologist

Major partnerships:

- County of Huron
- Environment Canada
- Maitland Valley Conservation Authority
- Emergency Management Ontario: Mandates all municipalities and provincial governments to have an emergency management program. EOM also supports municipalities and ministries in implementing their emergency management programs by providing them with advice, assistance, guidelines, training, and other tools.

Key Lessons Learned

Emergency plans are good; drills are even better

Goderich is proactive about preparing, reviewing, and updating its Emergency Management Program. The Emergency Management Program provides guidance to key officials, agencies and departments within the the Town regarding their expected response to to a serious, large-scale emergency as well as an overview of what their individual responses should be.

Goderich is particularly effective at taking its plan a step further via tabletop and live practice drills that simulate real emergencies. Goderich's officials stress the importance of these exercise in surfacing information gaps and the important roles that need to be filled.

Combine green infrastructure with education initiatives

Increasingly intense precipitation in the Great Lakes also leads to an increase in erosion levels and thus threatens Goderich's lakefront. To counteract this, Goderich has invested in planting beach grass and trees along its shore. To maximize the impact of this measure, Goderich combined it with a beachfront education initiative designed to inform community members about the flora and fauna of their beaches, as well as the various threats to water quality. Thus, Goderich was able to derive aesthetic, functional, and community engagement benefits from a single measure.

Small town interconnectivity lends itself to collaborative partnerships

Most of Goderich's municipal officials hold multiple roles and serve in multiple organizations. The interconnectedness of the municipality's staff helps break down the silos that other municipalities struggle with. For example, due to her role as Environmental Services Technician for both the Town of Goderich and Goderich Hydro, Jennette Walker is able to coordinate efforts between the two entities.

Past and Present Funding Strategies:

Wastewater infrastructure upgrades in 2005 were funded by Canada-Ontario Municipal Rural Infrastructure Fund. COMRIF responds to local needs and priorities by helping to provide cleaner water, better sewage systems, upgraded waste management processes, and safer roads and bridges. 67% of funding went to "green" projects (water, wastewater, and solid waste management), which was a commitment of the program. http://comrif.ca/eic/site/comrif-fimrco.nsf/eng/h_00014.html

The US$47 million dollar expansion of the Goderich Harbour in Ontario, Canada was funded by a public/private partnership between Sifto Salt, the Goderich Port Management Corporation and the Provincial government. http://www.sandandgravel.com/news/article.asp?v1=14838

More information on Goderich's resilience efforts:

Town of Goderich Emergency Management Plan: http://www.goderich.ca/en/townhall/resources/Emergency_Management_Plan_-_2014__3_.pdf

Emergency preparedness action plan guide: https://beprepared.emergencymanagementontario.ca/myplan/

Local identity and community spirit form important components of climate resilience

In the aftermath of its tornado, Goderich lost 90+% of its tree canopy--much of the loss occurred in Courthouse Square Park, the formerly "green jewel" of the Town. In November of 2012, Goderich community members gathered to watch a celebratory parade transporting trees in to be re-planted. Municipal officials stressed the symbolic importance to the resilience of the town spirit that this embodied.

Preventative infrastructure upgrades provide environmental and public health co-benefits

Raw sewage used to habitually contaminate adjacent waterways in Goderich due to wet weather and melting snow, causing the Town to bypass treatment for months at a time. However, after a 30-year, multi-million-dollar separation of combined sewers, sewage overflows became less frequent by the end of the 1990s. After a $3 million upgrade to their water pollution control plant in 2006, Goderich hasn't needed to bypass since early 2009. That same year, the Town switched to an ultraviolet disinfection system following tightening of chlorine effluent standards by the federal government.

Goderich also mandated eavestrough disconnection in the 1970s and currently sells rain barrels to residents at cost. Development requirements now include stormwater management as well.

Climate Change in the Great Lakes

Overview

1. Climate change across scales
2. Observations & projections in the Great Lakes
3. Impacts on Great Lakes cities

Image source: NASA's Marshall Space Flight, Flickr, June 14, 2012

Image source: NASA's Marshall Space Flight, June 14, 2012, https://flic.kr/p/cCTs3j

Climate change across scales

CLIMATE CHANGE: GLOBAL PHENOMENON, LOCAL EFFECTS

Although most people know climate change as a global phenomenon, it is ultimately the local impacts that city governments have to manage. This section will cover just the basics of global climate change, and will dive into the important role that regional variation plays in shaping how climate change plays out in the Great Lakes.

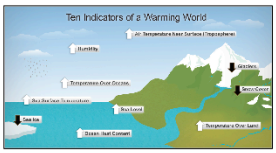
Image source (left): BBC News, “Global Warming is now ‘unequivocal’”, http://www.bbc.com/news/science-environment-24292615

Image source (right): Michigan Radio, “Warmer waters fuel toxic algal blooms in the Great Lakes”, http://michiganradio.org/post/warmer-waters-fuel-toxic-algal-blooms-great-lakes

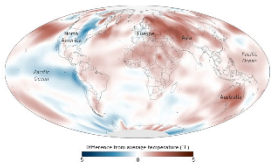
Climate change across scales

Global climate change

Observed changes: Indicators measured globally over many decades show the Earth's climate is warming.



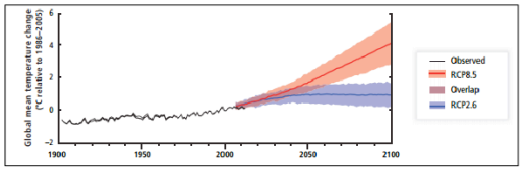
Ten Signs of a Warming World
(NOAA)



2013 State of the Climate Report
(NOAA & the AMS)

IPCC AR5, 2013: *High confidence* that human influence on the climate has warmed the ocean, melted snow and ice, raised global mean sea level and changed some climate extremes in the second half of the 20th century.

Future projections: Continued or increasing warming in all emissions scenarios



IPCC AR5

Observed changes:
NOAA's 10 key climate indicators all point to the same finding: the scientific evidence that our world is warming is unmistakable. More than 300 scientists from 160 research groups in 48 countries contributed to the report, which confirms that the past decade was the warmest on record and that the Earth has been growing warmer over the last 50 years.
(Source: http://cpo.noaa.gov/warmingworld/)

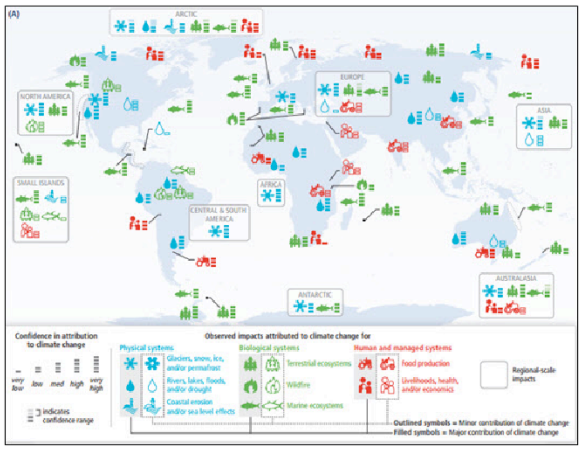
The 2013 State of the Climate Report, a peer-reviewed assessment of the world's climate released by NOAA and the American Meoteorological Society on an annual basis, reported that globally-averaged surface temperature for 2013 was 0.36 - 0.38° Fahrenheit above the 1981–2010 average, placing it among the top 10 warmest years since record-keeping began. This average includes the cooler than usual temperatures that North America saw.
(Source: http://www.climate.gov/news-features/understanding-climate/state-climate-2013-highlights)

Future projections:
The Intergovernmental Panel on Climate Change (IPCC), a body of several hundred scientists that won the Nobel Peace Prize in 2007, published its most recent summary in 2013. Published every five or six years, the IPCC's summaries are considered the definitive assessment of the risks of climate change, and they influence the actions of governments around the world. Their 2013 report states with near certainty that human activity is the cause of most of the temperature increases of recent decades
and emphasizes that the basic facts about future climate change are more established than ever, justifying the rise in global concern. It also reiterates that the consequences of escalating emissions are likely to be profound. "It is extremely likely that human influence on climate caused more than half of the observed increase in global average surface temperature from 1951 to 2010," the draft report says. "There is high confidence that this has warmed the ocean, melted snow and ice, raised global mean sea level and changed some climate extremes in the second half of the 20th century."

IPCC scientists state with medium confidence that globally-averaged surface temperatures will increase by 0.3°C - 0.7°C (0.5°F - 1.26°F) for the period 2016-2035 relative to 1986-2005, and up to 4.8°C (8.6°F) by 2100, depending on the level of CO2 emissions. The report warns that sea levels could conceivably rise by more than three feet by the end of the century if emissions continue at a runaway pace.
(Source: IPCC AR5, Summary for Policymakers, http://www.ipcc.ch/report/ar5/)

Climate change across scales

Global climate change: Widespread impacts



Now that there is strong international consensus about the significance of global climate change, scientists and decision makers are focusing on understanding regional and local impacts in order to respond effectively.

Image source: IPCC 2013, AR5, Summary for Policymakers

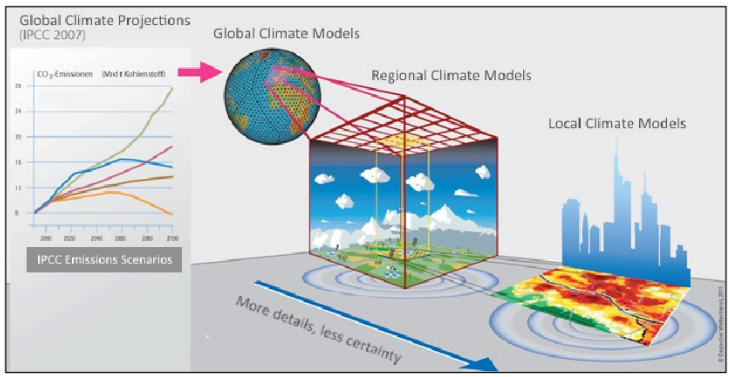
In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans. Evidence of climate-change impacts is strongest and most comprehensive for natural systems, though in its report "Climate Change 2014: Impacts, Adaptation, and Vulnerability", the IPCC also reports distinguishable impacts on human systems around the world:

- Changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality
- Many terrestrial, freshwater, and marine species have shifted their geographic ranges, seasonal activities, migration patterns, abundances, and species interactions in response to ongoing climate change
- Based on many studies covering a wide range of regions and crops, negative impacts of climate change on crop yields have been more common than positive impacts
- Impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires, reveal significant vulnerability and exposure of some ecosystems and many human systems to current climate variability (very high confidence)

While international policymakers grapple with how to mitigate and adapt to the effects of climate change via international pacts and accords, it is through actions by municipalities that adaptation that society will be able to adapt to the changes. In order to do so, it's important to understand the regional nuances of climate change impacts.
(Source: IPCC 2013 AR5, Summary for Policymakers, http://www.ipcc.ch/report/ar5/)

Climate change across scales

Global averages mask regional differences



Climate change is global in its nature; however, its precise impacts will vary on a regional level.

Natural variability plays a larger role at the regional scale due to changes in land use (e.g. urbanization) and geographic features (e.g. mountains and lakes).

Thus, local practitioners turn to downscaled global climate information.

Image source: Deutscher Wetterdienst, Klimaprojekten fuer die Stadtplanung (German Weather Service, Climate Project for Urban Planning)

Understanding—as well as predicting—something as complex as the climate is not done with a simple hypothesis. Models simulate the physical, chemical, and earth processes that drive climate. Models are used to study past changes in the Earth's climate—as well as project future changes. These models are our best, collective guess as to how the climate system works, based on past and current observations—and tested against historic and prehistoric conditions using data records from the past.

Downscaling is a process of progression from a broad scale (in this case, global or national) to a narrower scale (such as regional or local). In the case of climate change, researchers are taking predictions made by Global Climate Models and extracting statistical information on a regional or even local scale.

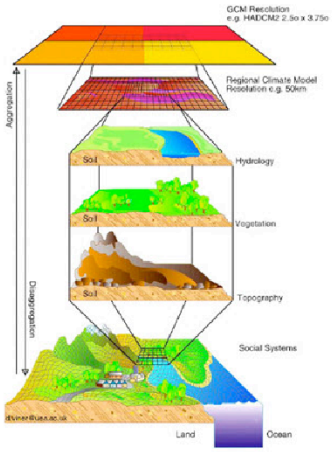
Why do we have to downscale global climate information to the regional scale? Global models don't have the resolution to handle local topographic features (such as mountains, valleys, and lakes) that have an impact on local and regional climates. Thus, the larger global climate projections must be adapted (statistically) to account for the presence of these features.

However, certainty does not increase with downscaling, and downscaling to the local level requires extra personnel and funding. **It is important to understand that climate models are scientific tools, not crystal balls.** They are, however, critical tools that are used by decision makers and planners to build our communities for the future.

(Image source translated from: German weather service, http://www.dwd.de/bvbw/appmanager/bvbw/dwdwwwDesktop?_nfpb=true&_windowLabel=dwdwww_main_book&T176000665321293013118916gsbDocumentPath=&switchLang=de&_pageLabel=P27200165321293012986287)

Climate change across scales

Historical trends and future projections



When assessing climate change in your region, consider both historical trends *and* future projections:

Historical trends focus on observed climate data that was recorded by climate stations in the past century. These trends provide greater certainty to estimate near-term weather, but aren't good at predicting extreme events.

Climate projections provide an idea of what to expect over the next century, but lose certainty as they are downscaled to the regional level.

Climate preparedness and resilience does not necessarily require climate data, but this data helps build the case for adaptation for city council and residents, and allows us to better prepare for extremes.

Image source: ConsulClimate, Downscaling GCM Outputs, http://consulclima.co.uk

Additional Resources:

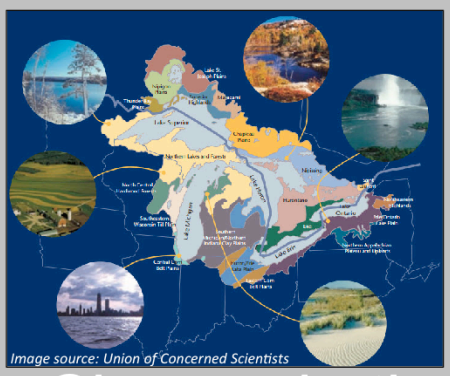
Global and National Climate Change

- **NOAA & BAMS State of the Climate**
  Peer-reviewed assessment of the world's climate released annually by NOAA and BAMS. 2013 report includes information on extreme events, surface temperature, global sea level, ocean heat content and more.
- **IPCC Assessment Reports**
  Peer-reviewed synthesis of the latest climate science, as well as number of special reports on particular topics, released every 6-7 years. Reports are prepared by teams of hundreds of international researchers.
- **US National Climate Assessment**
  US government interagency report focusing on observed changes, projected impacts to the US, and the state of adaptation and mitigation. It's released every 4 years
- **An Overview of Canada's Changing Climate**
  Chapter 2 of 2014 "Canada in a Changing Climate" report. Led by Natural Resources Canada, the development of the report involved over 90 authors and 115 expert reviewers.

Understanding Climate Models

- **Oregon SeaGrant Video (4:43 mins)**
- **World Meteorological Organization: Climate Models**

1. NOAA & BAMS State of the Climate: http://www.ncdc.noaa.gov/bams-state-of-the-climate/
2. IPCC Assessment Reports: https://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml
3. US National Climate Assessment: http://nca2014.globalchange.gov/
4. An Overview of Canada's Changing Climate: http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2014/pdf/Chapter2-Overview_Eng.pdf
5. Oregon SeaGrant "Understanding Climate Models": https://www.youtube.com/watch?v=ShteN1lLeEA
6. World Meteorological Organization "Climate Models": http://www.wmo.int/pages/themes/climate/climate_models.php



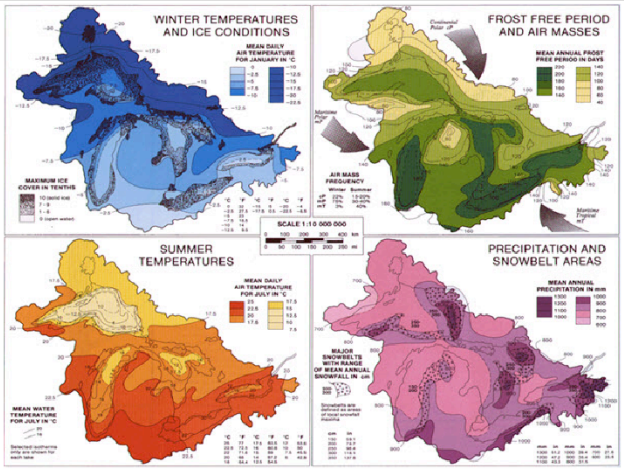
Climate Change in the Great Lakes

HISTORICAL OBSERVATIONS & FUTURE PROJECTIONS

Image source: Union of Concerned Scientists, Confront Climate Change in the Great Lakes Region, 2005, http://www.ucsusa.org/assets/documents/global_warming/gl-exec-summary-update-05-doc.pdf

Climate change in the Great Lakes

Regional variation due to the lake effect



The Great Lakes significantly influence the region's micro-climates by:

- ...moderating the temperature of surrounding land.
- ...increasing the moisture content of the air throughout the year.

So, cities on southern shorelines may deal with different impacts than those along a northern shore! It's critical to take lake effect, as well as land changes due to urbanization and agriculture into account.

Image source: Environment Canada and U.S. Environmental Protection Agency. 1995. Great Lakes Atlas.

What it really comes down to is the fact that we have a unique and diverse climate, influenced by its location in the middle of a large land mass (North America) and the presence of the Great Lakes.

The Great Lakes gain and lose heat more slowly that surrounding land masses. Warm temperatures over land rise and are cooled. A lake breeze front pushes the air up and over the lakes. Cooler air is blown off the lake toward the shore, cooling temperatures along the shoreline. This will not change in light of broader-scale, climatic changes; however, it will have some important effects:

- On a positive note, summer temperature increases will likely be less severe downwind of the Great Lakes as a result of lake-induced cooling. This could make parts of the region more appealing for summer tourism—as a place to "escape the heat."
- An increased difference between air and water temperatures in fall and early winter will likely lead to an increase in "lake-effect" precipitation. (Warmer summer temperatures heat up the lake in the summer. In winter, cold air moving across a warmer lake results in lake-effect precipitation.") In the winter, this moisture condenses as snow when it reaches the land, creating heavy snowfall in some areas (known as "snow belts") on the downwind shores of the lakes. The shores of Lake Superior are prone to this "lake-effect" snow, and they have recorded up to 350 inches of snow in a single year.
- As lake ice coverage decreases, the Union of Concerned Scientists predicts a "cultural shift" may occur as wintertime recreation held on previously frozen lakes becomes more difficult.

We can see evidence of how the presence of the lakes impacts…

1) Temperature in most areas (particularly east and south of the lakes, where its generally warmer in the winter and summer). Notice how Lake Superior's southern shore is cooler (in the winter) than the land mass just south of it and warmer (in the summer) than the land mass north of it.

2) The length of the growing season along the shorelines.

3) Precipitation. In winter, heavy snow bands occur along the eastern and southern shorelines. Lake impacts can even reduce summer precipitation downwind of the shore (due to stabilizing lake breeze effects).

Observations and projections in the Great Lakes

Observed changes since 1900

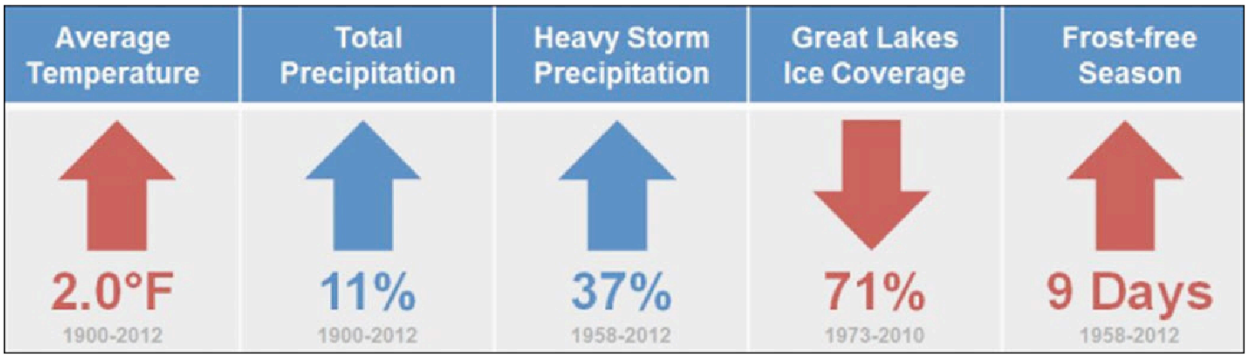


Image source: GLISA, Climate Change in the Great Lakes Region, 6/18/2014, http://glisa.msu.edu

Observations and projections in the Great Lakes

Projected changes through 2099

The climate future generations experience in the Great Lakes will be fundamentally different than the climate today.

What is changing?

Scientists often discuss changes in terms of averages, but our environments are managed in terms of timing and extremes. Thus, we take into account precipitation and temperature:

- Averages
- Extremes
- Seasonality

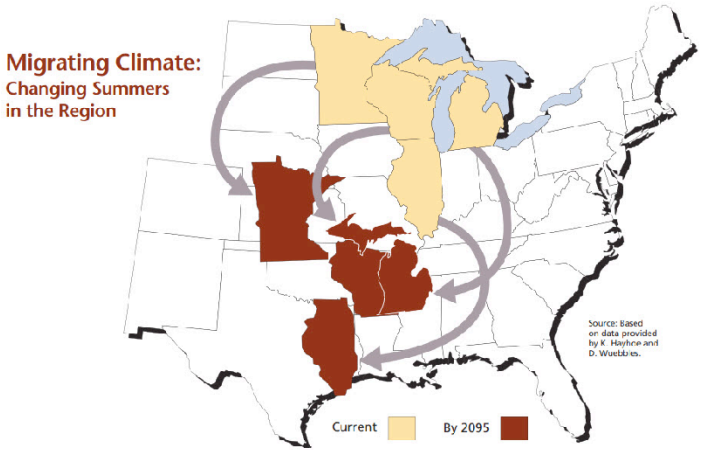


Image source: Union of Concerned Scientists, Confronting Climate Change in the Great Lakes, 2005

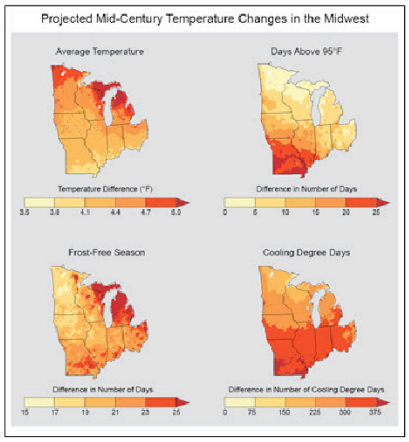
The climate future generations experience in the Great Lakes will be fundamentally different than the climate today.

By the end of this century, for example, Michigan summers will feel more like current summers in Arkansas. This comes with important implications for precipitation patterns.

Image Source: Union of Concerned Scientists, Confronting Climate Change in the Great Lakes, 2005, http://www.ucsusa.org/assets/documents/global_warming/gl-exec-summary-update-05-doc.pdf

Observations and projections in the Great Lakes

Temperature: More hot days each year



Higher annual average temperatures:
Historical trends show increasing rise in temperatures. Rise projected to continue.

Increased extremes:
Increase in frequency of 95°F+ days

Change in seasonality:
Frost-free season has increased by 9 days compared to 1901-1960.

Image source: Climate Change Impacts in the United States: The Third National Climate Assessment Report

There has been an increase in both **annual average temperatures** and a frequency in **extreme heat events**.

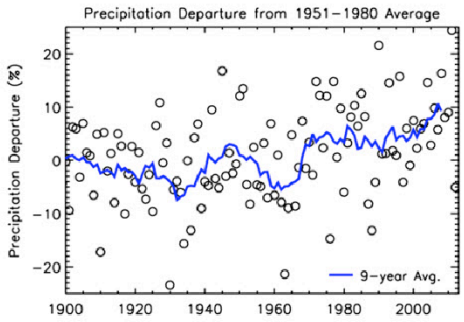
Higher average temperature: Since 1900, annual average temperatures have increased by 2°F (1.1°C) in the US Great Lakes region. 2000-2012 has brought faster warming than in any decade since 1900. By 2050, air temperatures are projected to increase by 1.8°to 5.4°F (1° to 3°C) in the region.

Winter and nighttime temperatures are warming faster than any other seasons or daytime temperatures. The **frost-free season length**, defined as the period between the last occurrence of 32°F in the spring and the first occurrence of 32°F in the fall, has increased in each U.S. region during 1991-2012 relative to 1901-1960. Increases in frost-free season length correspond to similar increases in growing season length. (Source: NCA 2014, Frost-free Season, http://nca2014.globalchange.gov/report/our-changing-climate/frost-free-season).

The **amount of future warming** for the region will depend on changes in the atmospheric concentration of heat-trapping gases. Projections for the middle of the 21st century (2041-2070) in the Great Lakes region suggest warming of 3.5-4.5F for a scenario with substantial emissions reductions, and 5.5-6.5F with continued growth in global emissions of heat trapping gases.

Observations and projections in the Great Lakes

Precipitation: More severe weather



11%
1900-2012

Increased annual precipitation:
Increase is expected to continue, though regional projections of future precipitation vary.

Increased extremes:
Precipitation via heaviest 1% of storms increased by 37% in the US Midwest from 1958 through 2012.

Climate change increases floods *and* droughts in the region.

Change in seasonality:
More precipitation is falling as rain instead of snow.

Snow melt:
Rapid winter snow melts, combined with precipitation events, can lead to extensive flooding.

Image source: GLISA, Weighted averages of nClimDiv divisional data from 8 U.S. Great Lakes States.

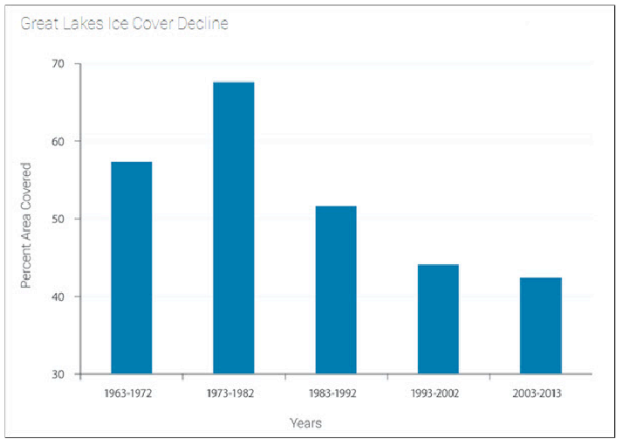
Annual precipitation has generally been increasing over the Great Lakes over the past several decades, with much of this increase being attributable for the increases in the intensity of the heaviest rainfall. This tendency towards more intense precipitation events is projected to continue into the future. More extreme weather events mean the frequency of heavy rain and flood events will likely increase (in late winter to early summer), due to increases in atmospheric heat and moisture capacity over the region. One recent study on future weather patterns in Southern Wisconsin concluded that the area will see a 10–40% increase in the intensity of heavy rain events by the end of the 21st century. This graphic is part of that study.

Model projections for precipitation changes are less certain than those for temperatures. Under a high emissions scenario, models project average winter and spring precipitation by late this century (2071-2099) to increase 10% to 20% relative to 1970 to 2000. Projected changes under the higher emissions scenario in summer and fall are not expected to be larger than natural variations. Regional climate model projections using the same emissions scenarios also project increased spring precipitation and decreased summer precipitation, though the largest increases are to the south of the Great Lakes.

Increased annual precipitation:
Since 1900, annual precipitation has increased by 10.8%, and is expected to continue to rise, though projections of future precipitation vary.
Increased extremes:
The amount of precipitation falling in the heaviest 1% of storms increased by 37% in the US Midwest from 1958 through 2012.
We can expect to see an increase in severe weather, causing more flood *and* drought events.
Change in seasonality:
Shorter winters have led to more precipitation falling as rain instead of snow. Though more lake effect precipitation have increased snow infall in some areas.

Observations and projections in the Great Lakes

Lake levels and ice cover: downward trend



Lake levels: Still some uncertainty, but likely overall trend is downward.

Year to year fluctuations due to other environmental factors (e.g. solar radiation, precipitation, wind speed, etc).

Ice cover: Rising temperatures will continue to lead to a reduction in seasonal ice cover.

Image source: Kenneth Kunkel, Cooperative Institute for Climate and Satellites - NC

Lake levels: There is still uncertainty about how exactly climate change will affect the levels of the Great Lakes. There is a range of predicted changes in lake levels over the next 50–100 years—with an overall downward trend in lake levels expected. However, that trend will be marked by significant variability and fluctuations due to
changing climate variables that influence lake levels.

The natural variation in lake levels is influenced by many environmental factors, including solar radiation, precipitation, humidity, evaporation, temperature, and wind speed. As climate change affects the relative strength and intensity of these environmental factors, natural lake level variation will likely become ev en more pronounced. Based on most peer-reviewed studies, scientists currently believe that lake levels will fall over the next century. However, there will continue to be a great deal of year-to-year fluctuation or variability.

Ice cover: One predicted impact of rising temperatures in the Great Lakes is a reduction in seasonal ice cover. Bars show decade averages of annual maximum Great Lakes ice coverage from the winter of 1962-1963, when reliable coverage of the entire Great Lakes began, to the winter of 2012-2013. Bar labels indicate the end year of the winter; for example, 1963-1972 indicates the winter of 1962-1963 through the winter of 1971-1972. The most recent period includes the eleven years from 2003 to 2013. (Data updated from Bai and Wang, 20121). Lake Superior could have little to no ice cover left by mid century.

Additional Resources:

Great Lakes Climate Information

- Climate.gov
- Latest Regional Climate Impacts and Outlooks (NOAA)
- Cities Impacts & Adaptation Tool (GLISA Tool)
  provides usable data such as demographics, socioeconomic data, and both current and projected climate trends.
- Summary Climate Information (GLISA Resources)
  GLISA provides accessible information about the climate change issues we face in the Great Lakes region. These materials provide valuable background information for those considering Great Lakes climate.
- Great Lakes Station Climatologies
  Find summaries of the observed historical climate for select sites across the Great Lakes region. Each summary includes an overview of temperature and precipitation to help guide local-level climate adaptation decisions.
- Canadian Climate Change Scenarios
  These maps provide a visual image of how the climate will change in any particular scenario, compared to the baseline climate period.
- Great Lakes Water Level Dashboard

1. Climate.gov: http://www.climate.gov/
2. Regional Climate Impacts and Outlooks: http://www.ncdc.noaa.gov/news/latest-regional-climate-impacts-and-outlooks
3. GLISA Cities Impacts & Adaptation Tool: http://graham-maps.miserver.it.umich.edu/ciat/
4. GLISA Summary of Climate Change Impacts in the Great Lakes Region: http://glisa.umich.edu/resources/summary
5. Great Lakes Station Climatologies: http://glisa.umich.edu/resources/great-lakes-climate-stations
6. Great Lakes Climate Divisions: http://glisa.umich.edu/resources/great-lakes-climate-stations
7. Canadian Climate Change Scenarios: http://www.cccsn.ec.gc.ca/?page=main&lang=en
8. Great Lakes Water Level Dashboard: http://www.glerl.noaa.gov/data/dashboard/portal.html

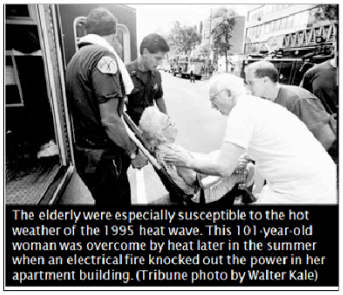
Impacts on Great Lakes Cities

THE CASE FOR ADAPTATION ACROSS MUNICIPAL SECTORS

Image source: NBC Chicago, White House Study Warns of Sever Climate Change Effects in Illinois, http://www.nbcchicago.com/weather/stories/White-House-Study-Climate-Change-Effects-Illinois-258139561.html?akmobile=o

Impacts on Great Lakes cities

Health and vulnerable populations



The elderly were especially susceptible to the hot weather of the 1995 heat wave. This 101-year-old woman was overcome by heat later in the summer when an electrical fire knocked out the power in her apartment building. (Tribune photo by Walter Kale)

Heat waves can be deadly:

- Chicago 1995: 550+ deaths
- Toronto 2005: 6 known deaths
- Ontario 2005: 17,000 hospital admissions and 60,000 emergency room visits due to air pollution

Heat risks:

- Heat related illnesses and deaths especially affect elderly, homeless, low-income, children
- Increased smog will worsen asthma
- Increase in food-borne illnesses
- Increase in ragweed pollen season
- Tick and mosquito habitat will increase

Precipitation risks:

- Increased waterborne diseases
- Injuries and deaths from flooding & winter storms
- Increases in basement mold from flooding events

Image source: Chicago Tribune, July 13, 1995

Humans are an integral part of Great Lakes ecosystems. Let's also talk about how human health and welfare might be affected by climate change.

Extreme heat is the natural hazard that kills far more people than any other. Heat can also impact air quality; smog is more frequent in hot, sunny weather. During heat waves in the Midwest, air pollutants are trapped near the surface as atmospheric ventilation is reduced. Without strict attention to regional emissions of air pollutants, the undesirable combination of extreme heat and unhealthy air quality is likely to result. Climate change will likely cause an increase in surface ozone over the Midwest, partly driven by decreased ventilation due to warmer temperatures.

Chicago 1995: In July of 1995, a severe, week-long heat wave hit Chicago. Temperatures peaked at 106 degrees Fahrenheit, with a heat index of 126 degrees. The use of electricity skyrocketed, resulting in power grid failures throughout the city. This was one of the worst weather-related disasters in Illinois history; 525 people died over a 5-day period. More frequent, extreme heat events are expected over the next century as a result of climate change. By 2080, the Midwest might see extreme heat events every three years. Considering higher emissions scenarios—and combining temperature increases with the urban heat island effect—we might see as many as 80 deadly, severe heat incidents in cities like Milwaukee or Chicago over a 30 year period.

Toronto: Research using climate change scenarios for the future suggests that Toronto's annual average heat-related mortality could triple by the 2080s (Toronto Public Health, 2005). The warming climate may also compound other health concerns in the future. For example, higher temperatures are expected to promote formation of secondary air pollutants that can lead to urban smog. Toronto Public Health estimated that even if air pollution emissions remain constant, air-pollution related mortality will increase 20% by 2050 and 25% by 2080, largely because of increased ozone levels (Toronto Public Health, 2005). Other potential impacts of hot weather include increased allergies due to an extended pollen season, food spoilage and related illness as peoples' usual food handling practises may become inadequate, and increased drownings as people seek relief from the heat in pools and at the beach.

Image source: Chicago Tribune, July 13, 1995

Impacts on Great Lakes cities

Government finance

Climate change related costs for municipalities:

- Repairing municipal infrastructure, facilities & parks
- Premature infrastructure replacement and increased maintenance
- Weather emergency expenditures
- Subsidies for uninsured residents & businesses
- Increased insurance costs
- Loss of taxes and incomes due to business disruption
- Lawsuits

Lower budgeting predictability:

- Extreme events --> unforeseen repairs
- Winter variability
- Liability and lawsuits

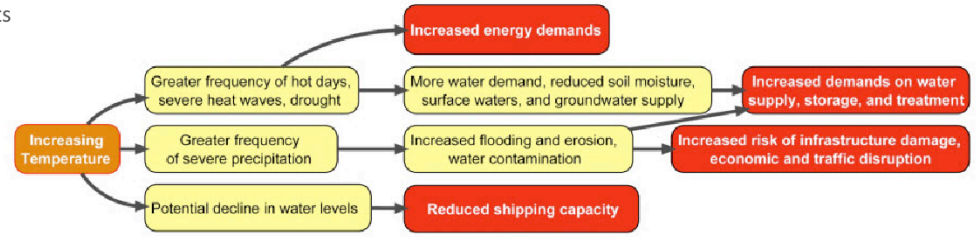


Image source: GLISA/HRWC Infrastructure Impacts Fact Sheet

GLISA/Huron River Watershed Council Fact Sheet on Climate Impacts to Infrastructure: http://glisaclimate.org/media/HRWC%20Infrastructure.pdf

NOAA Billion-Dollar Weather/Climate Disasters: http://www.ncdc.noaa.gov/billions/

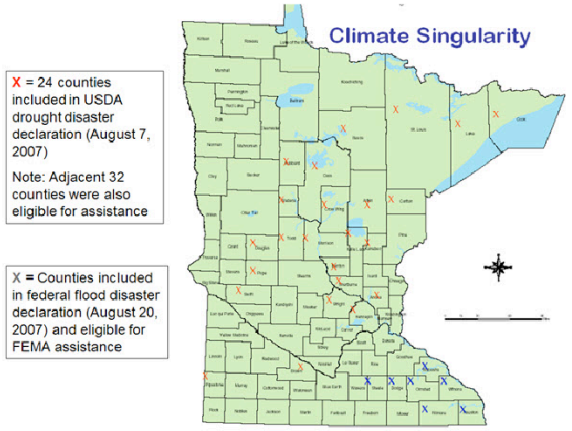
Examples:

Toronto July 2013: Single rain event: 130mm. 850m insured losses. The event cost the City of Toronto 65m (55m capital, 10m operating). In 2009 Toronto had set up Extreme Weather Reserve Fund of 30m, which was entirely drained by the 2013 event.

Chicago 2014 lawsuit: Farmers Insurance Co, a major insurance company, filed 9 lawsuits against Chicago-area municipal governments on behalf of itself, other insurance companies, and customers whose property was damaged by the surge of storm water and sewage overflow in 2013. Farmers Insurance said the City of Chicago knew of the risks posed by climate change and should have been better prepared. The class-action lawsuits raised the question of who is liable for the costs of global warming. (Gail Sullivan, Washington Post "Climate Change: Get Ready or Get Sued") The lawsuits were dropped later in the year, but not without raising important questions about who is liable for the costs of natural disasters, at a time when such calamities are ont he rise. (Alexis Petru, Triple Pundit "Farmers Insurance Drops Climate Change Lawsuits Against Chicago-Area Cities")

Impacts on Great Lakes cities

Water quality and supply



Climate change trends point to both an increase in flooding and an increase in droughts.

Water quantity: Heat waves increase evaporation and water demand, potentially leading to summer shortages

Water quality: Increased stormwater runoff, lower lake levels, and warmer water → more frequent algal blooms

Water infrastructure in the Great Lakes is aging and in poor condition, increasing the risk of waterborne illness

Image source: Mark Seeley. University of Minnesota Extension Climatologist

The Great Lakes region is already experiencing extreme weather events, which demonstrates the increased variability we will experience from climate change. Because the region is dealing with both increased flooding and drought events, due to increasing temperatures and intense rainfall, water quantity *and* quality are both at risk.

Water quality risks: As precipitation events become more extreme, storm and waste water overflow events will likely result in poor water quality and increased risk to public health and safety. This will also impact recreation and tourism in the Great Lakes. During storms, combined sewer overflows can cause sewage to flow into lakes. Of the 801 cities in the United States with active combined sewage systems, 65% are in Great Lakes states. NOAA scientists are improving their capabilities to forecast and warn people of poor water quality after storms.

Water quantity risks: Paradoxically, the Great Lakes may also experience increased drought due to warmer temperatures and increased evaporation between rain events. As temperatures increase, the loss of soil moisture between rain events (due to evaporation) could more than offset projected increases in rainfall and flood events. The graphic above shows the severe drought occurring over the upper Great Lakes last fall.

Minnesota, 2007: For example, in August 2007, several Minnesota counties experienced drought conditions—while at the same time neighboring counties were experiencing flooding. Drought and flood conditions happening at the same time and in the same region point to the need for states to develop response plans for a variety of extreme weather events that occur simultaneously.

Milwaukee 1993: Combined sewer overflows can also negatively affect human health, since waterborne diseases in drinking water can be more prevalent after heavy storm events. For example, in 1993, an outbreak of a parasitic disease (called Cryptosporidium) occurred in Milwaukee right after a large storm, causing 400,000 people to fall ill with diarrhea.

Toronto 2009: According to Michael D'Andrea, Director of Water Infrastructure Management, Toronto suffered 8 extreme precipitation events between 1986 and 2006 with severe surface and basement flooding. All of these storms were designated 1 in 25 year storms or greater. Since 2006, there have been several more intense storms, including one on July 26, 2009, which flooded Lakeshore Blvd and streets in the Beaches neighbourhood, and created huge sinkholes in Finch Ave. On June 29, this year, we had 44 mm of rain in an hour, which shut down Union Station, the Don Valley Parkway, and flooded parts of Bayview Avenue and the Lakeshore.

The 2007 drought involved 95 days without significant rainfall in the Toronto area, with 20-30 days above 30 degrees C. The drought killed thousands of trees and severely stressed many more. Grass fires occurred. Water levels in creeks and rivers were very low, and fish populations were affected.

Observations and projections in the Great Lakes

Shifting opportunities and challenges

Shifting patterns of energy demand:

- Reduced heating demand/costs in winter, increased cooling demand/costs in summer
- Increased agricultural production may strain rural energy systems

New business challenges & opportunities:

- Reduced summer water availability may interfere with industrial operations
- Increased energy and raw production market volatility
- Increased insurance premiums
- Longer shipping season due to lower lake ice cover, which may eventually be offset by lower lake levels
- Longer summer tourism and construction season

Image source: blogTO, "Remembering the massive Toronto blackout of 2003"

Climate change is expected to impact business operations in the Great Lakes region by providing both challenges and opportunities, including: Increased energy and raw product market volatility due to more extreme weather events Increased insurance premiums due to more extreme weather events Reduced heating demand and lower heating bills in the winter Increased cooling demand and higher cooling bills in the summer Shifts in business opportunities (for example, there will be a longer summer vacation season and a longer.

2003 Toronto/Northeast Blackout: The 2003 Northeast blackout was a major warning about the potential impacts of climate change, even though the role of weather in the blackout is disputed. The event started on August 14 in Ohio, near the end of a longish heat wave when a computer glitch caused an Ohio plant to go offline during a heavy demand period, followed by transmission failures due to "contact with trees" and ultimately triggering a cascading failure as automatic protective controls took 256 power plants offline in a couple of hours. Traffic lights, the subway and streetcars, the Toronto Stock Exchange and CBC studios were shut down. Highway 407 was gridlocked by people looking for a free ride. Power was restored to 95% of Toronto by 3 a.m. the next day, but rolling blackouts continued for several days and some areas were without power for much longer. Businesses and residents were asked to reduce their use of energy by 50%. Several major events were cancelled and a number of businesses reported economic and productivity losses. Many of the weaknesses of the grid have been or are being addressed, but severe weather continues to be a problem. One analyst estimates that over 60% of major power outages in the US are caused by weather events including: wind and rain, ice storms, hurricanes, lightning and tornadoes., several of which are predicted to increase under climate change.

Impacts on Great Lakes cities

Transportation

Residents of a Grand Rapids neighborhood look at a bridge washed away in April of 2013. The bridge was what connected residents from the neighborhood to main roads.

Roads & bridges:

- Extreme heat lowers lifespan of infrastructure
- Extreme precipitation may compromise routes and infrastructure

Shipping lanes:

- Likely open earlier and longer due to reduced ice cover

Lower lake levels will lead to decreased depth of navigation channels and a reduction in the maximum loads carried by vessels. For each inch of lost draft, the average 1,000 ft freighter loses $30,000 per transit (GLISA)

Image source: Emily Zoladz | MIjoe.com

Roadways & bridges: Higher temperatures can cause pavement to soften and expand. This can create rutting and potholes, particularly in high-traffic areas and can place stress on bridge joints. Heat waves can also limit construction activities, particularly in areas with high humidity. With these changes, it could become more costly to build and maintain roads and highways. On the other hand, certain areas may experience cost savings and improved mobility from reduced snowfall and less-frequent winter storms since warmer winters may lead to reductions in snow and ice removal, as well as salting requirements.

Climate change is projected to concentrate rainfall into more intense storms. Heavy rains may result in flooding, which could disrupt traffic, delay construction activities, and weaken or washout the soil and culverts that support roads, tunnels, and bridges. Exposure to flooding and extreme snow events also shortens the life expectancy of highways and roads. The stress of water and snow may cause damage, requiring more frequent maintenance, repairs, and rebuilding. In some locations, warmer temperatures are projected to cause more winter precipitation to fall as rain instead of snow. Winter flooding could occur more frequently, if the frozen ground cannot absorb precipitation. Landslides and wash-outs could also occur more frequently, as saturated soils are exposed to more rainwater. Drought in areas such as the Southwest could increase the likelihood of wildfires that reduce visibility and threaten roads and infrastructure.

Impacts on vehicles: As temperatures increase, many types of vehicles can overheat, and tires will deteriorate more quickly. But milder winters, reductions in the number of cold days, delays in winter freezing, and earlier spring thaws may reduce cold-weather damage to vehicles.

Shipping lanes: Ships are sensitive to many factors, including the depth of a channel and the extent of sea ice. Increasing temperatures could reduce the amount of lake ice in many important shipping lanes, extending the shipping season. Warmer winters will likely lead to less snow and ice accumulation on vessels, decks, and rigging in marine transportation. Shipping is an important component of the Great Lakes region's economy. There are 15 major international ports and approximately 50 smaller, regional ports in the Great Lakes-St. Lawrence River System. These ports ship over 200 million tons of cargo per year.

As we noted, there is a range of predicted changes in lake levels over the next 50–100 years, with an overall downward trend in lake levels expected—but that trend will be marked by significant variability and fluctuations. In inland waterways where water levels are expected to decline due to the warmer climate, ships could face weight restrictions, as channels become too shallow. These fluctuations may affect shoreline infrastructure, requiring increased dredging of channels for port access. Recreational and commercial harbors will also be impacted by shifting lake levels.

The net impact of these changes is likely to impose costs on the Midwest through increased shipping, maintenance, and repair costs, as well as lost recreation and tourism. The Great Lakes Restoration Initiative, an

Impacts on Great Lakes cities

Buildings

Climate change threats include:

- Risk to building foundations due to reduced soil moisture in the summer
- Increased basement flooding
- Rising energy costs in the summer, as well as increased thermal discomfort in buildings without A/C
- Damage from high winds and severe thunderstorms
- Roof damage from ice dams created by frequent freeze-thaw cycles, rain or snow
- Accelerated concrete deterioration (due to CO_2)

Image source: MPRNews, Flooded-out homeowners near Duluth face limited options a year later, Jun 2013

(From MPR article, "Flooded-out homes near Duluth face limited options a year later")
http://www.mprnews.org/story/2013/06/18/weather/cathedral-pines-flooded-homeowners-face-limited-options-a-year-later

Duluth basement floods: In 2012, the Moose Horn River in northeast Minnesota rose nearly 20 feet as a result of almost 10 inches of torrential rains. One of the hardest hit areas was the Gertzen's neighborhood of Cathedral Pines in Sturgeon Lake, an area of 18 homes and cabins nestled in an old red pine plantation along the river. Once dream homes for many of the owners, the properties about an hour's drive south of Duluth are now a source of anxiety. Residents struggle to decide whether to stay or leave.

"Even this spring, I was watching this river go up and down about four times," said Gertzen, who worries that another flood will come. "It's hard on my nerves!"'

Three months before last June's flooding, the Federal Emergency Management Agency redrew the region's flood maps, placing the homes were placed in a flood plain. But most of the homeowners had no idea. The city of Sturgeon Lake never notified them.

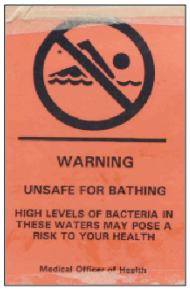
Klossner and her husband Bill saw their house nearly destroyed in the flood. They escaped in a 12-foot motor boat. The water rose so fast, the only thing they rescued was a laptop computer.
They gutted their home, but didn't have insurance money to rebuild.

Since January, the Klossners have lived in their daughter's home in Forest Lake since January. They are accepting the buyout.

Bill Klossner said his dream home has literally turned into a nightmare.

Impacts on Great Lakes cities

Tourism and recreation



Climate change is creating a cultural shift with the shortening of winter, new opportunities via longer summers, and challenges of beach and water quality.

Winter recreation:
- Reduced snow cover and shorter winters

Summer recreation:
- Increasing summer temperatures and a longer summer season
- Demand for beaches may increase, but…

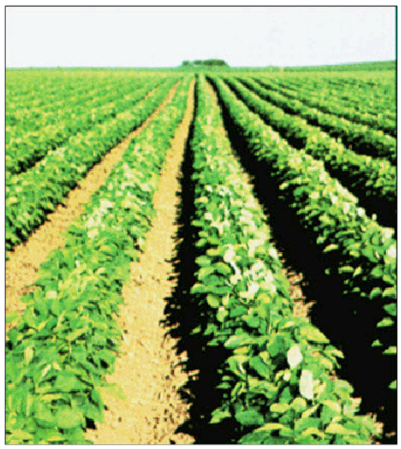
Beach quality:
- Increased algae, decreasing lake levels, receding shorelines
- Tourist location preferences will be impacted

Fishing:
- Many coldwater species
- Warmwater populations may grow

Beach quality:
As precipitation events become more extreme, storm and waste water overflow events will likely result in poor water quality and increased risk to public health and safety. This will impact recreation and tourism in the Great Lakes. However, overall Overall, summer tourism may grow before temperature rises become unfavorable for many recreational activities.

Impacts on Great Lakes cities

Agriculture



Longer growing season:

- The frost-free season lengthened by 9 days in the Midwestern US and 10 days in the Northeast from 1958-2012 and may be up to 1-2 months longer by 2100
- Through mid-century, higher CO2 concentrations will likely also have a positive effect on many crop yields

Long term climate change effects:

By 2100, the negative effects of increasing storm activity, flooding, extreme heat, summer drought risk, and pests may outweigh the benefits of other climate changes.

In the short term, climate change could help or harm agriculture, forests, and other ecosystems in the Midwest. On one hand, where sufficient water and other nutrients are available, crops and forests may benefit from a longer growing season and increased levels of carbon dioxide. On the other hand, climate change may negatively impact the health of crops, trees, and animals in the region.

- Wetter conditions in the spring may make it difficult for farmers to plant their crops. [1]
- More frequent heat waves, floods, and droughts, as well as larger populations of harmful insects, will likely place additional stress on the region's agriculture. [1]
- Higher temperatures may stress livestock animals. This will likely make livestock production more costly during the summer as livestock productivity decreases and ventilation and cooling costs increase. [1]
- Climate change may threaten forests in the Midwest. Threats include more frequent droughts, wildfires, and larger populations of harmful insects such as gypsy moths.
- Climate change is likely to alter fish populations in the Midwest. Cold-water fish such as brook trout, lake trout, and whitefish are projected to decline. Cool-water fish such as muskie, smallmouth bass, and bluegill are projected to replace these declining populations. [1]

For more information, see “Agriculture” section in UCS’s “Confronting Climate Change in the Great Lakes Region” and EPA’s “Climate Impacts”

Impacts on Great Lakes cities

Urban ecosystems

- Stress on vegetation from heat and drought
- Damage to parks and trees from floods and windstorms
- Loss of native biodiversity: As temperatures rise, the distribution and composition of tree species will change and shift northward
- More invasive species established
- Loss of wetlands and shorebirds

Toronto 2010: May 9, 2010, 85 kph winds took down enough trees in the City of Toronto to use up most of the City's tree planting budget for the year.

Additional Resources:

Great Lakes Climate Information

US EPA Impacts & Adaptation in the Midwest
Includes information on human health, water resources, agriculture, and ecosystems

Billion-Dollar Weather/Climate Disasters
NOAA-compiled list of climate events that have great economic and societal impacts

GLISA white papers for NCA on sectoral impacts and vulnerabilities:

- Recreation & Tourism Sector
- Water Resources Sector
- Agriculture Sector
- Coastal Sector
- Energy Sector

US Drought Monitor
Weekly map of drought conditions, produced by US government

1. US EPA Impacts & Adaptation in the Midwest: http://www.epa.gov/climatechange/impacts-adaptation/midwest.html
2. Billion Dollar Weather Events: http://www.ncdc.noaa.gov/billions/
3. GLISA white papers for NCA on sectoral impacts in the Midwest: http://glisa.umich.edu/resources/nca
4. US Drought Monitor: http://droughtmonitor.unl.edu/

Module 1B: Climate Adaptation Fundamentals

Overview

1. Introducing climate adaptation
2. Elements of successful adaptation planning
3. Adaptation models
4. Identifying our adaptation priorities

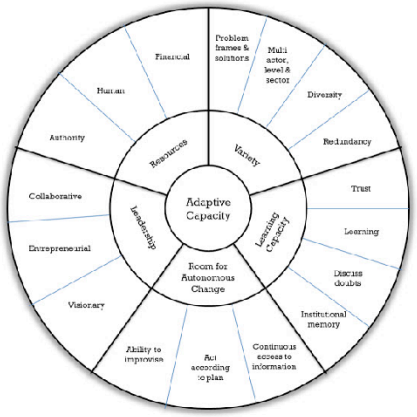


Image source: Adaptive Capacity Wheel, Gupta et al, 2010

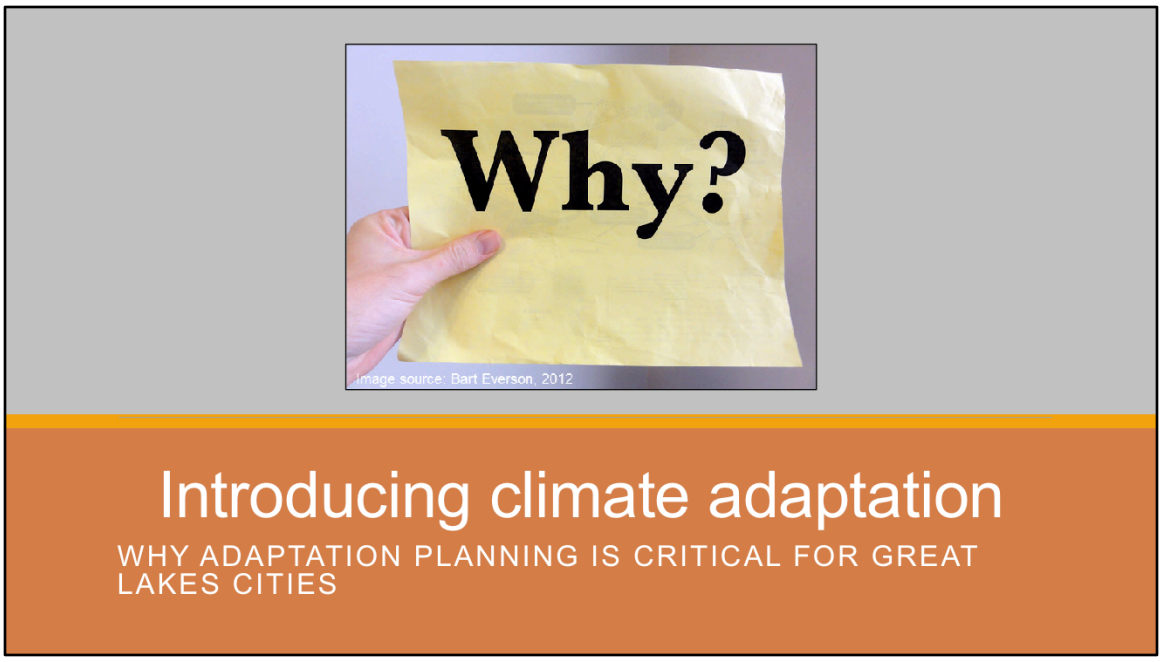


Image source: Bart Everson, Flickr, 2012, https://flic.kr/p/bcU5aD

Introducing climate adaptation

Climate change is *already* in motion: lowering GHG emissions is not enough

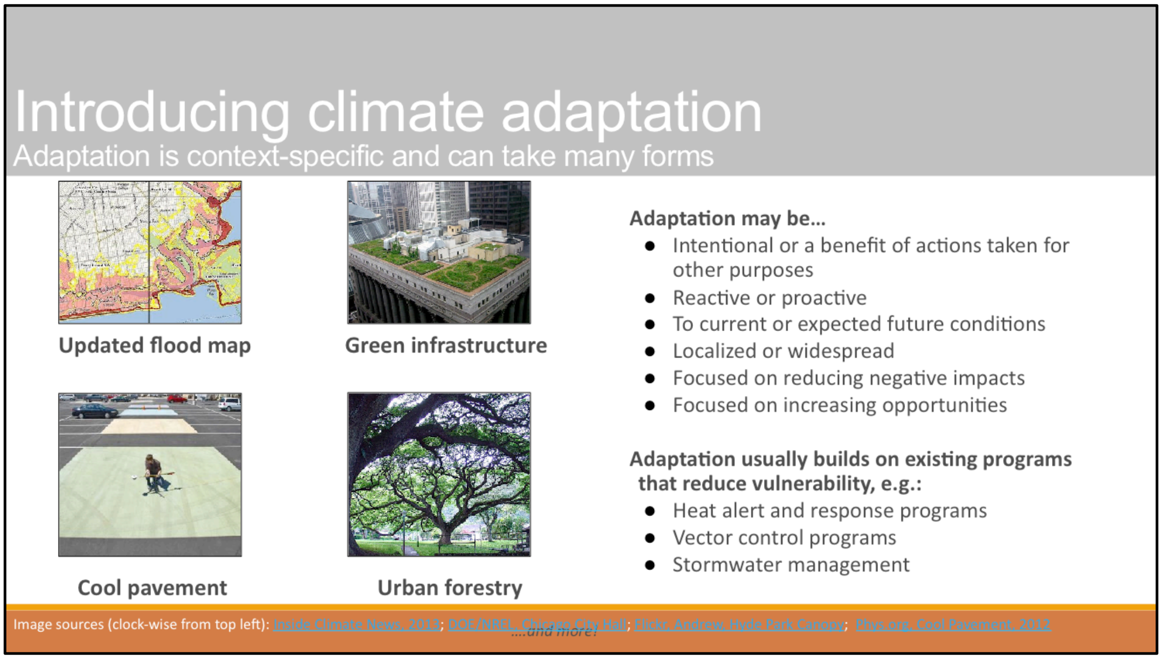
Mitigation: take action to reduce greenhouse gas emissions and prevent worst-case climate change scenarios

"Avoid the unmanageable"

Adaptation: take action to reduce vulnerability and increase resilience to existing and projected climate change impacts

"Manage the unavoidable"

There is growing recognition that the world's current efforts to improve air quality and reduce GHG emissions are not happening quickly enough to avoid the impacts of climate change in the present day and coming century. Thus, regardless of current climate mitigation actions (reduction of fossil fuel consumption, energy conservation, reductions in landfill emissions and the intensification of local development), the world is "committed" to a certain level of global warming and will be subject to a degree of climate change impacts that will require adaptive responses at all levels, particularly the local level.



Climate change adaptation refers to the adjustments that society or ecosystems make to limit negative effects of climate change. It can also include taking advantage of opportunities that a changing climate provides. For municipalities, adaptation involves the adjustment of policies and actions as a result of observed or expected changes in the local climate. An advantage to adaptation planning is that it's very context-specific, and builds upon the strengths of each community.

Introducing climate adaptation

Adaptation is not new

...but it was mostly reactive in the past:

- Following Hurricane Hazel in 1954, Ontario developed regulations that restricted developments on flood plains
- Following heat waves in the 1980s and 1990s, many municipalities developed heat alert and response systems
- Following the August 2005 storm, the City of Toronto developed new overflow protection for Black Creek

These actions all followed the impact of disaster events. Using historical climate trends and projection models, we now aim to reduce or prevent the impact of such future events.

Reactive vs proactive adaptation:

Adaptation can be reactive in nature, occurring in response to observed climate conditions, or proactive, occurring in anticipation of future climate change. Reactive adaptation has been occurring for thousands of years among human civilizations and it is typically informed by direct experience, whereas proactive adaptation actions have been enacted only in recent years due to our ability to better predict climate change related events. Although proactive adaptation presents challenges for infrastructure-related decisions that depend on precise information about the intensity, timing and distribution of climate impacts- this form of adaptation often results in lower long-term costs for municipalities and proves to be more effective than reactive adaptation actions in managing climate related risks.

Introducing climate adaptation

What *is* new for adaptation?

- Thinking ahead, rather than only looking back
- Estimating future impacts via historical climate trends and projections
- This new *proactive* form of adaptation is especially important for:
  - Climate impacts that could inflict major damage and suffering
  - Long-lived, costly infrastructure
  - Natural systems that educe municipal climate risks

*"I skate to where the **puck is going to be**, not where it **has been**." - Wayne Gretzky*

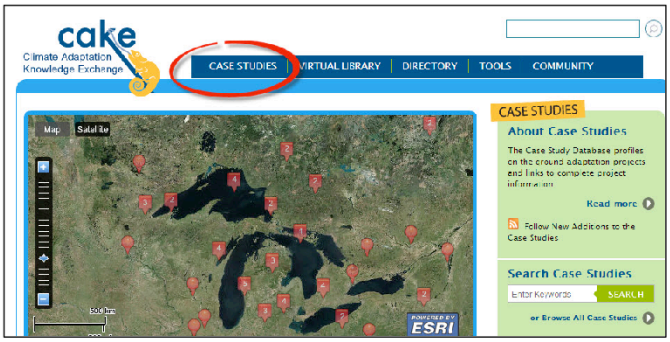
Much like Wayne, we want to plan ahead for a range of climate scenarios, and not just focus on what's happening in the present

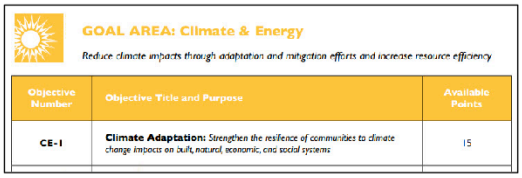
Image source: Sports Illustrated

Introducing climate adaptation

Proactive adaptation is drawing increasing attention

Cities are moving forward and many are taking note. CakeX collects case studies of municipal adaptation efforts.





STAR Community Rating System

Nationwide (US) sustainability rating system includes points for climate adaptation

More info: http://www.starcommunities.org/

Many municipalities have already developed adaptation approaches that effectively address the diverse challenges that the extremely variable climate has posed- often times not even recognizing these approaches as a form of climate change adaptation.

CakeX's Case Studies Database has been developed by the leading thinkers at EcoAdapt (through their State of Adaptation Program) to provide quick access to information about on-the-ground climate change adaptation projects. Through interviews and surveys, EcoAdapt synthesizes how people are preparing for or responding to climate change. The information collected is compiled into case studies and shared through CAKE.

Moreover, municipal adaptation efforts may be viewed as a point of competition in the future. The STAR Community Rating System, developed by experts on community sustainability, is the first national (US) framework for local community sustainability efforts. Its Climate & Energy goal area looks beyond just resource efficiency, and awards (or deducts) points depending on communities' climate adaptation efforts.

Introducing climate adaptation

"No regrets" adaptation provides benefits *now*

Look for the no-regrets strategies that create win-win scenarios:

- Adaptations that can be justified based on current climate *and further* justified based on climate change
- As the climate changes, there are *more* benefits
- If climate does not change, benefits still exist because we're better adapted to current risks

Hurricane Sandy proved we still haven't adapted to our current climate. No-regrets adaptation is the low-hanging fruit that benefits us no matter which climate change scenario comes to pass.

In assessing what the future climate holds, governments may find that many projected climate change impacts are in fact more extreme versions of what communities are experiencing today. Preparing for future climate change will build present-day community resilience along with making long-term sense.

Examples of no-regrets strategies:

- Warning systems
- Pollution reductions
- Risk-based insurance: discourage settlement in low-lying coastal areas and fire risk areas; could promote hazard mitigation

However, no-regrets scenarios will only go so far. In some cases, difficult, and possibly expensive adaptation strategies will be necessary. But, in the meantime, Hurricane Sandy proved that we still have a long way to go adapting to our *current* climate risks. These will only grow more sever in the future. If we are vulenrable to the current climate, we are *more* vulnerable to climate change.

Introducing climate adaptation

Proactive planning is more effective and less costly than reactive planning

Upfront investment vs. longer-term costs of inaction

- True fiscal responsibility requires a long-term view
- Upfront investment in adaptation efforts can pay off long-term by reducing:
  - Infrastructure damage
  - Energy costs
  - Liability risks (lawsuits)
  - Public health risks

Info source: Center for Science in the Earth System, "Preparing for Climate Change", Section 3.2 | Image source: Andrew Magill, 2009

Taking proactive steps to be flexible and to anticipate and address impacts can save money and protect the well-being of communities. For instance, considering the impacts of climate change on water supply and demand in design criteria for a new reservoir can help ensure that the new reservoir meets future water needs and may be less costly than having to expand the reservoir in the future.

Preparing for future climate change impacts may also provide opportunities to add value to existing capital projects. "Piggybacking" a reclaimed water system expansion, for example, reduces the marginal cost of adding the reclaimed water system onto a planned wastewater treatment system expansion while providing buffering capacity against projected water supply impacts.

(Information source: Center for Science in the Earth System, King County, "Preparing for Climate Change", Section 3.2 Reasons for Local, Regional, and State Governments to be Proactive, http://www.cses.washington.edu/db/pdf/snoveretalgb574.pdf)

(Image source: Andrew Magill, 2009, https://flic.kr/p/68zxij)

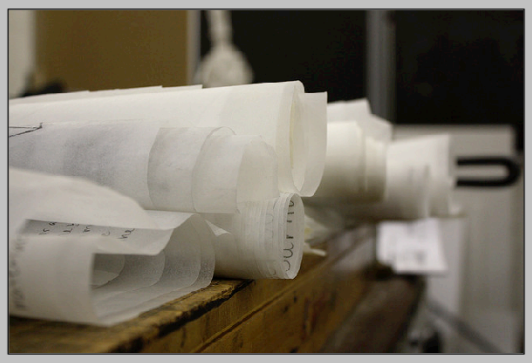
Additional Resources:

Freshwater Future & EcoAdapt: Consider Climate Change Adaptation
Helpful primer on climate adaptation in the GL region, including an overview of impacts and tips to getting started

US EPA: Climate Change Impacts and Adapting to Change
Evaluation of Climate Change by sectors, public use tools and federal and EPA programs.

Freshwater Future & EcoAdapt: Consider Climate Change Adaptation: http://freshwaterfuture.org/userfiles/Climate101FactSheet.pdf

US EPA: climate change impacts and adapting to change: http://www.epa.gov/climatechange/impacts-adaptation/



Elements of successful adaptation planning

A COLLECTION OF BEST PRACTICES

Elements of successful adaptation planning

Chicago Climate Action Plan's 5 Themes

1. Build resilient infrastructure and management systems
2. Embed climate readiness in routine planning process
3. Look for win-win (no regrets) actions
4. Take incremental steps
5. Be aware and flexible, continually incorporating new data

Source: Chicago climate action plan

Add sources

The Chicago Climate Action Plan includes five themes for successful planning that are useful for all planners to keep in mind:

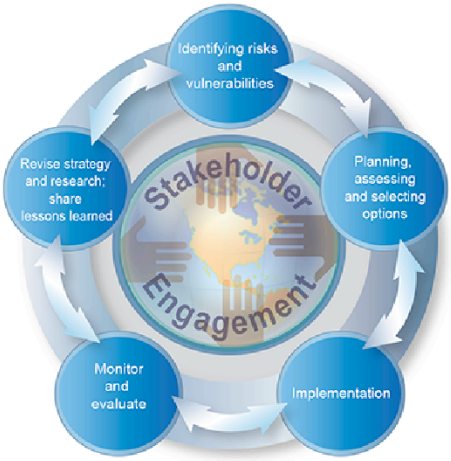
1. "Building adaptive capacity is the putting in place of support systems, data collection, evaluation processes, awareness-raising, and policy framework(s) which will encourage, allow or require individual businesses and regions to undertake adaptation. Only when such work has been undertaken in a particular organization or sector can the work of delivering adaptation actions begin."
2. Climate change will affect elements of community infrastructure and life that are already addressed by municipal planners and existing organizational structures. Planning for climate change is not about starting from scratch; it is about adding climate considerations to the existing short- and long-term community plans. Planning processes identify future organizational, operational, equipment, or infrastructure needs involving procuring new goods, services and/or products or building new infrastructure that must function under a new set of climate conditions. To manage risk, planning processes should be modified to account for potential impacts of climate changes." For example, New Zealand has issued guidelines for local authorities that include specific questions to be asked when drawing up individual plans, including:
    a. Does the risk management analysis take into account changes due to climate change?
    b. Do the effects of climate change reflect the current level of uncertainty in the region and should a cautious approach be adopted as a result? If not, is this explained?
    c. Does the plan include a specific commitment to keep up to date with changing understanding of climate change and its implications (including any relevant local monitoring or liaison)? Chicago Quick Guide to Climate Change Preparation p. 6.
3. Adaptation measures almost always have multiple benefits (such as reduced energy costs, improved aesthetics, and reduced air and water pollution). These should be considered to assess the overall benefit of the measures that may be taken—especially when the co-benefits either save money or outweigh the costs of the measures.
4. Incremental steps (rather than large actions) can keep options open so that plans can be adjusted as new data develops. Phased projects can help communities avoid getting locked into trajectories that may not be compatible with future climate risks. Phased projects are also easier to incorporate into existing community plans and are less politically difficult. Also, distributed infrastructure can be more flexible in responding to change than large, centralized systems.
5. "The paradox of process planning is the intermixed integration of past, present, and future. We plan for the future, do so in the present, and use data from the past." To plan for climate change, new data must be continually incorporated and decisions

Elements of successful adaptation planning

Adaptation process: iterative, non-linear, transparent

- Identify risks and vulnerabilities
- Plan, assess, and select options
- Implement
- Monitor and evaluate
- Revise strategy and research; share lessons learned

Stakeholder engagement throughout process



Source: NCA 2014, Adaptation, Section 3, Adaptation Process

There is no "one-size fits all" adaptation, but there are similarities in approaches across regions and sectors. Sharing best practices, learning by doing, and iterative and collaborative processes including stakeholder involvement, can help support progress. General patterns in adaptation processes are beginning to emerge, with similarities discernible across sectors, systems, and scales.[1]

This is not a stepwise or linear process; various stages can be occurring simultaneously, in a different order, or be omitted completely. However, as shown clockwise in the figure above, the process generally involves characterizing vulnerability, developing options, implementing actions, monitoring outcomes, and reevaluating strategies.

Elements of successful adaptation planning

Stakeholder engagement

In many cases it takes one or more champions to keep adaptation initiatives alive in the face of the many competing municipal priorities. Dialogue, discussion and public consultations are important means to arriving at a desirable adaptation action.

Elements of successful adaptation planning

Dealing with uncertainty

1. Acknowledge uncertainties
2. Manage uncertainties
   - Prepare for a range of extremes
   - Prioritize "no regrets" programs
   - Incorporate uncertainty into plans
3. Be firm about what we *do* know
   - Temperature is increasing
   - Precipitation patterns changing
   - More extreme events
   - Previous norms no longer hold

The topic of uncertainty will come up anytime you're dealing with climate change. It's important to acknowledge uncertainty and remember that uncertainty is a crucial part of any form of scientific research—and climate research is no exception. No matter how elaborate our models are (or how convincing our observations seem), a degree of uncertainty always exists. Global Climate Models also help us understand and quantify degrees of uncertainty associated with climate change forecasts. Climate change uncertainties include questions regarding the degree of future greenhouse gas emissions, solar output, and variations in ocean circulation patterns.

Make sure to acknowledge that there is significant uncertainty regarding:

- The level of future emisisons (and, thus, level of warming)
- The level and type of future changes in local land use
- Incomplete understanding of cloud and ocean dynamics

Many decisions and city plans are based on uncertainties:

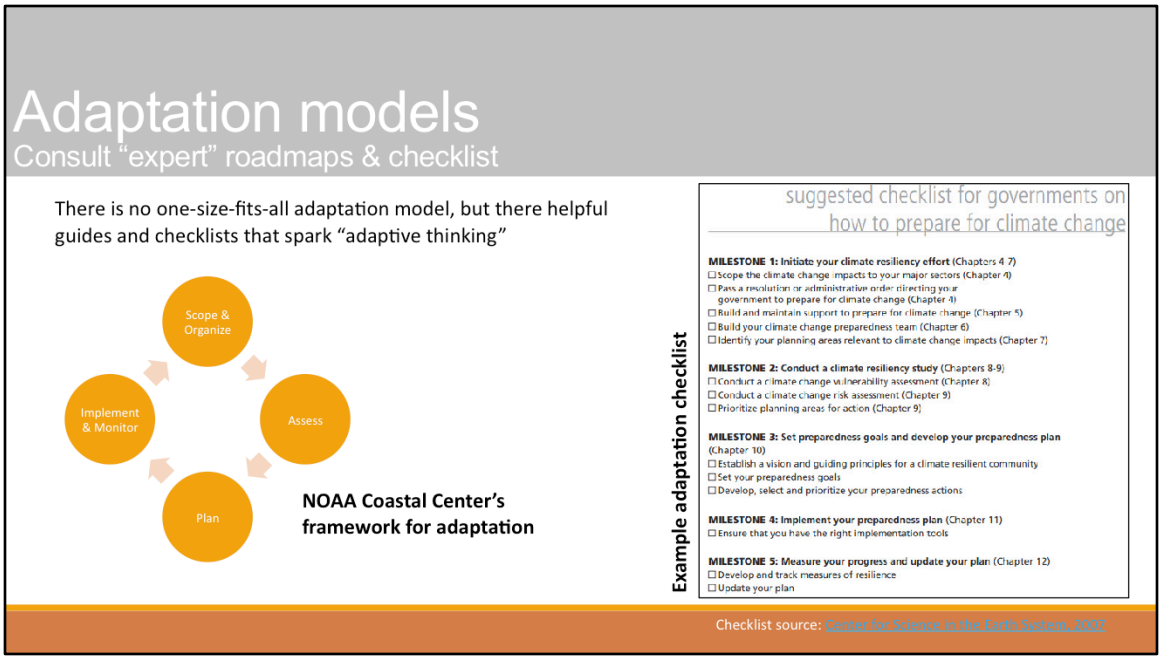
- Population growth
- Natural disasters
- Flood insurance
- Disease control

Adaptation Models

PATHS TO BUILDING ADAPTIVE CAPACITY

Image source: Flickr 2014, https://flic.kr/p/oqye3K

This section explores some of the ways in which city officials are integrating climate adaptation into their work. While some cities create adaptation plans, others do not.



The NOAA Coastal Center's framework for adaptation (see diagram) aligns with the sort of cyclical planning that most city officials already engage in. Many adaptation models align with this cycle. The key take-away here is that building resilience is an ongoing process.

Scope & Organize
- Review hazard impacts
- Identify stakeholders and get buy-in
- Build working group and subcommittees
- Identify planning areas

Assess
- Conduct vulnerability assessment
- Prioritize planning issues

Plan
- Identify, evaluate, and prioritize adaptation strategies
- Integrate strategies into other plans
- Create, plan, and schedule for implementing and monitoring

Implement & Monitor
- Implement high priority actions
- Utilize plans to seek funding
- Track progress and evaluate effectiveness
- Assess new impacts information
- Revise strategies and priorities as needed

Some of guides and checklists include:

1. Center for Science in the Earth System, 2007, "Preparing for Climate Change", Page 7: Suggested Checklist for Governments on How to Prepare for Climate Change, (http://www.cses.washington.edu/db/pdf/snoveretalgb574.pdf)
2. NOAA, Roadmap for Adapting to Coastal Risk: http://www.csc.noaa.gov/digitalcoast/training/roadmap

Adaptation models

Write adaptation actions into sustainability plans (example: Chicago)

- 2006 Mayor Daley established Climate Change Task Force (CCTF)
- CCTF evaluated potential climate impacts, economic costs, and risk assessments
- 2008 CCTF released **Chicago Climate Action Plan (CCAP)**, which included nine adaptation actions
- Implemented adaptation actions thus far include:
  - Tree canopy expansion
  - Integration of future climate scenarios into stormwater management
  - Development of green urban design projects
  - Extreme Weather Operations Plan

The Chicago Planning Commission adopted a green urban design document after the CCAP's release

Source: CakeX, http://www.cakex.org/case-studies/6661; Chicago Climate Action Plan: http://www.chicagoclimateaction.org/filebin/pdf/finalreport/CCAPREPORTFINALv2.pdf

The City of Chicago's climate change efforts began in 2006 when then Major Daley established a multi-stakeholder Task Force to develop plans to reduce the city's greenhouse gas emissions and help the city adapt to both existing and projected climate impacts. The Task Force commissioned in-depth impacts and vulnerability assessments and an economic analysis of projected impacts and costs of inaction. The CCAP effort has been funded by a coalition of diverse partners and has drawn financial support from a host of sources ranging from federal stimulus funds to private foundation support, state funds, and pro bono and in-kind support. Since 2008, the CCAP has received or leveraged over $142 million in funds.

After conducting impacts, economic costs, and risk assessments, the city released the Chicago Climate Action Plan (CCAP) in late 2008. The plan functions much like a roadmap for climate action with five overarching strategies, including nine adaptation actions. Implemented adaptation actions thus far include integration of future climate scenarios into stormwater management as well as the development of green urban design projects to reduce heat and flooding.

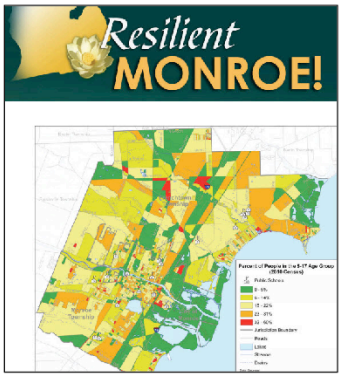
Chicago Climate Action Plan: http://www.chicagoclimateaction.org/filebin/pdf/finalreport/CCAPREPORTFINALv2.pdf

Chicago Climate Action Plan Progress Report: http://www.chicagoclimateaction.org/filebin/pdf/CCAPProgressReportv3.pdf

http://www.cakex.org/case-studies/6661

Adaptation models

Integrate climate adaptation into land-use planning



Resilient Monroe Project

2013: City of Monroe and two nearby townships pooled resources to revise master plans and form joined Community Planning Committee

Refined land use and development plans to adapt to unpredictable circumstances

Resilient Monroe Resource Atlas includes chapter on climate vulnerabilities, including:

- Historic climate data
- Climate trends & concerns
- Vulnerability mapping

Source: CakeX http://www.cakex.org/case-studies/resilient-monroe-resource-atlas; Resilient Monroe Resource Atlas: http://www.resilientmonroe.org/resourceatlas.asp

Early in 2013, the City of Monroe, Frenchtown Charter Township and Monroe Charter Township agreed to pool their resources and work together in reviewing and revising their respective master plans under the project name "Resilient Monroe." Each of these local governments conducts land-use planning and community development separately under Michigan's planning and zoning laws. However, when taken together, the three jurisdictions include the geographic area most people think of as the greater Monroe Community.

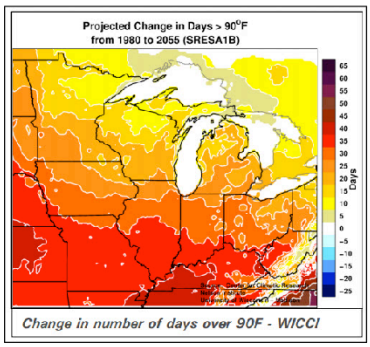
The Resilient Monroe project is designed to serve the whole community by supporting the work of all three planning commissions and the elected officials from each jurisdiction. Together, these public officials have formed a Community Planning Committee to review and consider the planning documents developed by the project. Research, planning and process facilitation services are being provided by the Land Information Access Association (LIAA) with support from the Community Foundation of Monroe County, Michigan Municipal League (MML), Michigan Townships Association (MTA), Michigan Association of Planning (MAP) and the Urban Planning division of the University of Michigan. Funding for this effort has been provided by the City of Monroe, Frenchtown Charter Township, Monroe Charter Township, the Kresge Foundation, and the Americana Foundation. Additionally, LIAA is contributing in-kind efforts.

Ultimately, the Resilient Monroe project is all about helping the leaders and citizens of the greater Monroe Community refine their land use and development plans to adapt to unpredictable circumstances, many of which are partially or wholly beyond direct local control. This effort will support the City of Monroe in rewriting its existing Master Plan and assist the participating townships in reviewing their master plans — working toward greater community resilience.

CakeX Case Study: http://www.cakex.org/case-studies/resilient-monroe-resource-atlas
Resilient Monroe Resource Atlas: http://www.resilientmonroe.org/resourceatlas.asp

Adaptation models

Create independent adaptation plan



Report includes WICCI info about projected climate change

Dane County Climate Change Preparedness Plan

In 2013, Dane County Climate Action Council was created to ensure county preparedness for weather extremes

Council facilitated internal review of preparations and potential modifications to operations and capital investments

Report identifies vulnerabilities and sector-based near-term and long-term strategies:

- Public health
- Public safety
- Emergency management

Source: Georgetown Climate Center: http://www.georgetownclimate.org/resources/dane-county-wisconsin-climate-change-and-emergency-preparedness-plan ; Count of Dane: http://danedocs.countyofdane.com/webdocs/pdf/press/9_-_30_Climate_Change_and_Emergency_Preparedness.pdf

In March of 2013, the Dane County Climate Change Action Council was created with the mission of ensuring that the Dane County government is better prepared for weather extremes brought on by global climate change. To support their mission and prepare this report, the Council facilitated an internal review of preparations and potential modifications to the county's operations and capital investments. Based on the internal review, this report identifies potential vulnerabilities to climate change, and provides sector based adaptation strategies.

The report addresses climate impacts for public health, public safety and emergency management, infrastructure and facilities, and Dane County lakes. The climate related risks within each sector are detailed and each are followed by "near term adaptations," as well as methods for preparing for projected adaptations through planning and mitigation.

Sources:
Georgetown Climate Center: http://www.georgetownclimate.org/resources/dane-county-wisconsin-climate-change-and-emergency-preparedness-plan
County of Dane: http://danedocs.countyofdane.com/webdocs/pdf/press/9_-_30_Climate_Change_and_Emergency_Preparedness.pdf

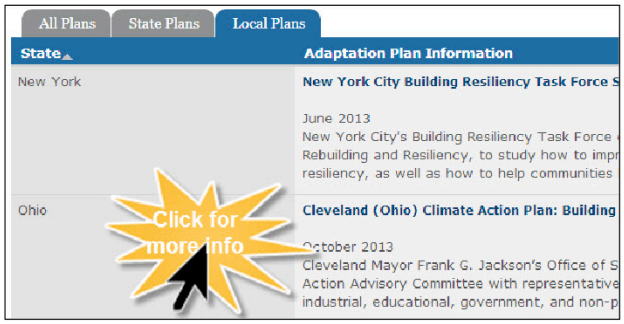
Adaptation models

Incentivize private sector and public involvement in adaptation

Additional Resources:

US State and Local Adaptation Plans

Georgetown Climate Center map and table that highlight the status of adaptation plans at the state and local levels.

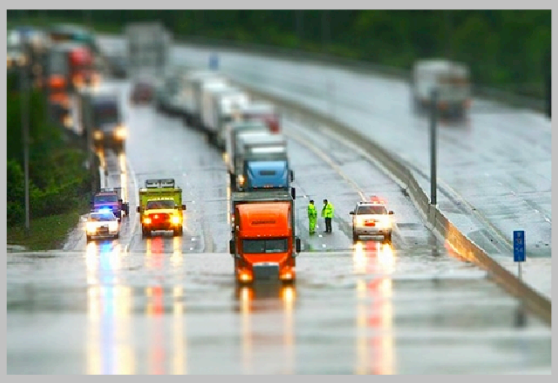


Federal and EPA Adaptation Plans

Including adaptation plans at national level at EPA and other government agencies such as USAID, USDA, DOD, DOE, HHS, DHS, etc.

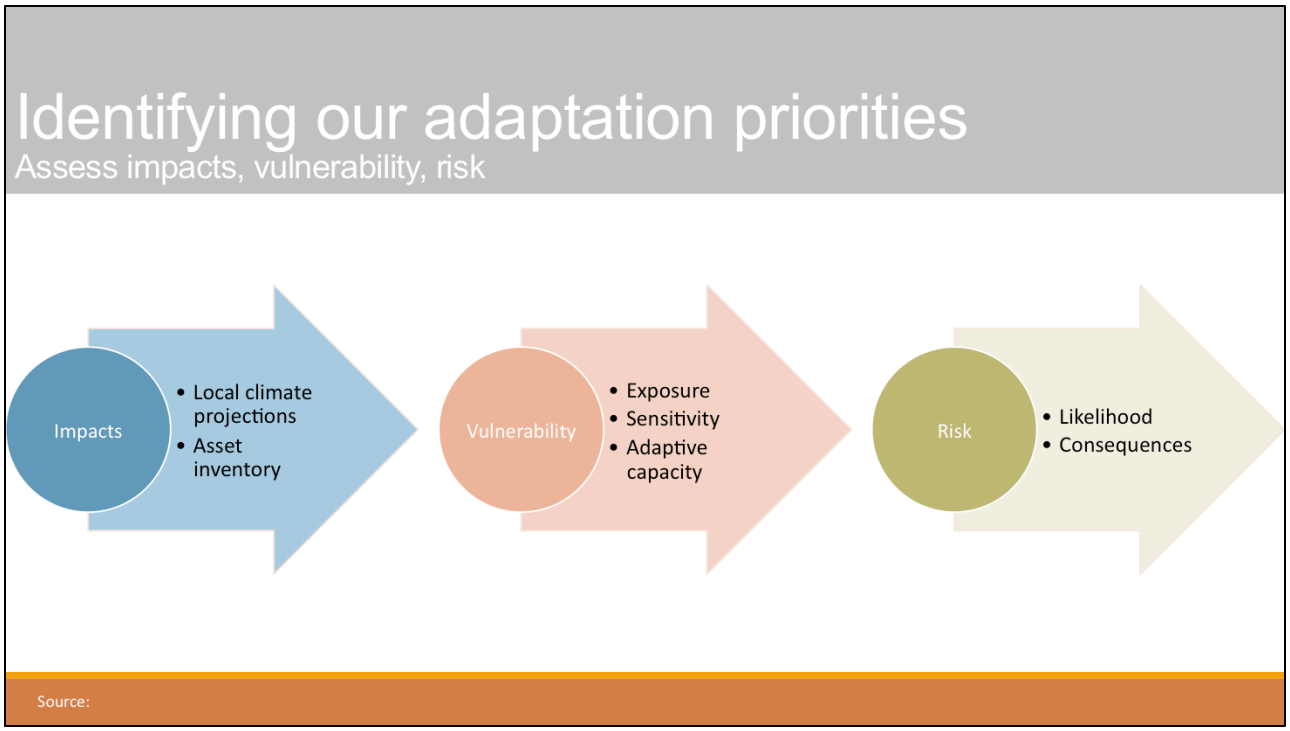
US State and Local Adaptation Plans: http://www.georgetownclimate.org/resources/us-state-and-local-adaptation-plans

Federal and EPA adaptation plans: http://www.epa.gov/climatechange/impacts-adaptation/fed-programs.html



Identifying our adaptation priorities

Image source: http://production.sustainabilitylt.netdna-cdn.com/content/postimages/image/495/normal_floods.jpg



Vulnerability Using refined maps that depicted projected inundation and flooding in the ART Project subregion based on 16" and 55" of sea level rise, project staff determined the exposure of assets to the new daily high tide and extreme tide levels as well as to wind-waves during a storm event. Analysis of sensitivity and adaptive capacity of the assets to higher high tides, periodic flooding and higher groundwater was informed by the Existing Conditions and Stressors Report and information for asset-specific metrics that the Subregional Working Group helped develop.

1. Impacts:
- Local climate projections
- Asset inventory: Identify assets to be assessed

2. Vulnerability generally includes three components: exposure, sensitivity and adaptive capacity.
- Exposure: Extent to which an asset experiences an impact
- Sensitivity: Degree to which an asset is impaired by an impact
- Adaptive capacity: Inherent ability of an asset to accommodate or adjust to an impact to maintain its primary functions

3. Risk:
- Likelihood: Chance or probability of an impact occurring
- Consequence: Magnitude of effects on society and equity, economy, governance, and environment if an impact occurs

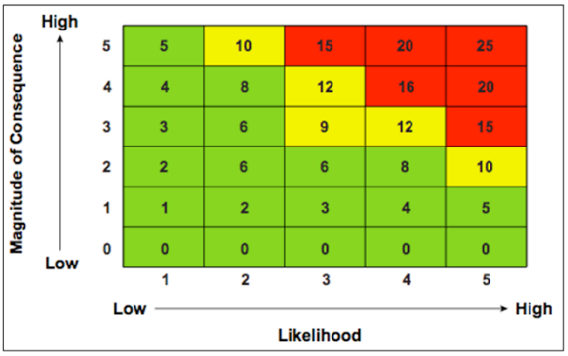
Identifying our adaptation priorities

Identify impacts and consequences

1. Identify climate change impacts and consequences
2. Assess physical characteristics and exposure
3. Consider adaptive capacities
4. Develop scenarios and simulate change
5. Summarize vulnerability and identify focus areas

Risk is a combination of:

1. Likelihood of an event occurring
2. Level of consequence if the event occurs



Chicago's risk assessment chart.

(From NOAA's *Adapting to Climate Change: A Planning Guide for State Coastal Managers*.)

Risk assessment requires data about the levels of exposure to climate impacts for the community:

- People
- Infrastructure
- Natural resources
- Cultural resources
- Economic resources

When considering areas of likely climate change impact, Chicago used four themes (Water, Health, Ecosystems, and Infrastructure) and then identified sub-themes within each group. The city wanted to know how climate change would impact each of these areas. For example,

•Water's subthemes included precipitation, river flow, and Lake Michigan.
•Health's subthemes included heat, air quality, and vector-borne diseases.
•Ecosystems' subthemes included natural vegetation, animals, invasive species, and agriculture.
•Infrastructure's subthemes included heating and cooling, operation and maintenance, labor, and other.

Although the primary focus of adaptation planning is on risks, climate change may also create new opportunities for a community. Including this concept in the research gives a more complete picture that is useful in determining the best local actions.

Identifying our adaptation priorities

Analyze impacts to calculate priorities

To calculate priorities, consider:

1. How many municipal activities would be affected by each risk?
2. How soon are the impacts likely to be realized?

Table 3.1 (cont)

Impact	Risk	Timing **	Construction, Buildings & Property	Tourism	Environment	Fire	Fleet Management	Housing	Human Services	Emergency Management	Police	Public Health	Streets and Sanitation	Transportation	Water Management	Parks and Open Space	Storm Water Management
Increase in heat related deaths	High	Now	x	x		x		x	x	x	x	x		x		x	
Increase in heat related hospitalization	High	Now				x			x	x	x	x					
Increase in health impacts due to "water-in-basement" incidents	High	Near	x			x				x		x	x		x		

Sample of Chicago's Prioritization
Now = 2010
Near = 2035
Mid = 2040-2069

1. Examples of municipal activities/services include construction, street maintenance, public safety, public health, tourism, business, and schools. Knowing what activities will be affected can help determine how widely the impacts will be felt in the community, what agencies may need to be brought into the planning process, and where adaptation resources may be available.
2. When considering the timeline for impacts, think about now, 10 years from now, 30 years from now, and 50 years from now.

Knowing the level of the risk, the extent of its impact on a municipality, and the immediacy of the threat, the planning team can set priorities for allocation of resources. It is important to retain some flexibility in this prioritization. As the community explores adaptation options, discovery of opportunities to address impacts that are lower on the priority list may appear. For instance, these could be tied to current development or government grants that will expire shortly. Cases like these will have to be evaluated on an *ad hoc* basis.

Identifying our adaptation priorities

Tools & guides

1. EcoAdapt's Climate Vulnerability Assessment Quick Guide
2. Guide to Climate Change Adaptation in Cities

EcoAdapt's Climate Vulnerability Assessment Quick Guide: http://freshwaterfuture.org/userfiles/EcoAdapt'sClimateVulnerabilityAssessmentGuide.pdf

Guide to climate change adaptation in cities: http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1318995974398/GuideClimChangeAdaptCities.pdf

Image source: http://climate-adapt.eea.europa.eu/image/image_gallery?img_id=1904042&fileName=ast_step5_new.png&t=1337933207838

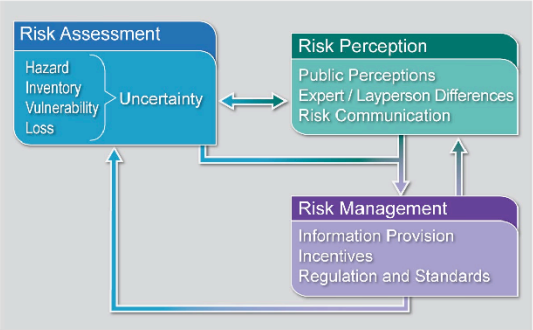
Identifying our adaptation priorities

Public feedback on risk assessment

Public discussion of the assessment is important because:

- Issues may have been overlooked
- People may disagree about the priorities or want to help determine priorities
- Private sector programs may offer opportunities for partnership in implementing adaptation plans

Linking Risk Assessment and Risk Perception with Risk Management of Climate Change



Successful adaptation requires community-wide planning; it is vital to bring all parties together to share information and ideas so that widespread implementation will be possible. Once there is a summary report on the risks climate change poses for an area, this report can be presented to the wider community.

- This can help make sure that no community concerns were overlooked.
- If people have a chance to take part in the process and feel that the resulting priorities are valid, they will be more likely to support the adaptation plans.
- There may be small-scale programs within the private sector that offer opportunity for partnership in implementing adaptation plans.

Image source: http://nca2014.globalchange.gov/sites/report/files/images/web-large/Figure-26.4-hi.jpg

Identifying our adaptation priorities

Evaluate, select, and prioritize actions

1. What strategy can help reduce or prevent the impact? *How* does it reduce the problem?
2. What other climate impacts does this strategy address?
3. What data do you need to determine how effective this strategy would be in your area?
4. What agencies or organizations would be responsible for implementing this strategy?
5. Are there ways to share costs? (e.g. through joint projects?)

Sample strategies:

- green infrastructure
- stream buffers
- tree planting
- water conservation
- zoning
- regulatory changes
- energy distribution
- light-colored roofing
- ecosystem restoration

Successful adaptation requires community-wide planning; it is vital to bring all parties together to share information and ideas so that widespread implementation will be possible. Once there is a summary report on the risks climate change poses for an area, this report can be presented to the wider community.

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Additional Resources:

Roadmap for Adapting to Coastal Risk
NOAA online training and resources that help communities address climate hazards and vulnerabilities. Includes link to 1-hour recorded introduction, resources, and case studies

Adopting to Coastal Climate Change
A guidebook for development planners in US coastal regions by USAID.

A Coastal Community Resilience Evaluation Tool
A non-regulatory tool to assist local decision-makers in the identification of planning, mitigation and adaptation opportunities to build capacity for coastal community resilience.

NOAA Roadmap for Adapting to Coastal Risk: http://www.csc.noaa.gov/digitalcoast/training/roadmap

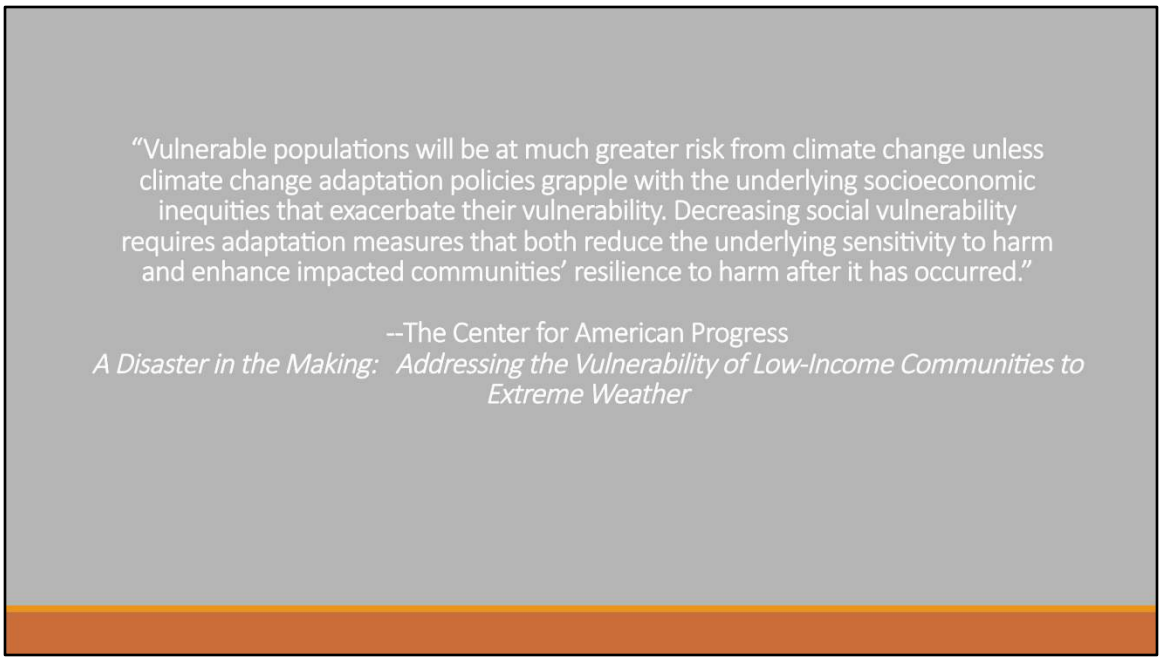
Adopting to coastal climate change: http://pdf.usaid.gov/pdf_docs/PNADO614.pdf

A coastal community resilience evaluation tool: http://www.state.nj.us/dep/cmp/docs/gtr-resilience.pdf




Module 3: Social Vulnerability

IDENTIFYING THE CHANGING CLIMATE'S HAZARDS FOR HUMAN HEALTH AND VULNERABLE POPULATIONS

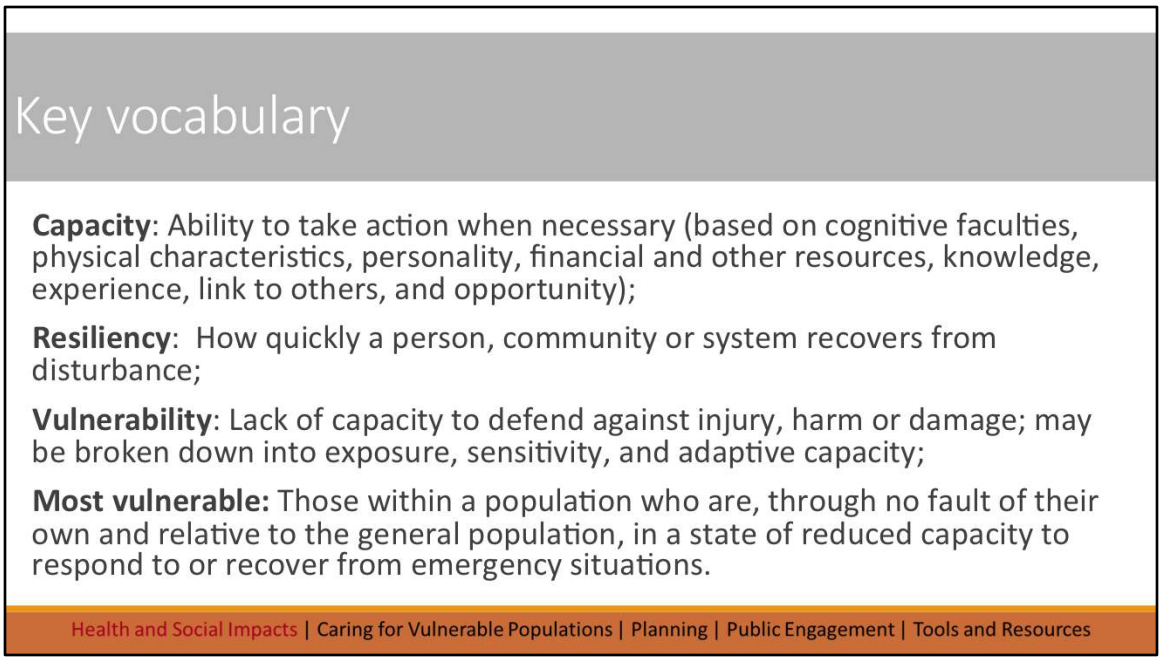


Source: http://cdn.americanprogress.org/wp-content/uploads/2013/08/LowIncomeResilience-3.pdf

Key Questions

1. What are the health and social impacts of climate change?
2. How do we care for vulnerable populations?
3. How do we consider vulnerable populations in climate change adaptation planning?
4. How do we engage the public, and vulnerable populations in particular?
5. Are there any tools, resources and examples to assist me?

Health and social impacts of climate change

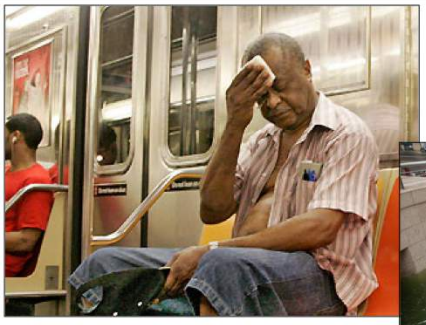


In the field of emergency management one has to be careful when discussing what otherwise might appear as common and readily-understood terms. The difficulty is that this field of practice does not have a consistent and universally understood set of terms. The following definitions are offered as a starting point, to clarify the discussion below. Please avoid getting concerned about the particular definitions used, and instead concentrate on their general meaning.

Source Citation:
Community-wide vulnerability assessment, https://www.ccadaptation.ca/en/component/k2/item/2671-community-wide-vulnerability-and-capacity-assessment-2001
Climate Change Adaptation and Health Equity Workshop (2011), https://www.ccadaptation.ca/en/component/k2/item/2648-climate-change-adaptation-and-health-equity-workshop-2011

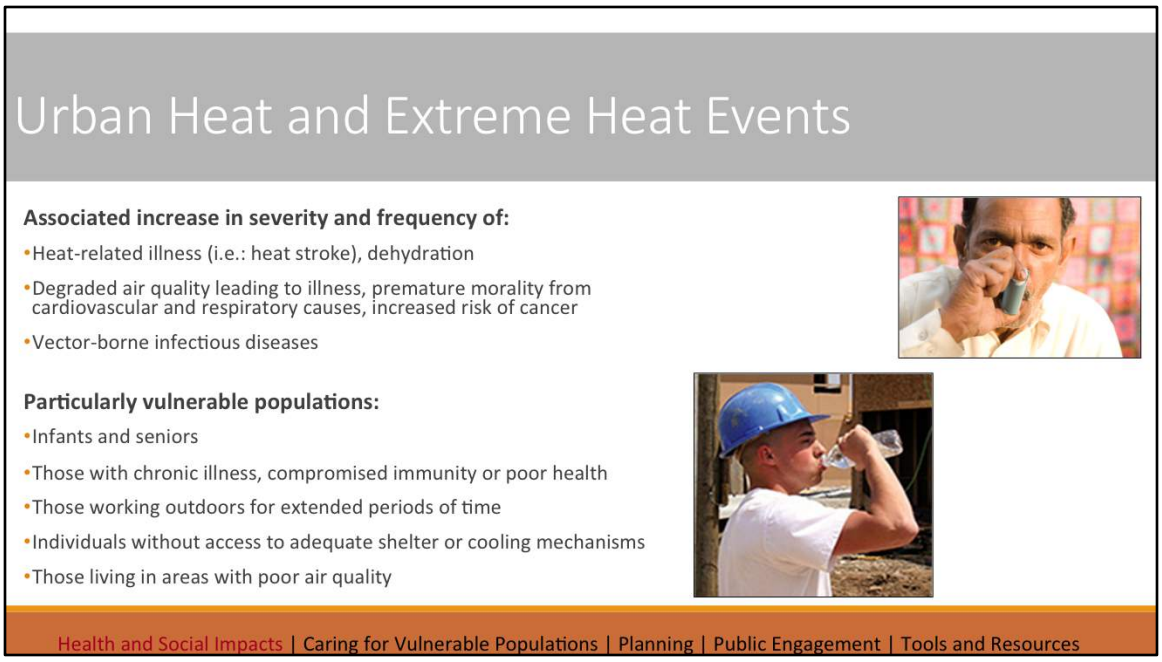
Health and Social Impacts of Climate Change

- Urban heat
- Air quality
- Water concerns
  - Water quality
  - Increased rainfall and flooding
  - Combined Sewer Overflows
- Changing seasons
- Severe storm events
- Secondary impacts



New York City's 2010 heat wave and 2012 Superstorm Sandy have posed many challenges for both residents and municipal leaders.

Images:
http://www.worldpreservationfoundation.org/blog/wp-content/uploads/2010/07/heat-wave-NYC.jpg
http://blogs.reuters.com/great-debate/files/2014/07/NYC-FLOODED-PLAZA-BETTER.jpg



[Waiting for the original MARS notes to add to here.]

Source Citation: The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars

Worsening Air Quality

Associated increase in severity and frequency of:

- Air temperature and stagnancy
- Pollutant emissions (for example, ozone alert days)

Particularly vulnerable populations:

- People with respiratory difficulties, existing allergies, or cardiovascular disease
- People who work outside
- Chronically ill or those with impaired immune systems, compromised health

Smog at the Chicago skyline.

Heat can also impact air quality. During heat waves in the Midwest, air pollutants are trapped near the surface as atmospheric ventilation is reduced. Without strict attention to regional emissions of air pollutants, the undesirable combination of extreme heat and unhealthy air quality is likely to result. Climate change will likely cause an increase in surface ozone over the Midwest, partly driven by decreased ventilation due to warmer temperatures.

Source citation:

Wu, Shiliang, Loretta J. Mickley, Eric M. Leibensperger, Daniel J. Jacob, David Rind, and David G. Streets. 2008. "Effects of 2000–2050 global change on ozone air quality in the United States." *Journal of Geophysical Research*, 113, D06302, doi: 10.1029/2007JD008917.

Image: http://ns.umich.edu/new/images/climate-change-to-profoundly-affect-the-midwest-Chicago-smog-orig-20130118.jpg

Increased Rainfall and Flooding Events

Associated increase in severity and frequency of:

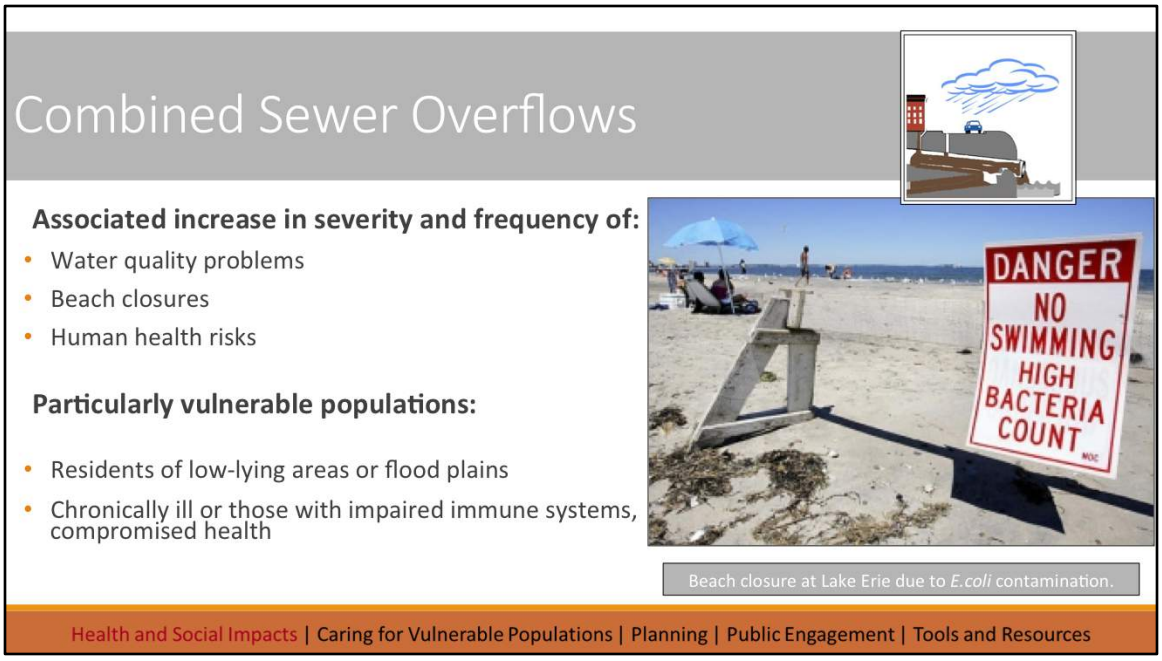
- Lake bacterial contamination from runoff; increase in waterborne disease
- Residential /commercial building structures contaminated by floodwater/ sewage backups
- Mold development in built structures, leading to respiratory illness

Particularly vulnerable populations:

- Residents of low-lying areas or flood plains
- Residents of substandard housing, and/or those who are homeless or under-housed
- Chronically ill or those with impaired immune systems, compromised health

The frequency of heavy rain events will increase with climate change.
[And waiting for the original MARS notes to add to here.]

Source Citation: The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars



During storms, combined sewer overflows can cause sewage to flow into lakes. How does this happen?

Combined sewer systems collect runoff, sewage, and industrial water in the same pipe. This was economical when all wastewater was discharged directly to rivers (before we had treatment plants in the 19th century). Now, the system can handle the whole load during dry weather and direct it all for treatment. But, during big storms, the plants can't handle the volume—and the systems are designed to overflow into lakes.

When over a billion gallons of sewage is released into our rivers and lakes from combined sewer overflows during heavy rains, water quality diminishes and beaches are closed

Combined sewer overflows can also negatively affect human health, since waterborne diseases in drinking water can be more prevalent after heavy

Changing Seasonal Climate

Associated increase in severity and frequency of:

- Vector-borne disease transmission from insects with longer survival periods in milder winters
- Introduction of new local infectious diseases
- Shifting crop growth and harvest cycles, timber lines and floral / faunal migration

Particularly vulnerable populations:

- Chronically ill or those with impaired immune systems, compromised health
- Communities dependent on natural resources

West Nile virus and other serious diseases are transmitted by insects like mosquitoes.

Health and Social Impacts | Caring for Vulnerable Populations | Planning | Public Engagement | Tools and Resources

Waiting for the original MARS notes to add to here.]

Source Citation: The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars
Image: http://blogs-images.forbes.com/melaniehaiken/files/2012/08/Screen-Shot-2012-08-22-at-2.43.00-PM.png

Severe Storm Events

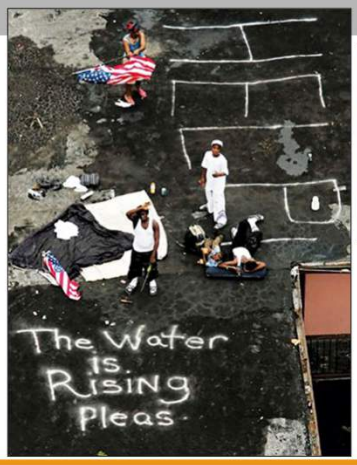
In 2012 alone, there were 11 extreme weather events in the United States, with each costing approximately $1 billion USD in cleanup costs. Every dollar spent on hazard mitigation saves $4 in avoided disaster costs. (National Institute of Building Sciences)

Associated increase in severity and frequency of:

- Extreme storms like Hurricane Katrina and Superstorm Sandy
- Flooding, polar vorteces, drought, wildfire and other disasters

Particularly vulnerable populations:

- Residents of assisted living facilities, nursing homes, substandard housing and high rises
- The homeless, disabled and chronically ill, including patients at hospitals whose health may be threatened by hospital power outages and medication or food shortages due to transit interruption.



Flood victims seek assistance in Hurricane Katrina's aftermath. The storm caused tremendous loss of life and property, and disproportionately affected low-income residents. 2014's polar vortex caused dangerously low temperatures.

Health and Social Impacts | Caring for Vulnerable Populations | Planning | Public Engagement | Tools and Resources

http://portal.hud.gov/hudportal/documents/huddoc?id=hsrebuildingstrategy.pdf
http://cdn.americanprogress.org/wp-content/uploads/2013/08/LowIncomeResilience-3.pdf

Images: https://encrypted-tbn2.gstatic.com/images?q=tbn:ANd9GcQZzGzQDFR0eluE3yhzpyg9_NeL2ZMASh9esSu8b76Dax47GUF2
Polar Vortex → globalnews.ca

Superstorm Sandy

- Sandy caused $65 billion in damages, with low-income households greatly impacted.
- 43% of the 518,000 households asking for federal aid from Sandy reported annual incomes of less than $30,000.
  - Low-income elderly and disabled NY City public housing residents were stranded in their apartments for weeks due to elevator outages or lack of anywhere to go. Many were unable to make it to food stamp centers for assistance.
  - Floodwaters damaged 402 public housing buildings, with more than 350,000 units in NYC.
  - 82% of properties hit by Sandy were built before 1980, when flood maps and standards were created.
- Storms are not "social equalizers". Severe weather exacerbates economic inequities, and low-income families have fewer resources to prepare for and recover from disasters. Low-income people are particularly vulnerable due to poor housing quality, environmental conditions and economic instability. Additionally, responder biases may negatively impact response times and quality of services provided to low-income populations.
- Low-income individuals are often expected to share the economic burden of disasters, which was once covered publicly. Federal aid programs may favor those who can take on debt. Because the application process for aid is complex, it is helpful if application assistance is available, especially for vulnerable populations that may have reduced English language literacy.

Stranded residents are evacuated after Superstorm Sandy.

http://cdn.americanprogress.org/wp-content/uploads/2013/08/LowIncomeResilience-3.pdf Excerpts:

"Many low income elderly and disabled residents of New York City's public housing complexes were stranded in their apartments for weeks after the storm due to elevator outages. Other residents remained in the high-rises, despite having no heat or power, because they had nowhere else to go or no means of getting out of their neighborhood. In other parts of the region, low income people were unable to make it to food stamp centers for assistance. The estimated cost of the destruction wrought by Sandy was $65 billion, with low-income households greatly impacted.... [Severe weather events] exacerbate our underlying economic inequities...disproportionately harming middle and low-income Americans. These households have fewer resources to prepare for and recover from such disasters."

"Low-income people are particularly vulnerable to extreme weather events due to their poor housing quality, poor environmental conditions, and economic instability…. …. When families
lack economic security, an unforeseen crisis that causes financial hardship can

Hurricane Katrina

80% of New Orleans was under water. The storm cost an estimated $125 billion in damages, making it the costliest hurricane in US history.

- Aging infrastructure and slow emergency response compounded the damage and loss of life. Levees were designed for Category 3 storms, but Katrina peaked at Category 5.
- 90,000 square miles were affected. Many residents had no place to go. The emergency shelter at the Superdome provided temporary shelter to 15,000 people.
- The storm killed nearly 2,000 residents, more than half of whom were seniors. 30% of the residents affected lived in poverty, and the storm left them even more vulnerable. The Lower Ninth Ward and Gentilly, which housed low-income minority residents and immigrants, had the highest death tolls.
- Many hospitals lost power and could no longer offer life-sustaining services for the critically injured.
- Nine years later, the impacted region still has not recovered fully, with many residents still jobless.
- Of the 818 Katrina fatalities for which race is listed, 55% were African-American, 40 % white, 2% Hispanic and 1% Asian-Pacific.

In Katrina's aftermath, healthcare worker Terri Johnson pleads for oxygen for her patient, Dorothy Duvic, outside the New Orleans Convention Center where tens of thousands were stranded.

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In 2006, a report by the Government Accountabiliity Office found that at least $1 billion (or 11%) of disaster payments given by FEMA were found to be improperly and fraudulently used. Thousands of citizens and officials were charged with wrongful use of emergency funds.

http://www.livescience.com/22522-hurricane-katrina-facts.html
http://www.history.com/topics/hurricane-katrina
https://www.dosomething.org/facts/11-facts-about-hurricane-katrina
http://www.nola.com/hurricane/index.ssf/2009/08/answers_are_scarce_in_study_of.html
http://www.poyi.org/63/photos/08/02.jpg – photo caption
http://www.journalofamericanhistory.org/projects/katrina/Landphair.html

Image: http://www.poyi.org/63/photos/08/02.jpg

Secondary Impacts

Associated increase in severity and frequency of:

- Electricity failure leading to food-borne illness, hypothermia, hospital and transportation outages, and water treatment plant shutdowns
- Food or water shortages
- Physical injury, drowning, electrocution, death
- Health impacts from infrastructure damage and interruptions to ambulance transport and other health services
- Indirect psychological health effects, including mental health and stress-related illness

Particularly vulnerable populations:

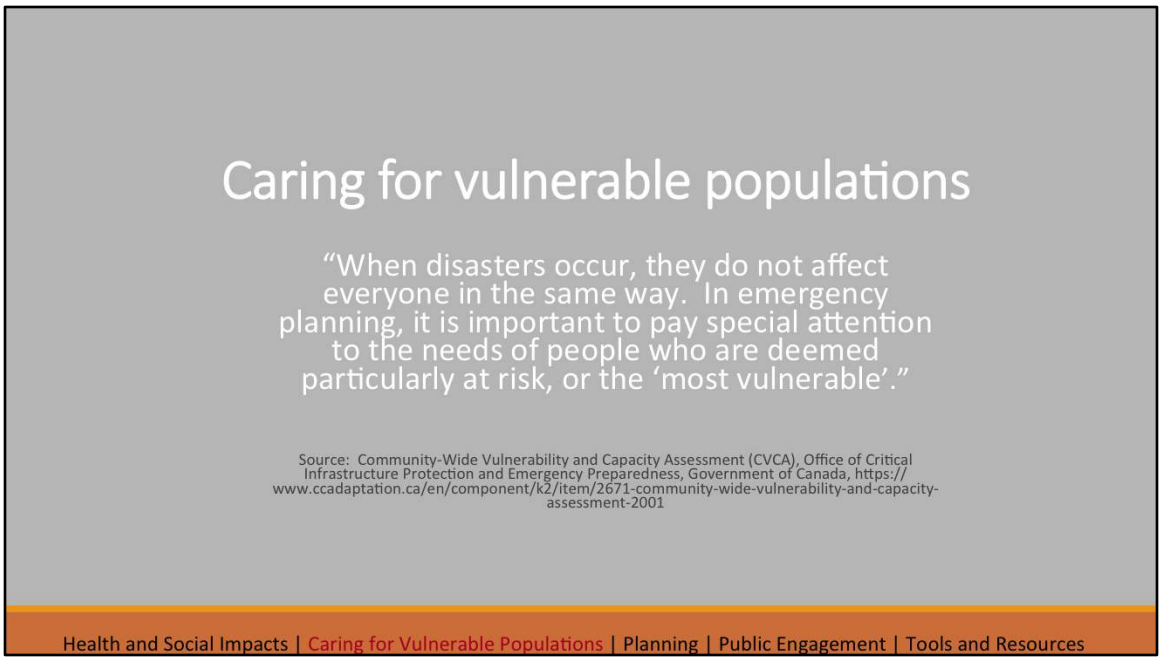
- **All**

Storms can damage power lines and cause local outages, creating potentially dangerous conditions for residents and repair crews.

Image: http://blog.emergencyoutdoors.com/tala/uploads/2012/09/down-power-line-survival-02.jpg

[Waiting for the original MARS notes to add to here.]

Source Citation: The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars



Source citation: Community-Wide Vulnerability and Capacity Assessment (CVCA), Office of Critical Infrastructure Protection and Emergency Preparedness, Government of Canada, https://www.ccadaptation.ca/en/component/k2/item/2671-community-wide-vulnerability-and-capacity-assessment-2001

The most vulnerable

Vulnerable populations may include:

- Children, the elderly and the disabled
- Poor or lower-income residents
- Veterans
- Health-compromised community members
- Immigrants
- Marginalized groups
- Single parents
- The homeless
- Those living in vulnerable housing (near floodplains, power plants, etc.)

Chicago's incidence of suburban poor increased 99% in the last decade. 42% of Illinois' children live below the poverty line, like this Peotone, Illinois girl.

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Sources:

http://www.chicagomag.com/city-life/March-2014/Child-Poverty-Is-Increasing-in-Illinois-Especially-in-the-Chicago-Suburbs/
Community-wide vulnerability assessment
https://www.ccadaptation.ca/en/component/k2/item/2671-community-wide-vulnerability-and-capacity-assessment-2001
From Theory to Practice: A Canadian Case Study of the Utility of Climate Change Adaptation Frameworks to Address Health Impacts (2011)
https://www.ccadaptation.ca/en/component/k2/item/2651-from-theory-to-practice-a-canadian-case-study-of-the-utility-of-climate-change-adaptation-frameworks-to-address-health-impacts-2011

Image: http://media.chicagomag.com//images/cache/cache_7/cache_7/cache_f/77f9b53ddac151d4c8918c27c7514381.jpeg?ver=1403126020&aspectratio=1.4761904761905

Additional characteristics of the most vulnerable

- Limited resources to plan or respond;
- Lack of support networks - cultural and/or linguistic isolation from the bulk of the community.
- Limited awareness and/or lack of education to understand emergency messages;
- Limited opportunity to express their unique needs;
- Presence of significant health problems that curtail ability to respond or recover
  - Dependency on technology, living aids or medication; reduced mobility;
  - Hospitalization or assisted care living.

Single parents may be especially vulnerable to a changing climate due to limited resources and support.

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The task is made difficult by the reality that people do not often fall solely into one category or another. Those who are deemed to be "most vulnerable" are typically in that category not because of their age (very young or old), gender (i.e., female), or culture (e.g., native populations). They are "most vulnerable" because they lack the capacity to respond or recover, which is generally assumed to exist for the general population. That lack of capacity often translates into a wide range of obstacles.

Source Citation: Community-wide vulnerability assessment, https://www.ccadaptation.ca/en/component/k2/item/2671-community-wide-vulnerability-and-capacity-assessment-2001
Image: http://static.guim.co.uk/sys-images/Guardian/Pix/pictures/2011/3/16/1300305788524/single-mother-with-baby-007.jpg

Caring for the most vulnerable: What can we do?

- Improve ability to **identify location of vulnerable populations**, and include this information in municipal emergency operations plans
- Consult geriatricians, community health specialists and other experts in plan development to **understand best ways to support low-income, minority and at-risk populations**
- **Improve surveillance, communication and emergency response** during severe weather events – particularly for elderly and transients, who are historically hard to reach during those times
- **Enhance general supportive services** for the elderly, disabled and homeless
- If possible, provide vocational training, career development, employment and budgeting skills, and job placement for homeless to **enhance people's resiliency**
- Enhance immigration and citizenship services
- Enhance educational services

The needs of the homeless are often overlooked during extreme weather and emergency events.

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Source and image citation:
Climate Change Adaptation and Health Equity Workshop (2011), https://www.ccadaptation.ca/en/component/k2/item/2648-climate-change-adaptation-and-health-equity-workshop-2011

http://www.chicagopsr.org/PDFs/climatechangepublichealthplancookcounty.pdf

Vulnerability creates more vulnerability

- Access to information about adaptation and climate change may influence a population's ability to act. Vulnerable populations often *do not have adequate access* to information.
- Vulnerable populations are often voiceless, with no say in the decision-making process or the allocation of resources in their communities.
- Vulnerable populations may have poor existing coping strategies to deal with change and stress, which can then become exacerbated from the pressures of climate change, making them less resilient overall.
- Involvement of all stakeholders and the use of participatory decision-making are crucial.

25% of Michigan residents qualify for assistance from the Department of Human Services.

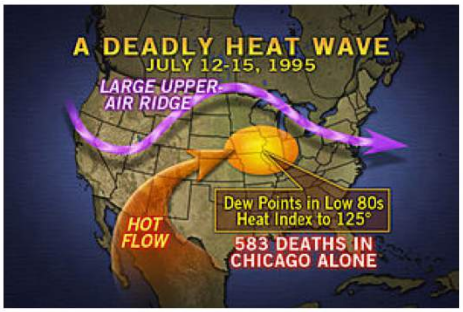
Imagery: http://detroitjcrc.org/sites/default/files/uploaded_images/Where_We_Stand/poverty.jpg

Source: http://www.careclimatechange.org/files/adaptation/CARE_Understanding_Vulnerability.pdf

The Health Inequality Gap

Health inequalities arise when certain groups experience inequities and multiple stressors .

- Low-income groups may have difficulty recovering from losses, property damage, or displacement after an extreme event such as a storm (e.g. Hurricane Katrina), or receiving health services in general.
- Among the homeless, extreme weather may worsen pre-existing conditions like mental illness, disease, social isolation and drug use.
- High-rise residents are likely to be exposed to higher temperatures. Many high-rise residents are low-income and new immigrants, with less access to air conditioning.
- Vulnerable communities typically have less green space and trees, leading to poor air quality and the Heat Island Effect in neighborhoods.



The death toll in Chicago's 1995 heat wave totaled 750, with the elderly, children and other vulnerable populations hit hardest.

Imagery: http://detroitjcrc.org/sites/default/files/uploaded_images/Where_We_Stand/poverty.jpg

http://vortex.accuweather.com/adc2004/pub/includes/columns/newsstory/2011/300x200_07201550_deadlyheatwave1995july.jpg

Source:
http://www.careclimatechange.org/files/adaptation/CARE_Understanding_Vulnerability.pdf
http://www.accuweather.com/en/weather-news/major-heat-hits-major-metropol/52689

Considering vulnerable populations in climate change adaptation planning

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Considerations for vulnerability planning

- Determine "most vulnerable" population's location
- Assess their capacity to recover from climate change-related events

"Most vulnerable" is sometimes misleading:

- Not all seniors, youth, disabled or marginalized people are "vulnerable"
- Some may be adept at responding

- Undertake risk management activities such as:
  - Population health assessments in partnership with public health officials
  - Public education and outreach
  - Creation of stronger social infrastructure

Urban climate change vulnerability and risk assessment framework.

Source citation:
Community-wide vulnerability assessment, https://www.ccadaptation.ca/en/component/k2/item/2671-community-wide-vulnerability-and-capacity-assessment-2001

Additional information/slides on this topic will be provided on next iteration of module submissions.

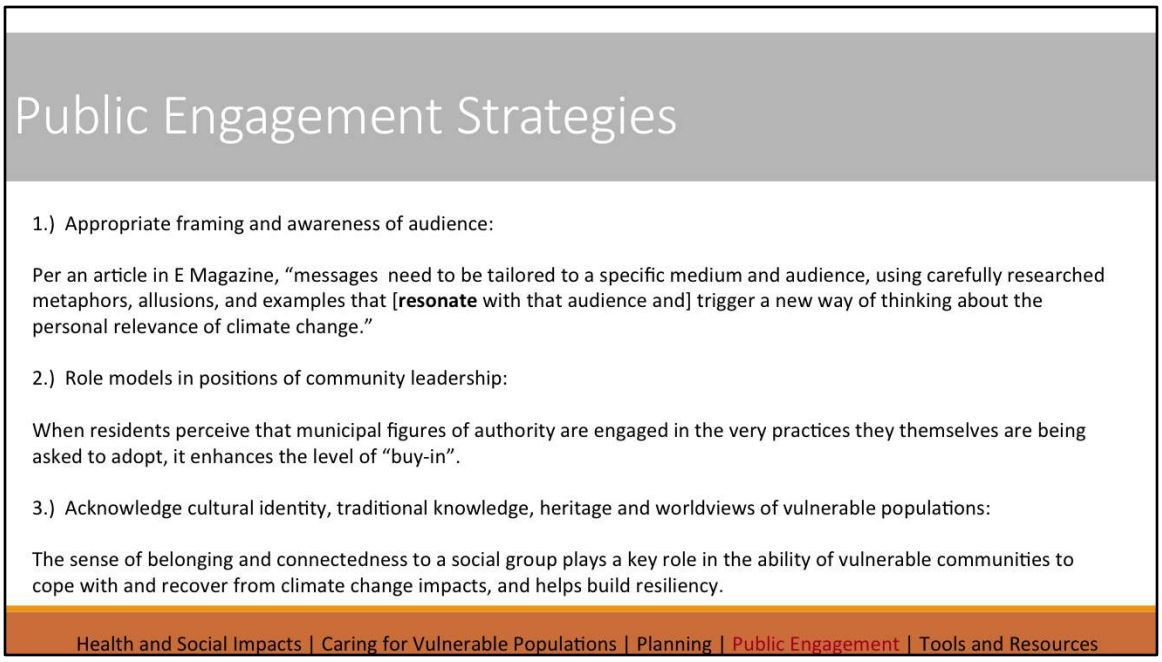
From Theory to Practice: A Canadian Case Study of the Utility of Climate Change Adaptation Frameworks to Address Health Impacts (2011), https://www.ccadaptation.ca/en/component/k2/item/2651-from-theory-to-practice-a-canadian-case-study-of-the-utility-of-climate-change-adaptation-frameworks-to-address-health-impacts-2011

"A robust social infrastructure plays a significant role in our everyday lives, serves as the first line of defense during disasters, and can mean the difference between survival and tragedy."
http://cdn.americanprogress.org/wp-content/uploads/2013/08/LowIncomeResilience-3.pdf

Guest speaker?

Insert bio information in this slide

Engaging the public and vulnerable populations



From http://www.cakex.org/content/using-social-media-foster-climate-change-resilience, document entitled "Using Social Media to Foster Climate Change Resilience":

"The underlying sense of 'belonging' and 'connectedness' to a social group can play a key role in the ability of vulnerable communities to cope with and recover from the impacts of climate change. Acknowledging the linkages between cultural identity and climate change resilience is particularly relevant within vulnerable developing contexts given the richness of their traditional knowledge and cultural heritage, the need for innovative responses to the challenges posed by climate change, as well as the new opportunities provided by information and communities technologies (ICTs) to access, assess and use information and knowledge. The notion of cultural identity is linked to the way in which we relate to the customs, practices, languages and worldviews that define a group or territory. It involves the conservation of social memory, the generational transfer of indigenous knowledge, the ability of a community to self-organise around common interests and shared values, and the maintenance of social networks that are based on trust and solidarity, among others. All of these factors are pivotal in the capacity of vulnerable communities to deal with change and uncertainty, and to build resilience in the face of climate change."

Social Media and Public Engagement

From cakex.org: *"The use of **ICTs** (internet and community technologies such as facebook, blogs, wikis, etc.), can change the way in which we see ourselves and interact with others, and thus influences cultural identities."*

Pros: ICT tools can strengthen cultural identity through the documentation and sharing of indigenous knowledge and traditions, the production of local content, improved access to updated information for decision-making, the facilitation of self-organization processes, and consolidation of effective communication networks, among others.

Cons: ICTs could undermine the cultural identity of marginalized rural communities by introducing new forms of exclusion, or by fostering homogenization, youth migration, or the adoption of external practices and values that weaken or even contradict traditional customs.

Source: http://www.cakex.org/content/using-social-media-foster-climate-change-resilience

Imagery: www.facebook.com, https://encrypted-tbn2.gstatic.com/images?q=tbn:ANd9GcQQ7Kib3E-SNRpX6f3JkeBuASADejyfQMFOfbJnoHFXYBApgbDJ
www.instagram.com

Social Media and Public Engagement

Socia media may:

- Provide real-time access to events as they unfold, aiding in emergency communications
- Facilitate rapid dialogue across distances, generations and party lines; foster diversity
- Help translate scientific or complex information into more comprehensible nuggets
- Foster dialogue about contentious issues
- Give voice to local needs and help connect people with essential resources in their neighborhoods
- Strengthen social networks and promote self-organization
- Empower youth and renew cultural identities

The sense of 'belonging' and 'connectedness' stemming from social media may help reduce vulnerable populations' anxiety and uncertainty associated with climate change impacts, as well as improve the local responses through stronger networks, flexibility and self-organization.

East Coast residents charge their mobile devices in the aftermath of Superstorm Sandy. Above: National Weather Service alerts keep cell phone users apprised of severe weather developments.

Source:
http://www.trust.org/item/?map=can-cultural-connections-boost-adaptation-to-climate-change/
http://www.cakex.org/content/using-social-media-foster-climate-change-resilience
http://www.gsmnation.com/blog/2012/11/16/shake-charge-phone/

Imagery: http://www.gsmnation.com/blog/wp-content/uploads/2012/11/Avoid-This-Sandy-Disaster.jpg
https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcQeiLwjOd3GFH8HOlPP0-Sj1BdcAmcjBZVUFkcX3FTe63oGfzRZ

Tools, Resources and Examples

Training and Guidance Tools

Training tools:

- MARS Seminars, developed by the Great Lakes and St. Lawrence Cities Initiative
- Climate Change Adaptation and Health Equity Workshop, offered by Clean Air Partnership, Toronto Public Health
- MGT 338 Risk and Vulnerability Assessments for Rural Communities

Step-by-Step guidance tool:

- Community-Wide Vulnerability and Capacity Assessment (CVCA)

Community-Wide Vulnerability and Capacity Assessment Tool (CVAT) is a GIS map overlay procedure that

- Enables a relative risk/vulnerability analysis of coastal communities to a series of existing threats
- Is comprised of 7 steps:
  - Hazard identification and prioritization;
  - Hazard analysis;
  - Critical Facilities analysis;
  - Social analysis;
  - Economic analysis;
  - Environmental analysis;
  - Mitigation opportunities analysis.
- Offers a CD-ROM step-by-step guide, with a detailed case study from North Carolina
- Illustrates use of Community Vulnerability Methodology Assessment in a specific community

The MGT 338 Risk and Vulnerability Assessments for Rural Communities is an 8 hour instructor led course on management-level. It is designed to educate

Hazard Assessment Models and Tool Examples

Hazard Assessment Models:

- Canada – Emergency Preparedness Canada (EPC)*
- US – Federal Emergency Management Agency (FEMA)
- Sweden – Swedish Rescue Services APELL program
- Australia – Emergency Measures (SMUG model)
- US – National Oceanic and Atmospheric Administration (NOAA)
- UN – UN Disaster Relief Organization (UNDRO)

Examples:

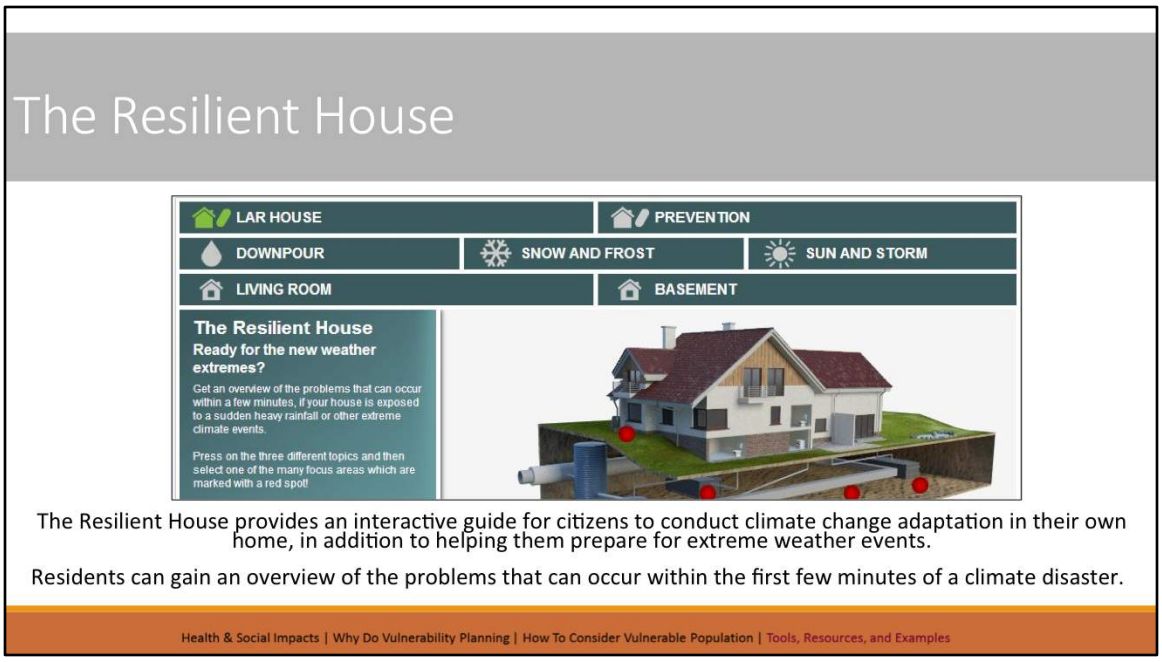
- Vector/water Borne Disease Programs, OMNR
- Heat Vulnerability Mapping, City of Toronto
- Case study of public health risk management in Ontario, Canada

Image: http://www.ping4.com/wp-content/uploads/2013/05/fema_logo.jpg

Additional Tools

- The Resilient House
- Maps of socioeconomics and climate change in the Great Lakes Region
- Community Vulnerability Assessment Tool (CVAT)
- Case studies!

Image: http://www.ping4.com/wp-content/uploads/2013/05/fema_logo.jpg

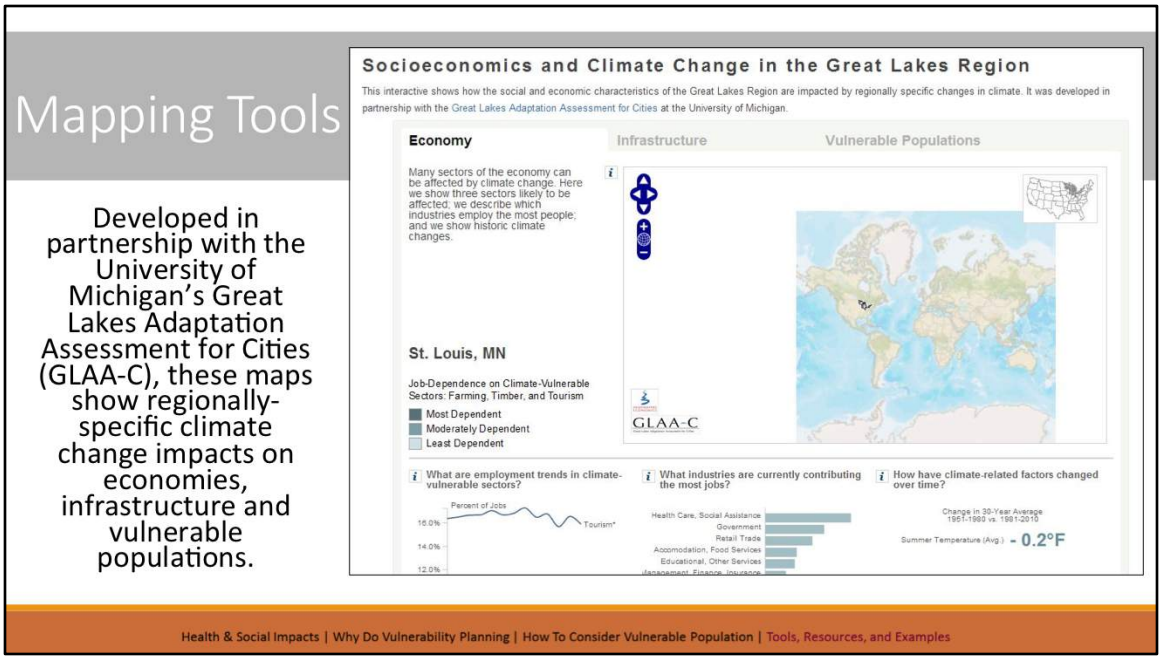


Source: http://en.klimatilpasning.dk/tools/theresilienthouse/theresilienthouse.aspx

Image: http://www.ping4.com/wp-content/uploads/2013/05/fema_logo.jpg

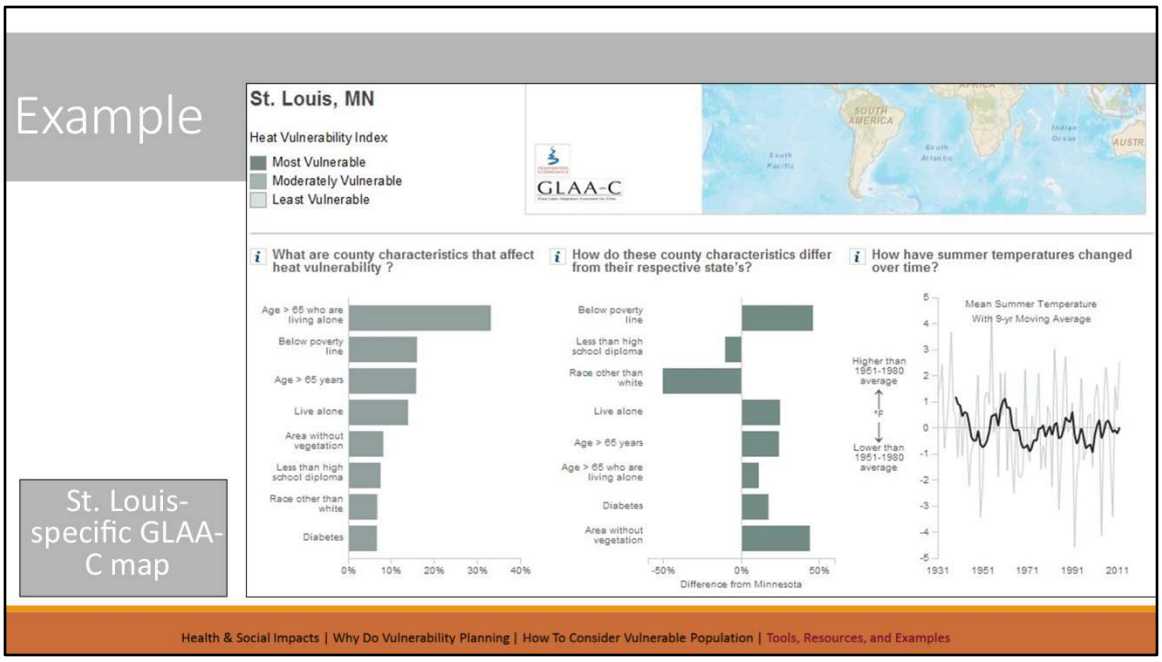
The Resilient House: There can be many reasons for a flooded cellar. Perhaps it is due to wastewater from the sewer or perhaps it is intruding groundwater and rainwater. A good approach to issues is often to perceive the water as a resource instead of a problem. Local drainage of rainwater (LAR) is one method by which excess rainwater can be managed close to the source. This can be by retaining the water and later allowing it to soak into the soil or evaporate, or by leading it to areas where it will cause less damage. The water can also be channelled into barrels and tanks, from where it can be used as a resource and reduce household water bills. In this scene there are examples of LAR methods and examples of how you can collect and use rainwater.

Source citation:
"The resilient House" http://en.klimatilpasning.dk/tools/theresilienthouse/theresilienthouse.aspx



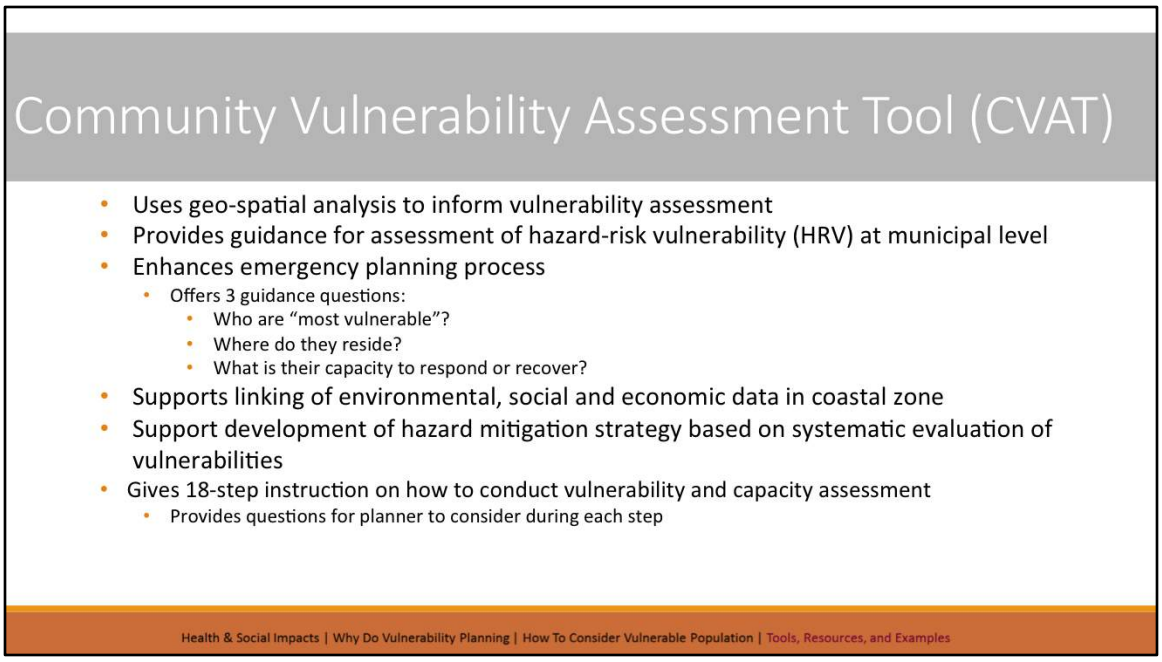
Mapping Socioeconomics and Climate Change in the Great Lakes Region Developed in partnership with the Great Lakes Adaptation Assessment for Cities (GLAA-C) at the University of Michigan, Mapping Demographics and Climate Change - Socioeconomics and Climate Change in the Great Lakes Region is an interactive map showing how the social and economic characteristics of the Great Lakes Region are impacted by regionally specific changes in climate. The map features statistical information on over 225 counties throughout the Great Lakes region. The site includes maps for Economy, Infrastructure and Vulnerable Populations.

Source citation:
http://graham.umich.edu/glaac/great-lakes-atlas
Image: http://graham.umich.edu/glaac/great-lakes-atlas

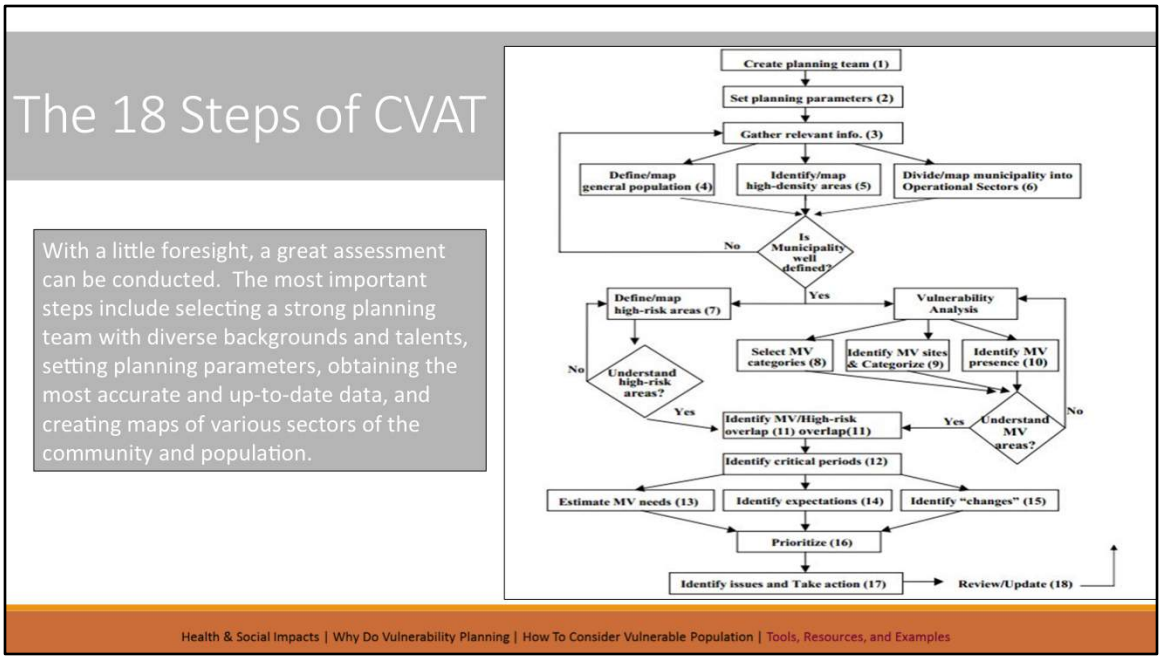


In the example shown, we've selected "St. Louis" on the map. This tool indicates all the demographic information of the vulnerable population(s).

Source citation:
http://graham.umich.edu/glaac/great-lakes-atlas
Image: http://graham.umich.edu/glaac/great-lakes-atlas

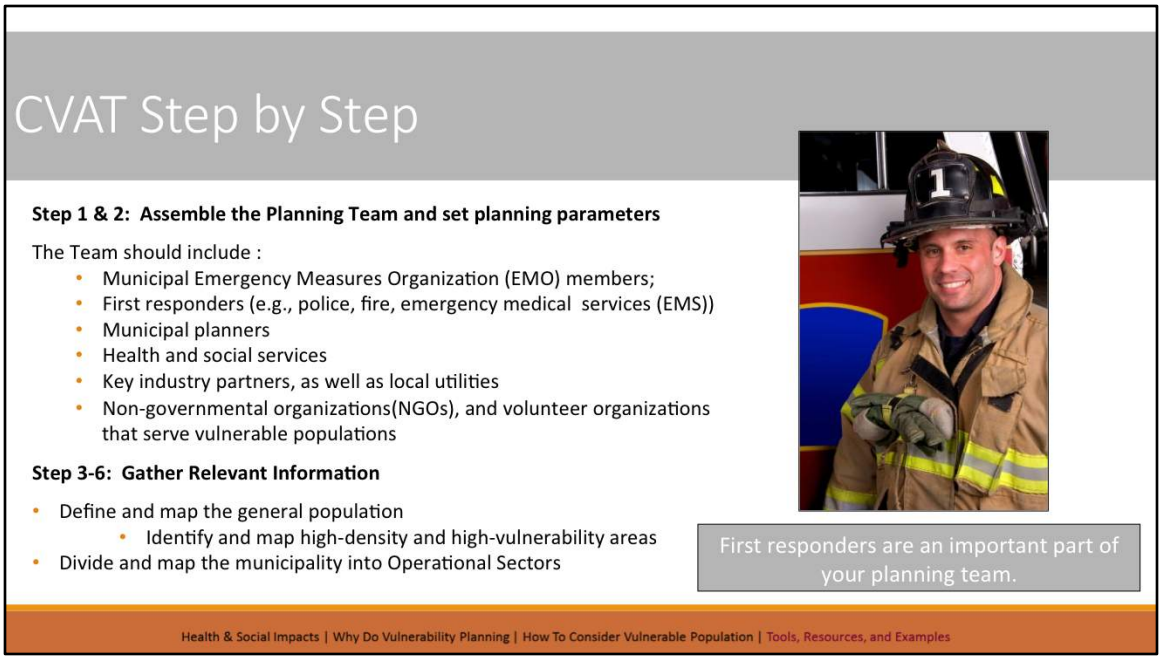


Source:
https://www.ccadaptation.ca/en/component/k2/item/2671-community-wide-vulnerability-and-capacity-assessment-2001



The Steps of CVAT

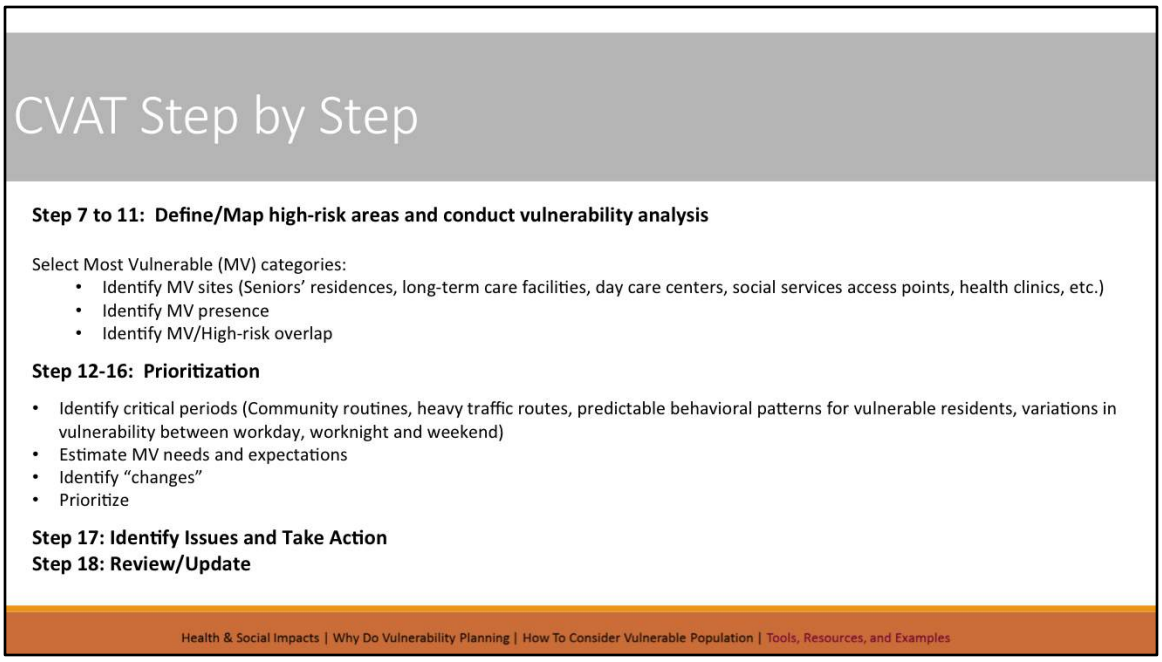
1.) Create the Planning Team;
2. Set planning parameters;
3. Gather relevant information;
4. Define and map the general population;
5. Define and map high-density areas;
6. Divide and map the municipality into "Operational Sectors";
7. Define and map "high-risk" areas;
8. Select applicable categories for the "most vulnerable" (see category list);
9. Identify, categorize (as full or part-time), and map sites related or specific to the identified "most vulnerable" groups (e.g., seniors' homes, long-term care facilities, day-care facilities, social services access points, or clinics);
10. Identify and map other areas where each of the "most vulnerable" groups has significant numerical presence;
11. Identify intersection or overlap of "most vulnerable" groupings and "high-risk" areas;
12. Identify critical periods (e.g., D=workday hours, N=workday night, H=weekend/holiday) when each group is particularly vulnerable;



Step 1: This is the first step of the process and involves establishing a multi-disciplinary team of "experts" or people knowledgeable about a diversity of issues relating to emergency planning, disaster response and recovery operations. The Team should include representatives of the following: The municipal Emergency Measures Organization (EMO), response organizations (e.g., police, fire, emergency medical services (EMS)), municipal planners, health services, social services, key industrial sites or industries, local NGOs, and key volunteer organizations (i.e., those representing or those servicing vulnerable populations).

Step 2: As early as possible, the Planning Team should establish the parameters for their planning process. In other words, they should attempt to define the boundaries of what they will strive to achieve, how they will work to do so, for how long, with what resources, and so on.

Step 3: This analysis process, like all others, is as accurate as the information upon which it is based. Therefore, it must have accurate, comprehensive and timely information, which is best provided by those who know best. Team members should be advised of the basic information desired or required, and be tasked to gather it before any other activity is commenced. Additional information is likely to be



Step 7: Define and map "high-risk" areas
This step is intended to focus attention on those areas that, for whatever reason, are deemed to be high risk. If the CVCA model is used with other HRV models, this information may already be well determined. In any case, consider natural hazards (e.g., rivers, lakes, mountain slopes, forested/bush area, or shorelines) as well asthe potential of human-induced hazards (e.g., production or storage facilities, transportation corridors or facilities).

Step 8: Select applicable categories for the "most vulnerable"
A key purpose of this step is to look at vulnerable populations in a broad perspective and to steer away from the more common and often misleading categories of vulnerable groups: young children, seniors, women, people with disabilities, or indigenous populations.

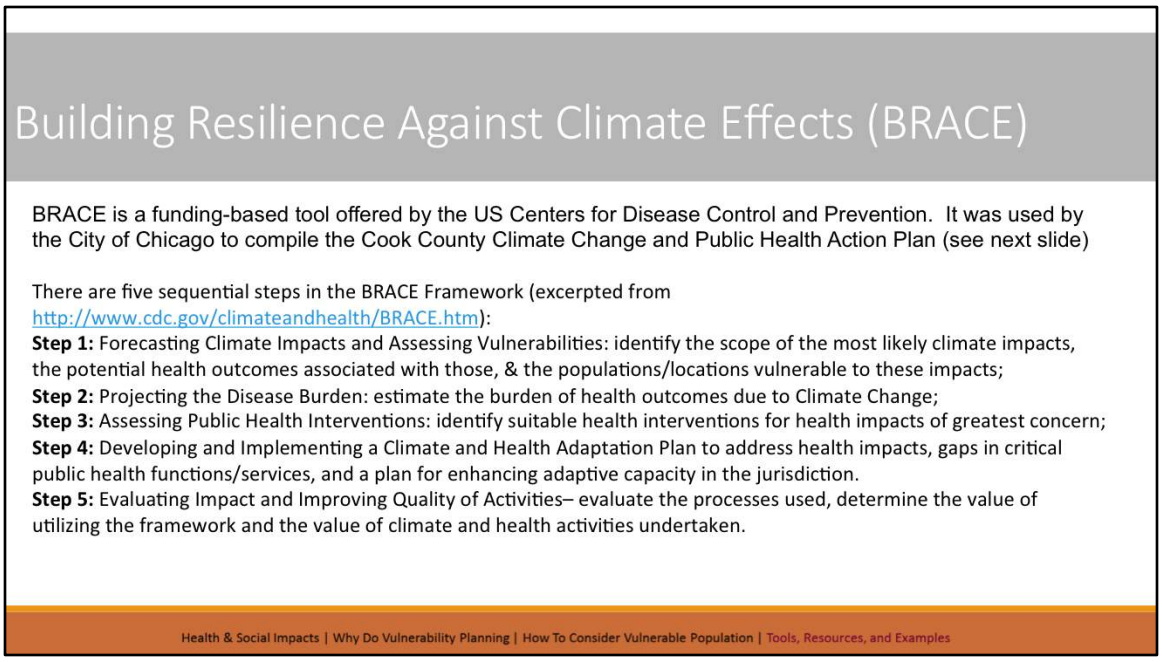
Step 9: Identify, categorize, and map sites related or specific to the identified "most vulnerable" groups.
This step focuses on sites that either relate to or service the needs of those previously identified as "most vulnerable". Such sites or facilities may include seniors' homes, long-term care facilities, day-care facilities, social services access points,

Summary of CVAT

- Provides tutorials, case studies, and framework to determine multi-hazard susceptibility;
- Assists in development and prioritization of hazard mitigation strategies;
- Improves and expedites response capabilities;
- Offers a CD-ROM step-by-step guide.

http://content2.learntoday.info/ben/HADM357_2012/media/CVAT.pdf

Source citation:
http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/5340.php



http://www.cdc.gov/climateandhealth/BRACE.htm
http://braceillinois.uic.edu/
http://www.cdc.gov/climateandhealth/climate_ready.htm

Chicago case study:
The Cook County Climate Change and Public Health Action Plan

In climate change, social factors will influence health and resiliency outcomes.

- Chicago context:
  - Cook County houses over 5 million people
  - 2nd most populous county in U.S.
  - Midwest will experience highest numbers of climate change-related illness and death (Greenough, 2001)
  - Needed a strategic plan to better equip and prepare public health officials

Developed a Public Health Action Plan with Northwestern University, in partnership with Physicians For Social Responsibility

Source citation: Cook County Climate Change and Public Health Action Plan,http://www.chicagopsr.org/PDFs/climatechangepublichealthplancookcounty.pdf

Chicago's resources and goals

Primary funding sources included:

- Northwestern University School of Engineering
- City of Evanston and City of Chicago Public Health Departments
- Board of Directors for Chicago PSR (Physicians for Social Responsibility)
- Sisyphus Family Foundation, as well as individual donors

Additional support provided by the CDC's BRACE program.

Goals and Objectives

1. Examine predicted health outcomes stemming from climate change;
2. Identify risks and vulnerable populations;
3. Focus on planning, preparation and adaptation that can extend to Statewide level.

Source citation: Cook County Climate Change and Public Health Action Plan, http://www.chicagopsr.org/PDFs/climatechangepublichealthplancookcounty.pdf

Focus areas and key takeaways

Focus Areas:

- Extreme Weather
- Foodborne Illnesses
- Vector-Borne Diseases
- Water Quality, Quantity and Waterborne Illnesses
- Air Pollution and Allergens

Mitigation recommendations:

- Properly insulate homes and install energy-efficient fixtures
- Conserve water and retrofit flush/flow fixtures
- Reduce motor vehicle use
- Encourage walking, cycling and public transit
- Eat locally-grown food
- Promote healthier lifestyle

Adaptation recommendations:

- Develop climate models specific to Cook County;
- Identify and map vulnerable populations;
- Promote awareness climate change dangers and improve public communication on all focus areas;
- Improve extreme weather surveillance programs;
- Involve geriatricians, community health physicians, and homeless advocates to review emergency operations plans; improve health services during infectious disease outbreaks;
- Comprehensive messaging regarding refrigeration / need to discard food after power outages;
- Strive to eradicate homelessness;
- Develop climate adaptation plans for local water /wastewater utilities, with more resilient, ecologically-based water treatment infrastructure.

Source citation: Cook County Climate Change and Public Health Action Plan, http://www.chicagopsr.org/PDFs/climatechangepublichealthplancookcounty.pdf

New York case study:

The Albany Climate Change Vulnerability Assessment and Adaptation Plan

Albany's Climate Change Vulnerability Assessment and Climate Adaptation Plan builds off of the ClimAID Report by analyzing how climate change could affect the people, infrastructure and natural resources of Albany. The Plan sought to offer recommendations and strategies for improving the city's resilience and adaptive capacity.

Context:

- The City of Albany is home to 2,398 acres of open space
  - Parks and natural preserves account for 17 percent of the land area in Albany
- In Albany, climate change will likely lead to:
  - Increases in temperature, average annual precipitation frequency and severity
  - Sea level rise

- Possible Local Impact:
  - Stormwater system overwhelm, increased flooding
  - Threats to public health
  - Additional stress on already sensitive ecosystems

Source citation: http://www.albany2030.org/files/Albany%20Vulnerability%20Assessment%20%26%20Adaptation%20Plan.pdf

In Albany, climate change will likely lead to: increases in temperature, including more frequent high-heat days and heat waves; increases in average annual precipitation; increases in the frequency and intensity of precipitation events; and sea level rise along the tidal Hudson River. There is also a possibility that Albany will experience more extreme weather events such as ice storms, thunderstorms (bringing hail and even tornadoes), and tropical storms including hurricanes and Nor'easters.

Source citation: http://www.albany2030.org/files/Albany%20Vulnerability%20Assessment%20%26%20Adaptation%20Plan.pdf

New York's resources and goals

Resources and Tools Used:

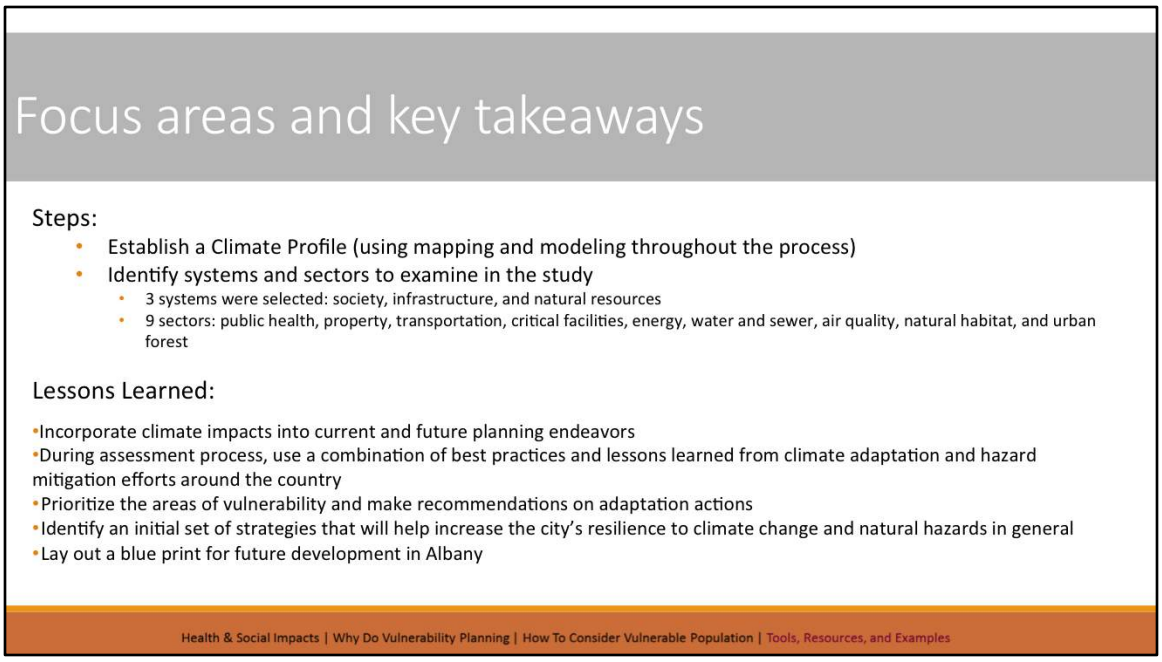
- The Albany County All-Hazard Mitigation Plan
- Historical documents/records
- Federal Hazard Maps
- Federal Emergency Management Agency's National Flood Insurance Program's detailed flood maps and studies
- Geographic Information Systems (GIS)
- Modeling Software - FEMA HAZUS-MH (earthquakes, hurricanes, wind, and floods)

Goals and Objectives

- Assess how climate change will affect the city's systems and sectors
- Provide recommendations and strategies on how to improve the city's resilience and adaptive capacity
- Provide a baseline understanding of the impacts of climate change
- Enable the city to incorporate these impacts into current and future planning endeavors.

In keeping with the concepts of *Albany 2030*, the city's comprehensive plan, the Climate Change Vulnerability Assessment and Adaptation Plan is designed to coordinate with other long-range planning efforts.

Source citation: http://www.albany2030.org/files/Albany%20Vulnerability%20Assessment%20%26%20Adaptation%20Plan.pdf



Source citation: http://www.albany2030.org/files/Albany%20Vulnerability%20Assessment%20%26%20Adaptation%20Plan.pdf

Focus areas and key takeaways

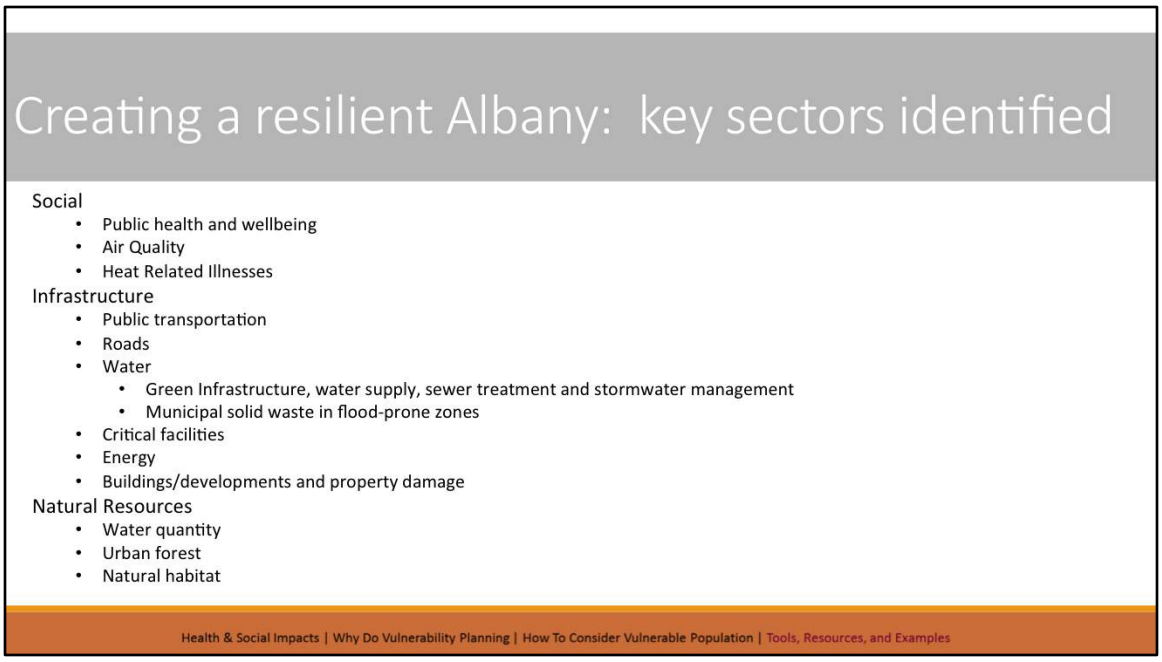
Risk assessment table with likelihood and magnitude of impacts.

Table 22: Risk Assessment with Likelihood and Magnitude Results

CHANGING CLIMATE CONDITION	SECTOR AFFECTED			
	PUBLIC HEALTH	TRANSPORTATION	WATER AND SEWER	CRITICAL FACILITIES
Average Temperature increase of 3 - 5.5 degrees F (high confidence)	High Confidence; Medium Impact	High Confidence; Medium Impact	High Confidence; Medium Impact	High Confidence; Medium Impact
17-49 days over 90 degrees F (high confidence)	High Confidence; High Impact	High Confidence; Medium Impact	High Confidence; Medium Impact	High Confidence; High Impact
5% increase in overall precipitation (medium confidence)	Medium Confidence; Medium Impact	Medium Confidence; Medium Impact	Medium Confidence; Low Impact	Medium Confidence; Low Impact
9 to 12 events with rainfall exceeding 1 inch (medium confidence)	Medium Confidence; Medium Impact	Medium Confidence; High Impact	Medium Confidence; High Impact	Medium Confidence; High Impact
17 to 26 inch rise in Hudson River water levels by 2050 (high confidence)	High Confidence; Low-Medium Impact	High Confidence; High Impact	High Confidence; High Impact	High Confidence; Medium Impact
Increase in frequency or intensity of Nor'easters (medium confidence)	Medium Confidence; Medium Impact	Medium Confidence; High Impact	Medium Confidence; Medium Impact	Medium Confidence; High Impact
Increase in frequency or intensity of Tropical Storms or Hurricanes (low confidence)	Low Confidence; High Impact	Low Confidence; High Impact	Low Confidence; High Impact	Low Confidence; High Impact
Increase in frequency or intensity of thunderstorms (low confidence)	Low Confidence; Medium Impact	Low Confidence; High Impact	Low Confidence; High Impact	Low Confidence; High Impact

This table is easier to see if viewed directly at the link provided below:

Source citation: http://www.albany2030.org/files/Albany%20Vulnerability%20Assessment%20%26%20Adaptation%20Plan.pdf



For specific strategies for each item, please refer to the report at Albany 2030 (link below)

Source citation: http://www.albany2030.org/files/Albany%20Vulnerability%20Assessment%20%26%20Adaptation%20Plan.pdf

Public Health Risk Management in Ontario

Lessons Learned:

- Streamline climate change and health adaptation frameworks to maximize resources;
- Risk management must be informed by good data on climate-related health risks;
- Robust population health assessments, coupled with public education/outreach, are key to protecting populations.

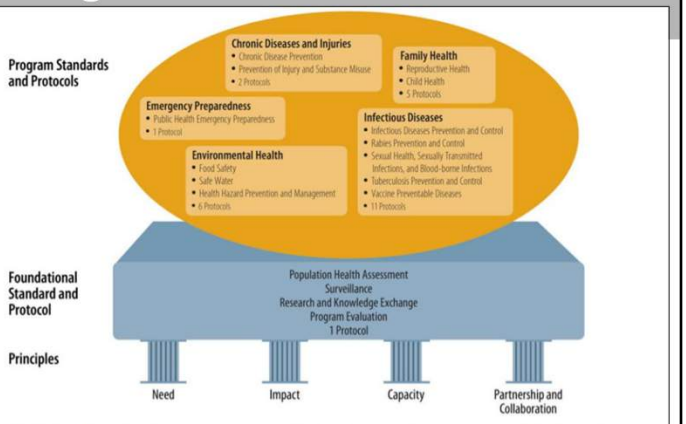


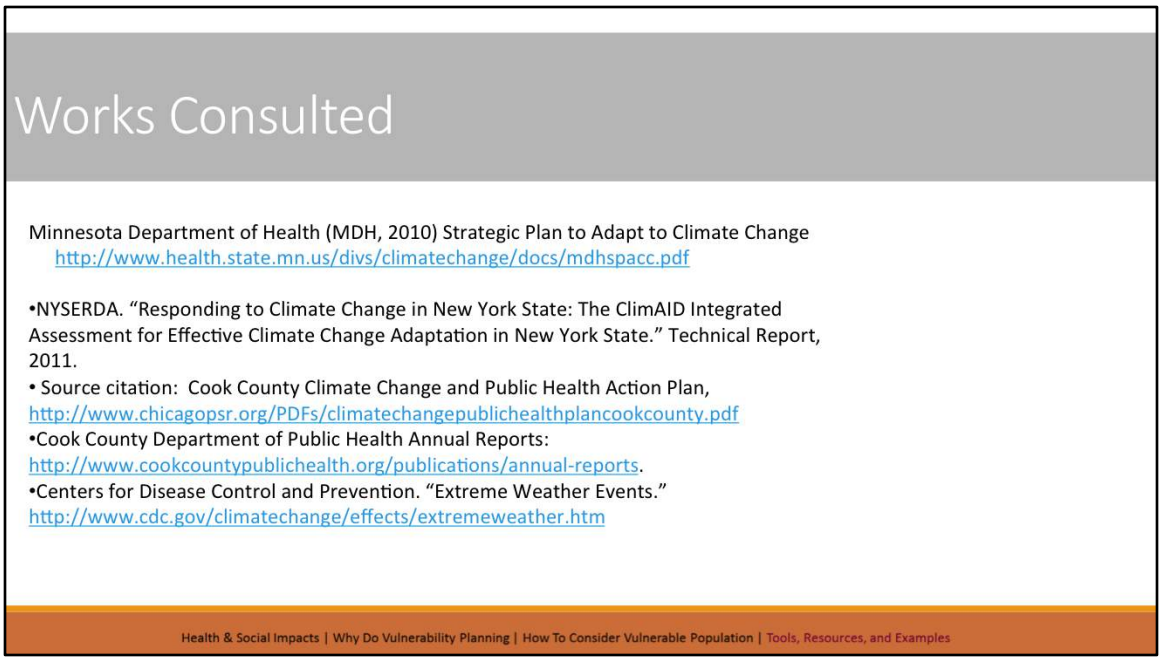
Fig. 1 Ontario Public Health Standards: relationship between the principles, foundational standard, and program standards. *Source*: Government of Ontario 2008

Source: Toronto Public Health, 2014

The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars

[Waiting for the original MARS notes to add to here.]

Source Citation: The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars



Source: Toronto Public Health, 2014
The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars
[Waiting for the original MARS notes to add to here.]

Source Citation: The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars

Supplemental Slide: Massachusets Schools Initiative

- Each school district has a designated school that acts as evacuation site in event of emergency;
- After identifying a need to protect vulnerable citizens during a heat event, the MA Health Department—in partnership with CDC's Climate-Ready States & Cities Initiative—is working with the state's Department of Education to secure funds to install air conditioning in these schools;
- These can then be used as cooling shelters during extreme heat events.

Source citation : http://www.state.gov/documents/organization/218994.pdf, page 19.

Supplemental Slide: Vector and Water-Borne Disease Programs

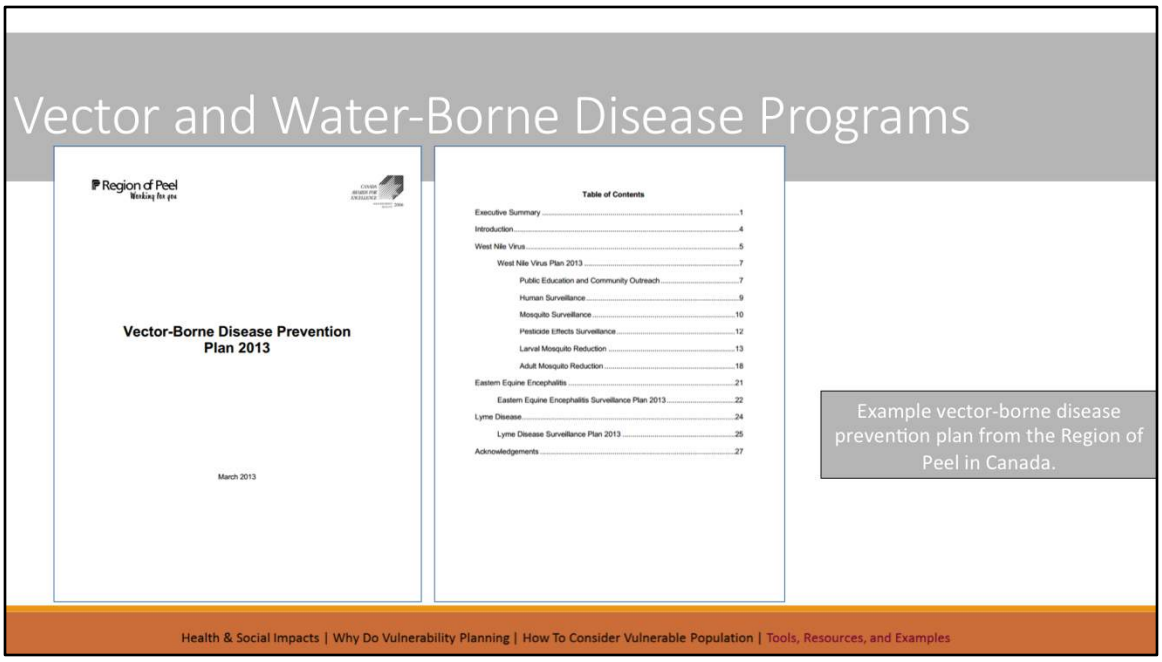
- Enhanced Surveillance
- Enhanced Research and Development
- Enhanced Public and health professional awareness
- Integrated and adaptive policy development

Organisms such as deer ticks pose significant health risks to humans and animals.

Health & Social Impacts | Why Do Vulnerability Planning | How To Consider Vulnerable Population | Tools, Resources, and Examples

[Waiting for the original MARS notes to add to here.]

Source Citation: The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars
Image: http://www.findavet.us/wp-content/uploads/2011/05/deer_tick_sign.jpg



[Waiting for the original MARS notes to add to here.]

Source Citation: The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars

Supplemental Slide: Mold and Bacteria Awareness

Increased basement flooding heightens mold and bacterial growth, which may cause:

- Respiratory distress, including asthma and allergy aggravation;
- Eye and nasal irritations, laryngitis;
- Flu-like symptoms

Adaptation strategies:

- Reduce basement flood risk
- Recognize mold early

Mold is more than a nuisance; it poses a major health threat, especially when undetected.

Health & Social Impacts | Why Do Vulnerability Planning | How To Consider Vulnerable Population | Tools, Resources, and Examples

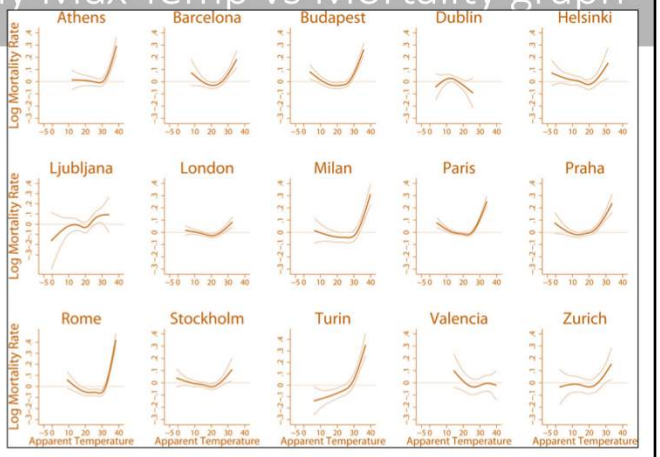
Mold is at a crisis level. Residents will not receive FEMA aid to pay for the mold remediation necessary to make their properties even temporarily livable. --Source: http://strikedebt.org/sandyreport/

Source: Toronto Public Health, 2014
The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars
[Waiting for the original MARS notes to add to here.]

Source Citation: The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars

Supplemental Slide: Daily Max Temp vs Mortality graph

Worldwide, mortality rates increase with increased temperatures, as illustrated by the graph on the right.



Baccinni et al., (2008

[Waiting for the original MARS notes to add to here.]

Source Citation: The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars




Module 5
Water Systems

CLIMATE IMPACTS & ADAPTATION STRATEGIES FOR MUNICIPAL WATER SYSTEMS

Image sources (left to right):

1. Geeta Nambiar, Flickr, 2010 https://flic.kr/p/7YxYkQ
2. Chesapeake Bay Program, Flickr, 2010 https://flic.kr/p/8ScZ6J
3. Arlington County, Flickr, 2004 https://flic.kr/p/6YYbdS
4. Matt Schilder, City of Milwaukee, Flickr, https://flic.kr/p/egqWW

Overview

1. Current and future challenges
2. Adaptation strategies
   - Issues to consider
   - Stormwater control measures (SCMs)
   - Flood prevention
   - Wetlands
   - Drainage and conveyance
   - Inflow & infiltration prevention
   - CSO management
3. Case studies

Image source: Wisconsin Department of Natural Resources, Flickr, 2011 https://flic.kr/p/egqWW

Current and future challenges

CURRENT CHALLENGES & PROJECTED CLIMATE IMPACTS

Image source: Christopher Zurcher, Flickr, 2006, https://flic.kr/p/nSMN8

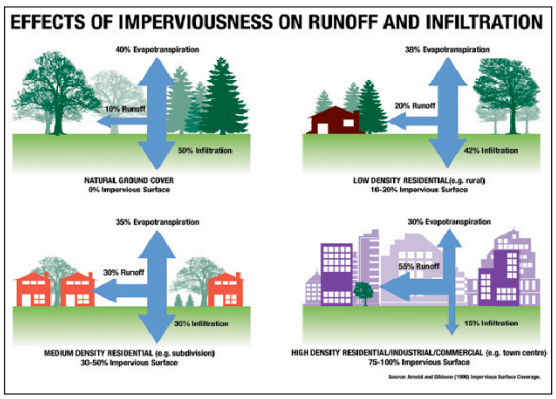
Current and future challenges

Current management challenges

Issues that we're already dealing with:

- Aging collection and distribution infrastructure
  - Over 70% of systems in US Midwest and Northeast are over 40 years old [see age chart and Black & Veatch report]
- Urban population growth and sprawl
- Lack of impervious surfaces
- Combined sewer & stormwater overflows

Today's challenges will be exacerbated by climate change in the coming years



Aging infrastructure:
The US Midwest & Northeast have the oldest water, storm water, and wastewater systems in the country. Even though the industry recognizes that its infrastructure is aging, competing demands for funding mean that renewal and replacement efforts are often slower than what is required. The current rate of replacement for aging collection and distribution systems nationwide is less than 1 percent for most utilities per year.

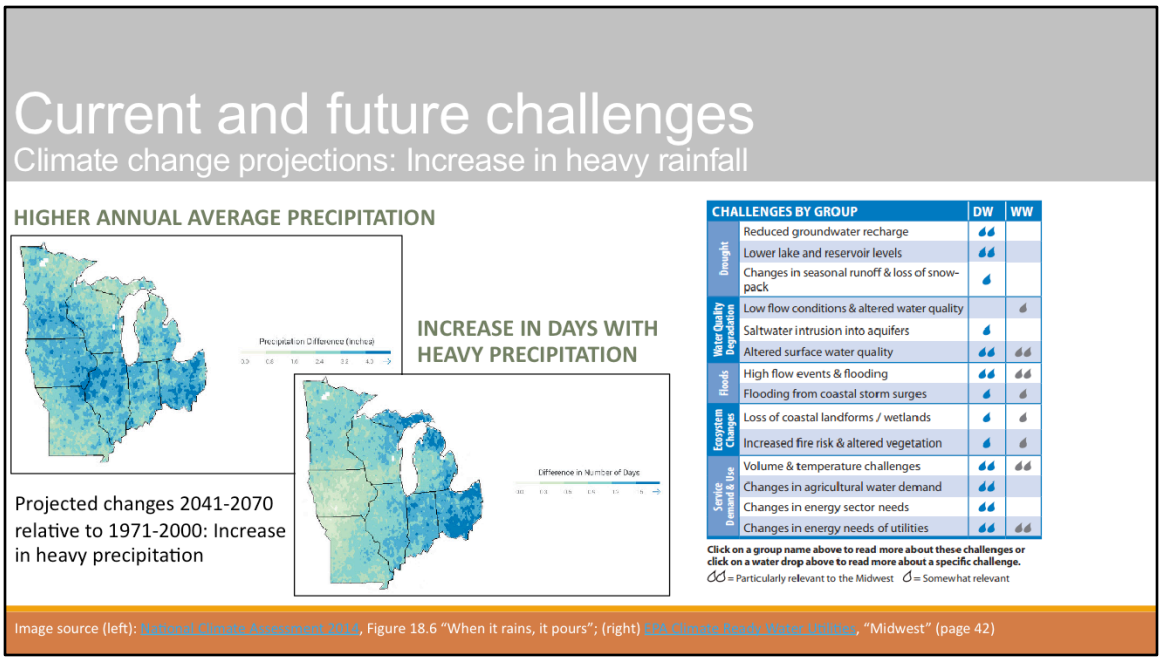
- see regional infrastructure age chart: http://bv.com/images/water-utility-report/2013-06-03-water-industry-report-charts-(bv-com)_fig-6.jpg?sfvrsn=2
- see Black & Veatch report: http://bv.com/reports/2013-water-utility-report/buried-infrastructure

The EPA predicts that the percentage of U.S. wastewater pipe that will be in "poor," "very poor," or "life elapsed" (older than its predicted life span) condition will rise from 23% in 2000 to 45% in 2020. As of 2008, the agency calculated that repairing the nation's sanitary and stormwater sewer infrastructure would cost $298 billion. Climate change could raise the tab even higher.

Urban population growth:
Under the pressure of rapid population growth in the Great Lakes region, mostly in the metropolitan cities, urban development has been undergoing unprecedented growth. For instance, the urban built-up area of the GTA has doubled since 1960s. Sprawl is increasingly becoming a problem in rural and urban fringe areas of the Great Lakes basin

Lack of impervious surfaces:
Changing land use and the expansion of urban areas are reducing water infiltration into the soil and increasing surface runoff. These changes exacerbate impacts caused by increased precipitation intensity.

Combined sewer & stormwater overflows: In CSOs, the same pipes collect rainwater runoff, sewage, and industrial water. Normally, the CSO can handle the whole load and direct it all for treatment. However, during heavy storms, the wastewater treatment plants can't handle the increased volume of



Both the quantity and intensity of precipitation are projected to increase in the Great Lakes due to climate change. Annual precipitation and river-flow increases are observed now in the Midwest and the Northeast regions.

Annual rainfall: Between 2010 and 2069, average annual rainfall could increase by 5 to 10 percent across the US Midwest region. During the late century (2070 to 2099), average annual rainfall could increase 20% over late 20th century levels. Most models agree that winter and spring will see increased precipitation; autumn and summer changes are less certain. In fact, some of these changes are already occurring: more winter precipitation is falling as rain than snow, and snow is melting earlier in the spring. However, it's important to note that there is a lot of regional variability in these projections (as can be seen by the dark vs light blue areas on the map)

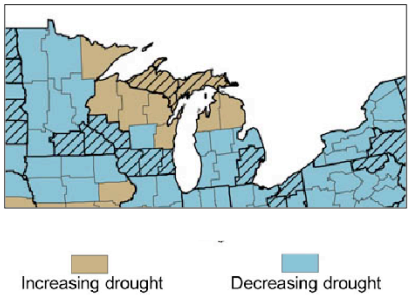
Intense precipitation: The frequency of intense storm events with very heavy downpours—more than 2.5 inches (6 centimeters) in a 24-hour period—is likely to increase as much as 50 percent between 2010 and 2039, and 80 to 160 percent by 2100. By 2100, average annual river and stream flows are projected to increase, though seasonal changes will vary.
- Source: NRDC

Figure source (left): National Climate Assessment 2014, Figure 18.6, http://nca2014.globalchange.gov/report/regions/midwest#statement-16942
Figure source (right): EPA, Climate Ready Water Utilities, Climate Region Brief > Midwest, http://water.epa.gov/infrastructure/watersecurity/climate/upload/epa817k11003.pdf

Current and future challenges

Climate change projections: Increased likelihood of droughts

BOTH WET AND DRY PERIODS INCREASE



PROJECTED CHANGES INCLUDE VARIABILITY IN WATER SUPPLY IN GREAT LAKES REGION

Frequency of both droughts and flooding are expected to increase.

Between heavy rainfall, longer periods without precipitation.

Increasing air temperature + changes in evaporation and evapotranspiration → more variability of water supply in region.

Image source: Impacts on Water Cycle and Water Demand (United States EPA & USGCRP 2009)

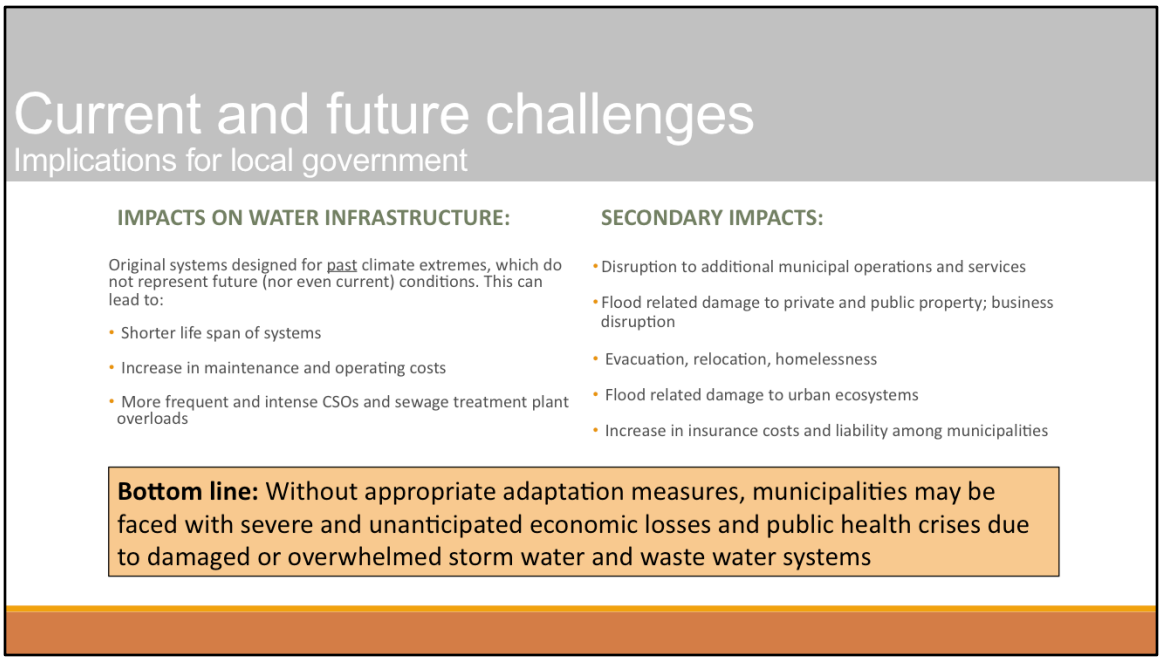
Between heavy rainfall events, there will likely be longer periods without precipitation. Increasing air temperatures along with associated evaporation and evapotranspiration changes as well as alterations to precipitation amount, timing, and duration could lead to more variability of water supply in the Great Lakes region. The frequency of both droughts and flooding are expected to increase. Stream flow, lake levels, and ground water are affected.

Historic context: Since 1970, more area of the United States has tended to be excessively wet (e.g. Mississippi flood). However, during the past few decades a greater proportion of the United States was either in severe drought or severe moisture surplus (Karl et al., 1996). Areas in southern Canada affected by both extreme dry and extreme wet conditions during summer increased when comparing the 1900-49 and 1950-98 periods (Zhang et al., 2000a).

Drought-like conditions in Ontario from 1997 to 2000 Consequences of Regional Climate Change revealed the vulnerability of southern Ontario rural areas to reduced ground water levels; some areas had reductions while others suffered a complete loss of water supply (Piggott et al., 2001).

More information:

- International Joint Commission: “Climate Change and Water Quality in the Great Lakes Region” (http://www.ijc.org/rel/pdf/climate_change_2003_part3.pdf)
- US EPA: Climate Impacts in the Midwest (http://www.epa.gov/climatechange/impacts-adaptation/midwest.html)



Overwhelmed systems: One study estimated that increased storm events will lead to an increase of up to 120% in combined sewer overflows into Lake Michigan by 2100 under a very high emissions scenario (A1FI), leading to additional human health issues and beach closures. Municipalities may be forced to invest in new infrastructure to protect human health and water quality in the Great Lakes, and local communities could face tourism losses from fouled nearshore regions. The bottom line, according to McLellan, is that, between CSOs and failing infrastructure, climate change will not be good for water quality. "If we see on average more intense rainfalls or more extreme rainfalls or a higher number of rainfalls, we're going to have

- Stormwater Strategies: Cities Prepare Aging Infrastructure for Climate Change. Environ Health Perspective. Dec. 2011. [http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3262001/]

Current and future challenges

In the news: Water quality compromised in Lake Eerie

CLIMATE CHANGE & INCREASED RUNOFF TRIGGERING POTENTIALLY TOXIC BLOOMS

- Algae and bacteria responsible for blooms need warm temperature and phosphorous + nitrogen to grow. Climate change creating warmer waters.
- Some blooms (such as the one in Toledo in 2014) can produce toxins that produce neurological problems like paralysis and seizures in people.
- When blooms die, bacteria feasting on decaying matter can result in ecological dead zones.
- Municipalities forced to deal with compounding factors: stormwater runoff, increasing temperatures, agricultural activity, etc

Image source: (Left) Robert Gould, National Geographic, 2014 ; (Right) Joshua Lott, Reuters, 2014

Increased and intense stormwater runoff into the Great lakes, particularly Lake Erie, contributing to algal growth and toxic *Microcystis* threat to drinking water (Toledo), that will put increasing pressure on municipalities to reduce stormwater runoff into the lakes.

More information:

- National Geographic: “Driven by Climate Change, Algae Blooms Behind Ohio Water Scare Are New Normal”, August 2014. (http://news.nationalgeographic.com/news/2014/08/140804-harmful-algal-bloom-lake-erie-climate-change-science/)
- NOAA: Harmful Algal Blooms (http://oceanservice.noaa.gov/hazards/hab/)

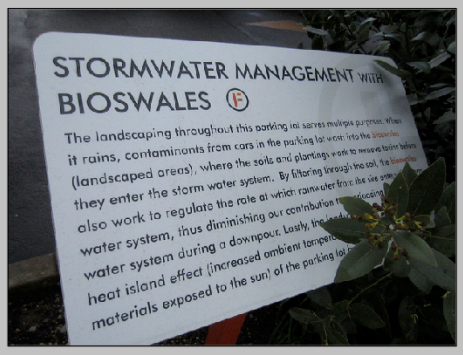
Climate Impact & Risk Assessment Resources:

Climate Resilience Evaluation & Awareness Tool
(CREAT)
Software tool created by the EPA to assist drinking water and wastewater utilities in understanding potential climate change threats and evaluating adaptation options. Free of charge.

EPA National Stormwater Calculator
Desktop application that estimates the annual amount of rainwater and frequency of runoff from a specific site anywhere in the United States. Estimates are based on local soil conditions, land cover, and historic rainfall records.

National Climate Assessment 2014: Midwest
See sections:

- Water Resources
- "Key Message 5: Increased Rainfall and Flooding"



Adaptation strategies

Issues to consider

Stormwater control measures (SCMs)

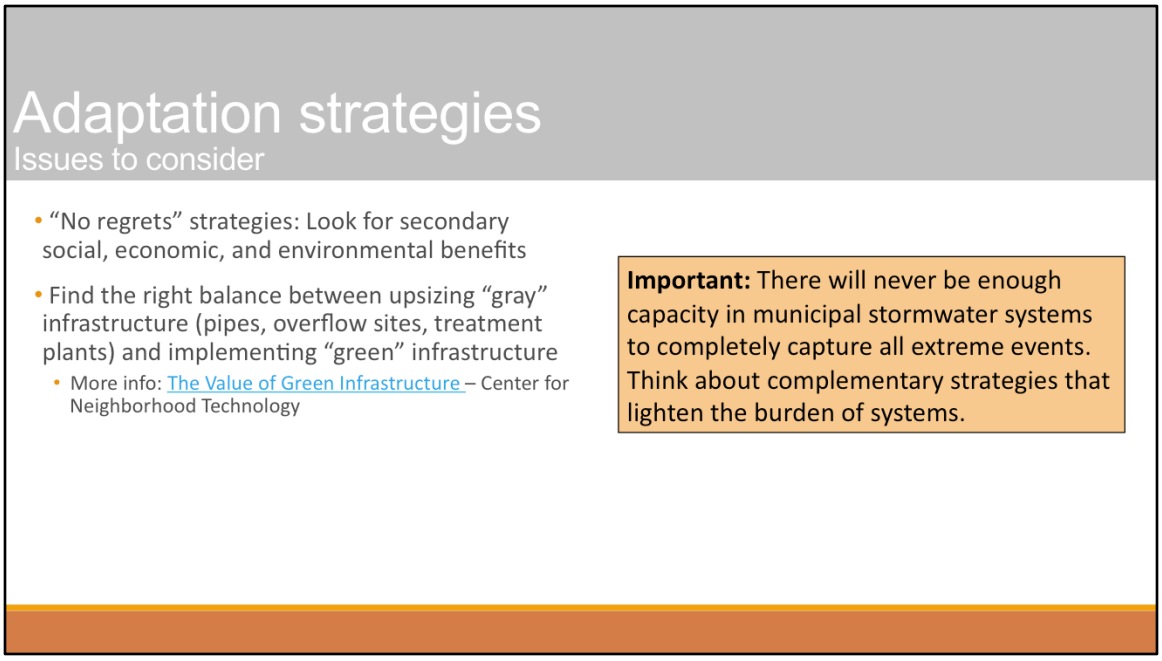
Flood prevention

Wetlands

Drainage and conveyance

Inflow & infiltration prevention

CSO management



No regrets strategies:

- When analyzing strategies that help with stormwater management, seek those that also provide secondary benefits such as:
    - energy reduction
    - cooler cities
    - property value improvement
    - job creation

Gray and green infrastructure:

- E.g. Project Clean Lake in Cleveland, OH: The Northeast Ohio Regional Sewer District (District) was found in violation of the Clean Water Act due to the periodic overflow of untreated wastewater into Lake Erie. In July 2011, the EPA and District filed a Consent Decree specifying new measurements the District would employ to reduce wastewater overflow over the subsequent 25 years. Initially, the District planned to upsize its "gray" infrastructure – pipes, overflow sites, treatment plants, etc. – for an estimated cost of $182 million. However, the District also considered a combination of upsized gray infrastructure coupled with the use of green infrastructure to capture and reduce stormwater flow. The District estimated that the inclusion of green infrastructure would actually save the city an estimated $87 million and achieve better combined sewer outflow capture results. (Source: CakeX, http://www.cakex.org/case-studies/project-clean-lake-updating-clevelands-sewer-systems-reduce-stormwater-overflows)

Adaptation strategies

Stormwater control measures (SCMs)

SCMs:

- Reduce runoff volume and peak flows
- Remove pollutants from runoff
- Can be:
  - **Structural:** any facility constructed to mitigate the adverse impacts of stormwater and urban runoff pollution
  - **Non-structural:** planning and design approaches that limit imperviousness and reduce stormwater and urban runoff pollution

Image: Bioswale in a municipal parking lot in Mt Clemens, MI

Stormwater Control Measures attempt to mimic natural hydrology to manage stormwater runoff closer to its source. SCMs reduce runoff volume by allowing stormwater to infiltrate the ground or evaporate after a storm, instead of piping the water offsite. For example, in this photo, water from an impervious surface (the concrete parking lot) flows into a vegetated bioswale, where it is allowed to seep into the ground. This helps to both reduce peak flows and remove pollutants from rainwater. SCMs can be both structural (such as the bioswale) or non- structural (conservation on natural areas).

Picture source:
http://www.cranbrookfreshwaterforum.org/protect-the-great-lakes.html

Adaptation strategies

SCMs: Best Practices

- SCM implementation works best when designed as a system incorporating both structural and non-structural SCMs on a regional or watershed scale
- Consider nonstructural SCMs before structural practices. Land use planning can reduce runoff and, thus, the need for structural SCMs
- SCMs that harvest, infiltrate, and evapotranspirate stormwater are critical to reducing the volume and pollutant load of small storms

SCMs, when designed, constructed, and maintained correctly, have demonstrated the ability to reduce runoff volume and peak flows and to remove pollutants. Some best practices include:

- **Systems planning and implementation:** SCM implementation needs to be designed as a system, integrating structural and nonstructural SCMs and incorporating watershed goals, site characteristics, development land use, construction erosion and sedimentation controls, aesthetics, monitoring, and maintenance. Stormwater cannot be adequately managed on a piecemeal basis due to the complexity of both the hydrologic and pollutant processes and their effect on habitat and stream quality. Past practices of designing detention basins on a site-by-site basis have been ineffective at protecting water quality in receiving waters and only partially effective in meeting flood control requirements.
- **Nonstructural SCMs such as product substitution, better site design, downspout disconnection,** conservation of natural areas, and watershed and land-use planning can dramatically reduce the volume of runoff and pollutant load from a new development. Such SCMs should be considered first before structural practices. For example, lead concentrations in stormwater have been reduced by at least a factor of 4 after the removal of lead from gasoline. Not creating impervious surfaces or removing a contaminant from the runoff stream simplifies and reduces the reliance on structural SCMs.
- **SCMs that harvest, infiltrate, and evapotranspirate stormwater are critical to reducing the volume and pollutant loading of small storms**. Urban municipal separate stormwater conveyance systems have been designed for flood control to protect life and property from extreme rainfall events, but they have generally failed to address the more frequent rain events (<2.5 cm) that are key to recharge and baseflow in most areas. These small storms may only generate runoff from paved areas and transport the "first flush" of contaminants. SCMs designed to

Adaptation strategies

SCMs: Summary of structural strategies

SCM	What it accomplishes	What it replaces	How it works
Bio-swales	Runoff Reduction	Curb/gutter and storm drainpipes	Shallow, well-drained bio-retention swales that help remove silt and pollutants
Wet and Dry Ponds	Runoff Reduction	Positive drainage from impervious surfaces to gutter	Grading front yard to treat roof, lawn, and driveway runoff using shallow bio-retention
Stormwater Wetlands	Peak reduction and runoff treatment	Large detention ponds	Long, multi-cell, forested wetlands located in the storm water conveyance system
Green Roofs	Runoff reduction	Concrete roofs	Use of vegetation on a roof, placed over a waterproofing membrane, to absorb rainwater as it falls
Pervious Pavement	Increase permeability of impervious cover	Hard asphalt or concrete	Use of permeable pavers, porous concrete, and similar products to decrease runoff generation from parking lots and other hard surfaces

Adapted from: National Research Council Report, 2008, "Urban Stormwater Management in the United States"

Adapted from: Urban Stormwater Management in the United States, National Research Council Report. The National Academies Press, Washington, D.C., 2008.

Structural/engineered SCMs help capture and retain stormwater near where it first falls. These SMCs serve multiple functions (such as preventing streambank erosion, flood control

Examples of structural SCMs include:

- **Bioswales**: a swaled drainage course with gently sloped sides, filled with vegetation, compost, and/or riprap. The swale is designed to remove silt and pollution from surface runoff water and allow water to drain.
- **Wet/dry ponds (also called detention basins)**: wet or dry areas sunk into the ground that are designed to collect runoff during rain events.
- **Stormwater wetlands**: wetlands constructed to absorb excess runoff from storm events.
- **Green roofs**: a roof that is partially or completely covered with vegetation (planted over a waterproofing membrane) that absorbs rainwater as it falls.
- **Pervious pavement**: a special type of concrete with a high porosity that allows water from precipitation events to pass through the pavement.

Source: NRC Stormwater Report

Adaptation strategies

SCMs: Summary of non-structural strategies

SCM	What it accomplishes	What it replaces	How it works
Earthwork Minimization	Conservation of soils and contours	Mass grading and soil compaction	Construction practices to conserve soil structure and only disturb a small site footprint
Watershed Planning	Off-site stormwater treatment or mitigation	On-site waivers	Stormwater retrofits or restoration projects elsewhere in the watershed to compensate for stormwater requirements that cannot be met onsite
Conservation of Natural Areas/ Reforestation	Maximize forest canopy and green space	Mass clearing	Preservation of priority forests and reforestation
Impervious Cover Minimization	Runoff reduction	Large streets, lots and cul-de- sacs	Narrower streets, permeable driveways, clustering lots, and other actions to reduce site impervious cover

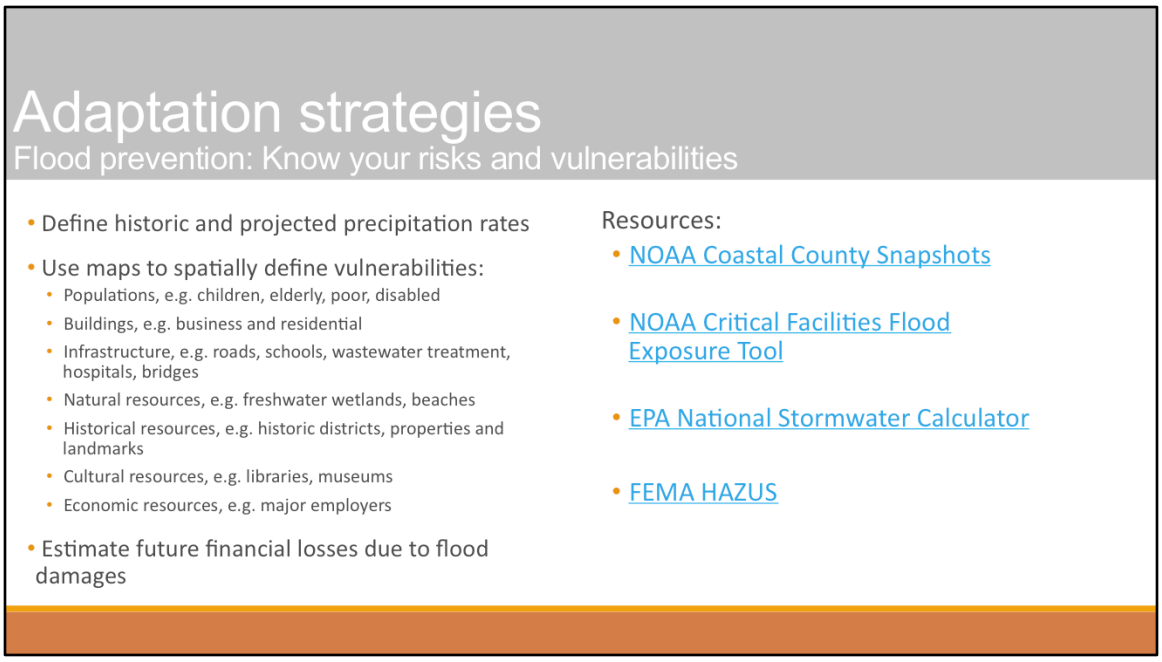
Adapted from: National Research Council Report, 2008, "Urban Stormwater Management in the United States"

Adapted from: Urban Stormwater Management in the United States, National Research Council Report. The National Academies Press, Washington, D.C., 2008.

Non-structural SCMs are generally longer-term and lower-maintenance solutions than structural SCMs, and can also greatly reduce the need for and/or increase the effectiveness of structural SCMs. Examples of nonstructural SCMs include:

- **Earthwork minimization**: limiting the degree of clearing and grading on a development site in order to prevent compaction, conserve soils, and prevent erosion from steep slopes.
- **Watershed and land-use planning**: making land-use decisions that change the location or quantity of impervious cover created by new development through zoning, watershed plans, comprehensive land-use plans, or Smart Growth.
- **Conservation of natural areas**: protecting natural features and environmental resources that help maintain the pre-development hydrology of a site by reducing runoff, promoting infiltration, and preventing soil erosion.
- **Reforestation and soil conservation**: improving the quality of native vegetation and soils present at a site by planting trees and plants, tilling, and amending compacted soils to improve their hydrologic properties.
- **Impervious cover minimization**: reducing the amount of impervious cover through practices such as reducing street, driveway, and parking lot areas; using permeable pavement; and installing swales and other bio-retention areas near impervious surfaces.

Source: NRC Stormwater Report



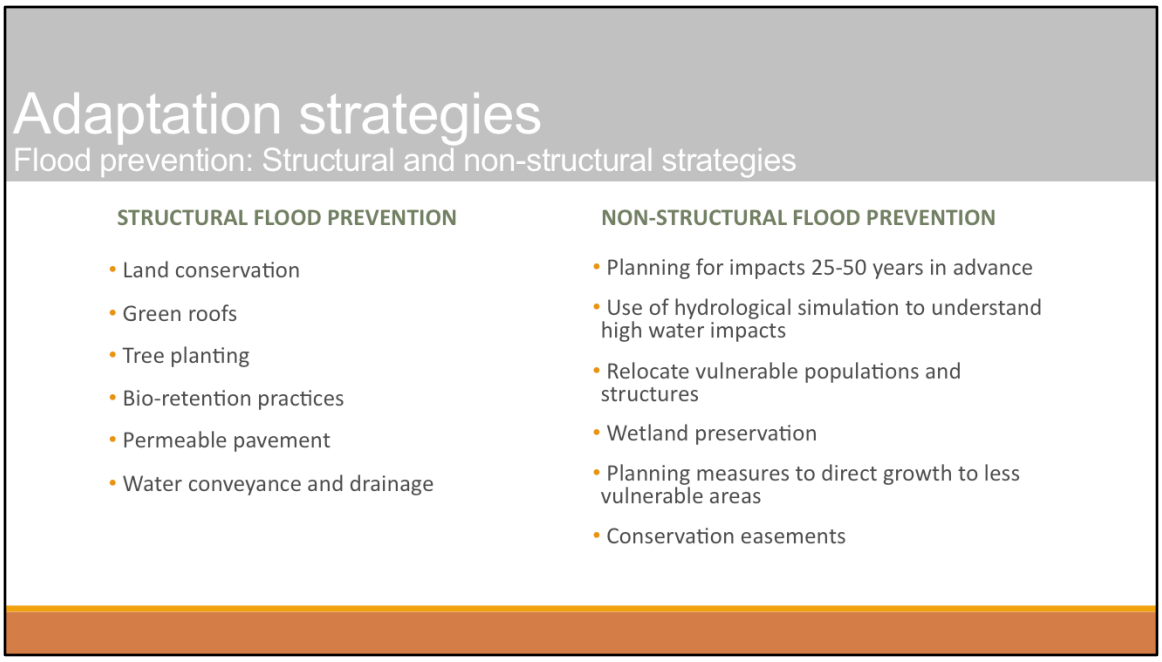
Resources:

NOAA Coastal County Snapshots

Easy to understand overview of hazards for coastal counties, including vulnerable populations and flood map

NOAA Critical Facilities Flood Exposure Tool

Provides quick assessment of



Though numerous flood risk reduction measures are possible, including levees, land-use zoning, flood insurance, and restoration of natural floodplain retention capacity, economic and institutional conditions may constrain implementation. The effective use of these measures would require significant investment in many cases, as well as updating policies and methods to account for climate change, in the planning, design, operation, and maintenance of flood risk reduction infrastructure.
(NCA 2014 – "Water Sector")

Structural flood prevention:
Structural flood prevention is still important. However, regulations may need to be adjusted (such as larger pipe diameters or different configurations of drainage channels). These changes can be incorporated into regularly scheduled maintenance.

Non-structural flood prevention:
Climate change will increase heavy precipitation events and may cause flooding in areas that have not been at risk in the past. Doing an analysis of flood risks using the new FEMA flood maps can help prevent development in areas that may become vulnerable in the future. Anticipating and preventing damage is much easier than restoration afterwards.

Setting aside flood-prone areas can have additional benefits. Often areas that are vulnerable to flooding, erosion, storm surge, and other climate change threats have scenic value that contributes positively to community character. Areas that are difficult to serve efficiently (rural, mountainous, or rocky) may also be scenic. Focusing conservation efforts in these areas can reduce risks to human populations while supporting quality of life, economic development, and infrastructure efficiencies. Such conservation can also create buffer zones to minimize climate change stresses on community resources.

Wetlands have enormous potential for reducing climate related impacts to infrastructure, recreation, agriculture, and other highly valued sectors if they are managed, restored and leveraged in ways that complement these activities. Wetlands can be conserved and restored to improve and manage both the quantity and the quality water resources ensuring that water is available when it is needed in appropriate quantities. Simultaneously this will provide habitat to sustain the Great Lakes' rich wildlife and fishery resources.

Wetland ecosystem services include:
1. Water quantity management – flood storage, groundwater storage, etc.
2. Water quality protection – filtering out pollutants as part of buffering against increased storm runoff and larger precipitation events
3. Hazard management – shoreline stabilization, storm surge buffering
4. Habitat/wildlife protection – including sustaining habitat corridors and maintaining biodiversity, and
5. Carbon sequestration – reducing greenhouse gases.

However, wetlands are more sensitive to climate change than other landscape or deep water habitat types for three major reasons:
1. Flora and fauna in wetlands are more sensitive to changes in water levels than those of lakes, rivers, and streams. For example, lowering long-term water levels even a few inches can be the difference between a wetland or dry ground.
2. Wetlands have been cut off from other wetlands by dams, dikes, roads, and other alterations so wetland plants and animals cannot migrate to other wetlands in response to changes in temperature or water levels.
3. Mankind has already stressed wetlands which has reduced the biodiversity. Reduced biodiversity makes wetlands less robust and more vulnerable to small

Adaptation strategies

Inflow and infiltration (I&I) prevention

REDUCING I&I REQUIRES CONSTANT VIGILANCE AND VARIOUS METHODS:

- Manhole testing with low-pressure air and vaccuum tests
- Inspection via closed circuit television (CCTV)
- Flow monitoring
- Focused electrode leak location system (FELL)

Information source: Water & Wastes Digest, Preventing I&I; RedZone Robotics, Sewer Inflow & Infiltration
Image source: NPCA, Vacuum Testing Backfilled Manholes

Infiltration is groundwater that enters the sanitary sewer system through cracks or leaks in sewer pipes or manhole covers. Inflow, on the other hand, is stormwater that enters sanitary sewers via an illicit connection like a roof drain or down spout. Either way, it's a serious issue for sanitary sewer systems and a community's right to clean water. While it is impossible to control all I/I, it is certainly desirable to reduce I/I when cost-effective.

Ground water infiltrates poorly constructed or aging pipes through pipe defects such as misaligned joints, cracks, fractures, and holes. In wet weather, inflow enters pipes of all conditions through manhole covers, catch basins, and rain water connections. Once in the pipe, excess water must be transported to the plant, reducing the pipe's capacity to transport wastewater. At the plant, the infiltrated water and inflow must also be treated, adding an unnecessary expense to the affected municipality.

The most effective solution for eliminating infiltration and exfiltration is to accurately test sewer lines and manholes. The two commonly used methods to test sewer lines and manholes are with water and pressure. Pressure testing is a proven method of testing sanitary sewer systems. Conducting a low-pressure air test on new sewer lines willensure pipe joints are tight and leak-free. Performing vacuum tests on new manholes ensure that they are structurally sound, correctly installed and leakfree. It is recommended that a vacuum test be given to verify the integrity of all manholes. Manhole testing is performed by creating a vacuum in the manhole and monitoring a gauge for vacuum loss. Vacuum testing identifies potential infiltration and exfiltration problems.

CCTV Inspections. CCTV inspections can be augmented with smoke testing or dye testing to improve their resolving power. However, these types of inspections capture

Adaptation strategies
Water conveyance and drainage

- Increase capacity of downstream systems to carry increased runoff
- Design to take advantage of natural systems
- Improvements can include:
  - Replacing existing pipes and storm systems with larger facilities
  - Armoring to prevent erosion
  - Removing debris
  - Installing smooth liners that reduce channel friction and increase capacity

However, these measures do not address water quality threats! They should be paired with SCMs.

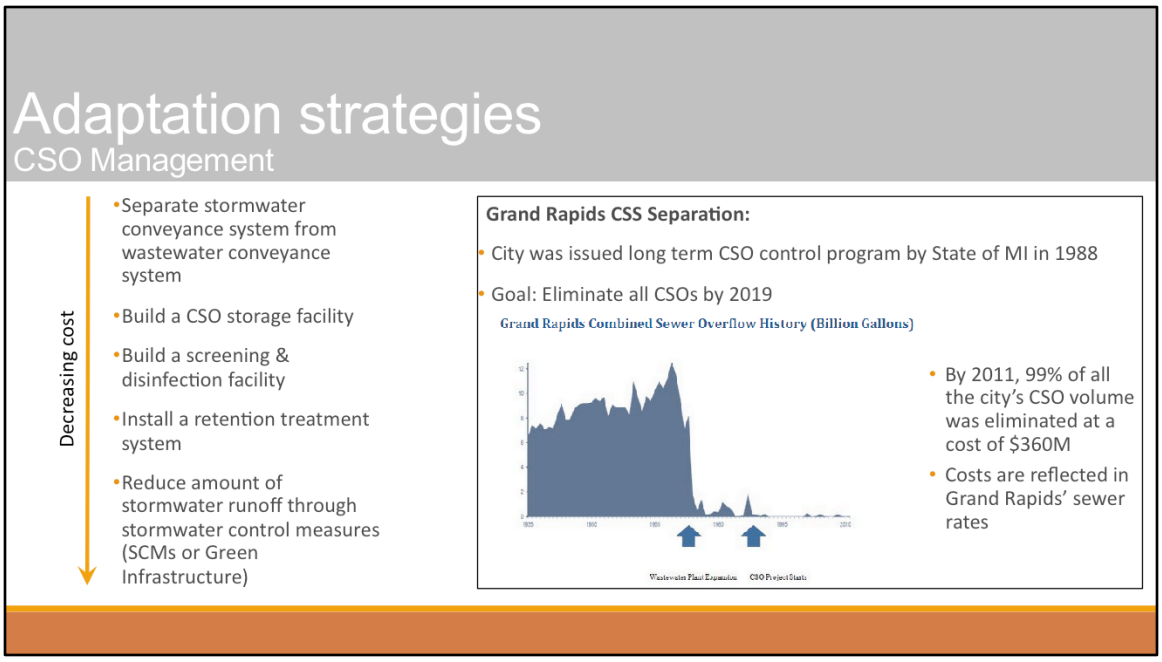
Image source: Amy Greene Environmental Consultants

Every watershed has a storm water conveyance system whether it is natural or manmade, planned or unplanned. When the existing system cannot accommodate existing or future runoff, conveyance system improvements may be warranted.

Increasing conveyance focuses on increasing the capacity of the downstream conveyance system to carry the increased runoff from urbanizing upstream areas. Conveyance improvements should be designed taking full advantage of the natural system, without impacting property, streams, wetlands, or receiving water. However, when the natural system is inadequate because site specific factors limit its utility, it may be necessary to construct structural conveyance devices.

Conveyance devices are designed for routing flows, improving the flow carrying capacity of a drainageway, controlling erosion or diverting flow away from problem or sensitive areas. These improvements involve either replacing existing pipes and storm systems with larger facilities, armoring to prevent erosion, removing debris or installing smooth liners that reduce channel friction and increase capacity.

These features do not improve water quality except by reducing erosion. Many structural facilities increase the concentration of storm water pollutants by directly discharging to streams and bypassing natural filtration processes available in drainageways. In most instances, these devices move flood peaks through a basin faster and worsen flooding in the downstream areas. Regardless of these shortcomings, structural conveyance improvements are sometimes necessary and therefore constitute viable options in the formulation of your stormwater adaptation plan.



CSO separation (most expensive): One of the most effective ways to address the CSO problem is for a city to undertake a sewer separation project—that is, build a second piping system for all (or part) of the community. However, high capital costs or physical limitations may preclude this as an option for most communities.

Alternative options:

- Another solution is to build a CSO storage facility (such as a tunnel) that can store flow from many sewer connections. Storage tunnels store combined sewage, but do not treat it. When the storm is over, the flows are pumped out of the tunnel and sent to a wastewater treatment plant.
- Installing retention treatment basins is another option. These large, concrete tanks store and treat combined sewage by (1) sending the most polluted water (from the first part of a storm) to the wastewater treatment plant after the storm and (2) treating the later flows with bleach.
- Screening and disinfection, or flow-through, facilities treat CSO without ever storing it. They use fine screens to remove solids and sanitary trash from the combined sewage, and inject disinfectant into the flows. All of the materials removed by the screens are then sent to a wastewater treatment plant.
- Stormwater control measures, or green infrastructure, is the least resource-intensive option. We'll dive into different SCMs in the next few slides.

Grand Rapids CSO Separation

[http://grcity.us/enterprise-services/Environment-Services/Pages/Combined-Sewer-Overflow.aspx]

Grand Rapids has been a leader in the State of Michigan in eliminating combined sewer overflow (CSO). Combined Sewers were a common construction practice until the 1920s. In the late 1980s the City of Grand Rapids embarked on a comprehensive

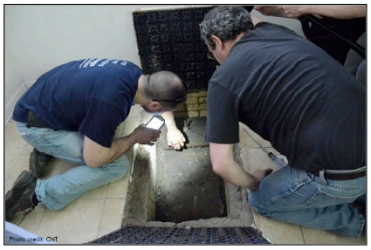
Adaptation strategies

Engaging homeowners and businesses

Most property is privately owned--it's critical to engage private property owners in becoming part of the solution.

Rain Ready for Homeowners
Home assessment, insurance, yard improvements, etc

Stormwater Communications Toolkit
Useful guide that includes sample talking points, "everyday terms", and sample fact sheets



Example programs focusing on property owners:

- Huron River Watershed Council: Work with neighborhood residents to implement low-impact development techniques
- Superior, WI Stormwater Flood Control Program: free site inspection, $150 grants for service lateral inspection, free backwater valve installation
- Milwaukee, WI: adoption of stormwater management fee based on amount of impervious surface

Rain ready for homeowners: http://rainready.org/for-homeowners
Simple methods for available for homeowners in order to better manage water problems.

Stormwater communications: http://choosecleanwater.org/toolkit/stormwatertoolkit.pdf
Tools to help your community understand and support an effective stormwater utility plan.

Huron River Watershed Council: http://www.hrwc.org/millerscreek/
HRWC takes a watershed-approach to increase the vibrancy of the Huron River and its communities. Its Millers Creek program is particularly apt at engaging residents.

Superior, WI Stormwater Flood Control Program: http://www.ci.superior.wi.us/index.aspx?nid=85

Milwauke, WI 2013 Stormwater Management Charge: http://milwaukee.gov/ImageLibrary/Groups/WaterWorks/files/StormWaterManagementCharge_201.pdf
Brief overview of Milwaukee's Stormwater Charge

Stormwater Management Resources:

- **EPA System for Urban Stormwater Treatment and Analysis Integration (SUSTAIN)** (Complex model)
  Decision support system to assist stormwater management professionals in developing implementation plans for flow and pollution control to protect source waters and meet water quality goals.
- **GLSLCI: Stormwater Management in the Great Lakes & St Lawrence Basin**
  Report focusing on specific stormwater practices in the Great Lakes and St Lawrence watershed.
- **EPA Green Infrastructure**
  EPA tools, case studies, and researches on green infrastructure.
- **NRDC: How Water Ready is Your State or City?**
  Interactive map that displays risks and readiness actions by state.
- **Rain Ready**
  CNT's Raiindividuals and communities work together with policies and guides to solve the problem of too much or too little waternReady initiative helps.
- **WERF Whole Life Costing Models**
  The models provide a framework for calculating capital and long-term maintenance costs of individual best management practices and low impact development techniques.

Case Study

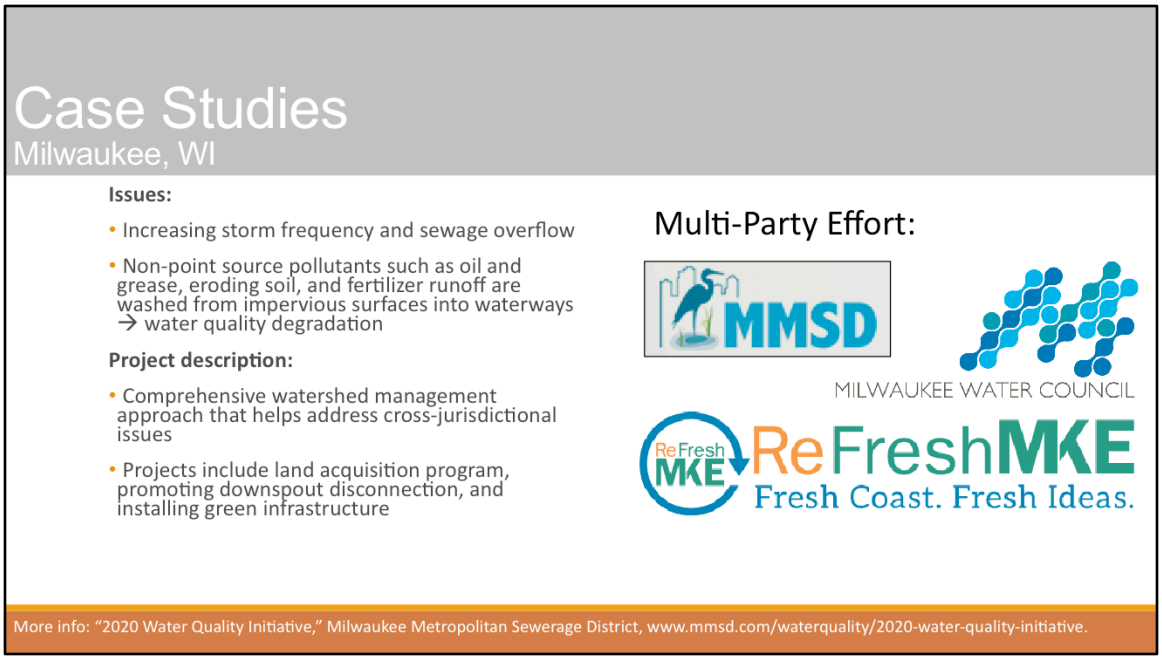
MILWAUKEE, WI

Image source: Brian Koprowski, 2013 <https://flic.kr/p/g3LxVj>

Milwaukee is a leader in climate change adaptation. An increase in extreme storm events have motivated the Milwaukee Metropolitan Sewerage District (sewerage district), City of Milwaukee Office of Environmental Sustainability (sustainability office), and The Water Council (water council) to build a network of programs that engage the public to build resilience to climate change. Building political capital for adaptation following various crises, these organizations have focused on shared resources to empower the private sector and community residents and to build adaptive capacity in Milwaukee.

I thought "building political capital out of various crises" sounded opportunistic—so tweaked.

Changed because "citizens" refers to people who owe their allegiance to the U.S., not local, regional, or state residents. Used "community members," "residents," and the like.



The City of Milwaukee is the largest of 28 communities in the Milwaukee metropolitan area, with a population of around 600,000 and a total area of 96.80 square miles, of which, 0.68 square miles are water. Milwaukee's access to water is a great opportunity, but it presents challenges for stormwater and wastewater management as well as beach quality.

Climate change is predicted to increase storm frequency and intensity in the U.S. Midwest region. The number, duration, and volume of combined sewerage overflows (CSOs) are expected to increase as well. Milwaukee is predicted to experience a 25- to 37-percent increase in the frequency of storm events by 2050.

Milwaukee is already experiencing impacts. In May 2004 Milwaukee experienced 8.9 inches of rain, the most in 110 years. This storm caused a 1.565-billion-gallon CSO. In June 2008, Milwaukee observed 12.27 inches of rain, setting a new maximum-rainfall record for any month.

Major storm events and the foreclosure crisis are two examples in which Milwaukee catalyzed crisis moments into climate action. The city and the sewerage district used the 2010 storms crisis to build the political capital necessary for addressing climate change in two areas: the funding of green infrastructure; and financing enabling homeowner to rebuild the lateral pipe structures that connect pipes in houses to the storm system.

The sewerage district is collaborating with municipalities, nonprofits, and the public to increase access to funds that can help protect water resources. "We helped the region understand that in order to either save money or protect our watershed, we all needed to work together," says Kevin Shafer, executive director of the sewerage district. Its plan identifies the facilities, programs, operational improvements, and

Other Resources

- **EPA Climate Ready Water Utilities Toolbox** (CRWU)
  CRWU Toolbox provides access to resources containing climate-related information relevant to the water sector, including activities, funding information, reports, models, and seminars.
- **EPA Adaptation Strategies Guide for Water Utilities**
  The guide provides adaptation options for drinking water, wastewater, and stormwater utilities based on region and projected climate impacts.
- **Climate Adaptation Knowledge Exchange (CakeX)**
  Hared knowledge base for managing natural and built systems in the face of rapid climate change. Just as importantly, it is intended to help build an innovative community of practice. Features extensive case study library and tools.

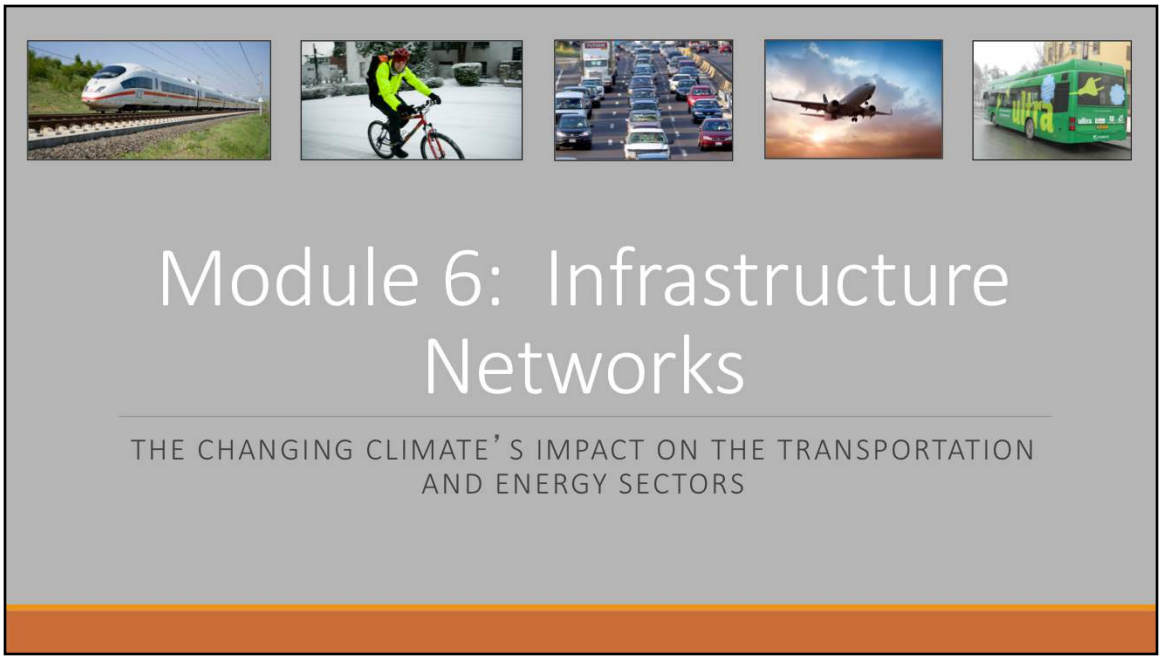


Image credits:

High speed train
http://drupal.in-cdn.net/cdn/article/public/transportation_and_driving_in_germany.jpg

Bike commuter http://www.900mpg.org/images/dave_snow_long.jpg

Traffic
http://media.cleveland.com/metro/photo/traffic-77n-july7-745amjpg-3ac2573c0e5530a6.jpg

Hybrid bus
http://greenbigtruck.com/wp-content/uploads/2011/04/SwedishHybridBus1.jpg

Overview

1. What are the primary impacts of climate change on infrastructure networks?
2. What are the key climate-related challenges and issues to consider in transportation and energy infrastructure planning?
3. Have there been recent, successful municipal efforts to create more resilient infrastructure networks?
4. Are there any resources to assist infrastructure planners?

Primary impacts of climate change on transportation and energy infrastructure networks

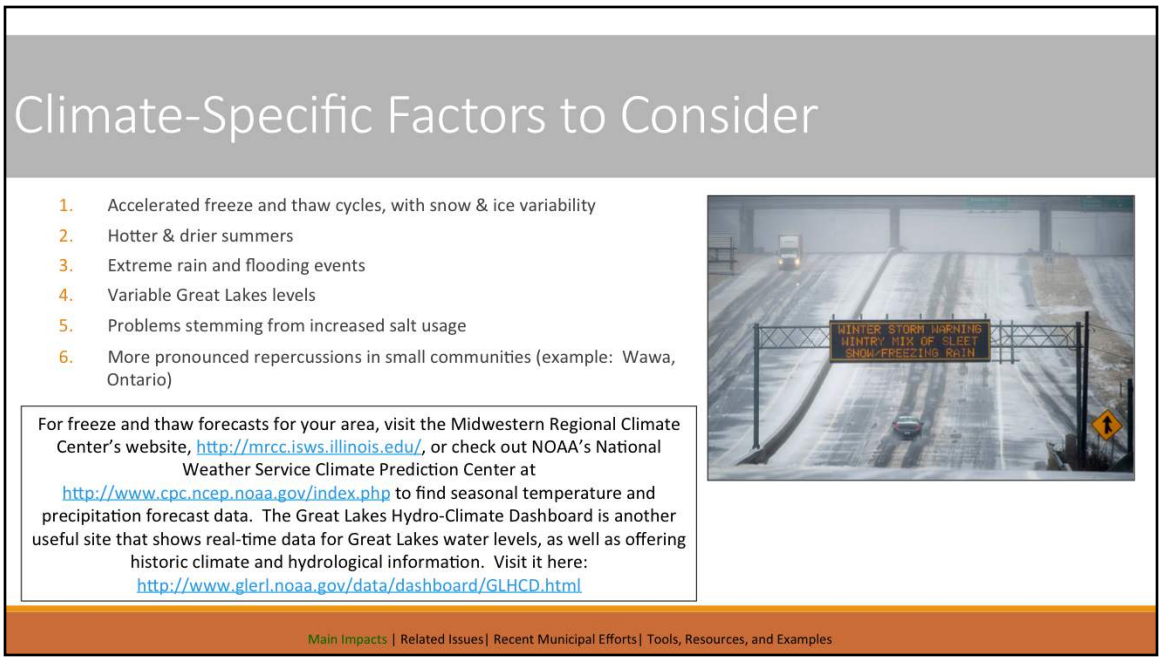
Main Impacts | Related Issues| Recent Municipal Efforts| Tools, Resources, and Examples

Overview of Municipal Infrastructure Impacts

Climate change-related challenges to infrastructure networks

- ✓Infrastructure may be exposed to weather extremes not accounted for in original design. Construction often assumes past climate extremes will represent future conditions
- ✓Severe weather causes shorter infrastructure life span and reduced overall performance, as well as increased maintenance and operating costs
- ✓Climate change may disrupt municipal transit and power operations, compromising public safety
- ✓Severe and unanticipated economic losses can occur due to damaged/overwhelmed infrastructure
- ✓Climate related risks are further aggravated by:
  - Aged infrastructure that has exceeded normal service life
  - Frequent co-location and interdependency of multiple structures
  - Decline in public spending
  - Ballooning populations

"While all orders of government share some responsibility for various aspects of public infrastructure, municipalities carry the greatest responsibility for adapting infrastructure to climate change. So what are the implications of climate change for municipal infrastructure? In the context of climate change, municipal infrastructure is increasingly being exposed to weather extremes that were not accounted for in their original design. This is because construction has historically been based on the assumption that past climate extremes will represent future conditions. In turn, the useable lifespan and performance of city infrastructure becomes reduced, maintenance and operation costs increase, public safety is compromised and municipal operations suffer significant disruptions. Extreme weather events also subject municipalities to severe and often unanticipated economic losses due to necessary repairs and updates to damaged or overwhelmed infrastructure required. These climate related risks are further aggravated by the frequent co-location and interdependency of municipal infrastructure systems. Municipal infrastructure is often like a web of interwoven strands- when one starts to fray, there is a potential for complex failures among surrounding infrastructure. Climate related risks are also further exacerbated by the fact that most municipal infrastructure is aged and has already exceeded its normal service life, and public spending in municipal infrastructure has declined as a result of budget limitations. Moreover, ballooning populations in Ontario municipalities put added pressures on existing infrastructure. Current and projected climate change impacts in the Great Lakes region of Ontario will affect all phases of municipal transportation infrastructure management, from planning and design and construction to operations and maintenance."



The MRCC offers frost/freeze maps, as well as the cli-MATE tool (the **M**RCC's **A**pplication **T**ools **E**nvironment for accessing climate data and value-added tools.) The MRCC also has helpful resources for forecasting vegetation and crop impacts, weather maps and other useful resources.

The National Weather Service Climate Prediction Center offers weather maps, drought and flooding information, and information for severe storm tracking and readiness planning. The Climate Prediction Center also offers climate outlooks that are customizable to a specific time frame: http://www.cpc.ncep.noaa.gov/products/predictions/90day/

The Great Lakes Hydro-Climate Dashboard provides water level information, monthly-level forecasts, decade-long weather trends compilations, and historic and paleoclimate reconstructions as well.

Image: Winter storm warning http://www.csmonitor.com/var/ezflow_site/storage/images/media/content/2014/0212-atlanta-ice-storm/18065471-1-eng-US/0212-atlanta-ice-storm_full_600.jpg

Accelerated freeze and thaw cycles

Accelerated freezing and thawing cycles have been implicated in destabilizing paved and built structures. This may impede automotive, railway, and other forms of transportation, and can undermine motorist, passenger and pedestrian safety. The following infrastructure elements may be negatively impacted:

- Ditches, culverts and drains
- Ramps, bridges, highways, railway lines and tunnels
- Sea walls, locks, lighthouses and water retention structures
- Power lines, generators and digital service towers

This may result in :

- Increased maintenance, repair and reconstruction costs
- Pavement bleeding, cracking and rutting, leading to traffic redirection
- Deterioration of motor, rail and seaways; damage to underground subway lines
- Electricity outages and cell phone service disruption

Road crews in Toronto attempt to clean up cracked pavement in January 2014

[Perhaps this slide could be omitted? I am leaving it in the deck for now, just in case it is useful.]

Notes: Climate change and resulting warmer temperatures has already resulted in a greater frequency of freeze-thaw cycles during the winter months in all of Southern Ontario, except in the Greater Toronto Area where there has been an observed decrease in freeze-thaw cycles. Accelerated freeze-thaw cycles contribute to the rapid deterioration and instability of paved surfaces, particularly ditches, culverts, drains, ramps, bridges and tunnels as water within these structure expand and contract with temperature fluctuations. This results in an increase in the frequency and intensity of bleeding (upward shift of asphalt to pavement surface), cracking and rutting of paved surfaces, and more rapid road surface and structural deterioration. This occurrence increases the potential for required maintenance, rehabilitation and reconstruction of paved structures earlier in their design life.

Sources: IISD Literature Review & References: Canada's First

Climate Change and Transportation

Impacts to motorways

The transportation sector is one of the largest generators of greenhouse gas (GHG) emissions, and contributes to climate change, which then impacts the transportation sector even further. In 2011, transportation represented approximately **27 percent** of total U.S. GHG emissions.

Challenges posed to roads and motorists

The US Department of Commerce estimates that 70% of automobile accidents resulting in death are snow or ice-related. Driving conditions in severe weather can be extremely perilous. Evidence from climate models suggests that an increase in overall severe storm and weather events is likely.

- Damage to paved surfaces from extreme heat, cold and excessive water may result in:
  - Increased danger to motorists from potholes, less stable bridges, visibility impairments (from blowing snow/dust), lessened vehicle traction, lane obstructions and/or submersion
  - Potentially higher repair and maintenance costs, including salting and plowing
  - Reduced life expectancy of roads
- Increased rainfall can heighten flooding, leading to traffic delays, health risks, erosion, infrastructure washout, landslides
- Temperature extremes (fast freezes, etc.) and flooding can also damage vehicles themselves

Main Impacts | Related Issues| Recent Municipal Efforts| Tools, Resources, and Examples

Weather impacts include visibility impairments due to precipitation and high winds (blowing snow, dust), temperature extremes that may affect driver capabilities, vehicle performance (i.e., traction, stability and maneuverability), pavement friction, roadway infrastructure (degree of proper maintenance), potential lane obstructions (downed tree limbs, telephone lines, etc.), crash risk, and overall traffic flow.
-- From http://www.ops.fhwa.dot.gov/weather/q1_roadimpact.htm

Ways to increase resilience to motor transportation include conducing infrastructure vulnerability assessments, ensuring that all new construction is planned and designed in accordance with the latest research on resilient transportation, and taking a systems view. "**System Resilience**: **Transportation systems are more than just the sum of their individual parts**. Some elements are of particular importance because of their vital economic role, absence of alternatives, heavy use, or critical function. The National Airspace System, for example, plays a vital economic role, while hurricane evacuation routes perform a critical function. Transportation systems are potentially vulnerable to the loss of key elements. Therefore, selectively adding redundant infrastructure may be a more efficient strategy than hardening many individual facilities on the existing system. System resilience is best viewed across transportation modes and multiple system owners. While some key elements are

Climate Change and Transportation

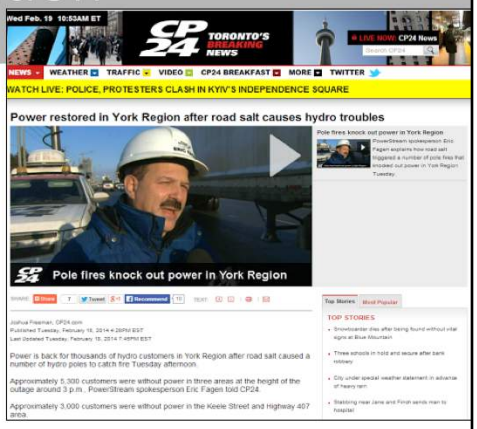
Road Salt Usage

Extreme precipitation events can lead to school, work and small business closures, with a resulting loss of productivity and profit. One way municipalities have traditionally combatted these challenges is with the use of road salt.

However, the chloride in road salt is toxic to aquatic vegetation, wildlife, soils, groundwater, rivers and lakes. Anti-caking agents in salt often contain cyanide, which the EPA classed as a toxic pollutant in 2003. Cold-weather states use 10-15 million tons of road salt every winter, according to the American Association of State Highway and Transportation Officials. Salt alternatives include sand, molasses, beet juice and cheese brine – some of which can cause their own set of environmental impacts.

Road salts may negatively impact ecosystem health (vegetation, wildlife, freshwater habitats, soil pH) and urban green spaces, including trees and parks. Even residents' pets may be harmed. Public drinking water security and private wells are at risk of salt contamination, and concrete infrastructure and railway crossings are often corroded by salt.

Road salt in high traffic areas results in a spray that may get inside electrical equipment and cause short circuiting. Excess salt accumulation can cause traffic signal box malfunctions and contribute to roadway congestion and accidents.



In York, Ontario, over 5000 customers were without power due to salt-created fires on utility poles.

The increased use of salt for incidences of freezing rain will likely corrode bridges and degrade the surrounding natural environment, causing damage to vegetation, street trees, birds & wildlife, freshwater fish, drinking water.Road salt used in high traffic areas results in a spray high in salt concentrate during thaw periods. This gets inside electrical equipment and causes shorting. As part of winter maintenance, crews remove salt buildup, but in harsh winters cannot keep up. Although a projected reduction in average snowpack signifies an overall reduction in snow removal costs for municipalities in Ontario as a result of warming, unusual extreme weather events in the winter months, namely; freezing rain, and rain-on-snow are projected to increase in our region. These types of weather events present a significant challenge to winter road maintenance and road safety in Ontario Great Lake

Climate Change and Transportation

Impacts to Rail Networks

Derailed train in Ohio

Challenges posed to railway infrastructure

Climate affects railroad safety and operations, efficiency, scheduling and demand. The viability of railway transit impacts many passengers, as well as businesses whose bottom line depends on a smooth-running railway system.

Railway tracks can buckle in instances of extreme temperatures, causing repair delays and even derailments. Crossings and bridges are particularly vulnerable. Severe weather may require sudden stops and even re-routing of common train routes.

Subways and below-ground transportation infrastructure are especially prone to risk of flooding. High-speed crosswinds can be particularly hazardous for train operators and travelers. Hazardous cargo may spill if trains derail.

Adaptation strategies may include:

- Increase forecasting capability with real-time data and additional monitoring stations. Improve operational responses to severe weather (avalanches, etc.)
- Identify high-risk earthworks, flooding sites, extreme temperature and high wind zones, and aging infrastructure. Example actions; raise sea walls, increase drainage capacity, increase vegetation of surrounding areas.

Main Impacts | Related Issues| Recent Municipal Efforts| Tools, Resources, and Examples

Network Rail in the UK has developed some interesting and useful adaptation plans (called “Route Weather Resilience and Climate Change Adaptation Plans”) for its various railways throughout the country. The Scotland report details how the country installed new weather monitoring stations: “Improvements in our capability to receive weather forecasts and alerts in Scotland Route
is being provided by the recently installed 102 weather stations” all along the train route. From: http://www.networkrail.co.uk/publications/weather-and-climate-change-resilience/

Sources:
http://www.epa.gov/climatechange/impacts-adaptation/transportation.html
http://2climate.dot.gov/documents/workshop1002/rossetti.pdf

Weather events, climate
oscillations, and climate trends hence affect
railroad safety, including fatalities, injuries, and
property damage. Through their interactions

Climate Change and Transportation

Impacts to Air Travel

Severe flooding at Chicago's O'Hare International Airport in July 2014 caused the delay and cancellation of many flights.
(Source: abc7Chicago.com)

Challenges posed to airlines

- Extreme weather can lead to the grounding of flights
- Runway and aircraft damage may occur with extreme temperatures and excessive precipitation
- Increased business costs (fuel, electricity, insurance, service disruption, ground transportation and lodging for displaced or stranded passengers)
- Sudden (or gradual) changes in demand
- Unhappy customers (and consequent economic losses)

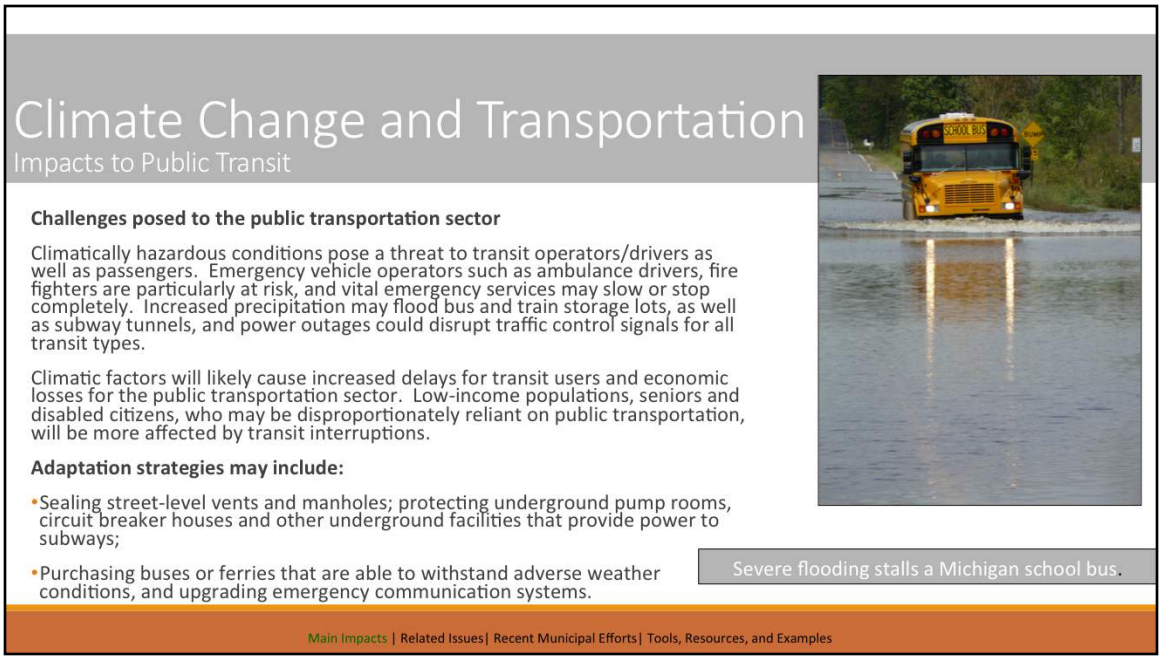
Adaptation strategies may include:

Infrastructure reinforcement, such as sea walls and coastal protection, diversified local supplies/resources (fuel, electricity, water), storm water improvements (like better drainage, pumping, storage), enhanced response programs for disruptions, and Emergency Management Plans.

Main Impacts | Related Issues| Recent Municipal Efforts| Tools, Resources, and Examples

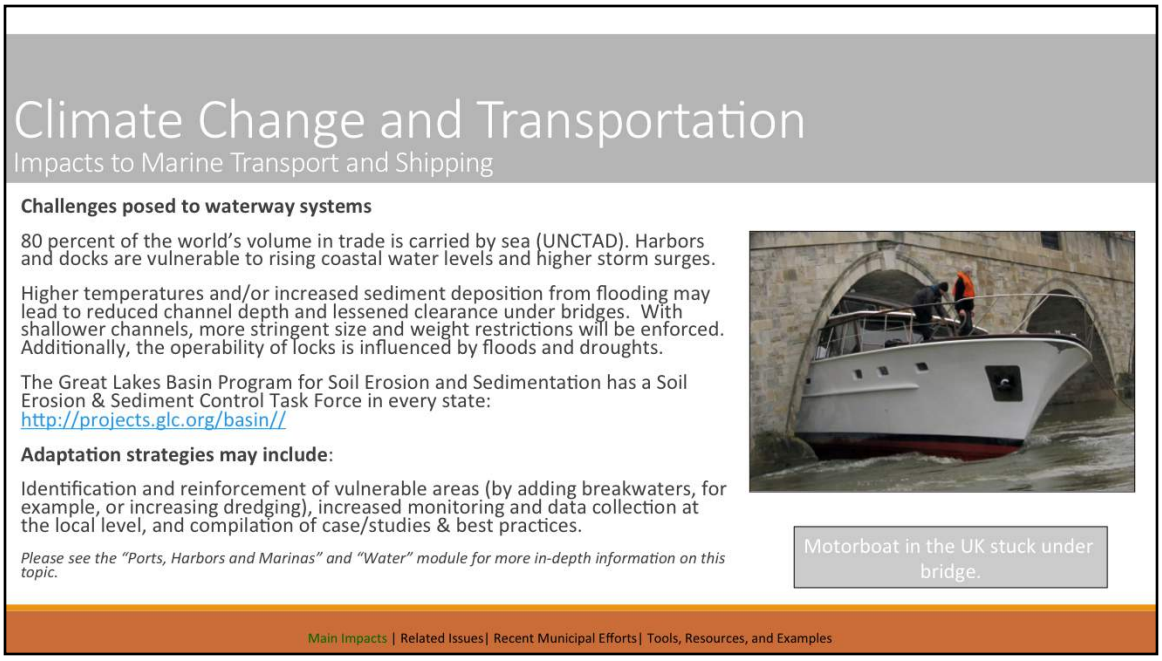
Source:
http://www.aci-na.org/sites/default/files/vanderbilt.p-climatechangeadaptation-sunday.pdf
http://www.epa.gov/climatechange/impacts-adaptation/transportation.html

Image:
http://abc7chicago.com/weather/chicago-weather-i-190-ramps-flood-after-storms/149380/



New York just allocated $3.6 billion in federal disaster releif funds to help rebuild and "harden" its public transit system against climate change. "In general, the projects selected for resilience funding were required to demonstrate that they would reduce the risk of damage to public transportation assets inflicted by future natural disasters. Emphasis was placed on a project's ability to protect the most essential and vulnerable infrastructure, as well as effective collaboration and coordination among local and regional governments. The project evaluation process was rigorous, involving specialists from the FTA, the Federal Highway Administration, the Federal Railroad Administration, and the Federal Emergency Management Agency. FTA received 61 proposals seeking a total of $6.6 billion."
Source: http://www.dot.gov/briefing-room/transportation-secretary-foxx-announces-nearly-36-billion-make-transit-systems-more

In New York in 2010, record snowfall stranded city buses. Flooding in 2007 shut down 19 major segments of the subway system, affecting 2million customers. Hurricane Katrina's storm surge flooded bus terminals and deposited debris, devastating public transit agencies and operations.
--From http://www.fta.dot.gov/documents/FTA_0001_-_Flooded_Bus_Barns_and_Buckled_Rails.pdf



"Sea level rise, which is correlated to changes in global temperatures, appears to be occurring faster than previously predicted and may exceed the ranges predicted by the IPCC AR4 (2007). Ports will be affected by climate change, with the main drivers being sea level rise and extreme events such as storm surges. When assessing the vulnerability of ports to climate change impacts, it is important to also take into account the potential impacts of climate change on coastal transport networks and port hinterland connections. Port operations depend on the integrity of relevant hinterland transport connections; for instance, a failure of critical inland network links may impact severely on port operations…. In 2005, about 40 million people and assets of $3 trillion (around 5 per cent of global GDP) were estimated to be exposed to flood risks, due to sea-level rise and increased storminess and subsidence in 136 major port cities. By 2070, population and asset exposure in the same 136 port cities could rise to 150 million people and $35 trillion respectively. Given the large number of ports globally, overall global asset and population exposure could be of a far greater magnitude. "
Source: http://unctad.org/en/Docs/dtltlb2011d3_en.pdf

Additional notes: (For more in-depth information, please also refer to Ports, Harbors and Marinas module.) Shipping plants and factories may have to adjust shipping

Climate Change and Transportation

Extreme Rain and Flooding

Increase in frequency and severity of:

- Drainage issues and erosion threats to road and bridge structures
- Collapsed culverts, wash out/ inundation of causeways, bridges, low-lying roads
- Pavement and bridge joint expansion and road asphalt softening; compromised bridge structure integrity, due to high winds and channel flow
- Soil moisture, unstable slopes and landslides that cause road and bridge damage, along with service disruption

Modeling and projections can be predictive:

A DOT-funded vulnerability assessment for transportation systems in New Jersey, completed in 2011, was predictive of many of the areas actually flooded by Hurricane Irene and Superstorm Sandy. Similarly, the transportation sections of the City of New York's adaptation plan, completed in 2010, anticipated much of the flooding and damage that actually occurred, particularly the disastrous consequences of flooding highway and subway tunnels into Manhattan.

Climate-related disruptions to transportation infrastructure in the central sub region of Ontario are most likely to be as a result from the increase in frequency and intensity extreme rain events, as well as flooding.More frequent and intense extreme rain and flooding events has the capacity to cause significant drainage issues and erosion to road and bridge structures. It also lends to increasingly overwhelmed culverts.Causeways, bridges and roadways, particularly low-lying ones are particularly vulnerable to wash outs or inundation as a result of more frequent and more intense rainstorms and the resulting overflow of streams and water bodies.An increase in extreme rain and flooding events also causes risks for the joint expansion of pavement and bridge infrastructure, as well as asphalt softening.Added precipitation also increases soil moisture, which lends to slope instability and landslides which could

Increases in the number and severity of hot days in Ontario will likely result in an increase in pavement softening and the distortion of pavement in wheel paths during extreme heat events. This may require municipalities to reduce maximum loads of transport vehicles on paved surfaces on certain routes. Extreme heat events also promote traffic related rutting, flushing or bleeding to old or poorly constructed paved surfaces. Pavement rutting, flushing and bleeding of course affects the functional performance of the pavement (ride quality) and presents implications for safety and maintenance costs. Hotter and drier summers also leads to a shorter lifespan among roads, rail, bridges and culverts

Reference: IISD Literature Review & From Impacts to Adaptation: Canada in a Changing Climate,

Climate Change, Energy and Electricity

An Introduction

The energy sector is a major contributor to global climate change, with renewable energy -- wind and solar fuels in particular – contributing the least. The operation of traffic signals, airline flight control decks, and public transit hubs all require energy to operate.

The National Resource Council and U.S. Global Change Research Program (USGCRP) found that **U.S. energy infrastructure is vulnerable to a range of climate change impacts-**-particularly infrastructure in areas prone to severe weather, blackouts and water shortages.

Air traffic control hubs are one example of where climate change could impact the energy and transportation sectors.

Source:
http://www.cakex.org/virtual-library/climate-change-energy-infrastructure-risks-and-adaptation-efforts

http://www.rff.org/News/Features/Pages/Electricity-Renewables-and-Climate-Change.aspx

Image: http://i.telegraph.co.uk/multimedia/archive/00435/air-traffic404_435384c.jpg

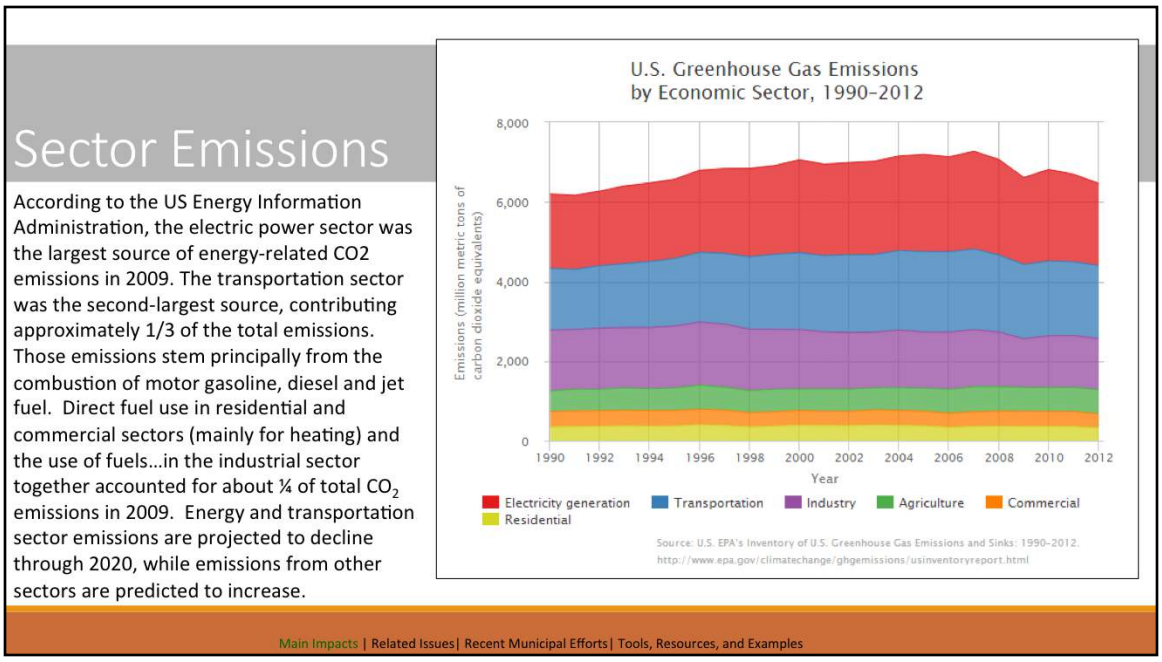


Image source: http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html

"The electric power sector was the largest source of CO2 emissions in 2009, accounting for 40 percent of all energy-related CO_2 emissions. The electric power sector consists of those entities whose primary business is the production of electricity. The transportation sector was the second-largest source, at 34 percent of the total. Those emissions are principally from the combustion of motor gasoline, diesel fuel, and jet fuel.

Direct fuel use in the residential and commercial sectors (mainly for heating) and the use of fuels to produce process heat in the industrial sector together accounted for 26 percent of total CO_2 emissions in 2009."

Greenhouse gas emissions from the energy and transportation sectors are, happily, projected to decline through 2020. However, emissions from other sectors may increase during this same time period.

Source: http://www.state.gov/documents/organization/218993.pdf

Energy and Transportation Infrastructure:

Impacts and Management Strategies

Risks to infrastructure:

Buildings, roads, shipping channels, shoreline conditions, energy supplies and usage may all be affected by climate change, via stress on the power grid during hotter summers and colder winters. Additionally, crucial energy infrastructure elements may be damaged by extreme weather.

Adaptation strategies include:

- Manage power vulnerability;
- Diversify current energy sources to improve resiliency of existing system;
- Incorporate better ventilation, reduced energy use (efficiency, renewables);
- Manage fleet vulnerability with varied purchasing strategies and rotating maintenance schedules;
- Include climate change in new development and renovation planning;
- Set appropriate codes and standards.

Buildings, roads, shipping channels, shoreline conditions, and energy supplies and usage may all be affected by climate change. Examples of infrastructure impacts include:

- Stress on the power grid due to more summer heat waves
- Increased annual energy costs due to probable need for additional air conditioning/cooling during summer
- Need to get greater penetration of A/C to residential units (particularly in areas of high risk resident populations)
- Increased vehicle-fleet replacement and maintenance costs
- Damage to key infrastructure (pump stations, electrical distribution equipment, etc.) caused by extreme weather events (temperature and/or precipitation)
- Increased wear on buildings due to heat and weather extremes

Energy & Transportation Infrastructure

Transportation Energy Usage and Reduction

Key areas of concern (excerpted from www.cakex.org) :

"Resource extraction refineries and processing plants are often located near the coast, making them vulnerable to severe weather and sea level rise. With lessened oil and gas availability, transportation fuel sources may become more costly and less available.

Fuel transportation and storage infrastructure, including pipelines, barges, railways and storage tanks, is susceptible to damage from severe weather, melting permafrost, and increased precipitation.

Electricity generation and transmission infrastructures, such as power plants and power lines, are vulnerable to severe weather and/or water shortages, which can interrupt transportation operations."

Adaptation strategies for reduced municipal energy usage:

- Shift primary power usage to off-peak hours and conduct energy audits routinely.
- Drinking and wastewater systems account for 25-40% of a municipality's energy use. Proper equipment sizing, regular maintenance, and efficiency are an important consideration.
- One idea is to purchase electricity from landfill gas power plants.

A worker attempts to repair a traffic light during a power outage after a severe storm.

Source: http://www.cakex.org/virtual-library/climate-change-energy-infrastructure-risks-and-adaptation-efforts

Image: http://www.newstalk980.com/sites/default/files/news-image/US%20Storm%20-%20Power%20Outage%20-%20AP%20-%20traffic%20lights%20-%20Washington%20-%20july%203%202012.jpg

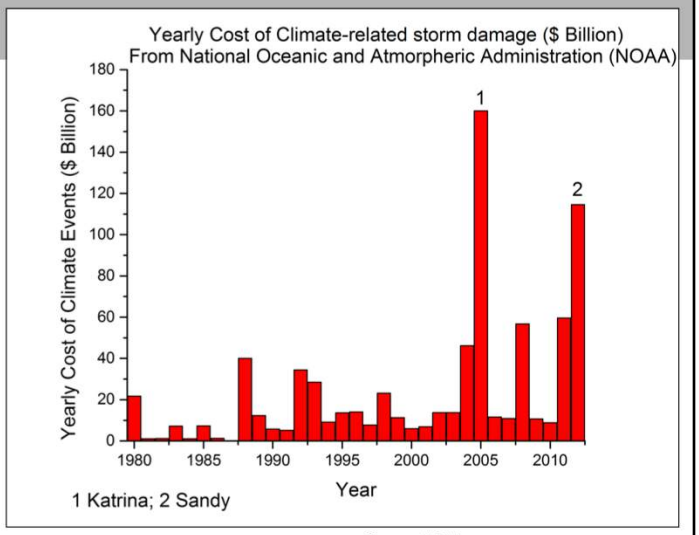
- "Plants may have to adjust shipping schedules, because shallower draft means lighter loads of fuel arriving at power plants by ship.
- If lake levels drop, extending water intake pipes can help maintain cooling.
- Shifting power usage can redistribute energy loads. For

Energy and Transportation Infrastructure

Financial implications

Municipalities may incur high costs related to the premature replacement of damaged infrastructure, or old and deteriorated infrastructure. The following financial considerations are important in the planning process:

- Increase in maintenance and operating costs;
- Expenditures set aside specifically for weather emergencies – response, evacuation and repair
- Increased insurance costs
- Loss of taxes and reduced income due to business disruptions
- Lawsuits stemming from transportation and energy grid safety issues



Source: NOAA

Climate-related impacts on transportation infrastructure have huge financial implications for municipalities, as a result of :

- The premature replacement of deteriorated transportation infrastructure
- Increases in maintenance and operating costs
- Expenditures during & after weather emergencies ; repair to weather-related damage

Infrastructure, Maintenance and the Law

Giuliani v. Halton, Milton Ontario

In April 1, 2003, Giuliani lost control of her vehicle on an icy road and travelled into oncoming traffic, colliding with another vehicle. In the three hours prior, 2cm of snow had fallen. The courts found that municipal authorities were lax in their roadway monitoring and clearing duties, and further, that the municipality was not in compliance with Minimum Maintenance Standards (2002) as they relate to snow accumulation and icy roadways. The standards stipulated that Milton authorities had a maximum of four hours to treat an icy roadway after becoming aware that the road was icy.

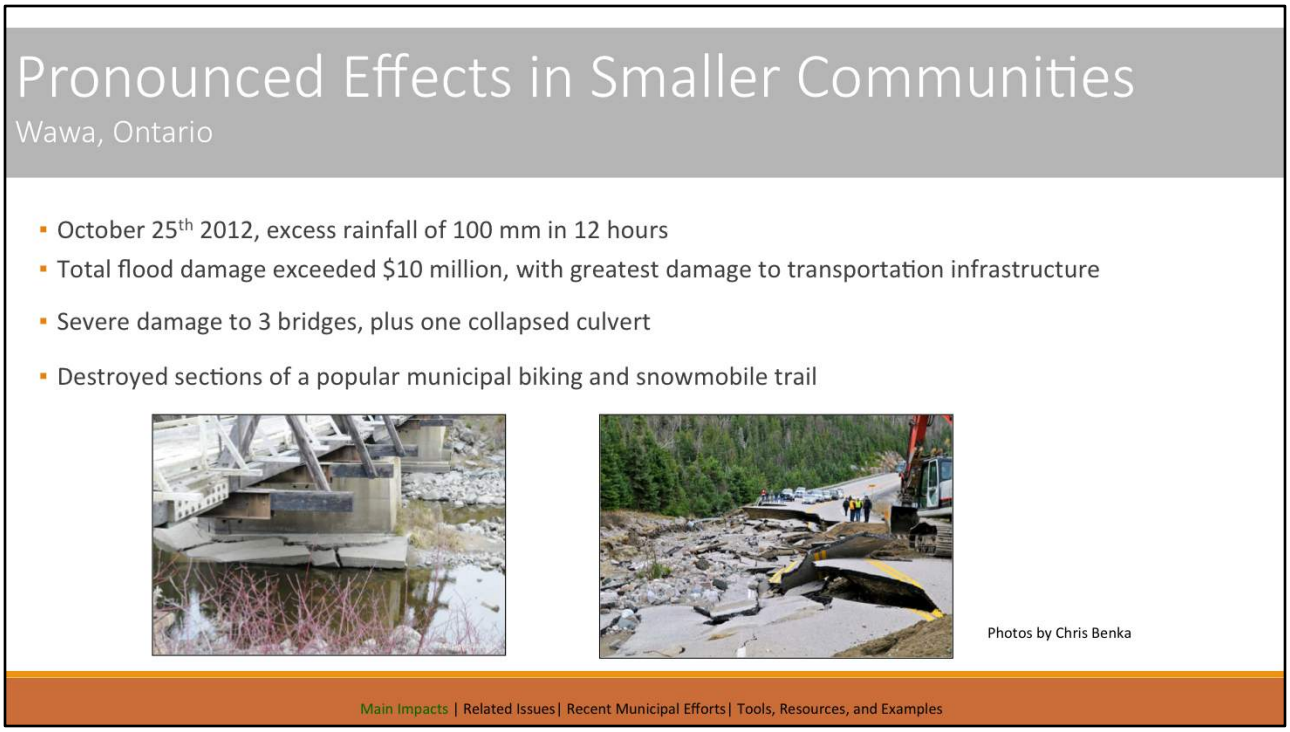
Failing to monitor the road conditions appropriately and in a timely fashion meant that de-icing did not commence on schedule. This implicated the municipality in the Giuliani incident.

Source Citation: The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars

And

http://www.shillingtons.ca/pdfs/Shillingtons%20LLP%20Municipal%20Law%20Bulletin%20-%20January%202012%20-%20Giuliani%20v%20%20Halton%20Bulletin.pdf

Image: Judge gavel
http://latest.com/wp-content/uploads/2014/06/wooden-judges-gavel.jpg



Wawa- total population 2,634

On October 25th 2012, an excess of 100mm of rain fell in a 12 hour period. Excessive rainfall had a severe impact on municipal government infrastructure, with total flood damage exceeding $3.5 million and transportation related infrastructure taking the greatest hit.Severe damage occurred among 3 bridges and one culvert collapsed. This culvert continues to cause washouts on the surrounding municipal roads still today- it requires the installation of a larger or 2 culverts, however the municipality is not able to install these different culverts without prior provincial approval. Such provincial requirements/legislation has been a great hindrance to Wawa in their attempts to repair the flood damage.Several sections of a popular municipal biking and snowmobile traiL were also destroyed. Severe damage also occurred to provincial Highways 17 & 101, as well as

Climate change-related strategies to consider in transportation and energy infrastructure planning

Main Impacts | Related Issues| Recent Municipal Efforts| Tools, Resources, and Examples

Adaptation Meets Mitigation

Walking and Bicycling

Alternative Transit Modes

Individual-level changes in transportation choices can add up to big impacts, improving local air quality and minimizing the urban heat island effect, for example.

- Private automobiles are responsible for 62% of transportation-related CO2 emissions (EPA 2006).
- Non-polluting forms of transportation such as biking and walking improve public health in several important ways. They:
  - reduce ground-level ozone;
  - lessen traffic congestion and minimize automobile accident risk;
  - offer the wellness benefits of physical activity.

Protected bike lane in Arlington, Virginia.

Source citation:
http://www.railstotrails.org/resources/documents/whatwedo/TrailLink%2007%20Program_Climate.pdf

Image:
http://www.bikearlington.com/tasks/sites/bike/assets/Image/ProtectedBikeLane.jpg

Adaptation Meets Mitigation

Electric Transit

Alternative Vehicle Types

Electric and hybrid vehicles help increase energy security, reduce emissions, improve fuel economy and reduce fuel costs. Since the electricity grid is available almost everywhere, electric vehicles are increasingly easy to charge. In fact, in 2014, the number of publicly accessible charging stations rose to more than 21,000 outlets.

Additonal benefits include:

- Electric vehicles convert about 59–62% of the electrical energy from the grid to the wheels. Conventional gasoline vehicles only convert about 17–21% of the energy stored in gasoline to power their wheels.
- Evs are also quieter and, on average, require less maintenance than their gasoline-powered counterparts.

Electric car at a recharging station.

Main Impacts | Related Issues | Recent Municipal Efforts | Tools, Resources, and Examples

"Using hybrid and plug-in electric vehicles instead of conventional vehicles can help reduce U.S. reliance on imported petroleum and increase energy security. Hybrid electric vehicles (HEVs) typically use less fuel than similar conventional vehicles, because they employ electric-drive technologies to boost efficiency. Plug-in hybrid electric vehicles (PHEVs) and all-electric vehicles (EVs) are both capable of using off-board sources of electricity, and almost all U.S. electricity is produced from domestic coal, nuclear energy, natural gas, and renewable resources."

Source: http://www.afdc.energy.gov/fuels/electricity_benefits.html

http://www.fueleconomy.gov/feg/evtech.shtml

Image: http://www.marketinginautomotive.com/tag/electric-vehicles/page/2/

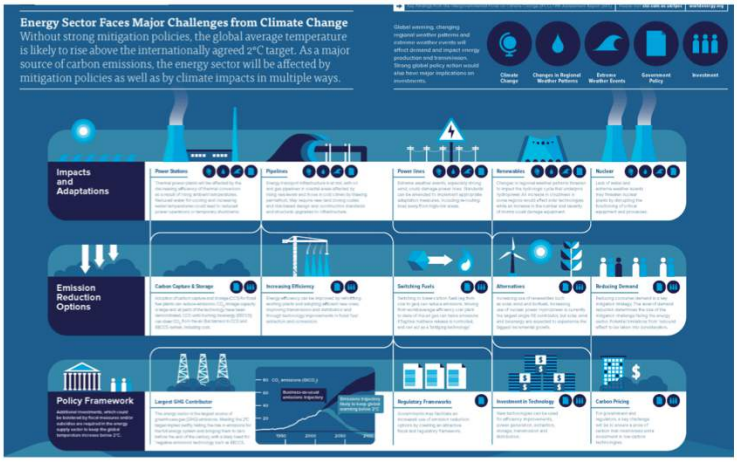
Infographic

Here is a link to an infographic that enumerates some of the mitigation and adaptation impacts of climate change to the energy sector.

Impacts may include:

- Reduced power plant operations, plant cooling, and fuel transportation vulnerabilities; rerouting of pipelines and power lines
- Changes to climate cycles which may impact renewable energy generation and production

Implementing "negative emissions" technologies, and reducing overall consumer demand is one possible strategy.



Main Impacts | Related Issues | Recent Municipal Efforts | Tools, Resources, and Examples

- Permanent, remotely activated warning signs free up personnel to focus on higher priority actions during an emergency.
- Housing areas that have only one entry road may need to add emergency secondary access roads. This can be added to development regulations.
- Dirt roads used for industrial transport (such as logging) often have higher weight limits during the winter, when freezing makes the roads firmer. These may need to be revised.

Adaptation Meets Mitigation

The role of building codes

Zoning is a key important regulatory tool which can:

- Ensure that more pervious surfaces are created, which reduces water inundation of roadways and submersion of key infrastructure
- Increase mixed land use to shorten vehicle trips, thereby reducing wear and tear on road surfaces
- Require landscaping, mature tree preservation, and open spaces to mitigate temperature extremes that may damage infrastructure networks

Pervious vs. Impervious

Main Impacts | Related Issues | Recent Municipal Efforts | Tools, Resources, and Examples

Zoning is an important regulatory tool that can:
•Minimize impervious surfaces to reduce heat island effects and water runoff.
•Increase mixed land use to shorten vehicle trips, which reduces road surface and repair and the need for parking. This also reduces paved land use and preserves natural areas.
•Require landscaping, mature tree preservation, open spaces, and other types of “green infrastructure” that help manage stormwater, reduce the heat index, and improve air and water quality.

Image:
•Pervious v. impervious
http://cbiconsultinginc.files.wordpress.com/2011/07/pervious-

Adaptation Meets Mitigation

Maintenance, the Low-Hanging Fruit

Routine maintenance of energy and transportation infrastructure is one of the easiest and most cost-effective strategies for dealing with the impacts of a changing climate. Additionally, providing information and training to employees can be beneficial in this regard as well.

- Establish a schedule for reviewing ingress and egress patterns, and identify highest priority repairs needed to culverts, power lines, roadways and facilities
- Identify areas at highest risk for flood and weather hazards
- Install warning signs and, when possible, barriers
- Conduct emergency drills and ensure evacuation plans are up to date and personnel are trained in emergency response measures
- Revise plowing guidelines, add emergency routes and revise weight and speed limits for winter road, bridge and railway use

Main Impacts | Related Issues | Recent Municipal Efforts | Tools, Resources, and Examples

- Permanent, remotely activated warning signs free up personnel to focus on higher priority actions during an emergency.
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Recent municipal efforts to create more resilient transportation and energy infrastructure networks

Case Study: Transportation

Ann Arbor, Michigan

Issues

- 24.7% of Ann Arbor's citizens use alternative transit modes to commute to work. This is higher than the national average (8%), but the City wished to do even better.
- Goal: discourage highway traffic, connect the City's existing bike paths, reduce traffic congestion and pollution, and encourage a healthier and more sustainable lifestyle among residents.

Adaptation Measure: Enhanced Bicycling Infrastructure

- Part of City's Climate Action Plan to incentivize residents to live within 2 miles of work
- City added over 4 lane miles of on-road bike lanes in 2012, bringing the total to over 71 lane miles.
- Offers ample bike parking, with 400+ bike hoops, 26 secured bike lockers and on-street bike parking racks, as well as fix-it stations
- Will begin offering bike sharing program, "ArborBike", in 2014

Bike lane, fix-it station and storage locker in Ann Arbor.

Source citations:

http://www.a2gov.org/government/publicservices/systems_planning/Transportation/Documents/2010Presentation_2008-07-02.pdf

http://www.annarbor.com/news/ann-arbor-adopts-climate-action-plan-with-goal-of-reducing-greenhouse-gas-emissions-by-90-by-2050/

http://www.a2gov.org/government/publicservices/systems_planning/Transportation/Pages/Bike.aspx

http://cec-mi.org/mobility/programs/ann-arbor-bike-share/

Imagery:

http://www.a2gov.org/government/publicservices/systems_planning/Transportation/PublishingImages/SeventhStreetNewBikeLane.jpg

http://www.annarbor.com/assets_c/2013/05/fixitstand-

Case Study: Energy

San Francisco and Electric Cars

Issue

San Francisco sought to help reduce US dependency on fossil fuels, while simultaneously lowering smog and stimulating its local economy. To this end, the City is determined to become the electric vehicle (EV) capital of the US, and as such, has installed public charging infrastructure and is engaging in EV regional planning. The program is called "SF Electric Drive".

Adaptation Measure: Electric cars and charging

- Offered FREE charging of EV vehicles at public stations through 2013, and provides maps of station locations so that drivers can quickly recharge
- Is Integrating EVs into City fleet and reducing fleet size, and now has the cleanest transit fleet in the nation. Is helping businesses transition to EV use through incentives programs
- Involved the private sector by piloting an EV car rental program through Hertz and Marriott
- Developed an EV Strategic Council as part of its SF Environment Department at the City of San Francisco. It also has a designated "Clean Transportation Team" that helps communicate news to the public and engender excitement about energy-saving shifts.

Source:
http://www.sfenvironment.org/transportation/clean-fuels-vehicles/electric-vehicles-sf-electric-drive
http://www.prnewswire.com/news-releases/hertz-and-marriott-announce-game-changing-ev-car-sharing-partnership-san-francisco-airport-marriott-waterfront-and-downtown-san-francisco-first-launch-locations-128266128.html

Case Study: Transportation

York Region, Ontario

Issues

- Increased population led to higher vehicle and road usage
- Increase in road widening, resulting in lack of space to store snow
- Increasing weather variability and extreme weather, particularly freezing rain, freeze/ thaw and extreme cold
- Increase in road salting, posing risks to environment and watershed

Adaptation Measure: Salt Management Plan

- Pre treated Rock Salt
- Road Weather Information System (RWIS)
- Vehicle global positioning system (GPS)

As a rapidly growing municipality, York Region has had to accommodate an increase in vehicles and higher road usage. This has result in road steadily growing wider and less space to store snow.

York region is also experiencing a long term trend of warmer winters and more variable weather. Snow is increasingly replaced with more frequent episodes of freezing rain, extreme cold, as well as accelerated freeze thaw cycles.

These local characteristics have posed distinct challenges to winter road maintenance in the region and necessitates increased road salting. We know that standard road salting practices, if used excessively, can be hazardous to the surrounding environment and watersheds and can also accelerate the corrosion of road infrastructure.

Case Study: Energy

Power Grid "Hardening" in New York State

Issues

Severe weather, geothermal disturbances, even terrorist threats make power grids vulnerable to disruption. In the wake of Hurricane Sandy and other extreme weather events, New York is embarking on an ambitious plan to "harden" – or make more resilient- their existing energy infrastructure. The state has suffered nine federally-declared disasters in the last three years.

Adaptation Measures:

- New York Governor Cuomo has allocated $1.37 billion to harden the state's energy grid and create 10 "microgrids" at the community level
- Part of the "Reimagining New York for a New Reality" master plan
- The plan includes replacing and repairing aging bridges, installing an advanced weather detection system, and creating a Statewide Strategic Fuel Reserve that will enable gasoline-powered backup energy generation in the event of outages
- New coastal surge protection infrastructure will be built
- Citizens will be trained to become part of a Citizen First Responder Corps

Main Impacts | Related Issues | Recent Municipal Efforts | Tools, Resources, and Examples

Sources on power grid "hardening":

http://www.governor.ny.gov/news/governor-cuomo-announces-broad-series-innovative-protections-vice-president-biden-credits
http://money.cnn.com/2012/11/07/news/economy/power-grid-sandy/
http://www.elp.com/articles/2014/04/ameren-illinois-improves-electric-power-grid-with-storm-hardening.html
http://www.smartgridnews.com/story/new-york-launches-massive-grid-hardening-and-modernization-effort/2014-01-16

Case Study: Transportation

Kingston, Ontario

Issues

- Aging road surfaces and increase in weather variability
- Increase in the incidences of large potholes, pavement surface cracks
- Increase in traffic jams due to road maintenance problems
- Soaring road maintenance costs

Adaptation Measure: Academic Partnership & Road Construction Standards

- Scientific testing and support by Queen's University Chemical Engineering Dept.
- Mandatory new standards in asphalt used in arterial and collector road construction and repaving
- Use of asphalt free of cheap and harmful additives and modifiers

Main Impacts | Related Issues | Recent Municipal Efforts | Tools, Resources, and Examples

In an effort to address the increasingly costly maintenance of potholes, pavement and surface cracks, as well as increasing traffic jams as a result of road maintenance, the city of Kingston, City Road engineers has partnered with Queen's university in the testing of alternative standards for asphalt use in road construction and repaving. These standards involve the use of a purer type of asphalt that is free of cheap and harmful additives and modifiers. According to Queen's University Engineering Dept., although these standards are 10% percent more expensive than traditional asphalt standards, these standards less harmful to the environment and offer significant savings in road repair.

Research findings supporting this initiative has yet to be release and remain in the testing stage (just in its 5th winter of use).

Case Study: Transportation

Wisconsin Department of Transportation

Issue

Climate change in Wisconsin is projected to worsen smog and cause local vegetation to produce more pollen, increasing respiratory health threats such as allergies and asthma.

Adaptation Measure: Congestion Mitigation and Air Quality Improvement Plan

Wisconsin State's preparedness strategy includes:

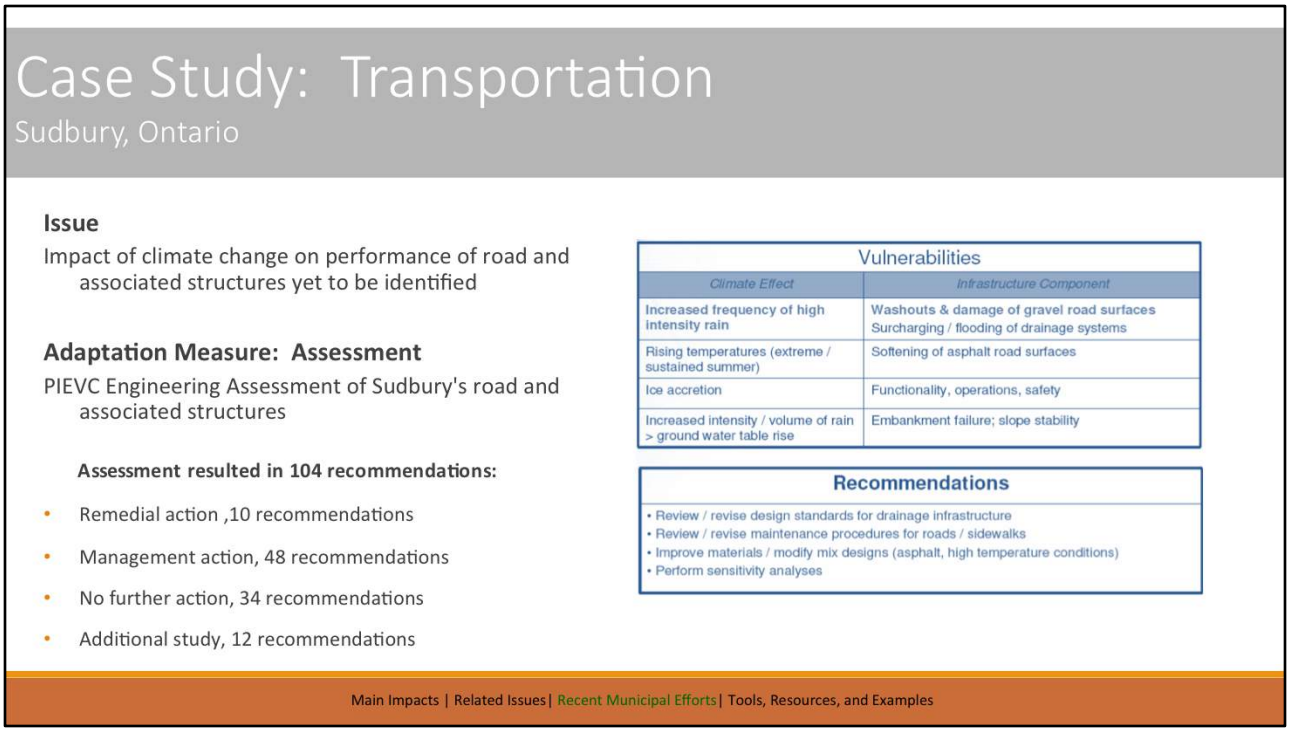
- Measures to track and respond to air quality threats; expanded public health tracking
- Reduction of air pollution levels by increasing tree canopy, championing transportation alternatives and ridesharing, local power production, and lowering carbon fuels usage
- Outreach and education to county and city public health departments, school nurses, daycare centers, nursing homes, and other facilities about the Wisconsin statewide air quality notification system.
- Milwaukee's plan includes reduction of current levels of air pollution and improved air quality warning systems.

in Impacts | Related Issues| Recent Municipal Efforts| Tools, Resources, and Examples

Sources:
http://www.nrdc.org/health/climate/wi.asp#ap_airpollution

Creating Transportation Choices: Congestion Mititgation and Air Quality Improvement Program Success Stories

http://nepis.epa.gov/Exe/ZyNET.exe/00000FI7.txt?ZyActionD=ZyDocument&Client=EPA&Index=1995%20Thru%201999&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5CZYFILES%5CINDEX%20DATA%5C95THRU99%5CTXT%5C00000013%5C00000FI7.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g



In order to get a better understanding of the impact of climate change on the performance of road and associated structures- the city of Sudbury underwent a Public Infrastructure Engineering Vulnerability Committee (PIEVC) assessment, similar to that adopted in Toronto.

These were the main road and associated infrastructure vulnerabilities that were identified in the assessment, as well as PIEVC recommendations to the city, based on the findings

The City of Greater Sudbury assessment resulted in 104 recommendations:

• Remedial action 10 recommendations:
-3 related to the effects of rainfall on drainage infrastructure, 1 related to the effects of high temperatures on road surfaces

Case Study: Transportation

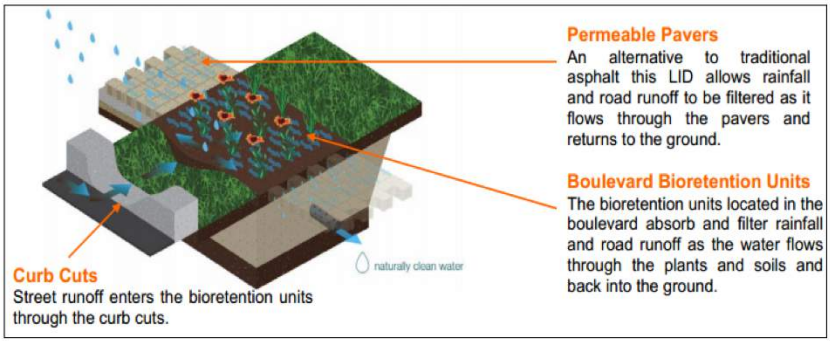
Peel Region, Ontario

Issue

Rainfall and runoff management

Adaptation Measure: LID Road Retrofits

- LID stands for "Low-Impact Development"
- LID retrofits are intended to help capture stormwater runoff
- LIDs help to calm traffic by reducing road width, thereby improving pedestrian safety



Main Impacts | Related Issues | Recent Municipal Efforts | Tools, Resources, and Examples

This next road adaptation measure will be discussed in further detail by John Nemeth, Manager of Infrastructure Programming and Studies in the Transportation Division of Peel Region in our webinar training session on March 27th as it overlaps with storm water management in the context of climate change.

However given its overlap with transportation infrastructure, we thought we'd point out the innovative LID road retrofit projects they have introduced in the region involving permeable pavement, curb cuts and bio retention units.

Permeable pavement allows rainfall and road runoff to be filtered as it flows through the paved surface and returns to the ground. Curb cuts acts as an entrance point for street runoff to flow into bio-retention units which absorb and filter rainfall and road runoff as the water flows through plants, soils and back

Resources to assist infrastructure planners

Main Impacts | Related Issues| Recent Municipal Efforts| Tools, Resources, and Examples

Reports

GLISA:

1. http://glisa.umich.edu/media/files/NCA/MTIT_Transportation.pdf
   a. Assesses current literature on potential impacts of climate change on transportation systems in the Midwestern region of the United States. Four sections follow:
   b. Synopsis of recent research on general transportation impacts
   c. Current climate projections for different parts of the Midwest, to assess levels of risk for transportation impacts from climate change
   d. Assessment of ongoing transportation adaptation measures
   e. Gaps in knowledge and research are discussed
2. Impacts discussed: Temperature and precipitation change, snow, water levels.
3. Ongoing efforts were highlighted, in areas including Chicago, Wisconsin, Iowa and Michigan

GLISA
GREAT LAKES INTEGRATED SCIENCES + ASSESSMENTS

Image: http://images.natureworldnews.com/data/images/full/5871/great-lakes.jpg?w=600

GLISA logo: www.glisaclimate.org

Reports

EPA United States Environmental Protection Agency

EPA: Climate Impacts on Energy

1. http://www.epa.gov/climatechange/impacts-adaptation/energy.html
2. Impacts discussed:
   1. Temperature, energy demand and energy supply
   2. Water availability and energy
   3. Sea level rise, storm surge and extreme events
   4. Wind speed, cloud cover and renewable energy
3. Climate changes will affect energy production, delivery, distribution and consumption in the US.
4. Problems like the cost of creating new infrastructure or updating old fixtures and facilities, as well as lesser known issues of competition, economic and population growth, and land use are addressed.
5. Useful links to many additional reports are provided.

Source: www.epa.gov/climatechange/impacts-adaptation/energy.html (including imagery and logo)

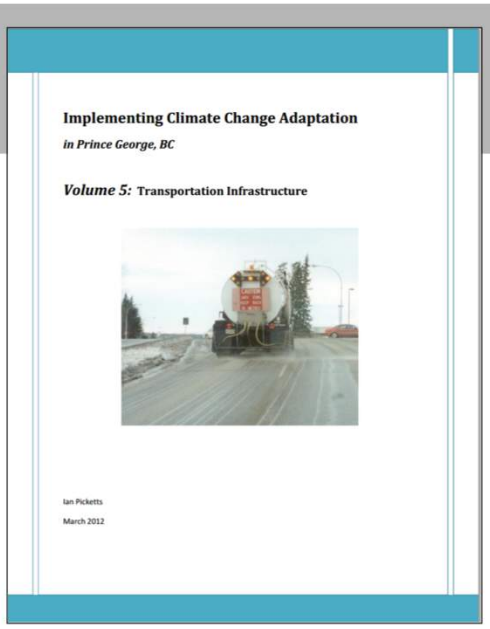
Reports

Municipal:

Implementing Climate Change Adaptation in Prince George, BC: Transportation Infrastructure

https://www.ccadaptation.ca/en/component/k2/item/2794-implementing-climate-change-adaptation-in-prince-george-bc-transportation-infrastructure

- Explores how Prince George is adapting its transportation infrastructure to climate change
  - Assesses climate change's impacts on road safety, conditions and vehicle crashes
  - City is considering using pervious paving to improve conditions



Sources:
http://princegeorge.ca/environment/climatechange/adaptation/pages/default.aspx

http://princegeorge.ca/environment/climatechange/adaptation/Documents/2012_PGRAC_Transport_volume%20with%20Exec%20Sum.pdf

Reports

GLISA:

Freezing-Rain in the Great Lakes

http://glisaclimate.org/media/Freezing%20Rain%20in%20the%20Great%20Lakes%20(6.7.13)_0.pdf

a. A winter adaptation plan focused on Chicago
b. Highlights the significant impacts from freezing-rain (issue stems from Chicago's proximity to Lake Michigan)

Image: http://3.bp.blogspot.com/-M9FudPw1vW4/TyLHKlE1hyI/AAAAAAAAAuY/HWQWKx9AdRs/s1600/freezing+rain+Jan17+07+007.jpg

Additional Reports

Improved Data and Tools for Integrated Land Use-Transportation Planning in California Project

http://ultrans.its.ucdavis.edu/projects/improved-data-and-tools-integrated-land-use-transportation-planning-california

Up-to-date California-specific data on built environment-travel relationships allows decision-makers to consider the effects of transportation infrastructure and land use investment choices

FHWA's Climate Change and Extreme Weather Vulnerability Assessment Framework

https://www.ccadaptation.ca/en/component/k2/item/2674-the-federal-highway-administrations-climate-change--extreme-weather-vulnerability-assessment-framework

Guide for transportation agencies interested in assessing their vulnerability to climate change and extreme weather events. Provides overview of key steps in conducting vulnerability assessments and uses examples to demonstrate a variety of ways to gather and process information. The framework is comprised of three key steps: defining study objectives and scope; assessing vulnerability; and incorporating results into decision making.

Supplemental Slides:

Green Infrastructure Tools (EPA)

Green Infrastructure Tools available from EPA

Source: http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm#tabs-3

1. **Cost-Benefit Resources**
   Help conduct cost benefit analyses of green infrastructure approaches. Includes completed analyses which demonstrate that green infrastructure's benefits and overall benefits can be well worth the investment.

2. **Funding Opportunities**
   Green infrastructure serves many community purposes, and is thus eligible for an array of federal funding.

3. **Policy Guides**
   Offers policy and planning strategies to encourage / require green infrastructure.

4. **Design and Implementation Resources**
   Green infrastructure is most effective when the design is tailored to the context, when the installation follows the design, and when routine maintenance is performed.

5. **Modeling Tools**
   Modeling tools are available to help assess the performance, costs, and benefits of green infrastructure, on a range of scales.

6. **Federal Regulatory Programs**
   EPA encourages the use of green infrastructure in stormwater permits and Combined Sewer Overflow (CSO) enforcement agreements.

Source citation: http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm#tabs-3

Additional reading on green infrastructure tools: http://publications.naturalengland.org.uk/publication/6264318517575680

Supplemental Slides:

Green Infrastructure Tools – Valuation Tools Assessment

http://publications.naturalengland.org.uk/publication/6264318517575680

A report that highlights tools including:

- CAVAT: Capital Asset Value for Amenity Trees
- Green Infrastructure NorthWest‟s Green Infrastructure Valuation Toolkit
- Guide to valuing Green Infrastructure from the Centre for Neighborhood Technology Chicago
- Health Economic Assessment Tool for walking and cycling (HEAT);
- Helliwell
- i-Tree Design
- InVEST: Integrated Valuation of Environmental Services and Tradeoffs

Source citation: http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm#tabs-3

Additional Resources

NOAA Factsheets:

•Civil Infrastructure:
http://www.ncdc.noaa.gov/sites/default/files/attachments/Civil%20Infrastructure_Low%20Rez.pdf
•Construction:
•http://www.ncdc.noaa.gov/sites/default/files/attachments/Construction_Low%20Res.pdf
•Transportation:
•http://www.ncdc.noaa.gov/sites/default/files/attachments/Transportation_Low%20Res.pdf

Other resources:

•NRC (2008). *The Potential Impacts of Climate Change on U.S. Transportation.* Research Board Special Report 290. National Research Council (NRC). http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf
Contains an in-depth study of the impacts of climate change on land, marine, and air transportation in the United States. The report recommends that state and local governments, as well as private infrastructure providers, incorporate climate change into long-term improvement plans, design, and operations and maintenance activities. It also discusses the potential benefits of using "smart" technologies for monitoring infrastructure, re-evaluating infrastructure design standards, updating maps used for flood insurance, and integrating climate change into transportation and land use planning.

•FCM/ CSA Infrastructure Adaptation Training:
http://shop.csa.ca/en/canada/infrastructure-solutions/adapting-your-infrastructure-to-climate-change/invt/2703207wt/&bklist=icat,4,shop,training,infrastructuretrain

•IISD Literature Review on Climate Adaptation and Canadian Infrastructure:
http://www.iisd.org/publications/pub.aspx?pno=2854

This PPT will be posted on the MARS CoP website for your reference

Source Citation: The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars

Additional Resources

Other resources:

- City of Toronto Vulnerability Assessment Info & RFP for project

http://www.merx.com/English/SUPPLIER_Menu.asp?WCE=Show&TAB=1&PORTAL=MERX&State=7&id=183752&print=Y&src=osr&ForceLID=&HID=&hcode=psexcgqiP32jggDNO6ttqA%3D%3D

- Road Construction Standards in Kingston:

http://www.thestar.com/news/gta/transportation/2014/01/15/potholefree_roads_yes_its_possible_with_better_asphalt_says_queens_university_professor.html

http://www.chem.queensu.ca

http://www.cbc.ca/news/canada/ottawa/kingston-asphalt-program-takes-aim-at-potholes-1.2505845

- Case Study of PIEVC Road Infrastructure Assessment in City of Sudbury: http://www.pievc.ca/e/doc_list.cfm?dsid=3

- LID road retrofits in Peel Region

http://www.creditvalleyca.ca/low-impact-development/showcasing-water-innovation-2/road-right-of-ways/

- Case study of Prince George

http://princegeorge.ca/environment/climatechange/adaptation/Documents/2012_PGRAC_Transport_volume%20with%20Exec%20Sum.pdf

- York Region De-Icing Strategies

http://www.cleanairpartnership.org/files/2%20Case%20Study.pdf

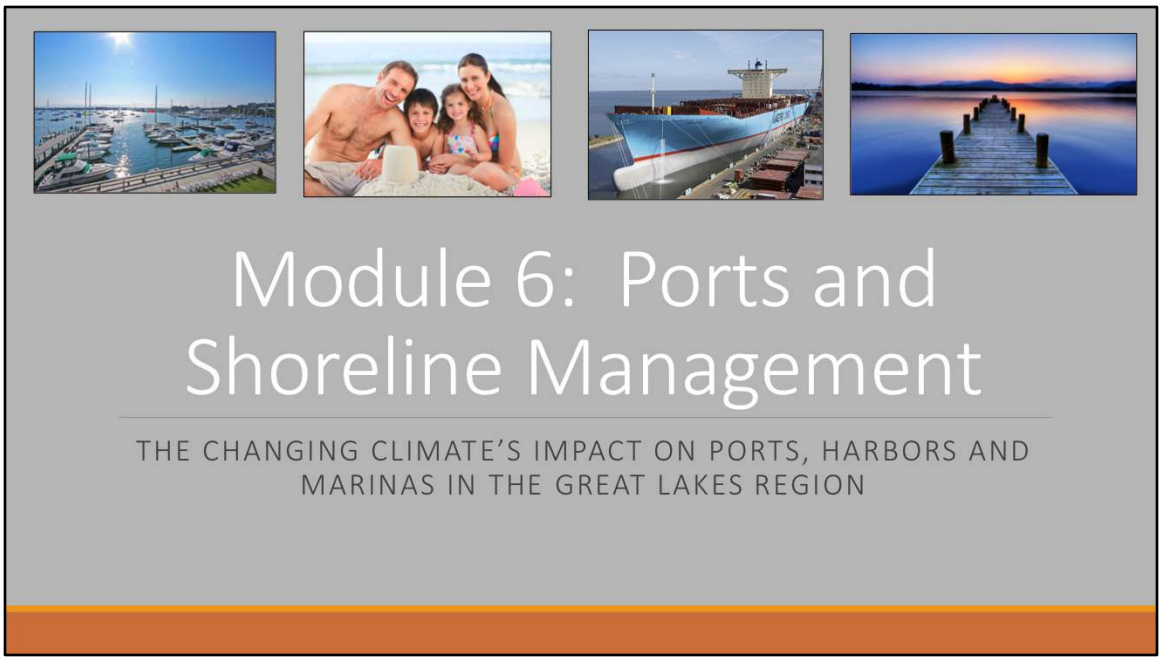


Image credits:

Marina
http://www.newporthotel.com/wp-content/uploads/2013/03/Marina-View.jpg
Family
http://springmaidbeach.com/family-hotels-myrtle-beach-sc-attractions-wonderworks/
Cargo ship at port http://hamptonroads.com/node/143291
Dock
http://dotsoft.info/wp-content/uploads/2013/09/lake-dock-wallpaperdownload-boat-dock-windermere-lake-engl-wallpaper-248732-wmxgjzu6.jpg

Table of Contents

Background

Background

- 130 U.S. coastal communities have structures such as channels, breakwaters and piers to safeguard navigation.
- Such structures also provide critical storm and flood protection – particularly for coastal power plants, water supply intake systems and wastewater treatment facilities.
- More than half of these structures were built prior to WWI, and over 80% are older than their typical 80-year lifespan.
- Thus, most coastal infrastructures are vulnerable to changes in climate, such as increased or decreased precipitation.

Lighthouse structure and pier in Manistee, Michigan.

Adapted from: OSU Webinar "Economic Implications of Climate Change Impacts on Great Lakes Ports, Harbors and Marinas": http://changingclimate.osu.edu/webinars/archives/2011-03-01/.

Image:
http://fineartamerica.com/featured/4-manistee-michigan-lighthouse-and-pier-twenty-two-north-gallery.html

Notes:

In the Great Lakes, on the U.S. side alone, there are 130 coastal cities and towns with federal navigation projects that include channels for navigation, and structures like breakwaters and piers.
Although originally authorized to safeguard navigation and maritime commerce, these navigation structures also provide critical flood and storm protection for public and private buildings, roads, facilities and waterfront areas, and in some cases, for things like power plants, water supply systems, and wastewater treatment facilities.
More than half of these structures were built prior to WWI, and over 80% of them are older than their typical 80-year design line and are thus vulnerable to climate change.

Background

Ports are critical to the trade and transportation networks of the United States.

- Ports handle 78% of all U.S. foreign trade by weight and 44% by value.
- Ports represent billions of dollars in capital improvements and new investments.
- While the risk that climate change poses to ports is unclear, what is clear is that ports will be impacted and shoreline managers should plan for ports' continued resiliency and reliable operations.

Primary needs:

- Port and shoreline authorities need additional information about specific impacts they may face
- Data and recommendations are not yet scaled down to be useful at the regional/local level

Adapted from: EPA White Paper "Planning for Climate Change Impacts at US Ports": http://www.epa.gov/sectors/pdf/ports-planing-for-cci-white-paper.pdf.

The Port of Detroit is the largest seaport in Michigan.

Source: http://www.epa.gov/sectors/pdf/ports-planing-for-cci-white-paper.pdf
http://en.wikipedia.org/wiki/Port_of_Detroit

Image: http://www.howard.edu/asb/2013/detroit/default.htm

Quick Facts and Statistics

There are…

- 610 miles of channels in the Great Lakes
- 117 harbors that are federally serviced by the Corps of Engineers
- 104 miles of breakwaters, with $3.3 billion investment in breakwaters alone
- 20 dredge disposal facilities, which may be valued at $20-35 million USD **each**
- There are locks in Chicago, Sault Ste. Marie and Buffalo, New York
- Marinas have a shorter lifespan than other infrastructures, at approximately 40-50 years

Adapted from: OSU Webinar "Economic Implications of Climate Change Impacts on Great Lakes Ports, Harbors and Marinas": http://changingclimate.osu.edu/webinars/archives/2011-03-01/.

Breakwater in Michigan made from salvaged materials.

Background | Main Impacts | Related Issues| Recent Municipal Efforts| Tools, Resources, and Examples

Additional sources:
http://www.seagrant.wisc.edu/Home/Topics/PortsHarborsandMarinas/Details.aspx?PostID=1562

Image: http://www.roensalvage.com/stone-breakwaters.html

Impacts of climate change on ports, marinas, harbors and shorelines in the Great Lakes Region

Climate impacts

to ports, marinas, harbors and shorelines

Climate change impacts may include:

- Changes in rainfall and increases in storm intensity
- Increased erosion and sediment load
- Water-level changes in Lakes
- Increased wave height and speed
  - Greater wave heights will be associated with higher water levels and could result in damage to port structures, harbor infrastructure and marina docks and boats

A storm surge can damage coastal infrastructure considerably.

Source:
http://www.seagrant.wisc.edu/Home/Topics/PortsHarborsandMarinas/Details.aspx?PostID=1562
Image:
http://i2.cdn.turner.com/cnn/dam/assets/131028083308-01-uk-storm-1028-horizontal-gallery.jpg

Climate impacts

Three primary

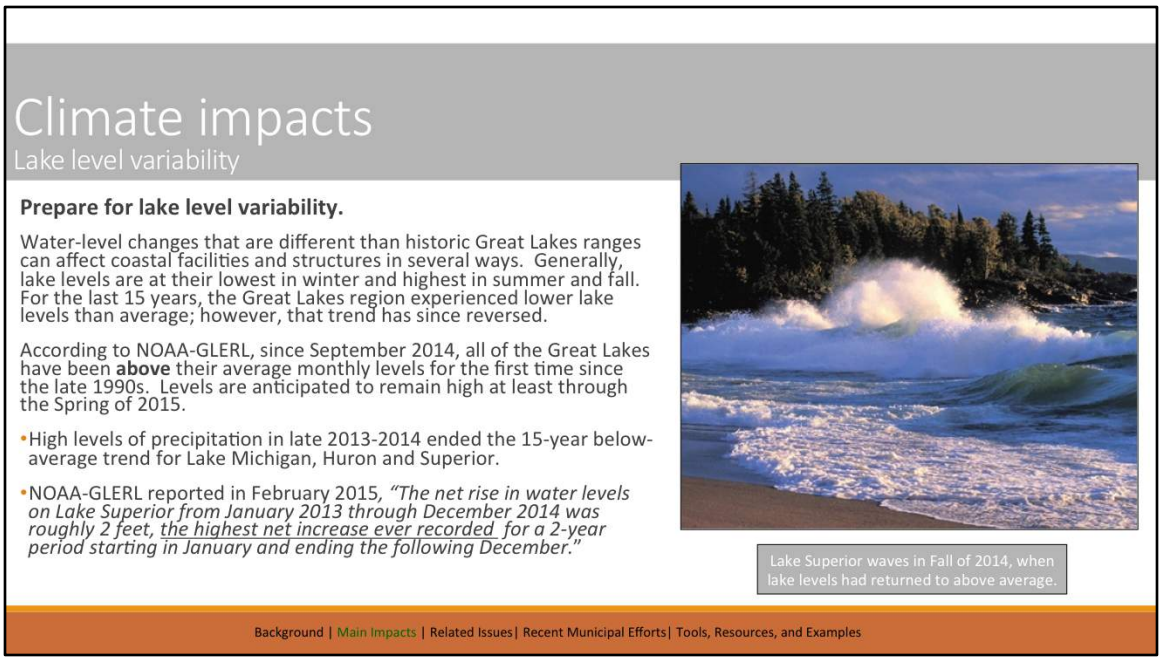
According to Wisconsin Sea Grant, **the three major** climate change impacts that are most relevant to Great Lakes ports, harbors and marinas are:

1. Water level changes
2. Storm water
3. Precipitation and temperature changes

Impacts can be wide-ranging in the Great Lakes, and can vary regionally.

Source:
http://www.seagrant.wisc.edu/Home/Topics/PortsHarborsandMarinas/Details.aspx?PostID=1562

Images:
http://blog.mlive.com/chronicle/2007/12/Low_water.jpg
http://sustainable19125and19134.org/sites/default/files/stormwater_1.jpg



Sources:

http://www.glerl.noaa.gov/pubs/brochures/lakelevels/lakelevels.pdf
Please note: the GLERL brochure linked above is updated seasonally Find the latest iteration here: **http://www.glerl.noaa.gov/pubs/brochures/**

http://research.noaa.gov/News/NewsArchive/LatestNews/TabId/684/ArtMID/1768/ArticleID/10944/NOAA-and-partners-document-surge-in-Great-Lakes-water-levels-.aspx
http://www.therecord.com/news-story/5201585-great-lakes-water-levels-bounce-back-but-long-term-future-uncertain/
http://michiganradio.org/post/16-years-later-great-lakes-levels-rebound

Image:
http://www.therecord.com/news-story/5201585-great-lakes-water-levels-bounce-back-but-long-term-future-uncertain/

Climate impacts

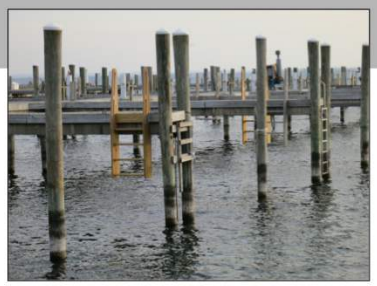
Lake level variability

Benefits of higher lake levels may include enhanced hydropower capacity, the potential for increased tourism from recreational boating, and ease of commerce via shipping. Drawbacks can include shoreline property damage, coastal erosion, flooding, reduced beach access/beach tourism and impacts to the fishing industry.

- When levels are low, ships cannot be fully loaded and must carry less cargo per trip. Vessels may become damaged by hitting the channel bottom, or become stuck beneath structures when water levels rise. Lower water levels may also reduce access to shipping channels and ports.
- As levels fluctuate, harbor structures may become unstable. Beaches may become exposed, thus affecting the aesthetic quality and tourism potential of the area.
- If sedimentation occurs, additional dredging may be required, which is costly and may take up to several years to complete. This can result from both higher or lower than average lake levels.

Environmental journalism agency Circle of Blue discussed the economic costs of low lake levels in 2012:

"Every centimeter of lost draft equates to 95 fewer metric tons of cargo…That's lost revenue for companies and less efficiency…When lake levels were high, the biggest ships carried 70,000 tons…The biggest loads this summer are 64,000 or 65,000 tons.'"



Exposed docks during low lake levels on Lake Michigan and Lake Huron in 2012.

Background | Main Impacts | Related Issues| Recent Municipal Efforts| Tools, Resources, and Examples

Source:
http://www.glerl.noaa.gov/pubs/brochures/lakelevels/lakelevels.pdf
http://research.noaa.gov/News/NewsArchive/LatestNews/TabId/684/ArtMID/1768/ArticleID/10944/NOAA-and-partners-document-surge-in-Great-Lakes-water-levels-.aspx
http://www.seagrant.wisc.edu/Home/Topics/PortsHarborsandMarinas/Details.aspx?PostID=1562
http://www.epa.gov/sectors/pdf/ports-planing-for-cci-white-paper.pdf
http://www.circleofblue.org/
http://glisa.msu.edu/media/files/projectreports/14-728%20Increase%20Resilience%20at%20Marinas%20and%20Harbors.pdf

Article "**Great Lakes Ports and Shipping Companies Confounded by Climate Changes and Water Levels"** by Keith Schneider:
http://www.circleofblue.org/waternews/2012/world/great-lakes-ports-and-shipping-companies-confounded-by-climate-changes-and-water-levels/

Image: http://media.cmgdigital.com/shared/lt/lt_cache/thumbnail/960/img/photos/

Climate impacts

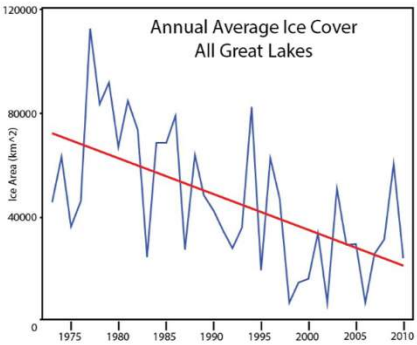
Lake level forecasting

Water level forecasting for the Great Lakes is a complex process and accounts for a variety of factors, including "over-lake precipitation, evaporation and runoff"(NOAA-GLERL). Hydrologic simulation models are often used – for example, the AHPS (Great Lakes Advanced Hydrologic Prediction System) combines historical data on climate and weather patterns, with emergent forecasting methods.

Still, weather anomalies (such as the polar vortex that hit the Midwest in 2014) can make lake level prediction more difficult. Also, each lake is unique in its geology, watershed, volume and size, yet all lakes are interconnected, which further compounds forecasting ability.

Data from GLISA demonstrates that ice coverage on the Great Lakes – as well as how early in the season the ice forms - has a direct effect on evaporation from the lakes and is a factor in overall water levels. Ice cover is key for the health of many species and ecosystems in the Lakes. From 1973-2010, there was an average 71% decline in ice levels across all Great Lakes.

Given forecasting uncertainties, it is best to prepare for both higher and lower lake levels in the future.



Observed Decline in Great Lakes Ice Cover, 1973-2010. From Wang et al. (2012).

This chart from GLISA reflects ice coverage trends over the last 30+ years.

Background | Main Impacts | Related Issues| Recent Municipal Efforts| Tools, Resources, and Examples

Sources:

http://glisa.umich.edu/climate/great-lakes-ice-coverage
http://www.miseagrant.umich.edu/downloads/climate/11-700-Preparing-for-Variable-Lake-Levels.pdf
http://www.glerl.noaa.gov/pubs/brochures/lakelevels/lakelevels.pdf
http://research.noaa.gov/News/NewsArchive/LatestNews/TabId/684/ArtMID/1768/ArticleID/10944/NOAA-and-partners-document-surge-in-Great-Lakes-water-levels-.aspx

Image: http://glisa.umich.edu/climate/great-lakes-ice-coverage

Climate impacts

Lake levels and resiliency planning

Because it is difficult to anticipate Great Lakes water levels into the future, municipalities may wish to engage in resiliency planning for both higher and lower lake levels. Many communities have already begun drought and flood contingency planning. Strategies can include:

- Installing "floating" docks that can move with varying water levels
- Incorporating softshore engineering practices to stabilize and protect coastal areas against wave erosion. This includes the use of natural features and vegetation, rather than "hard" infrastructures such as sea walls. Softshore engineering offers added aesthetic benefits.
  - Softshore engineering often incorporates habitat for fish and wildlife, whereas hard engineering does not.
  - Softshore engineering is not appropriate for all vulnerable areas and is best used where hard infrastructure is not needed.
- Shoreline setbacks
- Plans for navigation and dredging in adverse conditions

Softshore engineering at the Detroit River offers aesthetic and ecological benefits.

Sources:
http://www.miseagrant.umich.edu/downloads/climate/11-700-Preparing-for-Variable-Lake-Levels.pdf

http://www.fws.gov/uploadedFiles/BestManPracticesManual2000.pdf

Image: http://www.fws.gov/refuge/detroit_river/what_we_do/resource_management/soft_shoreline_engineering.html

Climate impacts

Storms, waves and high winds

A changing climate may result in increased severity and frequency of storms, causing:

1. Larger waves and storm surges, which can damage infrastructure and docked watercraft. This can also cause shoreline erosion and coastal property damage. Bluffs are particularly vulnerable.
2. Reduced vessel mobility and hindered harbor operations. Human health threats and shipping delays may result.
3. Heightened sedimentation, requiring additional dredging.
4. Infrastructure and sensitive harbor / port equipment damage from high winds.
5. Spreading of contaminated materials. Beach closures from excessive storm runoff may result, causing health impacts, loss of tourism, and reduced quality of life.
6. Varying water levels can warp wooden structures and/or cause them to rot once they are exposed to oxygen.

Credit: Timothy Wenzel

Hurricane Sandy caused about $17.7 million in damages to federal navigation structures in the Great Lakes region.

Background | Main Impacts | Related Issues| Recent Municipal Efforts| Tools, Resources, and Examples

Source:
http://www.seagrant.wisc.edu/Home/Topics/PortsHarborsandMarinas/Details.aspx?PostID=1562
http://www.epa.gov/sectors/pdf/ports-planing-for-cci-white-paper.pdf
http://greatlakesresilience.org/stories/ohio/climate-change-implications-port-toledo
http://glisa.msu.edu/media/files/projectreports/14-728%20Increase%20Resilience%20at%20Marinas%20and%20Harbors.pdf

Image:
http://www.seagrant.wisc.edu/home/Portals/0/Images/Coastal%20Communities/photo_lighthouse.png
Caption: http://glisa.msu.edu/media/files/projectreports/14-728%20Increase%20Resilience%20at%20Marinas%20and%20Harbors.pdf

Alternate image available here:
http://www.npr.org/blogs/thetwo-way/2013/10/28/241415669/storm-packing-hurricane-force-winds-hits-western-europe
Additional notes:
Marinas and harbors may contain contaminated sediments once considered “safe”,

Stormwater impacts

Highs and lows

Marine transport and shipping may be negatively affected in the following ways:

- Higher temperatures and/or increased sediment deposition from flooding may lead to reduced channel depth and lessened clearance under bridges. Costly dredging may be required.
- With shallower channels, more stringent size and weight restrictions may be enforced. Similarly, with flooded channels, navigation may be temporarily halted, resulting in economic losses.
- Harbors and docks are also vulnerable to higher storm surges

Resiliency planning that includes more pervious surfaces, as well as diversion channels and subsurface stormwater holding tanks, are some of the municipal strategies that have been successful in managing stormwater.

Leland Harbor in Leland, Michigan: differences in water levels threatened the summer tourism economy.

Background | Main Impacts | Related Issues| Recent Municipal Efforts| Tools, Resources, and Examples

Sources:
http://www.epa.gov/climatechange/impacts-adaptation/transportation.html
http://www.leelanau.com/blog/lowest-water-levels-ever-a-problem-for-leland-and-other-harbors/
http://www.glisaclimate.org/media/HRWC%20Infrastructure.pdf

Image: http://michpics.files.wordpress.com/2013/01/low-great-lakes-water-levels-by-ken-scott.jpg?w=480

Climate impacts

Precipitation and temperature changes

- Extreme heat and cold may require additional energy to protect cargo being stored at harbors and ports
- Port employees who work primarily outside may be exposed to harsher and more dangerous conditions
- Warmer temperatures heighten the risk of invasive species spread
- Excessive freezing and thawing can crack breakwaters and other structures
- Changes in lake ice cover can impact sensitive species such as whitefish and trout

The invasive sea lamprey disrupts food webs in the Great Lakes.

Source:
http://www.seagrant.wisc.edu/Home/Topics/PortsHarborsandMarinas/Details.aspx?PostID=1562
http://www.epa.gov/sectors/pdf/ports-planing-for-cci-white-paper.pdf
http://glisa.umich.edu/climate/great-lakes-ice-coverage

Image:
http://www.nwf.org/news-and-magazines/national-wildlife/animals/archives/2007/alien-invasion-a-great-lakes-dilemma.aspx

Climate impacts

Water Quality

- According to GLISA, "Rising carbon dioxide concentrations, warming lake temperatures, a longer stratified-lake season, increasing extreme precipitation, and an abundance of nutrients are conspiring to increase the risk of harmful algal blooms, particularly on Lake Erie."
- These blooms increase the risk of hypoxic "dead zones", fish kills, beach closures and threats to human and ecosystem health.
- Lake Erie is especially vulnerable to HABs, because roughly 63% of its watershed is used for agriculture. Phosphorus from fertilizers is a contributor to algal blooms.
- Economic losses stemming from reduced recreational boating and beach usage can be significant; Lake Erie's harmful algal bloom of 2011 caused a $2.4 million loss to Ohio's recreational fishery alone, and a $1.3 million loss to the State Park system because of fewer visitors.
- NOAA-GLERL has developed a HAB bulletin that offers the most current information on HABs in Lake Erie.

Harmful algal blooms in the Great Lakes threaten human health, harm ecosystems and wildlife, and cause considerable economic losses.

Source:
http://glisa.umich.edu/climate/algal-blooms
http://www.businessinsider.com/lake-erie-algal-blooms-are-out-of-control-2014-3
http://www.glerl.noaa.gov/res/waterQuality/?targetTab=habs

Image: http://www.businessinsider.com/lake-erie-algal-blooms-are-out-of-control-2014-3

Climate impacts

Water Quality

- Many strides have been made in protecting and improving water quality in the Great Lakes.
- Measures such as wastewater infrastructure improvements and sewage treatment plant upgrades, pollution prevention, site restoration, enhanced monitoring and more stringent environmental standards can be credited.
- The EPA has identified key Areas of Concern (AOCs) that are environmentally degraded. These remaining areas may have contaminated sediment and/or restrictions on dredging activity, restrictions on drinking water, fish and/or wildlife consumption.
- The EPA has developed Remedial Action Plans (RAPs) to help restore these areas.
- At present, 43 AOCs have been identified, with 26 in the US, 12 in Canada and 5 that span the borders of both nations.
- The ultimate goal is to clean up and "de-list" these sites.

The map above depicts the locations of the 43 remaining AOCs in the US and Canada.

Source:
http://epa.gov/greatlakes/glwqa/usreport/part1.html
http://epa.gov/greatlakes/aoc/index.html

Image: http://www.ec.gc.ca/raps-pas/

Dredging

The facts

Climate change may result in an increased need for dredging to avoid bottoming out of commercial ships and recreational boats. Low water levels may adversely affect boat launches at marinas and public access points as well, but both increasing AND decreasing water levels can necessitate dredging, which is costly and time-consuming.

- For the 58 docks in the Duluth/Superior harbor (the largest port in the Great Lakes), dredging would cost $12/cubic yard, totaling $37.6 billion.
- For Toledo's harbor, which is much smaller, the cost would be $11-12 million. Dredging also poses an additional problem: what to do with the waste??
- Contaminated materials may be brought to the surface, creating environmental risks and requiring additional expenditures

Lake dredging.

Background | Main Impacts | Related Issues| Recent Municipal Efforts| Tools, Resources, and Examples

Source:
http://www.seagrant.wisc.edu/Home/Topics/PortsHarborsandMarinas/Details.aspx?PostID=1562
http://www.seagrant.wisc.edu/Home/Topics/PortsHarborsandMarinas/Details.aspx?PostID=641

Image:
http://www.dredgingtoday.com/2013/01/21/lake-julia-dredging-progresses-well-usa/

- Cost-intensive dredging to deepen harbors for commercial shipping, with associated treatment costs and environmental risks related to contaminated materials brought to surface
- More frequent adjustment of docks and water intake pipes

Harbors and channels in Great Lake municipalities may also require extensive, cost intensive dredging- dredging also results in treatment costs and environmental risks as a result of the contaminated materials that it brings up

Dredging
Repurposing

The average annual dredging volume in Great Lakes is 3-5 million cubic yards of material, half of which is contaminated.

- Contaminated material is placed in CDFs (confined disposal facilities) which are costly to build and are filling rapidly
- Per Wisconsin Sea Grant, non-contaminated dredged material can have many beneficial uses:
  - Provides "fill" for new developments, like parks, planned communities and beaches
  - Can be used to cover landfills and cap / seal off hazardous sites and inactive mines
  - Can be used to create valuable topsoil for agricultural and urban greening use
  - Habitat restoration and mineland reclamation

Wetland created from dredged material. Source: Wisconsin Sea Grant, photo credit: Richard Price, US Army Corps of Engineers

Background | Main Impacts | Related Issues| Recent Municipal Efforts| Tools, Resources, and Examples

Source:
http://www.seagrant.wisc.edu/Home/Topics/PortsHarborsandMarinas/Details.aspx?PostID=1562
http://www.seagrant.wisc.edu/Home/Topics/PortsHarborsandMarinas/Details.aspx?PostID=641

Image:
http://www.seagrant.wisc.edu/Home/Topics/PortsHarborsandMarinas/Details.aspx?PostID=641

Text below excerpted from Wisconsin Sea Grant:

In the Great Lakes alone, average dredging volumes from just the federally maintained channels is 3-5 million cubic yards of material per year. Nearly half of this volume is considered not contaminated and does not need to be placed into confined disposal facilities (CDFs) built to contain contaminated sediments. The CDFs are filling rapidly, costly to build and take many years to design and permit. Therefore, alternative uses need to be implemented for the clean dredged material.
The ***beneficial use of dredged material*** is the term used for utilizing dredged

Primary challenges facing Great Lakes shoreline managers

Primary challenges

- Climate models' inability to supply dependable modeling information on which to make predictions.
- Need dependable data to get investors and local governments to start allocating more funding toward adaptation.
- Difficulties in time frame and scale – threats are long-term, therefore effects may not be seen immediately – which can make it difficult to sustain interest in and funding for adaptation efforts. For example, IPCC predictions may take full effect in 80-90 years, but port authorities typically have 5-10 year planning horizons.

Source: Forum for the Future.
http://sd.defra.gov.uk/2010/12/insurance-central-to-global-agreement-on-climate-change/

Background | Main Impacts | Primary Challenges | Recent Municipal Efforts | Tools, Resources, and Examples

Need to develop / expand upon each bullet further…

Source: http://changingclimate.osu.edu/webinars/archives/2011-03-01/
http://www.seagrant.wisc.edu/Home/Topics/PortsHarborsandMarinas/Details.aspx?PostID=1562
http://www.epa.gov/sectors/pdf/ports-planing-for-cci-white-paper.pdf

Image:
http://sd.defra.gov.uk/2010/12/insurance-central-to-global-agreement-on-climate-change/

Consider discussing the possible opening of the Northwest passage – benefits and drawbacks

Primary challenges

- Higher insurance premiums for ports and municipalities
- Oftentimes, port authorities themselves do not own or have control over the infrastructure they depend on, nor are they able to secure funding sources independently.
- Each state defines its coastal management practices differently. There is variation between municipalities in terms of coastline jurisdiction and how to best operate a coastal management program. 34 states currently have approved coastal management programs. The goal of these programs is to:
  - Protect natural resources;
  - Manage development in high hazard areas;
  - Give development priority to coastal-dependent uses;
  - Provide public access for recreation;
  - Coordinate state and federal actions.

For more information, see the National Coastal Zone Management website at www.coastalmanagement.noaa.gov.

The National CMZ program strives to balance water-dependent coastal uses, like fishing and recreation, with preservation, so that all residents can continue to enjoy coastal resources in the future.

Background | Main Impacts | Primary Challenges | Recent Municipal Efforts | Tools, Resources, and Examples

Source: http://changingclimate.osu.edu/webinars/archives/2011-03-01/
http://www.seagrant.wisc.edu/Home/Topics/PortsHarborsandMarinas/Details.aspx?PostID=1562
http://www.epa.gov/sectors/pdf/ports-planing-for-cci-white-paper.pdf

http://coastalmanagement.noaa.gov/programs/czm.html

Image: http://coastalmanagement.noaa.gov/about/media/about_220_3.jpg

Recent municipal efforts to create more resilient shorelines

Case Study

Goderich, Ontario

Issues

- Climate change, ecosystem disruption and unsustainable development were identified as three major issues facing Goderich
- In 2011, a massive tornado swept through Goderich causing $110 million in damage and the Town wished to rebuild – but to do it better than before, in a more climate-resilient way
- Maitland Valley Conservation Authority identified that coastal activities like tourism and fishing were threatened by climate change
- 66 gully watersheds drain into Lake Huron. They are increasing in size and rate of erosion. Potential loss of land due to gully erosion: 1,897 acres or 767.7ha.
- Value of land and development that would be potentially lost: $89.5 million.

Adaptation Measure: Maitland Watershed Resiliency Challenge

- In 1988, Rotary Beach Cove was created from 300,000 m^3 of dredged sediment from the harbor as a way to control erosion and improve wildlife habitat.
- Groynes, jetties, and recent installations of beach grass are continuing to improve erosion to this day
- MWRC will potentially establish 30,000 acres of stream buffers and connections across the watershed
- Will potentially reforest or create permanent cover for 58,340 acres of fragile land.
- Demonstration sites are a key piece in educating landowners and municipalities of the value gained from using rural storm water management, natural infrastructure and erosion-control measures to develop a more resilient landscape and coast.

Aerial view of Goderich coastline. The Maitland River flows into Lake Huron.

Sources:
http://www.torontosun.com/2012/08/17/life-almost-back-to-normal-a-year-after-goderich-tornado
http://www.southwesternontario.ca/news/creating-resiliency-the-goal-of-mvca/
http://www.goderich.ca/en/visitors/resources/dl-BlueFlagBrochure.pdf
http://lakehuron.ca/uploads/pdf/Bluff.conservation-erosion.process.pdf

Source: Maitland Watershed Resiliency Challenge, May 2014 – document supplied by Town of Goderich officials

Image: http://www.goderich.ca/en/townhall/resources/Aerialjuly16%20041.jpg

Case Study

Port of Toledo

Issues

- Port of Toledo is one of the busiest ports in Great Lakes, and is also the most heavily dredged
- US Army Corps of Engineers dredges 700,000 cubic meters (900,000 cubic yards) of mud and sand, or 1 million metric tons, per year.
- In the past, for every 10-11 metric tons of cargo that moved into and out of the Toledo port, about one metric ton of sediment left the channel. (Last year, 10.4 million metric tons of cargo were handled at the port.)
- With climate change, more mid-winter snow melts and more frequent heavy rainfalls may lead to higher soil-erosion rates, with more soil ending up in the channel. Higher air temperatures are warming the Great Lakes, blocking ice from forming and increasing rates of evaporation that may lead to lower lake levels.
- This all equates to more frequent dredging to keep the Port operating smoothly, which could require tens of millions of dollars in port planning and operations costs.
- The Port and the Toledo economy depend on a better understanding of weather and water conditions over the next several decades.

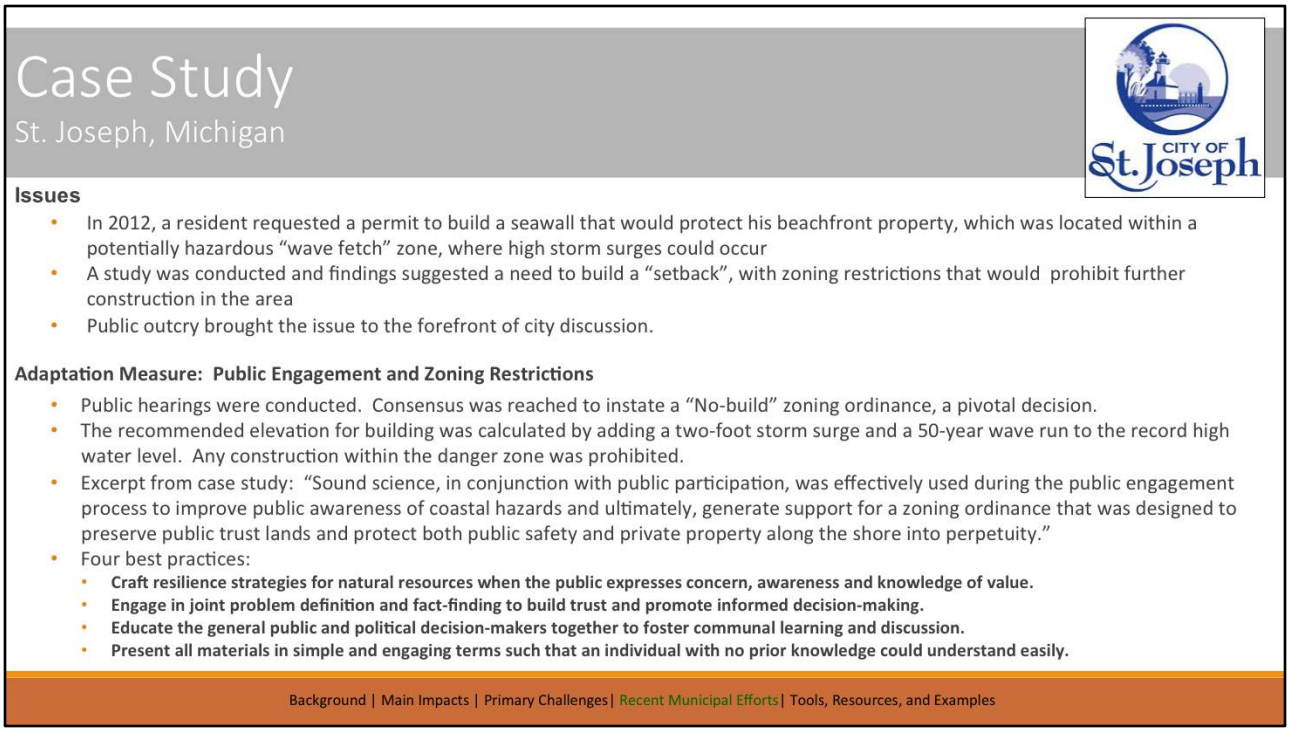
Adaptation Measure: Sediment Management and Use Plan

- Combined approach that incorporates wetland restoration and shoreline protection, agricultural field protection, deposition in pre-identified areas and other beneficial uses.

Background | Main Impacts | Primary Challenges | Recent Municipal Efforts | Tools, Resources, and Examples

Source: http://greatlakesresilience.org/stories/ohio/climate-change-implications-port-Toledo
http://greatlakesresilience.org/case-studies/infrastructure/economic-valuation-port-infrastructure

Sediment Management and Use Plan:
http://lakeerie.ohio.gov/Portals/0/GLRI/Final_THSMUP_GLE00523_20121231.pdf



Source:

http://greatlakesresilience.org/case-studies/land-use-zoning/engaging-communities-promote-coastal-zoning

http://www.heraldpalladium.com/news/local/no-more-mistakes-on-the-lake/article_07442a1b-ea73-58a0-9dd4-586c01725b16.htmlorg/case-studies/land-use-zoning/engaging-communities-promote-coastal-zoning

http://www.heraldpalladium.com/news/local/a-line-in-the-sand/article_7a3fb082-2768-5e7c-b0c2-ac6cfacc7648.html

Image: http://stjosephcitymi.iqm2.com/Citizens/default.aspx

Tools to assist shoreline managers

Tools and Funding

NOAA Sectoral Applications Research Program Grant (SARP)

- 5 objectives:
  - Climate change modeling: bringing global climate change aspects down to Great Lakes region;
  - Economic impacts for ports, harbors and marinas;
  - Geospatial tools to visualize impacts - in particular, water level changes;
  - Communications products;
  - Integrating results into municipal strategic plans

CE Dredge, US Army Corps of Engineer's database

http://ce-dredge.usace.army.mil/

Great Lakes Maritime Research Information Clearinghouse (very helpful)

http://www.maritime.utoledo.edu/

WEPPCAT: EPA's tool for sediment loading prediction

http://cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=153583

Great Lakes Maritime Research Information Clearinghouse: Data repository for vessel movements, port functions, economic activities, environmental impacts, GIS mapping tools, visualizations and graphics, stakeholder communication tools, workshops, public policy issue considerations, financial information and links to US maritime agencies such as the Coast Guard.

CE Dredge: national database for dredging info; provides aid with forecasting budgets and schedules, in addition to future volumes, capacities, and needs for dredging and disposal facilities. Aims to improve environmental analysis capabilities relevant to dredging operations, such as: delineating sea grass beds, bird islands, and marsh creation areas; and enhancing environmental compliance monitoring and assessments

Tools and Funding

Clean Marinas Program

The program is a collaboration between Michigan, Ohio and Wisconsin Sea Grant, and is funded through Great Lakes Restoration Initiative (US EPA). Six of the eight Great Lakes states offer Clean Marina certification.

In this program, participating marinas voluntarily pledge to maintain and improve local waterways by reducing or eliminating releases of harmful substances and phasing out practices that can damage aquatic environments. Per the Michigan Clean Marina's program website, "In Michigan to date, more than 40 marinas have been awarded certification. Since the program began in 2005, 30 Michigan marinas have been recertified, showing continued commitment to keeping Michigan waters clean."

According to the program website, the benefits of certification include reducing insurance and waste disposal costs, reducing pollution, improving water quality, protecting fish and wildlife habitat, and enhancing public image and relations through the promotion of environmentally sound practices.

The Great Lakes Clean Marina program also offers educational webinars on topics such as stormwater management, boat bottom washing to reduce invasives spread, and increasing resiliency for harbors and marinas.

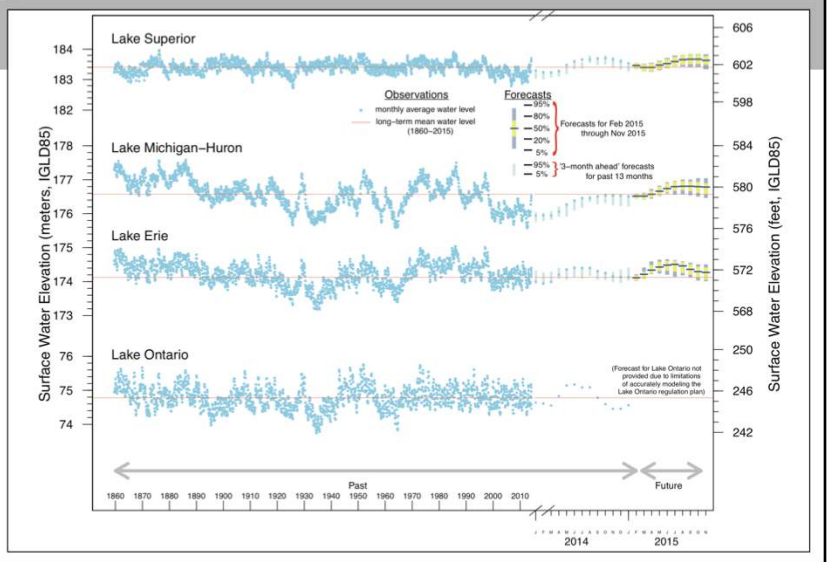
They provide pollution and recycling kits for marina operators and boaters, and have compiled a Best Practices Management Guide for Great Lakes. The Clean Marina Classroom is an online educational tool for marina owners and operators hoping to pursue Clean Marina certification.

Sources:
http://www.miseagrant.umich.edu/great-lakes-clean-marina/about/
http://www.miseagrant.umich.edu/michigan-clean-marina-program/

Tools and Funding

The NOAA-GLERL AHPS (Great Lakes Advanced Hydrologic Prediction System) forecasts are used by the U.S. Army Corps of Engineers and Environment Canada as part of their operational water level forecasting.

- The US Army Corps of Engineers' Detroit District website shows recorded, projected, and average water levels for each lake in a Monthly Bulletin report.
- Bulletins are uploaded on the 5th or 6th day of every month.
- The Army Corps offers funding for dredging through their Operation and Maintenance budget (O&M), through the Harbor Maintenance Tax. Projects with a Great Lakes Area of Concern (AOC) are eligible.



Sources:
http://www.lre.usace.army.mil/Missions/GreatLakesInformation/GreatLakesWaterLevels/WaterLevelForecast/MonthlyBulletinofGreatLakesWaterLevels.aspx
http://www.glerl.noaa.gov/pubs/brochures/lakelevels/lakelevels.pdf
http://glisa.msu.edu/media/files/projectreports/14-728%20Increase%20Resilience%20at%20Marinas%20and%20Harbors.pdf

Tools and Funding

Nature Conservancy's Climate Wizard

- Explores future climate scenarios to assist with planning, prioritization and development

The Association of Floodplain Managers Great Lakes Coastal Resilience Planning Guide

- Offers analysis tools for coastal managers

NOAA's Coastal Services Center

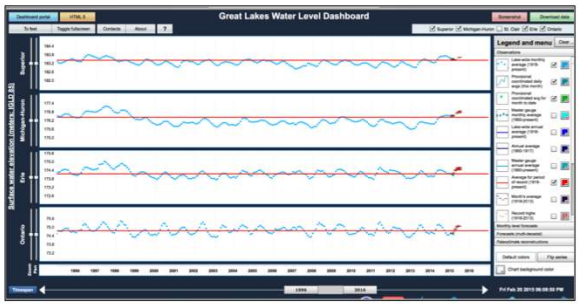
- Provides geospatial data on Digital Coast. Offers tools, training and resources for municipal officials.

The Collaboratory for Adaptation to Climate Change

- Offers tools and case studies and provides a collaborative framework where municipal decision-makers can connect with one another

Halifax Climate SMART: Sustainable Mitigation & Adaptation Risk Toolkit

- Kit includes risk management, community-based vulnerability assessment, cost-benefit, environmental impact analysis, and communications/outreach tools. Combines mitigation and adaptation.



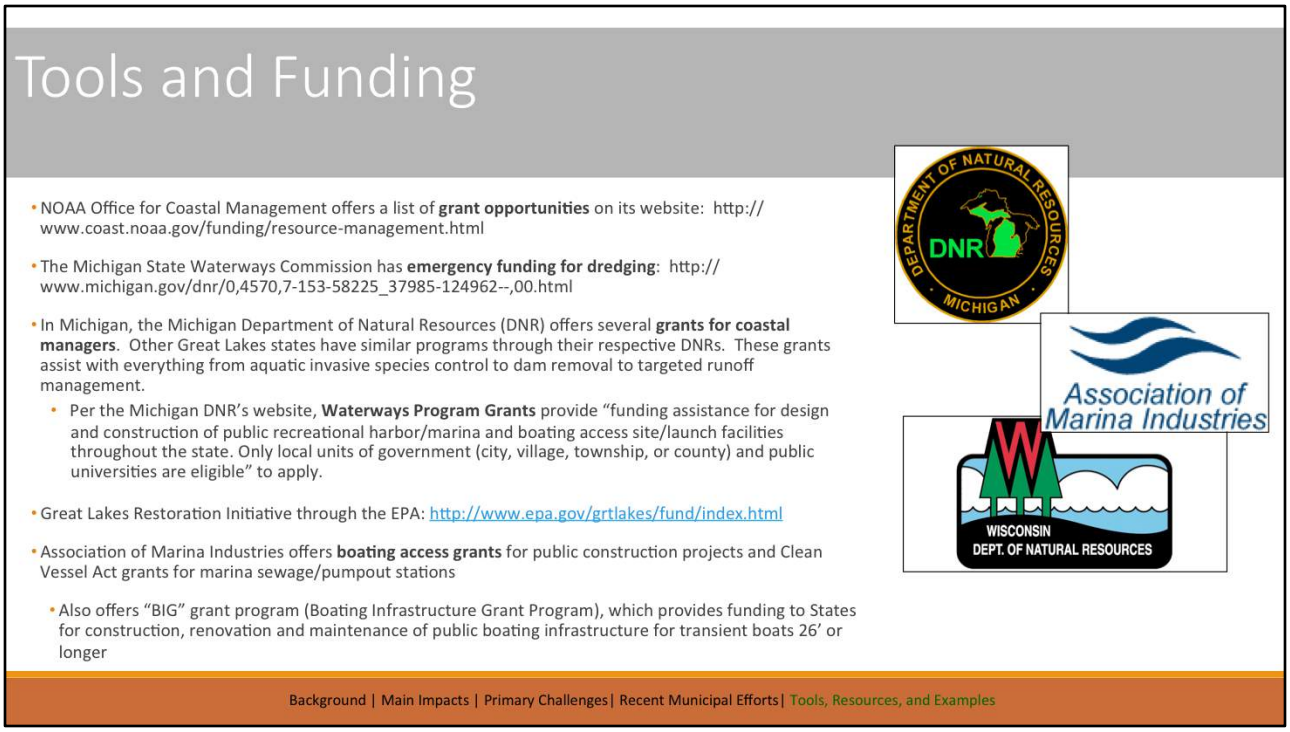
The Great Lakes Environmental Research Laboratory's Great Lakes Water Level Dashboard (pictured above) visualizes historic and future lake levels, with user-specified time scales.

Additional info:

The Great Lakes Environmental Research Laboratory's Great Lakes **Water Level Dashboard** provides a way to visualize and examine historic lake levels and future projection comparisons at a variety of user-designated time scales. Options are available for customizing output graphs in addition to time scale.

The Nature Conservancy's **Climate Wizard** allows users to explore future climate scenarios (change in temperature and precipitation under different future carbon emissions) for specific regions. This information can be used to inform a community's planning goals, resource management, and investment decisions.

The Association of State Floodplain Managers new **Great Lakes**



Additional info:
Please note that MANY more funding resources and tools are listed in the document below:
http://glisa.msu.edu/media/files/projectreports/14-728%20Increase%20Resilience%20at%20Marinas%20and%20Harbors.pdf

BIG grants program →
This program provides funds to States for the construction, renovation, and maintenance of public boating infrastructure tie-up facilities for transient boats 26' or more in length. The program is designed to provide transient dockage for recreational opportunities and safe harbors, as well as to:
Enhance access to recreational, historic, cultural and scenic resources;
Strengthen community ties to the water's edge and economic benefits;
Promote public/private partnerships and entrepreneurial opportunities;
Provide continuity of public access to the shore; and,
Promote awareness of transient boating opportunities.

This website offers links to at least a hundred different grant opportunities in the US

Benefits and drawbacks of tools

Considerations for municipal planners

Benefits:

- These tools can help provide a very valuable starting point for discussion and planning
- May assist in envisioning multiple scenarios, with various adaptation strategies, to gauge which are most effective at the least cost
- Offer quantifiable metrics that community members and municipal officials can easily understand and budget for
- Empower users to take immediate action in their own localities

Drawbacks:

- Tend to oversimplify – can't capture all aspects of a scenario completely
- Some tools tend to rely heavily on data that may or may not be fully complete
- Can undermine credibility if used incorrectly
- Tools need to be scalable

http://changingclimate.osu.edu/webinars/archives/2011-03-01/

Best Practices

From EPA's "Planning for Climate Change Impacts at US Ports":

"Ports can adopt **capital improvements, maintenance projects, or operational changes** to adapt to climate change.

For example, the construction of a protective sea wall would be a capital improvement. Reinforcing existing structures against stronger wind and waves would be a maintenance project. Reducing cargo loads in the face of lower water levels would be an operational change.

Likewise adaptation measures can **protect, adapt, or retreat**. Raising docks and warehouses would protect those assets. Developing more robust emergency procedures for storms would accommodate climate change. Relocating a port operation, as the Port of New Orleans is considering, would be a retreat measure."

Sea wall.

http://changingclimate.osu.edu/webinars/archives/2011-03-01/
http://www.epa.gov/sectors/pdf/ports-planing-for-cci-white-paper.pdf

Image:
http://geographyrachel.blogspot.com/2011/06/land-forms-and-sea-defences.html

Sample infrastructure modifications:
•Increase dock elevation and infrastructure heights when possible; install floating docks
•Reinforce dock walls or if no other recourse, may require relocation of entire facility

Best Practices

Summary

1. Assess risks and impacts in your area. Variable water levels, changes in precipitation and temperature, and increased storm frequency and severity are among the most likely climate-related outcomes to consider.
2. Conduct routine monitoring of shorelines and infrastructure to catch any issues or erosion early. Consider how facilities may operate in extreme temperature and weather conditions, and plan to stabilize or even relocate critical infrastructures as necessary.
3. Invest in long-term planning. This can include the installation of larger breakwaters, reinforced sea walls, and updated stormwater systems. Prioritize dredging in the most key areas first.
4. Form community partnerships and alliances. This helps with securing funding and enhancing/encouraging participation and buy-in from other stakeholders. Consider creating a Marine Investment Fund, wherein non-marine users pay a tax to help allay maintenance and adaptation upgrades.
5. Seek out solid data from reputable sources, and be honest with stakeholders about the degree of uncertainty in the projections used. Strive for transparency to minimize potential liability.
6. Look for scalable tools with a good usage track record.
7. Plan for the unknown. Projections for the Great Lakes region are useful but incomplete by their very nature. **Having contingency plans in place for unexpected variability is the most sensible approach.**

Background | Main Impacts | Primary Challenges | Recent Municipal Efforts | Tools, Resources, and Examples

Sources:
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http://www.epa.gov/sectors/pdf/ports-planing-for-cci-white-paper.pdf
http://glisa.msu.edu/media/files/projectreports/14-728%20Increase%20Resilience%20at%20Marinas%20and%20Harbors.pdf

Image:

Sample infrastructure modifications:
•Increase dock elevation and infrastructure heights when possible; install floating docks
•Reinforce dock walls or if no other recourse, may require relocation of entire facility

Additional Resources

1.) GLISA has compiled a guide for Great Lakes coastal managers on how to best increase resiliency in the face of climate change. This is an <u>invaluable resource</u>:

http://glisa.msu.edu/media/files/projectreports/14-728%20Increase%20Resilience%20at%20Marinas%20and%20Harbors.pdf

2.) Climate Change and Water Quality in the Great Lakes Region
http://www.ijc.org/rel/pdf/climate_change_2003_part3.pdf

3.) The Gulf Coast Study
Transportation Research Board
Miami-Dade Climate Change Action Plan:
http://www.miamidade.gov/greenprint/pdf/climate_action_plan.pdf

This PPT will be posted on the MARS CoP website for your reference

Source Citation: The MARS Webinars, https://www.ccadaptation.ca/en/training/webinars