Climate Ready Infrastructure and Strategic Sites Protocol (CRISSP) in Great Lakes Municipalities

Technical Paper

Pilot Project – Gary, Indiana

FINAL

December 2015

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Acknowledgements

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I. INTRODUCTION

Increasing costs and damages from extreme weather have become major concerns in the US/Canada Great Lakes St. Lawrence Region as well as throughout North America and beyond. Headlines document the impacts, including significant multi-year drought in California accompanied by wildfire, flooding in Colorado due to record-high precipitation, flooding in Texas after years of drought, high winds in the Midwest, and a cold-weather hurricane (Superstorm Sandy). Weather events continue to defy convention and expectation of timing and levels. Swiss Re, a global reinsurance company, recorded 189 natural catastrophes across the globe in 2014; the highest number they have ever recorded. Some of these unprecedented levels can be attributed to climate change and the attendant increase in global temperatures shifting weather patterns. Many types of weather events are becoming more severe and occurring at higher return rates.

This project provides municipalities with an easy-to-use protocol to triage areas of greatest concern in terms of the vulnerability of critical facilities. While the primary focus is in on storm surge and flooding events, it is applicable to other hazards associated with climate change and extreme weather. However, it also addresses chronic impacts that have a significant effect on community assets and resources such as how consistently warmer summers reduce water supply and makes wastewater treatment more difficult.

Presented within is a Climate Ready Infrastructure and Strategic Sites Protocol (CRISSP) that identifies short and long-term actions needed to reduce risk. It can also serve to raise awareness, among municipal staff and others, of the risk of extreme weather to critical facilities. In so doing, it builds a case for adaptation, greater readiness and preparedness.

CRISSP offers a flexible, non-technical approach to uncover climate-vulnerable points at key community assets and sites. It is designed to minimize labor intensity by helping communities rapidly assess and respond to their vulnerabilities. The protocol can also help prioritize actions and communicate risks to audiences that may not be as familiar with the subject matter. Going through the steps of the protocol can also help substantiate the need for facility retrofit and target areas where grants funds might best be directed.

The CRISSP process is summarized in the following steps:

- Assembling a CRISSP Team across municipal departments and engaging members to determining the scope of the evaluation;
- Gathering data and information to assess climate change impacts;
- Identifying infrastructure and strategic sites in predicted extreme weather hazard zones;
- Evaluating the vulnerability of identified critical infrastructure and strategic sites using the CRISSP Risk Matrix; and
- Determining mitigation measures and taking action.

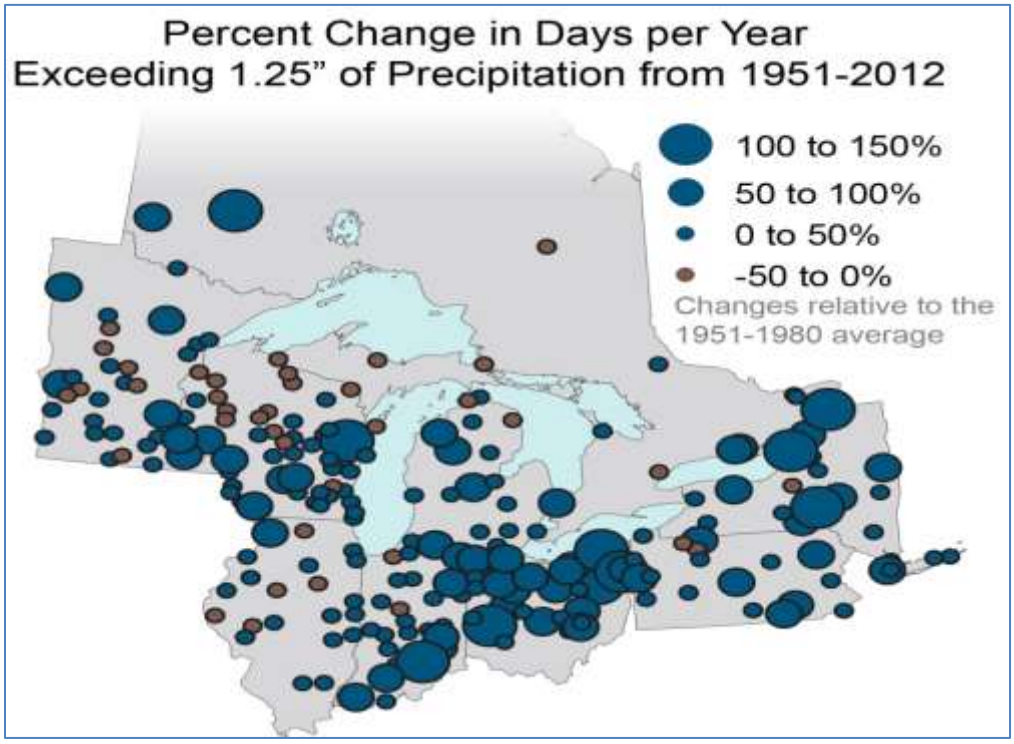
This technical paper is part of the Cities Initiative's Municipal Adaptation and Resiliency Service (MARS). Associated with the paper is a PowerPoint guide (to assist cities in undertaking a similar process), and a white paper in which "lessons learned" from the process are recorded.

II. PURPOSE

This technical paper draws from extensive research on how climate change is impacting areas in the US/Canada Great Lakes St. Lawrence Region, and what can be done to address these impacts. Intense weather events, attributable to climate change, are occurring more frequently around this region and beyond. Over the last few years, a number of Great Lakes and St. Lawrence Cities Initiative (Cities Initiative) member cities have experienced severe weather with devastating impacts on public and private property and critical municipal infrastructure. In considering approaches to address the impacts, it is necessary to take into account both reactive modes (e.g., responding to events in the short-term to contain impacts), and proactive modes that lower the risk but generally require substantial funding and several years to fully implement.

The most tangible change observed and measured from climate change is that of precipitation. Periods of less-than-normal precipitation lead to drought, while extreme levels of precipitation (in a short period of time) can lead to flooding and associated risks to human health and critical infrastructure. **Figure 1** shows the increase in the number of days (over the 1951-2012 period) where precipitation in the Great Lakes- St. Lawrence Region exceeds 1.25 inches, a threshold where nuisance flooding starts. Blue dots in the figure show an increase in days, with the largest dots showing the greatest increase.

Figure 1- Change in Days with 1.25 inches of precipitation (threshold of nuisance flooding)



Source: NOAA National Centers for Environmental Information GHCN-Daily data, quality-controlled by GLISA

While nuisance flooding may sound more like an irritation than a major concern, it can cause road closures, overflowing storm drains, and lead to the deterioration of roadbeds and rail beds. Also, this trend of increased nuisance flooding is an indicator of higher than normal precipitation that could also lead to more frequent and larger flood events.

Climate Trends

Overall, a growing body of literature focusing on climate trends indicates that observed climate changes will lead to more extreme weather. The Midwest section of the 2014 National Climate Assessment (NCA) provides the following description of climate change impacts:

> "Extreme heat, heavy downpours, and flooding will affect infrastructure, health, agriculture, forestry, transportation, air and water quality, and more. Climate change will also exacerbate a range of risks to the Great Lakes."

NCA lists the following as risks in the Midwest:

- Extreme weather that will negatively impact agriculture;
- Extreme weather that will negatively impact the composition of forests;
- Increased heat wave frequency and intensity, increased humidity, and degraded air and water quality;
- Increased rainfall and flooding including erosion; and
- Increased risk to biota in the Great Lakes

A report by the Union of Concerned Scientists states that the following trends will likely occur in the Great Lakes region due to climate change (from Confronting Climate Change in the Great Lakes):

- While, overall, the climate may be warmer and drier, thus creating susceptibility to droughts, there will be more frequent extreme rainstorms;
- Lake levels will likely decline and create difficulty for shipping and navigation;
- Wetland areas are likely to be drier, resulting in degraded water quality and wildlife habitat;
- A drier climate will reduce the flood-absorbing capacity of wetlands and floodplains; and
- Outbreaks of waterborne infectious diseases (e.g., cryptosporidiosis, *giardiasis)* may occur due to flooding from more extreme rainstorms. (Note: Milwaukee experienced a *cryptosporidium* outbreak in 1993 when an extended period of rainfall and subsequent runoff overwhelmed the city's drinking water system.)

Examples of Impacts

In this section, several examples are provided where communities in the Great Lakes St. Lawrence Region experienced damage and disruption from extreme weather events. These examples illustrate some of the potential impacts from extreme weather events and show a pattern of changing weather with greater temperature extremes and more intense storms.

Detroit Flooding (2014)

On August 11, 2014, the Detroit, Michigan area experienced a major flash flooding event. Some areas received more than six inches of rain in a short period of time, overwhelming the drainage systems of several freeways. Some roads were closed for days while the runoff systems caught up with the overload of water. In the city of Detroit, a record rainfall of 4.57 inches occurred, with most of the precipitation falling during a three hour period. This is the second highest rainfall record in Detroit; the only higher record is from 1925 when 4.74 inches fell in one day. To put the rainfall into perspective, the city's average rainfall for the entire month of August is three inches.

Other hard hit cities were Warren, Dearborn, and Dearborn Heights. In Dearborn, over six inches of rain damaged 40 percent of homes and businesses and closed 75 percent of roads. In Warren, 33 percent of homes were damaged (over 18,000 buildings). To help offset the high cost of damages, the US federal government approved Michigan Governor Rick Snyder's appeal for a disaster declaration. An estimated $1.1 million in home and business properties were damaged. Additionally, $16.7 million in damages was estimated to have affected public buildings and equipment.

In October 2014, Metro Detroiters were still dealing with the flood damage. On October 7, Detroit mayor Mike Duggan reported that 25,000 Detroiters had applied to the Federal Emergency Management Agency (FEMA) for help recovering from the flood damages. On October 24, 2014, the federal government approved $110 million, adding to the already approved $69 million in funding. While this funding certainly helps flood victims, it is far from covering the estimated $1.1 billion in damages. (Data sources- National Weather Service and local observers.)

Winter Storms in Canada and US (2013-2014)

The winter of 2013-2014 was particularly brutal in both the U.S. and Canada. A southward shift in the North Polar Vortex in December 2013 and early 2014, known as the North American cold wave, resulted in heavy snowfall and record low temperatures. The severity of the event caused business, school, and road closures, as well as mass flight cancellations in area impacted within the US/Canada Great Lakes St. Lawrence Region.

Environment Canada describes some of the noteworthy characteristics of this unusually cold winter:

- "On January 7 at 2:00 p.m., Canada's most southerly city, Windsor, was -17.4°C – 10 degrees colder than Canada's most northerly city, Iqaluit.
- February 26 was Hamilton's 47th day under a cold alert, the identical number of cold alert days for the city over the past three winters combined.
- Freezing-degree days below 0°C were 15 per cent higher than average over southern Ontario and Quebec, which explains the unusually thick river and lake ice.
- Toronto experienced its coldest winter in 20 years, which prompted the public health office to issue 36 extreme cold alerts compared to nine the previous year. Further, the city had snow on the ground for more than 100 consecutive days on top of a layer of pre-Christmas freezing rain."

The severe winter caused shortages of road salt, and heating fuel prices were extremely high. There were record levels of power consumption due largely to heating homes and business, and frequent power blackouts were experienced. The weather also caused Canada's biggest airport, Toronto's Pearson International, to shut down with serious implications for air travel across the country[1].

Angus (Ontario) Tornado (2014)

In 2014, Environment Canada confirmed 19 tornadoes in Ontario, far greater than the annual average of 12. While most tornadoes had negligible impact, the exception was one that struck Angus, a town located north of Toronto between Nottawasaga Bay on Lake Huron and Lake Simcoe:

> "Around 5:00 p.m. a line of severe thunderstorms moved into the Lake Simcoe region and ten to fifteen minutes later a tornado tore through the community of Angus. Rated at the high end of an EF2, it featured peak winds between 200 and 220 km/h, a width of 300 m at its widest point and tracked over 20 km."

The tornado damaged 102 homes, included 14 that were devastated, and left 300 homeless. While insurance claims exceeded $30 million, no one was seriously injured or killed[2].

Grand Rapids, Michigan (2013)

In April 2013, heavy rainfall caused the Grand River, which flows through Grand Rapids, Michigan, to reach the highest water levels in the recorded history of the city. Drawing on

[1] From Environment Canada, at http://ec.gc.ca/meteo-weather/default.asp?lang=En&n=C8D88613-1&printfullpage=true#ws32F86E8A
[2] From Environment Canada, http://ec.gc.ca/meteo-weather/default.asp?lang=En&n=C8D88613-1&offset=10&toc=show

lessons learned from a major Thunder Bay, Ontario storm (discussed below), the city fortified its wastewater treatment plant with 3000-3500 feet of trapbags (i.e., 4' tall sandbags). The plant was spared from the rising floodwaters thanks to this quick action on the part of the mayor and his emergency response team. This storm served as a wake-up call to the community; highlighting its need to re-examine its land use practices, including rapid urbanization, and consider how to better address the increased risk of flash flooding[3].

Southern Ontario Flash Flooding (2013)

On July 8, 2013, a storm and the resulting flash flooding that hit the Toronto metropolitan area caused more than $850 million in estimated damage to insured property. This storm would set a record as Ontario's most expensive natural disaster, according to the Insurance Bureau of Canada. The flooding impacted many homes, trains (e.g., GO Train), and nearly severely disrupted the power system.[4]

Thunder Bay, Ontario (2012)

In May 2012, thunderstorms in Thunder Bay, Ontario pounded the city with approximately 91 to 97 mm of precipitation (3.82 inches), resulting in flash flooding that impacted between 4,000 and 5,000 homes[5]. Floods also washed out numerous roads and trails and tore up large chunks of asphalt on roadways. The city's Water Pollution Control Plant experienced extreme flows, causing flooding of below-grade tunnels and the main pumping station. The flooding of this plant led to pump failures which caused hundreds of basements to flood.[6]

Duluth, Minnesota (2012)

In the summer of 2012, heavy rainfall caused the most severe flood on record to heavily visited Duluth, Minnesota, on the shores of Lake Superior. In some areas, up to 10 inches of rain over two days fell on already saturated soil, wreaking havoc throughout the city. Duluth has steep topography and, as a result, water rushed through stream traversing the city, carrying debris and blowing out culverts. An estimated $100 million in damage occurred from the storm, resulting in a Presidential Disaster Declaration and for Duluth and nine surrounding counties. City infrastructure and residential populations were severely affected. Approximately one year after the flood, an estimated 10-15% of the flooded homes were still in various stages of disrepair.

[3] http://www.mlive.com/news/grand-rapids/index.ssf/2014/01/2013_flood_experts_describe_ho.html
[4] http://www.thestar.com/business/2013/08/14/july_flood_ontarios_most_costly_natural_disaster.html
[5] http://www.glslcities.org/greencities/SMWM/Oct31_ThunderBay.pdf
[6] http://news.nationalpost.com/news/flooded-thunder-bay-asks-province-to-declare-it-a-disaster-area

This flood prompted a study on how various types of green infrastructure could benefit the city by providing enough stormwater storage to reduce peak discharges by up to 20%[7].

Midwest Derecho Events (2011 and 2012)

In 2011, the Great Lakes area experienced devastation from two severe straight-line windstorm events known as derechos. On July 11, 2011, a derecho event impacted Iowa, Illinois, Indiana, Michigan and Ohio. This powerful windstorm formed over central Iowa, intensified and the accelerated on an eastward path into Illinois, Michigan, and Ohio with winds up to 105 miles per hour. It caused a large amount of damage to both trees and structures, and had peak winds estimated at around 130 miles per hour. The strong winds of this storm caused a seiche event on Lake Michigan where the strong winds pushed large amounts of water on the downwind shore (in Indiana and Michigan), and the water then sloshed back and forth across the lake for many hours. Over 850,000 people in Chicago lost power due to the storm. Later, on July 17, 2011, a major heat wave impacted eastern U.S. and Canada and helped spawn another significant derecho event that impacted Ontario and Quebec.[8]

Another heat wave in June of 2012 (June 29-30) create another large derecho event that again started in Iowa and moved eastward to impact Illinoi, Indiana, Ohio and Pennsylvania. This derecho had peak wind gusts of 91 miles per hour in Fort Wayne, Indiana and caused approximately $2.9 billion of damage. Some of the greatest impacts were in Ohio, where over one million people in approximately two-thirds of the state lost power.[9]

Indiana Storms and Massive Flooding (2008)

In 2008, fifty Indiana counties were declared federal disaster areas due to severe storms and flooding. The state received more than $560 million in federal disaster assistance, making it one of the most costly years in history. From January through September of that year, floods affected most of the state and resulted in three federal disaster declarations. The most intense storms in early June spawned tornadoes and extreme rainfall, from two to 10 inches over two days, in central and southern Indiana. Flooding and flash floods forced thousands to evacuate. Damages to more than 25,000 homes, businesses, and infrastructure totaled more than $1 billion. Source: GLISA

Chicago Heat Wave (1995)

[7] From ASFPM at http://greatlakesresilience.org/stories/minnesota/duluth-re-evaluates-infrastructure-two-years-after-disastrous-flood-0
[8] From Wikipedia, http://en.wikipedia.org/wiki/July_2011_Midwest_Derecho
[9] From Wikipedia, http://en.wikipedia.org/wiki/June_2012_North_American_derecho#Ohio

From July 12-16, 1995, Chicago endured an abnormally intense heat wave. On two of the days, high temperatures were over 100°F; on July 13, a high of 106°F was recorded. Little relief was felt at night as low temperatures were in the upper 70s and 80s. A heat index, produced by high relative humidity and temperature, caused temperatures to feel even hotter – around 120°F on the hottest days. An urban heat island further impacted the city (i.e., higher temperatures in the city versus surrounding areas due to human activity, including building more reflective surfaces and increased greenhouse emissions).

The heat wave was generated by a strong upper-level ridge of high pressure and temperature and very moist ground conditions. This caused a slow-moving, hot, humid air mass to form over the region. Chicago was the hardest hit city, but Iowa, Wisconsin, and other parts of Illinois also felt the effects of extreme heat and humidity. Because the heat lasted several days, those who owned air conditioners operated them at maximum capacity. Chicago set records for electricity use and many areas lost power. At one point during the heat wave, 49,000 houses had no electricity. In desperate attempts to stay cool, some fire hydrants were illegally opened, causing entire neighborhoods to lose water pressure. The city's infrastructure was also affected as roads buckled and train tracks warped.

In Chicago alone, 465 heat-related deaths were reported from July 11-27, 1995, the most deadly weather related disaster in the city's history. By far, the most vulnerable populations were the elderly and the poor, with highest risk to individuals that lived alone, had a lack of transportation, were sick, did not have social contacts nearby, and/or did not own an air conditioner. In low-income neighborhoods with higher crime rates, it was reported that many residents kept their doors and windows closed for fear of their safety. Source: GLISA

Focus of this Project

This project evaluates the weather trends of a changing climate and their resulting impacts. As described in the section above, these impacts include extreme weather which has the potential to create massive damage and risk to health and safety. While extreme weather can impact almost everything in the built and natural environment, it is important to focus on allocating scarce resources to protection efforts in areas that provide the most benefit to the most people. For this reason, this project is focused on the impacts to critical assets that serve the whole community.

These assets provide basic community functions or other tangible benefits related to mitigating the impacts of climate change to the entire community. If an extreme weather event should damage or destroy one of these types of assets, the impacts are profound and ripple out to the wider community. Damage to these types of assets, and the resulting economic disruption from loss of service, can lead to staggering financial losses as well as human suffering and health risk.

These assets are categorized as either strategic sites or critical infrastructure; definitions are provided in Section III of this paper.

This project, including this technical paper, has the following outcomes:

- Description of how extreme weather can typically impact strategic sites and critical infrastructure;
- Preparation of a strategic sites and infrastructure protocol (CRISSP), including a risk matrix;
- Piloting the CRISSP in a representative city (i.e., Gary, Indiana);
- Preparation of recommendations to decision-makers in Gary on short and long-term actions they can take to address risk to strategic sites and critical infrastructure; and
- Education and outreach efforts to the Cities Initiative's 110 member US and Canadian cities.

The CRISSP approach is designed to be customized by each municipality that uses it. At the facility level, the considerations listed in the matrix may be added to by facility operators to best capture facility-specific vulnerabilities. The CRISSP approach, which harnesses the knowledge and expertise of facility and site operators and managers, can be free-standing or complementary to a more comprehensive climate vulnerability assessment. The value of this bottom-up approach is that it engages facility and site operators and managers, so that they are not only informed of vulnerabilities, but they become active participants in identifying and addressing the vulnerabilities in their own facilities.

While the CRISSP is comprehensive and helps identify long-term actions needed to reduce risk, it also raises awareness of the risk of extreme weather and urgency in taking more immediate actions toward greater readiness and preparedness. It is hoped that raised awareness will spread to the entire community and will be the catalyst for new or renewed efforts to make facilities and infrastructure more resilient, as well as influencing future land use decisions.

Limiting Factors

This technical paper provides a comprehensive overview of the risk from extreme weather events as well as an expedited approach (without requiring modeling) to assessing the potential impacts of extreme precipitation events to infrastructure and strategic sites. This rapid assessment process will raise awareness of risk and, in so doing, spur faster preparations for a potential event, either in a reactive (i.e., emergency response) or proactive mode.

Developing and employing precipitation projections to help estimate future flooding scenarios is complex and extremely data-intensive. It requires comprehensive data on multiple ground conditions, including the presence of flood control structures, and local hydrology conditions, both of which are beyond the scope of this effort. Another limiting factor is that the data needed to define risk (i.e., both current and future) vary from one community to the next; each is characterized by a unique and dynamic risk environment.

These limitations aside, this technical paper focuses on making use of readily accessible data, examining past events, and securing input from experienced staff at universities, federal agencies, and local officials familiar with past events. Through desktop reviews using this type of information, as well as use of the CRISSP Risk Matrix presented later in this paper, this combination of experience and data provides the information needed to depict future risk in sufficient detail to better prepare and address the risk.

To demonstrate its practical application, the City of Gary, Indiana was selected as a pilot. As with any pilot effort, it is expected that this approach will be modified as this protocol is applied to other communities. As this takes place, these communities may find that they need more detailed information for their own risk assessment and response planning purposes. This is particularly likely in larger, highly populated, and vulnerable watersheds. Among other resources, communities may want to consult a publication of the National Oceanic and Atmospheric Administration (NOAA); the agency developed an innovative approach to evaluating the effects of green infrastructure for climate change adaptation purposes in Toledo, Ohio and Duluth, Minnesota. The study can be accessed through NOAA Pilot Study in Toledo & Duluth.

Target Audience

The following groups comprise the target audience for CRISSP products (i.e., technical paper, white paper, Risk Matrix):

- ***Key municipal and county departments*** (e.g., land use planning, public works, stormwater, public health, environmental services, parks and recreation, emergency response personnel, utility facility operators) – Raise awareness of the hazard, how the extreme weather hazard might affect their facilities, and what measures can be taken to address the risk.

- ***Elected officials, including mayors and local councils*** – Raise awareness of the hazard, implications to the entire community, the need to prepare for public communication

during an extreme weather event, the need to elevate the issue to a community priority where appropriate, and influence budgetary decisions to set aside funding for highest priorities in addressing risk.

- ***Other stakeholders*** (e.g. state level, watershed agencies, affected businesses and residents) – Raise awareness of the hazard, implications to the entire community including mobility considerations, impacts to businesses and schools, impacts to service providers, impacts to homes, the need for resource contributions from agencies, and establish public support for addressing the risk.

It is recommended that any follow-up public outreach to this initial pilot effort build on information in this paper, and develop materials that explain the importance of this process to the general public as a means to raise awareness and enlist support.

III. METHODOLOGY

A changing climate results in several different impacts: existing types of storms are exacerbated, larger scale events are more frequent, and temperature extremes become more common. The first part of this section describes various scenarios, presents data supporting the observed changes to climate, and explains how it will impact communities in the Great Lakes St. Lawrence Region. The section then describes how particular assets essential to the community are impacted.

In the interest of developing a methodology that is readily implementable by most communities, our approach focuses on accessible data and established best practices. This approach has been tailored to best fit communities within the Great Lakes St. Lawrence Region. It entails a combination of a desktop review using available data sources (identified later in this section); interactions with local, regional, state, or provincial officials with subject matter expertise; a general estimation of increases in precipitation using gauges; and planning focused on potential future flood scenarios (also described later in this section).

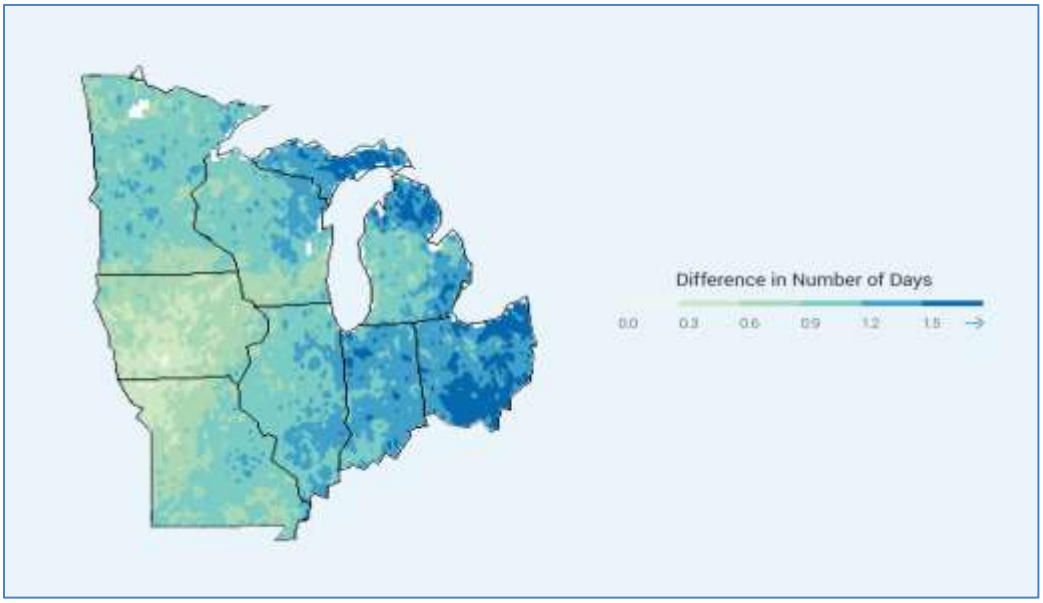
Hazards Identification and Scenario Awareness

This section identifies the major types of hazards that will likely become more frequent or severe as a result of climate change. It also describes the scenarios in which these hazards may emerge to raise awareness.

Extreme precipitation

Multiple climate models predict increased rainfall events to occur with climate change. In the Great Lakes St. Lawrence Region, the overall climate will become warmer and moister. In **Figure 2**, a National Climate Assessment map is provided, showing the increase in days with heavy precipitation, defined as the 2% of days with the highest precipitation. This increase is expected to cause more flooding. Areas in progressively darker shades of blue are the places where the increase is over one and higher. Another result of this projected change is nutrient pollution.

Figure 2 – Increase in heavy precipitation days



Source: NCA report (original figure source: NOAA NCDC/CICS-NC)

Potential flooding from increased precipitation levels, as well as increased rainfall frequency curves, could be compounded by any, or several of the following potential existing ground conditions:

- High lake levels (difficult for streams and rivers to outfall);
- Rivers and streams already at high levels due to previous precipitation events;
- Land saturation from frequent rainfall resulting in a high water table (and limited absorption capacity);
- Rapid snowmelt that contributes additional runoff volume;
- Partially frozen ground acting as an impervious surface that causes more runoff;
- Older stormwater conveyance infrastructure that is poorly maintained or under capacity; and
- Increased urbanization resulting in a less pervious landscape and more stormwater runoff.

Extreme precipitation will likely lead to more flooding, particularly in urban areas where there are high levels of paved (i.e., impervious) surfaces. Green infrastructure studies conducted by NOAA include information that shows a 45% increase in stormwater runoff when a natural, undeveloped area is compared to a highly developed (75-100% impervious surface cover) area[10]. Large

[10] "Economic Assessment of Green Infrastructure Strategies for Climate Change Adaptation: Pilot Studies in The Great Lake Region", p. 1-8; original reference from Federal Interagency Stream Restoration Working Group (FISRWG). (1998). Stream Corridor Restoration: Principles, processes, and Practices. PB98-158348LUW.

amounts of impervious surface also diminish the amount of infiltration into the ground, thus reducing groundwater resources.

For many of the reasons listed above and, combined with storms that may occur in late winter and early spring, this time period is conducive to flooding.

Winter storm (icing and freezing)

While the climate is generally warming as a long-term trend, regional factors will continue to produce significant variability from year-to-year, as experienced during the extremely cold winters of the 2013 – 2015 time period.

High wind events (straight-line winds and tornadoes)

Larger and more frequent storms will likely bring damaging winds in the form of straight-line winds and tornadoes. While these types of storms are somewhat typical of the Great Lakes St. Lawrence Region, the changing climate may increase the frequency and magnitude of these storms. Damaging straight-line wind phenomenon, like derechos, would likely migrate northward in the US and Canada due to a migrating jet stream. Derechos are massive wind storms with longevity, and characterized by large areas with rapid thunderstorms and straight-line winds (as opposed to tornadoes that have circulating winds). The NOAA-NWS-NCEP Storm Prediction Center notes that "derechos tend to form on the equatorward side of jet streams, especially those that mark the northern fringes of warm high-pressure ('fair weather') systems". NOAA Storm Prediction Center. The Great Lakes St. Lawrence Region may experience more derechos in the future.

Tornadoes are fairly common in the Midwestern United States but have the potential to become more intense with greater climate fluctuation. It is also possible that tornadoes may become more common on the Canadian side of the Great Lakes.

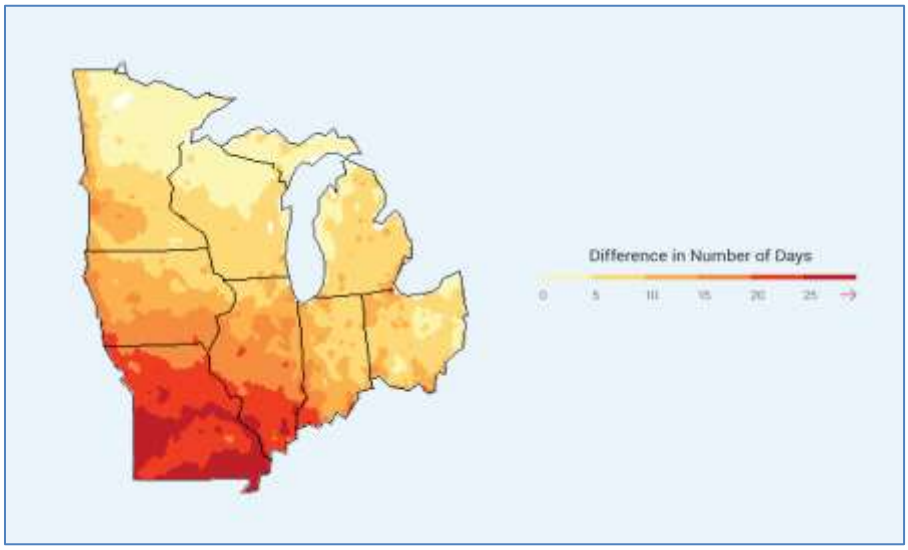
Extreme Heat

Extreme heat is a hazard that will likely increase in frequency due to climate change. Extreme heat is primarily a threat to human health and agriculture. **Figure 3** shows the difference in increase of days above 95 degrees which is the temperature threshold associated with negative human health impacts and suppressed agricultural yields. As described earlier in this paper, the 1995 Chicago Heat Wave also caused damage to transportation infrastructure, with roads buckling and train tracks warping.

Extreme heat events have also been linked to power outages. While Climate Central reports that from 2003 to 2012, only 2% of weather-caused power outages can be attributed to extreme heat

or wildfire, it also states that extreme heat was the reason for 64 restricted power advisories in that time period (from Climate Central's "Blackout: Extreme Weather, Climate Change and Power Outages") .

Figure 3 – Increase in extreme heat days (above 95 degrees Fahrenheit)



Source: NCA report (original figure source: NOAA NCDC/CICS-NC)

Social conditions contribute to the fact that heat waves can quickly become dangerous to the health of vulnerable populations. Elderly and low income populations typically suffer the most in instances where there is a lack of air conditioning, limited mobility, and safety concerns that cause people to keep their windows and doors closed. Eric Klienberg, author of *Heat Wave: A Social Autopsy of Disaster in Chicago*, stated in a 2002 interview:

> "We know that more heat waves are coming. Every major report on global warming- including the recent White House study- warns that an increase in severe heat waves is likely. The only way to prevent another heat disaster is to address the isolation, poverty, and fear that are prevalent in so many American cities today. Until we do, natural forces that are out of our control will continue to be uncontrollably dangerous."

Other impacts of extreme heat include the following:

- Increased evaporation rates and the subsequent impacts to river and lake levels, as well as decreasing groundwater levels. Drinking water supplies, as well as stream and lake health, could also adversely impacted lower water levels.
- Decreased groundwater levels that result in less infiltration into the sanitary sewer conveyance system, thereby increasing wastewater stream strength that could lead to difficulty in adequate treatment of wastewater, increased odor issues, greater risks to

worker safety, and impacts to existing vegetation and associated changes in the health of streambanks.

- Inadequate surface water to operate hydropower facilities.

With the increasing likelihood of extreme heat events, it becomes important to identify and mitigate, where possible, conditions that exacerbate the impacts.

Hazards Location and Impact Analysis

The remainder of this section focuses on data sources that help better define the location and magnitude of geographic-specific hazards (e.g., floods). Some hazards (e.g., extreme heat) are not confined by geography and have a relatively uniform effect on an area, although the risk will be gauged on existing conditions on the ground. This section will list sources of the data and some description of their use. The following section (IV) of this paper will address impacts of hazards outlined in "Hazard Identification and Scenario Awareness" via a Risk Matrix.

Flood Maps

Flood maps are useful tools, developed with engineering and terrain data that forecast the location and probability of defined flood events. A flood is commonly defined as "an overflow of water that submerges land which is usually dry. … Flooding may occur as an overflow of water from water bodies, such as a river or lake, in which the water overtops or breaks levees, resulting in some of that water escaping its usual boundaries, or it may occur due to an accumulation of rainwater on saturated ground".[11]

In the United States, flood maps are developed by the Federal Emergency Management Agency (FEMA). In Canada, from the mid-1970s until 1998, a national flood damage reduction program under Environment Canada involved the mapping of over 900 communities. The results of the mapping also included designation of 320 flood risk areas. While this program is no longer active, the maps remain available for reference at Environment Canada Flood Maps.

There are several different types of flooding that can occur in the Great Lakes St. Lawrence Region, including storm surge from the Great Lakes, riverine flooding, and stormwater ponding. On FEMA flood maps, surge areas are generally labeled as "V"; while other types of flood zones regulated by FEMA are called "A" or "AE" zones. All of these regulatory flood zones use the 100-year flood (also called the 1% annual chance flood), referred to as the Base Flood Elevation, as the regulatory flood height for new development or substantial improvement to existing

[11] BBC (British Broadcasting Corporation). (n.d.). "Floods." Available at http://www.bbc.co.uk/science/earth/natural_disasters/flood

development. It is important to note that over 30% of flood claims occur outside the regulatory floodplain (100-year flood zone).

FEMA generally also maps the 500-year floodplain (or 0.2% annual chance flood) which is the shaded area in the "X" Zone on Flood Insurance Rate Maps (FIRM). It may also be marked as the "B" Zone on older maps. Through Executive Order 11988, FEMA advises that all critical actions (i.e., those for which even a slight chance of flooding is too great) should be protected to the 500-year level. Examples of critical actions are generating plants and other principal points of utility lines. Another Executive Order was released in 2015 (EO 13690) that reinforces 11988 with the recommendation that federal agencies factor in the effects of climate change and build structures and infrastructure to one of three levels of protection:

- "Utilizing best-available, actionable data and methods that integrate current and future changes in flooding based on science,
- Two or three feet of elevation, depending on the criticality of the building, above the 100-year, or 1%-annual-chance, flood elevation, or
- 500-year, or 0.2%-annual-chance, flood elevation".

FEMA maps can be viewed on-line by going to the FEMA Map Service Center at FEMA Map Service Center. Another resource for flood maps is FEMA's official comprehensive web site focusing on storm and wind studies of the Great Lakes basin (Great Lakes Coastal Flood Study). The web site provides updated coastal flood hazard information and flood map data for Great Lakes coastal communities.

While various cities in the Great Lakes St. Lawrence Region (e.g., Gary, IN and Grand Rapids, MI) have extensive protective levee systems, flooding can still occur under several scenarios:

- on the land side of the levee if there is improper drainage;
- if the levee is overtopped; and/or
- if the levee fails due to structural collapse, scouring, or overtopping.

More recently, revised maps may be supplemented with beneficial non-regulatory products like depth and velocity grids that indicate areas of higher risk within a mapped floodplain. This can be combined with a review of local topographic maps to understand ground elevation.

Floods can cause damage in a variety of ways. Structural damage can occur through inundation, erosion and scour, and resultant moisture can cause mold, further compromising affected structures. Flood waters are breeding grounds for pests like mosquitoes and, when their presence alters hydrologic connections between otherwise separated bodies of water, they can provide an avenue for invasive species (e.g., Asian carp) to expand their range into previously un-infested

waters. Additionally, water quality is negatively impacted when floodwaters stir up contaminants present in water bodies.

Areas of Historical Flooding

Many community residents are generally aware of problem areas for flooding, based on personal experiences that might include a home or yard being flooded, or recurrent flooding problems that affect driving routes. This is also the case with local officials who regularly contend with flooding incidents in some capacity (e.g., first responder or public works official). In many communities, such flood events are noted in a local plan (e.g., stormwater management plan, floodplain management plan, hazard mitigation plan). Where possible, these areas should be mapped to record patterns of flooding to benefit future mitigation efforts. This is particularly important in areas of historical flooding where flooding patterns are not normally captured in flood maps or addressed through ordinances which tend to be focused on rising river and lake levels. Stormwater flooding, especially in urban areas, is likely to become more common and severe with increased precipitation events.

Lake Levels

Variations in water levels in the Great Lakes St. Lawrence system can have pronounced implications for an array of water-dependent activities, and can cause coastal flooding when lake levels are high. In combination with storm events (and associated storm surge), high levels can block river and stream outfalls and cause backups in the tributaries. When lake levels are particularly low, water-dependent industries (e.g., commercial shipping) can be adversely affected. Also, lower lake levels may result in a decrease in groundwater levels that, in some instances, can result in subsidence problems that can negatively impact older buildings and facilities.

NOAA's Great Lakes Environmental Research Laboratory (GLERL) maintains a Great Lakes Water Level Dashboard in cooperation with the Canadian government. (Great Lakes Water Levels). The dashboard provides historical lake levels data as well as a six month forecast for water levels.

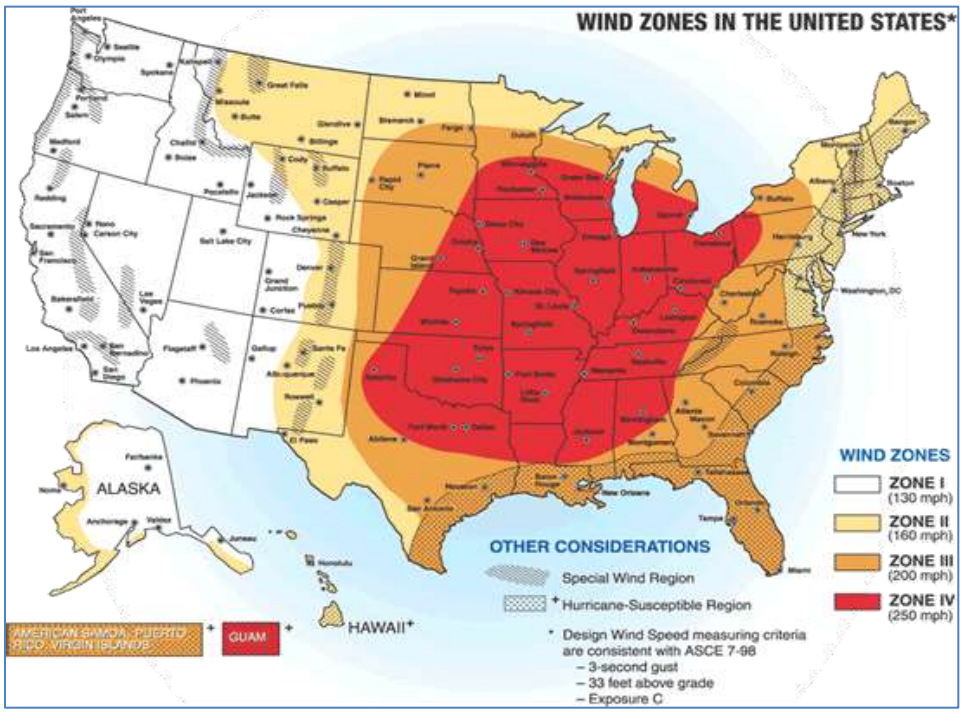
NOAA has also developed a lake level viewer to show how changing levels affect land areas; it can be accessed at: NOAA Lake Level Viewer. The viewer provides an overlay of each of the Great Lakes and ground features/facilities up to six feet above and below the long-term historical average. Another useful reference is a NOAA report entitled "What Could Changing Great Lakes Water Levels Mean for our Coastal Communities? A Case for Climate-adapted Planning Approaches". It is available at NOAA Great Lake Level Case Study.

Wind Zones

High winds that can damage property and endanger people come from a variety of sources. High winds in the Great Lakes St. Lawrence Region are usually generated by severe thunderstorms and severe winter storms. Much of the U.S. portion of this region is in the highest risk wind areas (i.e., Wind Speed Zones III and IV), and can experience wind speeds of up to 250 mph (see **Figure 4**).

Wind is defined by FEMA's Multi-Hazard Identification and Risk Assessment as "the motion of air relative to the earth's surface." A microburst is a strong, localized thunderstorm downdraft which, when it strikes the surface, produces winds affecting an area less than 2.5 miles across. High winds cause damage to crops, buildings or infrastructure through impacts to the buildings themselves or causing debris or trees to crash into the asset creating damage. Flying debris in high winds can also cause injuries to people and animals. High winds are a hazard that generally has a large geographic impact being caused by larger scale storms, like thunderstorms and winter storms. The likely impacts of high winds in the Great Lakes St. Lawrence Region is damage to manufactured homes, disruption of power and telephone services, highway closures, and disruptions to emergency communications capabilities.

Figure 4 – FEMA Wind Zone Map

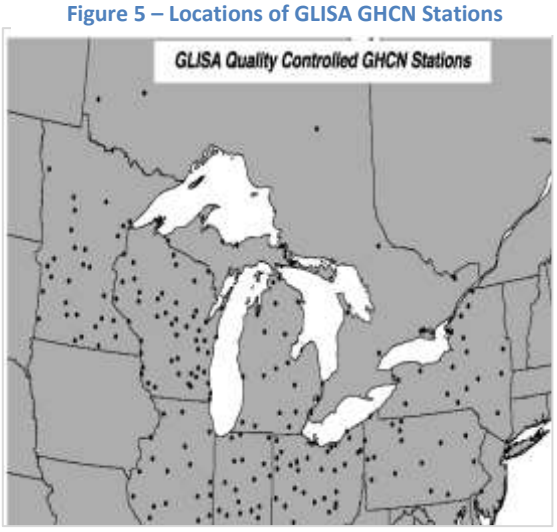


Source: FEMA website at https://www.fema.gov/safe-rooms/wind-zones-united-states

Winter Storms

Winter storms generally have a relatively uniform impact on the affected city or area. While there is generally no way to map the potential impacts of winter storms, recent experience in the pilot city of Gary shows two major snowstorms in the last five years (2011, 2014). A warmer climate may lead to more freezing rain, or rain on frozen ground conditions in the winter. This type of scenario can also lead to increased power outages. Further, any increase in the use of chlorides (i.e., road salt) can have adverse impacts on receiving water bodies. Chloride toxicity negatively impacts survival, growth and reproduction of aquatic species.

Figure 5 – Locations of GLISA GHCN Stations



Source- Locations high-quality of NOAA NCEI GHCN-Daily stations

Extreme Heat

Extreme heat conditions, another potential outcome of climate change, can be widespread. However, certain areas may be more susceptible to the effects of extreme heat due to existing air quality conditions. In addition to effects on population (e.g., risk of heat sickness and heat stroke), such conditions also worsen air quality by increasing ground-level ozone, a particularly dangerous occurrence in U.S. Environmental Protection Agency (USEPA) air quality non-attainment areas.

As described earlier, extended periods of extreme heat will also likely decrease groundwater and lake levels, potentially leading to subsidence as well as increased strength and temperature of wastewater streams. Due to changes in temperature and water levels, periods of extreme heat will also impact vegetation. Public officials are well-advised to evaluate their infrastructure for vulnerability to extreme heat.

Identification of Strategic Sites and Infrastructure in predicted extreme weather hazard zones

Many communities in the Great Lakes St. Lawrence Region share common challenges in facing the potential of an increasingly warm and moist climate with greater variability. An important aspect of this challenge is the need to assess, and then minimize the risk to critical infrastructure.

Critical infrastructure

A common focus in hazard mitigation is the protection of critical infrastructure and facilities that provide function and use for the entire community. They are considered to be "critical" because so many people are dependent on them for basic services as well as for life support functions. FEMA describes critical infrastructure as follows:

> "Simply stated, critical infrastructure comprises the goods and services that are necessary for business continuity and are vital to daily life for each and every American. Disrupting or destroying our Nation's critical infrastructure would have major impacts, because we are all connected to it—individual citizens, the private sector, and all levels of government. Critical infrastructure is defined as systems and assets, whether physical or virtual, so vital that their incapacitation or destruction may have a debilitating impact on the security, economy, public health or safety, and/or the environment."[12]

As noted earlier, Executive Order 11988 addresses floodplain management and, through FEMA, advises that all critical actions (i.e., those uses for which even a slight chance of flooding is too great) should be protected to the 500-year level. FEMA, through the 2013 Community Rating System Manual, has a similar definition for critical facility:

> "A structure or other improvement that, because of its function, size, service area, or uniqueness, has the potential to cause serious bodily harm, extensive property damage, or disruption of vital socioeconomic activities if it is destroyed or damaged or if its functionality is impaired. Critical facilities include health and safety facilities, utilities, government facilities, and hazardous materials facilities. For the purposes of a local regulation, a community may also use the International Codes' definition for Category III and IV buildings."

The Thunder Bay and Grand Rapids examples (provided earlier in this paper) illustrate the need for communities to understand where their vulnerable critical infrastructure is located, and have a plan (both proactive and reactive) for its protection.

The following critical infrastructure list is based on definitions provided by FEMA as well as input from the Advisory Group assembled for this project. It is not meant to be an exclusive list, but provides general guidance:

[12] http://emilms.fema.gov/IS921/921_Toolkit/faq.htm

- **Water supply plant(s) and distribution network –** A water treatment and supply plant is a critical facility that provides water for uses that include residential, industrial and fire protection. Water supply plants are generally located in low-lying areas near the source of the water (e.g., next to rivers, lakes or man-made reservoirs) and may be contain many underground pipes and tunnels potentially subject to back-up infiltration by stormwater. Electrical components and Supervisory Control and Data Acquisition (SCADA) control panels, a type of industrial/infrastructure control system, are needed to power and operate the plants and, in the event of extreme weather events, may be vulnerable to flood or wind damage.

- **Wastewater treatment plants and collection network –** Due to their need to be close to water sources or in low-lying areas due to gravity feeds, wastewater treatments plants are also generally vulnerable to flooding. Wastewater plants also generally contain many underground tunnels into which floodwaters can infiltrate, thereby rendering the plant inoperable. A flood event could lead to bypass of raw sewage into surface water and/or backup of sewage into homes and businesses within the service network. High winds may pose a threat to critical components of the treatment plan if the building housing these components is damaged by the wind or wind-driven debris. Warmer wastewater streams caused by extreme heat also might pose issues related to treatment and less groundwater infiltration will cause lower flows during periods of drought. These impacts could increase levels of Hydrogen Sulfide (H2S) which could cause more odors, corrosion of sewers, and worker safety issues.

- **Electric power generation facilities, transmission and distribution network –** As most development requires electrical power to operate, the loss of electric power can range from an inconvenience, to loss of revenue due to business interruption, to a serious health risk to people dependent on a power source (e.g., medical equipment). In addition, other critical facilities such as wastewater treatment plants are dependent on electric power and are usually rendered inoperable with a loss of power. Electric power generating facilities and their transmission/distribution networks can be vulnerable to a variety of natural hazards including flooding, high wind, tornadoes, winter storms, and extreme heat.

  The non-profit research group Climate Central, using 28 years of utility-submitted data to the federal government and the North American Electric Reliability Corporation, shows that the number of major power outages increased 10 times between the mid-1980s and 2012. Outages doubled between 2003 to 2012, with weather causing 80% of the outages during this period. Further, Climate Central reports that five states in the Great Lakes St.

Lawrence Region are in the top 10 nationally for the number of major weather-related power outages. This includes Michigan (#1), Ohio (#3), (#4), Illinois (#9) and Indiana (#10). (Climate Central's "Blackout: Extreme Weather, Climate Change and Power Outages").

- **Natural gas supply facilities and distribution –** Natural gas service is critical for providing heat to buildings, particularly so in the winter months in the Great Lakes St. Lawrence Region. As with electric power, its distribution system can be vulnerable to a variety of hazards.

- **Communication facilities –** Communication capability is essential for basic public services, and particularly important in addressing disaster events. Examples of communication facilities include communication towers, police communication systems, and traffic control systems.

- **Essential government facilities for emergency and continuity of government –** Essential facilities for maintaining continuity of government include the following:

    - Government facilities critical for the immediate preceding period and aftermath of a disaster (i.e., 72 hours before and after incident), including emergency operations centers, first responder facilities, and local executive capacity for command and control of the operation (e.g., Mayor); and

    - Facilities needed to help normalize city functioning including city hall, courts and other government facilities. Damage or loss of function to critical public facilities can result in extremely chaotic situations post-disaster and can pose a risk to individual and community health, as well as business disruptions and hardships to residents.

- **Key transportation infrastructure –** Transportation infrastructure provides mobility both for typical community functions (i.e., personal and commercial traffic), as well as emergency vehicles. The loss of such infrastructure can have devastating impacts on the health, safety and economic viability of a community and its residents, and also result in a "ripple effect" with broader regional implications. The following are generally considered components of key transportation infrastructure: major highways, rail, airports, ports, bridges, tunnels, and emergency response corridors. The way in which these facilities can be damaged includes: loss of use due to flooding, power outages, permanent damage to key areas (e.g., bridge segment collapse), damage to road surface, and/or blockage (e.g., due to debris from damaged buildings or trees).

- **Major hospitals and public health facilities –** The protection of major hospitals and health care facilities is a priority in any weather-related event, given the imperative to safeguard patients who cannot be easily evacuated or relocated; the need to maintain capacity to treat victims from the event; and their role in containing any public health threats that may emerge as a result of the event (e.g., drinking water contamination). Considerations include maintaining power and access to the facilities as well as protecting their structural integrity.

- **Top commercial facilities/employers –**While all businesses are important to a community, there are typically a few large businesses that employ substantial numbers of people and, therefore, have a significant economic impact on the community (i.e., other smaller businesses depend upon them either directly or indirectly). Their protection during extreme weather events is particularly important for that reason.

- **Other facilities of note –** These are additional types of facilities that, if damaged, could have major consequences on the surrounding community by posing health risks and/or causing additional damage (e.g., a manufacturing plant that produces, uses, or stores toxic materials; aboveground/underground storage tanks). Other facilities of note include data storage centers, given that they may house computer systems essential to the operation of other critical facilities such as communications systems. In addition, they may contain important records that could become lost or damaged during a weather event.

Strategic sites

In addition to critical infrastructure, there are other important community or regional assets that require special attention due to their cultural or natural significance. These areas are referred to as strategic sites, and are comprised of areas of unique physical, biological, and/or cultural attributes of importance to the community in which they are located. Strategic sites can be of any size; their key attribute is that they are vital to maintaining a community's sense of place. An illustrative list is as follows:

- **Culturally significant sites** (e.g., iconic and/or historically significant structures) **–** Historic and cultural sites that are important to the identity of the community.

- *Historical resources* – These are buildings, monuments or other types of historical resources that are unique and provide intrinsic value. In some cases, these sites might also be important to the tourism business.
- *Other cultural sites* – These may be religious or other types of cultural sites.

- **Ecologically significant natural areas –** Areas that are valuable to the community and/or provide benefits such as absorbing floodwaters. If destroyed or developed, there may an increase to natural hazards risks such as flooding. Temperature variability due to climate change (and changes in precipitation patterns) could impact the vulnerability of existing vegetation regimes.

  - *Wetlands* – Wetlands are areas where saturation with water is the main determinant for soil development and the plants and animals that live there. Wetlands serve as natural sponges that can help soak up storm water. Environment Virginia, a citizen-based environmental advocacy organization, has noted that an acre of wetland one foot deep can hold about 330,000 gallons of water[13]. Development of wetlands can displace stormwater and reduce community stormwater storage, potentially resulting in flooding problems. The U. S. Fish and Wildlife Service (USFWS) has a National Wetlands Inventory that provides information on existing and past wetlands in areas across the country (National Wetlands Inventory).
  - *Beaches* – As valuable recreational and ecological resources, beaches are susceptible to erosion from fluctuating lake levels and storm events. Beaches and surrounding waters are also susceptible to pollution from the outfall of flooded rivers.
  - *Parks* – Communities may have parks, such as greenways in stream corridors that provide recreational benefits to residents and ecological benefits. Depending upon their location, they may be vulnerable to extreme weather events.

- **Environmentally contaminated areas at risk of adversely affecting surrounding areas –** These are highly contaminated areas that, if disturbed, may contribute to environmental degradation of biologically sensitive areas essential to the maintenance of ecological diversity.

  - *Brownfields* – USEPA defines brownfields as properties whose redevelopment or reuse potential is compromised or prevented by the presence or potential presence

[13] From Newport News Daily Press, http://www.dailypress.com/news/science/dp-nws-wetlands-flood-protection-20150418-story.html, accessed May 2015

of a hazardous substance, pollutant, or contaminant. If disturbed by floodwaters or other hazards, there is a potential for contaminants to be further dispersed within and beyond the brownfield site.

- *Superfund sites and other contaminated areas* – These are generally abandoned hazardous waste sites that may require substantial remediation to remove or neutralize toxic and hazardous waste. Any disturbance of these sites or areas by natural hazards could result in widespread release of the waste materials and additional damage to surrounding land and ecosystems.

Subsequent sections of this paper will assist local officials in assessing the potential impacts of extreme weather events on these assets. In addition, recommendations and best practices are highlighted for prospective application when considering risk reduction. Local officials will need to consider two inter-related aspects when addressing risk: 1) immediate measures to protect these assets from extreme weather events; and 2) additional steps that will help lower long-term risk. In addition, where rapid growth is occurring (e.g., Grand Rapids, MI) there is also a need to manage land use and rapid urbanization such that the potential to exacerbate flooding (e.g., increased impervious surfaces, loss of wetlands) is avoided or minimized.

IV. CRISSP RISK MATRIX

To better understand specific risks to critical infrastructure due to extreme weather, a Risk Matrix has been prepared for use by local officials. The Risk Matrix draws on information from other risk assessment best practices, and then tailored to the specific needs of this project. One such best practice referenced is the FEMA/DHS Critical Infrastructure toolkit, which raises key overarching issues and questions to consider:

- What are the essential elements of your business? Is it your physical plant or facilities? What about your networks and systems? Your workforce? What goods or services do you require to continue functioning? Do you have specialized equipment?
- How vulnerable are your essential business elements to the different types of hazards that you may face?
- What would the consequences be in terms of human lives and economic impact if these essential elements were damaged, disrupted, or destroyed by an event in your community?

It is important to note that the initial damage from an extreme weather hazard can lead to a cascading series of additional damaging events. For example, a severe winter storm can cause power outages that may cripple critical facilities such as water and wastewater treatment plants and result in business interruption costs. Where initial damage cannot be prevented, or where an event may exceed a design level of protection, there must be a focus on containing secondary impacts such as securing adequate backup power supply for critical operations. The Risk Matrix addresses some of the resources needed for containing secondary impacts.

The hazards of extreme weather can impact a strategic site or infrastructure in a number of ways. High wind, winter storms and extreme heat typically result in relatively uniform effects, while site-specific impacts will be proportionate to the degree of the facility's vulnerability to the hazard (e.g., some structures may have rooftop equipment that is vulnerable to high wind). Flooding, however, is more geography-specific, with impacts that vary widely from facility to facility. (For this reason, an entire section of this paper is dedicated to flooding.)

The Risk Matrix is a self-assessment tool that facilitates an understanding of the current status of a given facility relative to best practices. It also helps identify next steps to increase resiliency. The intent is to provide officials with a confidential tool to support planning efforts.

It is recommended that community officials first discuss which structures may be most vulnerable based on desktop reviews of available risk information such as flood maps. However, it is important to note that all critical infrastructure is at some risk to extreme weather and, therefore, should be subjected to the self-assessment process via the Risk Matrix. Infrastructure

and facility managers (and their staff) are best positioned to apply the Risk Matrix. In so doing, it is important that they focus on both the impacts of the hazard on the physical structure, and on lifelines (e.g., utilities) that are necessary for operations.

The self- assessment is organized as follows:

- General site information
- Identification of geographic-specific risk factors
- Identify degree of risk from other extreme weather hazards
- Evaluate immediate hazard event emergency preparedness and response capability
- Site-specific risk related to flood hazard
- Potential risk to strategic sites
- Critical dependencies
- Long-term mitigation efforts

In undertaking the assessment, the manager/operator of a critical facility or infrastructure, will completed all components of the following Risk Matrix except for Part F (Risk to Strategic Sites). The manager/operator should also ask themselves the question "What keeps us up at night?" to determine where the greatest vulnerabilities are and which scenarios are mostly likely to occur. Part F pertains specifically to strategic sites and should be completed by the manager/ operator, as appropriate. In the Risk Matrix, the right column provides space for local officials to make comments, and also offers suggestions on mitigation measures that merit consideration. These mitigation measures are described in greater detail in Section V.

In completing the Risk Matrix, it must be remembered that an extreme weather event impacting a facility or infrastructure typically has a cascading effect that can result in secondary impacts. Additionally, it is important to realize that threats due to climate change may be emerging and, therefore, can be addressed in a proactive manner.

CRISSP Expedited Risk Matrix

Hazard/Risk Element	**Status/Comments; Suggested Mitigation Measures (in bottom row per item)**
A. General Site Information	
Location of your facility/site and basic description	
Purpose of site including key products and services	
Maximum number of people at site per	

day	
Number and type of vehicles at site per day	
Number of Structures Buildings: Other:	
Elevation: Number of Floors above ground	
Elevation: Number of Floors below ground	
B. **Identify Risk Areas (**Geographic –specific)	
Is the main facility located in the FEMA regulated floodplain – either A or V (100-year), or shaded X or B zone (500-year)?	
	If critical action, protect to 500-year flood level. Consider meeting higher standards of Executive Order 13690, "Federal Flood Risk Management"
From Elevation Certificate, what is the Base Flood Elevation (A or V zone) and what are the elevations of the main facilities	
Is there other vital utility infrastructure (e.g., electrical components) or facilities necessary for operating the main facility in the floodplain or below ground? For example: Wastewater Treatment Plant (WWTP) – open lagoons, clarifiers, enclosed solids treatment, pumping stations, main sewer influent lines to plant – force mains. Water Treatment Plant (WTP) – pump stations, treated water supplies, water distribution system.	
	Consider elevating, floodproofing or relocating components above-ground but in floodplain, consider floodproofing or relocation for components below-ground
Has either the main facility or connecting infrastructure (e.g., roads providing ingress/egress) ever experienced flooding on-site? In the general area?	
Are you located in an area that could be impacted by higher than average lake levels and/or coastal storms?	
	Consider elevating, floodproofing or relocating facilities impacted by higher lake levels or coastal storms.
If your facility uses a supervisory control and data acquisition (SCADA) system to operate, are components of this system vulnerable to flood and other hazards? For example, critical	
	Protect the room or facility with SCADA controls system from flooding. Remember to protect the SCADA system from cyber threats also.

components at WWTP - level switches, pumps, pressure control valve for force mains.	
Where available, evaluate any studies that show specific climate change risk data for your area.	
	Adjust mitigation measures accordingly.
C. Identify Risk From Other Hazards	
Are your facilities, including equipment on roofs or outside the main facility, vulnerable to high winds?	
	Consider wind retrofit for building structure. Relocate or protect vulnerable equipment on the roof or building exterior. Protection could be building a small protective structure around equipment.
Are there particular parts of your facility or infrastructure that are vulnerable to extreme heat? Check roof areas for extreme heat damage and water sealants for leaks.	
	Consider increased energy efficiency (e.g., more shade trees, better building insulation). Maintain and replace water sealants causing leaks during rains.
Are there particular parts of your facility or infrastructure that are vulnerable to extreme cold, icing, freezing, or excessive snowfall (e.g., snow loads on roof; freezing of pipes)?	
	Consider a roof retrofit for snow (and also potentially wind and heat). Protect utilities on the exterior (roof and sides of buildings) and insulate any interior pipes that have freezing potential.
Are the routes of the utility connections (e.g., electrical power lines) located in areas susceptible to damage by wind, ice or extreme heat?	
	If possible, bury the utility lines on property or lessen the span of overhead wires. Secure back-up power supply.
D. Immediate Hazard Event Response Capability	
Does your facility/department have an emergency response plan? Does the plan include sources of outside assistance (e.g., Mutual Aid Agreement) during an emergency? Your Emergency Response Team should provide temporary services to the public to stabilize the situation.	
	Prepare an emergency response plan if one does not exist, or update periodically if there is one. Develop a Mutual Aid Agreement with another facility or jurisdiction if one does not exist.
Is your staff provided with specific roles and responsibilities during emergency response operations?	
	If no assignments are made, consider formalizing roles and responsibilities and list them in an emergency response plan.
Is someone on your staff assigned to daily weather monitoring during all shifts? Is there a reliable weather notification system (either external or on-site) available?	
	Each facility and department should have someone assigned to weather monitoring via reliable weather news stations. The assigned person should have a method to communicate to other staff. The facility should consider obtaining notification systems (e.g., weather radios) to assist in monitoring.

Has the emergency response plan been tested through an actual event or an exercise? Has the staff been trained to carry out their individual response roles and responsibilities?	
	If the plan has not been tested, conduct (at the minimum) a tabletop exercise. Also, consider a functional and/or full-scale exercise. Urge training for all staff involved in emergency response.
What materials are immediately available to construct an emergency flood barrier? Are these sufficient to install an emergency flood barrier to protect the facility?	
	If sufficient material is not available, purchase emergency flood barriers (e.g., sandbags, inflatable bladder).
Is there a designated storm shelter inside the facility for staff and visitors (e.g., emergency shelter, overnight shelter)?	
	If no shelter space is designated, evaluate areas that would be appropriate to serve as shelter – both an emergency shelter (e.g., for events such as tornadoes) and an overnight shelter (e.g., for a winter storm).
Have first responders, such as fire rescue personnel, visited the facility and know where key operational components are located?	
	During an exercise, invite first responders to participate and have them tour the facility.
Estimate the amount of time it takes a power outage to affect operations at your facility.	
Is there permissible downtime/ interruption to operations?	
	If not, prepare a Continuity of Operations (COOP) Plan. Check insurance policies to see if the facility is adequately covered for interruptions due to potential hazard events.
Does your facility have an adequate back-up power supply needed to support critical functions of the facility?	
	If there is no back-up power supply, obtain a generator sufficient to maintain critical functions.
What is the worst case scenario involving a power outage at your facility?	
	Prepare/update a business/operational continuity plan that addresses both diminished operations on-site, and relocation to another site during an emergency. Develop a worst case scenario as a basis for plan development/update.
Does the facility have a recovery plan that establishes repair priorities to restore operations rapidly?	
	Prepare/update a recovery plan to ensure that repair priorities are clearly stated.
E. Site-specific Flood Risk Components	
Are any sections/components (e.g., operation rooms, control panels, equipment, electrical) of the facility/ infrastructure elevated above grade?	
	Determine whether components are elevated above the 500-year flood level, if included in FEMA mapped floodplain.

Are any sections/components (e.g., operation rooms, control panels, equipment, electrical) below grade, such as tunnels leading to a wastewater plant?	
	Consider protecting these components, if vulnerable: floodproof, elevate, or relocate to at least a 500-year flood level.
Are there equipment and/or contents critical to the facility's operation (or potentially harmful if disturbed) at risk to flooding (i.e., either below the 100-year flood level or in areas that have been historically flooded)?	
	Consider elevating or floodproofing this equipment/contents, or relocating to another elevated portion of the facility (e.g., from the 1st floor to the 2nd floor or another building outside the floodplain).
Are ingress/egress routes (e.g., roads) protected/elevated if vulnerable to flooding?	
	If not protected, elevate the road and construct culverts under the road with sufficient capacity to allow flood water to pass underneath without backing up.
Any there any particular supply-chain vulnerabilities: a critical item such as fuel or a chemical needed for operations that may be blocked if the area is hit by disaster?	
	Work with suppliers to discuss and develop contingency plans. When addressing potential ingress issues, include consideration of storing more of the critical item on-site.
If you facility is inoperable, are there are any major secondary impacts to a developed area of natural resource? For example, if a wastewater treatment plant loses power, does it bypass into a lake or river?	
Does the facility have any underground or aboveground storage tanks that could become dislodged or ruptured and pose a risk to the facility or surrounding areas?	
	Relocate the above-ground tank to a less hazardous area, secure it, or elevate it. For underground tanks, evaluate the potential for the tank to be dislodged from flooding. Consider anchoring or relocating vulnerable underground tanks. For both types of tanks, consider emergency shutoff valves.
Does your facility have a sewage backflow prevention device?	
	If not, consider installing one in all sewage lines to prevent sewage from backing up into the facility due to excessive pressure from floodwaters.
Does the facility store or have in use any hazardous materials that need to elevated or secured?	
F. Risk To Strategic Sites	
Is your site (natural or cultural) susceptible to flooding?	
	Consider green infrastructure options for natural sites to control

	the level and location of floodwater. For cultural sites, consider appropriate nonstructural measures sensitive to the historical/cultural context.
Is your site (natural or cultural) susceptible to high winds, extreme heat, or severe winter storms?	
	For cultural sites, consider wind retrofit for buildings and, in particular, for vulnerable equipment that may be on the roof or on the exterior of the buildings. Research retrofit measures appropriate for historical/cultural context.
If a wetlands area, is this area susceptible to potential future development?	
	Protect wetlands through designation as a park, the purchase and retirement if development rights, and/or a conservation easement. For potential development, find alternative sites that are more suitable.
G. **Critical Dependencies -** Select Infrastructure or utilities that, if subjected to a partial or total loss, would significantly impact operations. The right column includes questions to help identify key issues. Single-point failures refer to a specific vulnerability in a single location that if damaged, could disable the entire facility, or at least critical operations.	
Power	How long can the facility function without power? Are there sources of back-up power or alternative energy supply? If so, please describe. Is there an alternative site that serves this function while this site is being repaired? Are there contracts in place to restore power?
Water	What is the amount of time it takes an outage to effect operations at this site? Is there a redundant water supply that can be provided to this site? Are there back-up sources of water? Are there contracts in place to restore water to this site?
Wastewater	What is the amount of time it takes for an outage to effect operations? Is there a redundant wastewater supply that can be provided to this site? Are there back-up methods to deal with wastewater? Are there contracts in place to restore wastewater to this site?
Natural Gas	How critical is natural gas to the operations of the facility? How long can the facility function without natural gas? What is the worst case scenario and where are the single-point failures? Are there contracts in place to restore natural gas? Does the facility have an emergency plan that establishes repair priorities?
Other Energy Sources (Petroleum Fuels)	Does the facility depend on other energy sources other than power and natural gas? How critical are these sources to the operations of the facility? How long can the facility function without these sources? What is the worst case scenario and where are the single-point failures? Are there contracts in place

	to restore these energy sources? Does the facility have an emergency plan that establishes repair priorities?
Continuity / Supply Chain	What critical supplies are needed on a daily/weekly/monthly basis for operation of the facility? How critical are these supplies? How long can the facility function without these supplies? Are there contracts in place to restore the provisioning of these supplies or a back-up provider or an alternate delivery system?
Transportation	What are the critical available transportation mode(s) to this facility (e.g., road, rail, navigable water)? What is the amount of time it takes an outage to effect operations? What is the worst case scenario and where are the single-point failures? Are there backup or redundant systems in place if the primary transportation routes are disrupted? Does the facility have an emergency plan that establishes repair to the transportation infrastructure or rerouting priorities to the site?
Information Technology (SCADA, cyber)	What critical information technologies service the facility? What is the amount of time it takes an outage to effect operations? What is the worst case scenario and where are the single-point failures? Are there backup or redundant systems in place if the primary systems are disrupted? Does the facility have an emergency plan that establishes repair priorities? Is there another site that can house the operations of this facility to ensure continuity of operations?
Telecommunications	Which telecommunications are critical to operations at this site? What is the amount of time it takes an outage to effect operations? What is the worst case scenario and where are the single-point failures? Are there backup or redundant systems in place if the primary systems are disrupted? Does the facility have an emergency plan that establishes telecommunication repair priorities?
What are the impacts to your community if your facility was damaged to the point of not being able to operate?	What loss of services are likely to result, and how would this impact the community? Are there specific demographic groups that would be most impacted? Are there back-up or alternative service suppliers that can address needs during the disruption? Does your facility have a continuity of operations plan?
H. **Long Term Mitigation**	
What is the greatest need for mitigation?	
Are there current plans to mitigate vulnerable parts of the	
	Consider including a mitigation strategy in an existing and

facility/infrastructure?	anticipated capital improvement plans. Support community efforts for larger mitigation projects such as green infrastructure and drainage improvements.

While the Risk Matrix tool is focused on protecting a specific site, facility, or infrastructure, the community at large can also take action to lower the overall risk. This is discussed in the following section.

V. MITIGATION MEASURES

Adapting to the impacts of extreme weather will require both short-term strategies (for events that may occur at any time), as well as a commitment to long-term risk reduction investments that entail permanent physical changes to buildings and infrastructure. Short-term strategies include the use of existing resources (e.g., emergency staff and equipment) to improve preparedness. Long-term investments will require funding, typically from grants and/or local funding sources such as capital improvement budgeting or a stormwater utility fund.

Capital improvements can be leveraged in a couple ways: either as a stand-alone risk reduction project or by adding a mitigation component to an existing project (i.e., piggybacking). For example, a section of a road in the community may need to be rebuilt or expanded due to damage and/or heavy usage. For an incremental additional cost, the community could use this opportunity to improve the existing drainage system. By combining projects, the cost of tearing up the road twice (and associated disruption) can be avoided. Ideally, a community will consider resiliency and mitigation in all of its major investments ranging from new construction to repair, renovation and redevelopment.

Process to determine mitigation measures

A community should consider several types of measures when developing a state of readiness by addressing near and long-term needs and building up multiple lines of defense (i.e., alternate forms of mitigation and back-up). Regardless of how many sound mitigation measures are in place to protect against extreme weather, there will always be an event beyond the design threshold of a particular mitigation measure and, therefore, emergency response must be a key component of preparedness.

To comply with Executive Order 11988, for example, a facility that is considered a "critical action" must be protected to the 500-year flood level. However, there is still residual risk to events that exceed the 500-year flood threshold. Further, that threshold may also change over time should 500-year flood events become more frequent. Therefore, regardless of the level of protection provided by a mitigation measure, there is residual risk and a need for emergency preparedness. An exception to this general rule would be an acquisition project where a property at risk is purchased, and the site cleared and maintained as open space. In this example, the structure is permanently removed from the hazard source.

The essence of community protection is about managing overall risk to infrastructure by minimizing threats, reducing/eliminating weaknesses and vulnerabilities, and minimizing the impact or consequences of negative events. The FEMA/DHS Critical Infrastructure toolkit offers guidance reflected in the Risk Matrix presented in the previous section. This includes:

- Strengthening facilities to reduce risk associated with different kinds of hazards through improved security measures or better design.
- Building resiliency and redundancy into various systems used in day-to-day operations.
- Implementing cybersecurity measures.
- Conducting business continuity planning, training, and exercises.

Resources for Information on Existing Mitigation Actions

- *State and Local Hazard mitigation plans*
- *Local comprehensive or masters plans*
- *Local emergency management plans*

This guidance, as well as the content of the Risk Matrix, should be accommodated and reflected in a community-focused risk management plan.

The balance of this section provides a range of risk management/reduction actions to consider, and ideas on capabilities needed to design and execute them. Not all of the actions will work in every community and, therefore, a range is provided to enable officials to select those that are most relevant.

Emergency Response

Emergency response activities are the first "line of defense" following a weather-related event, and can be initiated with limited capital investment. Proven techniques are available (as illustrated by the Grand Rapids example described in Section II) to ensure that this capability is in place and ready to be implemented on short notice.

A checklist (non-exhaustive) of activities for developing and maintaining Emergency Response capability is as follows:

- Access to and notifications from warning systems

  - Access to publicly available networks (e.g., National Weather Service) for local information on high wind, flood, and other weather events. Communities should designate an individual should be assigned the responsibility of monitoring the weather and notifying other staff when circumstances suggest the prospective need for action.
  - Availability of on-site weather notification systems (e.g., weather radios)
  - Emergency alerts and notifications to the public

- Identification and training of key staff in safety measures and emergency checklist duties

- Emergency Operations/Post-Disaster Redevelopment Plan (pre-disaster) – who does what and when/how are they notified? Plan elements must address, among others:
  - Command and control of event (i.e., Incident Command System)
  - Responsibility and timing of implementing flood fighting measures
  - First responder and medical response
  - Critical asset management
  - Communications, including inter-operability
  - Evacuation and shelter
  - Triage policies
  - Public information
  - Assimilating volunteer materials and labor into the recovery effort
  - Recognizing hazard mitigation opportunities under FEMA recovery programs post-disaster

- External resources
  - Regional, state, federal, and/or private sector assistance
  - Mutual Aid Agreements
  - Volunteer assistance

- Exercise the plan
  - Table-top exercise
  - Where needed, a functional or full-scale exercise
  - Invite first responders

- Materials
  - Sandbags or other similar ‘fillable’ flood barriers
  - Portable flood barriers

An example of a warning system is found in Sarnia, Ontario where a community notification network (Everbridge) provides citizens with improved access to emergency alerts and public notifications, including extreme weather events.

Nonstructural

These types of measures are also referred to as property protection measures, and are available to protect against a range of hazards including flood, wind, and snow. Participation is often voluntary, given that nonstructural measures often apply to a range of property owners. A descriptive listing of some of the more common nonstructural measures is as follows:

- *Acquisition* – Purchase of a hazard-prone property to maintain the site as permanent open space. The property can be modified to enhance its ability to retain stormwater, or provide other benefits.

- *Relocation* – The physical removal of a hazard-prone structure and its relocation to another site that is less hazard-prone.

- *Elevation* – The lifting of a structure, in place, for the purpose of constructing a new, elevated foundation underneath it. In the United States, elevated structures are generally lifted to at least the 100-year flood level.

- *Floodproofing* – Can entail either dry or wet floodproofing methods. Dry floodproofing involves making a building watertight up to an established elevation, while wet floodproofing allows water to enter the structure in areas where it will cause no, or minimal damage. The latter is appropriate for structures functionally dependent on close proximity to water (e.g., docking facilities) and accessory structures such as detached garages.

- *Green infrastructure* – Projects generally designed to retain water in a natural manner to reduce the overall impacts of stormwater runoff. (Given the emphasis on a "natural" solution, these projects are not placed in the "structural" category). They can be combined with recreational/landscaping objectives to achieve multiple objectives. These projects include:

    - Bioretention
    - Blue roof (i.e., to absorb water)

- Permeable pavement
- Underground storage
- Stormwater tree trench
- Retention pond/basin
- Extended detention wetland

- *Wind retrofit* – Addresses the impact of high winds, including the force of the wind itself and wind-driven debris, through common measures such as shutters over windows and strengthening roof systems.

- *Insurance* – Recognizes that, regardless of the level of protection a structure may have, an event may exceed the design level of protection. Therefore, it is important to maintain an insurance policy that includes vulnerable facilities/structures. Those that are already protected may receive significant insurance discounts.

- *Sewer backup protection* – Floodwaters may cause backup up into sewer line systems that may eventually cause sewage backup into homes. Backflow preventers should be installed to prevent this problem.

These various nonstructural measures typically require varying degrees of maintenance. Further, many may also be appropriate for protecting strategic sites, such as acquisition of a parcel that contains wetlands. Natural resource protection will be described more extensively later in this section.

Structural

Structural measures are generally comprised of larger-scale flood barrier and flood control measures that contain, store or divert floodwaters away from developments. They typically alter the physical environment as a means to keep water in an existing basin or river bed, and/or away from a developed area. Properly designed, constructed and maintained, such structures can be effective in preventing flooding to the design level of protection. However, they can still be susceptible to overtopping, breaching, and/or scouring, depending upon the severity of the weather event. Some measures, like levees, may be susceptible to interior flooding on the land side of the levee if no interior drainage measures are installed. A descriptive listing of common structural measures is as follows:

- *Levees/ring levees* – Typically composed of compacted soil, levees can be of substantial size (e.g., large structures along major rivers) or of a more modest size

when providing perimeter protection around a structure or group of structures. Construction requires significant space and sufficient quantities of quality earthen fill.

- *Floodwalls* – As defined by FEMA, a floodwall is "a freestanding, permanent, engineered structure designed to prevent encroachment of floodwaters." Floodwalls are typically constructed of reinforced concrete or masonry, and provide a barrier surrounding one or more structures requiring protection.

- *Berms* – Earthen structures that reduce flood risk by encircling or otherwise protecting one or more vulnerable structures. Berm construction requires significant space and sufficient quantities of quality earthen fill.

- *Stormwater Management* – The installation, in some combination, of channels, pumps, and retention/detention basins to control the location and volume of stormwater runoff.

- *Diversions* –Include channels or canals to move floodwaters and excess stormwater away from developed areas to locations of lesser impact (e.g., water impoundment area or outfall into water body).

Structural measures are characterized, in general, by high capital costs and physical alterations of the natural watershed flow that may have implications to the environment and/or developments upstream/downstream. These measures require diligent maintenance to retain effectiveness. In addition, given that a continuous line of defense is typically required (particularly for coastal protection), any weak point in that line can compromise the effectiveness of the entire protection system.

Planning

The planning process affords communities an opportunity to take stock of their facilities and critical infrastructure, and develop strategies for repair, maintenance and new construction with weather-related protective measures in mind. The process should also include consideration of, and the development of response action for various types of contingencies. Types of planning that may involve preparedness and mitigation for extreme weather impacts include the following:

- Continuity of operations/continuity of government
- Business continuity
- Hazard mitigation

- Land use including zoning, setbacks, flood ordinances
- Floodplain mapping and data
- Building codes
- Coastal setbacks
- Open space preservation
- Comprehensive planning
- Capital improvement budgeting
- Infrastructure planning (e.g., transportation, stormwater, green infrastructure)
- Executive Order 13690 – Federal Flood Risk Management Standard

Natural Resource Protection and Restoration

Protection of natural resources is a particularly important component of the community planning process. It is characterized by multiple implementation options that typically involve a variety of partners (e.g., state/provincial/federal agencies, non-profit organizations, public and private foundations, business/ industry). Examples of protection and restoration actions can include the following:

- Wetlands protection
- Water quality improvement
- Erosion and sediment control
- Coastal or lake barrier protection
- Natural area preservation
- Environmental corridors
- Natural area restoration
- Natural functions protection

In planning for and implementing such projects, communities are advised to be aware of the direct and cumulative impacts of draining and/or filling wetlands and floodplains. These types of activities will reduce the land's natural flood storage capacity and contribute to increased future flooding.

Financing of Improvements

When planning for and financing improvements, communities must take into consideration the costs and requirements associated with protecting facilities and infrastructure from weather-related events. These include, among others:

- Capital costs associated with designing, renovating and/or constructing facilities to maximize protection from extreme weather events.
- Creative approaches to "piggyback" mitigation and other extreme weather protection measures onto other projects (e.g., enhance stormwater infrastructure when building/ rebuilding roads).
- Operations and Maintenance (O&M) costs associated with both structural and nonstructural measures put in place to address extreme weather events.
- Maintaining staff capability to successfully write grant proposal and administer grant funds typically required to design and implement protection programs.
- Providing an adequate contingency fund to promptly address costs associated with extreme weather events.
- Providing adequate insurance (e.g., replacement values, appropriate coverage for various hazards, umbrella and business interruption insurance, re-insurance).

Stakeholders/Capability

Providing adequate planning and protection services related to extreme weather events demands a community-wide partnership involving many stakeholders. Among others, parties to be involved in such efforts should include the following:

- Mayor's office, City Manager, and/or representatives from the City Council
- Local first responders (police, fire and paramedics)
- Representatives overseeing communication systems
- Stakeholders that regulate land development (zoning, land use planning and comprehensive planning)
- Stakeholders that seek and write grants
- Stakeholders that operate critical infrastructure or oversee strategic sites (e.g., parks and recreation)
- Local public works and engineering
- Local parks and recreation department
- Building department and code enforcement
- Emergency management officials
- Local public information office
- State and Federal partners including
- Non-profits interested in disaster response and resiliency
- Other local champions involved with the betterment and welfare of the community

VI. PILOT IMPLEMENTATION OF CRISSP IN GARY, INDIANA

Introduction

The City of Gary, Indiana was selected as a representative Great Lakes St. Lawrence Region municipality to pilot the CRISSP methodology. Gary is a mid-sized coastal community with significant coastal development and assets, a history of vulnerability to storm events, and municipal staff willing to partner with the Project Team. The most recent US Census (2013) identifies Gary's population at 78,450. The city is located in Lake County and borders Illinois and Lake Michigan. It is located in the greater Chicago Metropolitan Area which has greatly influenced past and present development patterns in the city and surrounding areas.

Gary is highly urbanized but also has several areas of wetlands. It has two major waterways running approximately west to east, the Grand Calumet and East Arm of the Little Calumet River (referred to as the Little Calumet in this technical paper). Due to relatively flat topography, these two rivers can reverse direction. Gary has a proud industrial past, having housed one of the largest steel mills in the United States, but this legacy also means the presence of industrial waste resulting in several Superfund sites. Susceptible to flooding, Gary experienced two recent significant events (2007 and 2008).

The 'new normal' caused by climate change will require an adjustment to future risk in Gary, the Great Lakes St. Lawrence Region, and beyond. A recent example in south central United States (i.e., primarily Texas and Oklahoma) occurred in May 2015 when extreme weather once again revealed its destructive nature. Houston, a city in Texas accustomed to flooding, was overwhelmed by a series of storms that led to unprecedented levels of flooding. This increase in risk from natural hazards is also highly relevant to ongoing efforts to rebuild and redevelop Gary.

The challenge of addressing extreme weather events in Gary also provides an opportunity. Residents, businesses and tourists want to see a thriving city that showcases its natural resources. Areas that flood can be converted into greenways, and vacant parcels can be converted into green infrastructure. When such improvements begin to connect with those in neighboring communities, and to large resources like Lake Michigan, the benefits increase substantially. In preparing this technical paper, the Project Team recognizes and applauds what Gary has been able to accomplish to date, and provides guidance to assist the city in adjusting to future weather-related challenges with its ongoing redevelopment efforts.

Conduct of the pilot study for Gary entailed a thorough literature search/review, as well as active engagement with city officials from Gary and other supporting agencies such as the Northwestern Indiana Regional Planning Commission (NIRPC).

Recent Climate History in the Lake Michigan Area (trends in susceptibility to extreme weather events)

NOAA's National Weather Service operates that Hydrometeorological Design Studies Center, providing a portal for NOAA Atlas 14 data and export. In the past, NWS-HDSC conducted Probable Maximum Precipitation (PMP) Studies but, over time, funding for this work diminished and then ceased. The most recent studies concluded around 1998-1999 for most locations. In all cases, PMP was estimated based on observed precipitation and did not include amplification or potential changes in climate.

The most recent MRCC Bulletin 71 update is from 1992. The NOAA Atlas 14 was updated for Indiana in 2004. This is a much closer time span than other states in the region. As such, historical differences in recurrence intervals are not significant between the two reports.

Below is a summary of key data from the NOAA Atlas 14:

Type of storm or Observed Change	Measurement or Increase
5-year storm	Approximately 3.6 to 3.8 inches
25-year storm	Approximately 5.2 to 5.8 inches
100-year storm	Approximately 7 to 8 inches
Observed change in regional (IL, IN, MI, WI stations) frequency of 5- and 25-year storms	30 to 35% increase
Observed change in lower volume nuisance storms 1.25 to 2.25 inches	10 to 75% increase in frequency is typical, with average changes of 25 to 40%

Flood

Gary has a recent history of severe flooding, including 2007 and 2008, as described earlier. The floods of 2008 were catastrophic, affecting critical infrastructure and major facilities such as Indiana University Northwest. The severity of the flooding was explained as follows by the USACE Chicago District, which was engaged in a Little Calumet River project:

> "While some flooding on the landside of the levee can be expected during large storm events due to interior drainage issues, the flooding in Gary during the September flood event was more severe than expected. The effectiveness of the flood protection system in Gary appeared to be compromised from two different issues. Road closure sections (where roadways cross the levee system below the top of the levee) were not closed

according the operations plan. In addition, floodwaters appeared to have entered sewer lines on both the landside and riverside of the levee system. The sewer network transmitted the floodwaters throughout the area behind the levee system."[14]

Below are excerpts of descriptions of the 2008 flood impacts from the State of Indiana website, a Times of Northwest Indiana article, the 2010 Lake County Hazard Mitigation Plan, and article by an Indiana University Northwest professor, respectively:

"Presidential disaster declarations were made following four severe weather incidents that caused widespread flooding in portions of Lake County between summer 2007 and spring 2009. More than 35,000 applications resulted in $61 million in federal public and individual assistance to Lake and nearby counties as a result of damage. Among the most severe recent flooding incidents in the Little Calumet River project area was in September 2008 when remnants of Hurricane Ike dumped as much as 10 inches of rain."[15]

"In September 2008, Interstate 80/94 running through Lake County was closed for a week as a result of flooding when the Little Calumet River overflowed an unfinished levee.
The loss of commerce was staggering — more than $88 million in losses, according to William Baker, chairman of the current Little Calumet River Basin Development Commission."[16]

"The City of Gary experienced major flooding in 2008. Flooding occurred in several areas of the city including major damage at Indiana University Northwest (IUN). In addition, Interstate 80/94 was closed due to flooding. An aerial photograph depicting the 2008 flooding is shown in Figure 5-21." [Figure 6][17]

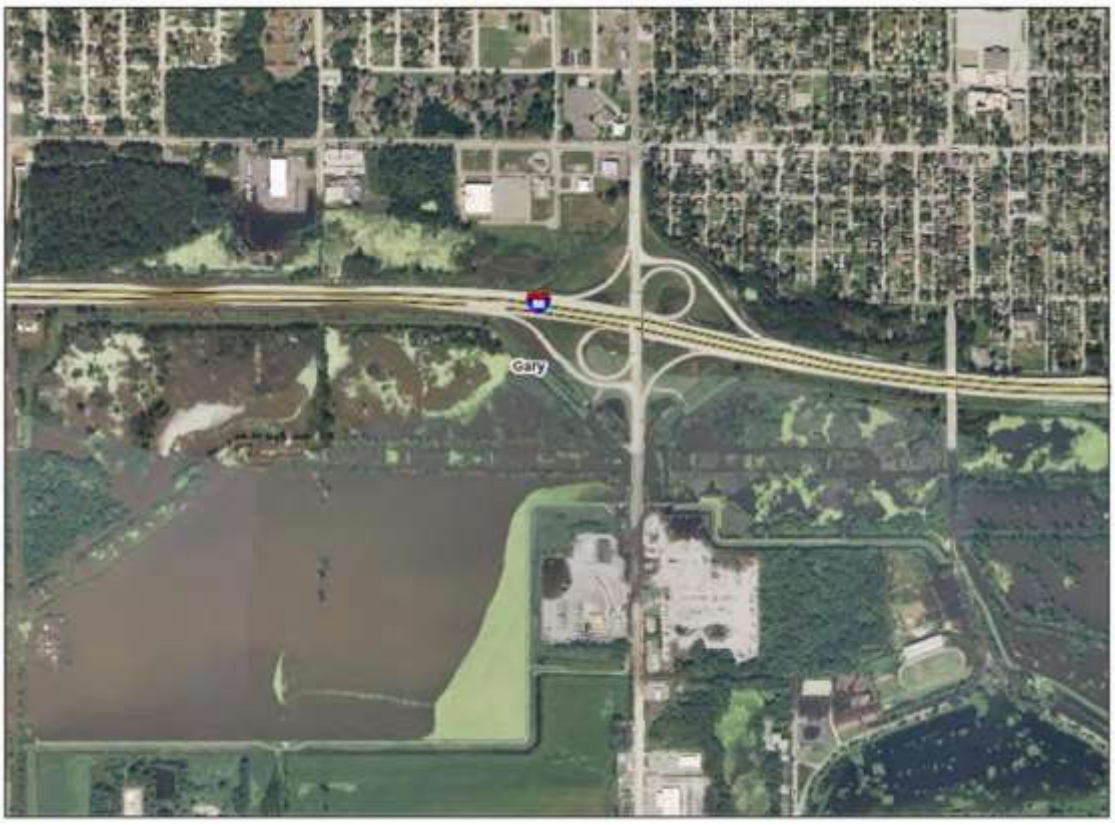
"The campus of Indiana University Northwest (IUN) in Gary, Indiana was closed for two weeks (September 15-28, 2008) due to extreme flooding. Flood waters submerged the

[14] From USACE Chicago District website found at http://www.lrc.usace.army.mil/Missions/CivilWorksProjects/LittleCalumetRiver/FAQ.aspx#Q1, Accessed May 2015
[15] From IN.gov article dated September 29, 2009 found at http://www.in.gov/activecalendar/EventList.aspx?view=EventDetails&eventidn=61934&information_id=124943&type=&syndicate=syndicate, accessed May 2015
[16] From the Time of Northwest Indiana article dated March 17, 2013 found at http://www.nwitimes.com/news/local/lake/gary/flood-fighting-drill-set-for-kennedy-avenue-this-week/article_b03faec4-6d67-5fc2-84cd-944f05e95962.html, accessed May 2015
[17] From the 2010 Lake County Hazard Mitigation Plan

IUN parking lot spreading over the campus, causing minor water damage to several of the other buildings and ultimately forcing the closure of Tamarack Hall."[18]

Figure 6 provides an aerial photo of the flooding that occurred along the Borman Expressway.

Figure 6 – Aerial photo of 2008 flooding in Gary



Source: 2010 Lake County, IN Hazard Mitigation Plan (Figure 5-21)

The community rallied after the 2008 floods, re-energizing its flood protection efforts. Elected officials called for the completion of the Little Calumet River Federal project to complete the levee system (described in more detail later in the "Mitigation Measures" part of Section VI). With the assistance of many partners (i.e., non-profit, faith-based, business, public, other community organizations), the Lakeshore Are Regional Recovery of Indiana (LARRI) committee was formed to assist impacted residents in the long-term recovery from this event.

[18] From "Understanding the Geologic Background for the September, 2008 Flooding Event that Led to the Temporary Closure of IU Northwest" by Erin P. Argyilan, PhD

FEMA flood maps were updated in early 2012; additional preliminary flood maps are presently under development. A Flood Risk Map is presently available and identifies two essential facilities vulnerable to flooding. One is an electric power substation on Chase Street just south of I-80. (The other, which is not specifically identified in the Flood Risk Map, is just east of Highway 55, south of I-80 and Ridge Road, west of I-65 and north of 45th Street – near Grant Street and east of the Embassy of Christ Ministries on the Cady Marsh Ditch). The Flood Risk Map also shows several Public Assistance data points in this area.

Non-regulatory products, including Changes Since Last FIRM (CSLF) and Depth/Velocity Grids may be available in the future and can provide more information than previous FIRMS. On the current flood maps, areas along the Grand Calumet and Little Calumet Rivers are included in the Special Flood Hazard Area (SFHA). While Grand Calumet River water levels are controlled by nearby industrial uses, the river is in close proximity to many important critical infrastructure sites and should be monitored closely. In addition, the contamination level in the Grand Calumet River is a concern because any future flooding could spread these contaminants inland.

The shorelines and banks of Gary's major water bodies are generally armored or otherwise protected. Along Lake Michigan east of Marquette Park, most of the Gary lake shoreline is armored. Levees are on both sides of the banks of the Little Calumet River. The Grand Calumet does not have levees but its water levels are controlled by industrial users. Both rivers are surrounded by relatively flat terrain and are susceptible to changing direction with even heavy wind events or high lake levels.

As extreme precipitation becomes more common, the risk of flooding will rise. With warming spring and summer temperatures, severe weather typically found more often to the south of Gary may occur farther north. It is probable that Gary will experience more events similar to 2008 in the future. Events like the 100-year flood (1% annual chance) will likely become more common and could be at the 25-year (4% annual) chance recurrence interval. Other factors like rising lake levels, melting snow and ground cover by ice will likely exacerbate the risk. While many improvements have been made to the Little Calumet River levee system, increased extreme precipitation events could lead to higher stormwater levels on the landside of the levee and floods.

Rough Projections of Extreme Weather Hazard Zones and Scenarios

Hazard Mitigation Considerations

The current 24-hour, 100-year storm size (a storm with a one in 100 chance of occurring in a given year) is seven inches. This is somewhat less than the size of the September 10th, 2008 storm where about nine inches of rain resulted in major damage from widespread flooding.

At a magnitude of seven inches of precipitation in 24 hours, stormwater systems will be completely overwhelmed. Combined sewer overflows are virtually unavoidable, and untreated waste discharges may be necessary to prevent severe damage elsewhere or overflows at water treatment facilities. Depending on the level of precipitation in the previous days, the Little Calumet River and its tributaries may reach a near record flood stage similar to 2008. Widespread property damage and public health risks is anticipated under such a scenario.

Storms of this extremely large magnitude may become 2-5 times more frequent in the future, though they are so rare that observed regional trends are not yet significant. (National Climate Assessment 2013, GLISA)

Large but less catastrophic storms in the Great Lakes region have typically occurred once every 25 years, resulting in 5-6 inches of precipitation in a 24 hour period, accompanied by widespread flooding and damage, From 1958-2012, storms of this size became about 33% more frequent throughout the Great Lakes region, and are increasing in magnitude. It is possible that, by mid-to-late century, the current 100-year storm could become the future 50-year or 25-year storm.

Stormwater Management Considerations

Smaller but still significant storms occur far more frequently. Many communities in the Great Lakes region begin to recognize the impacts of flooding when more than one inch of rain falls in 24 hours. For events that occur once or twice per year, (typically 1.75 to 2.25 inches in 24 hours) nuisance flooding and minor damages are often reported with occasional lingering effects on infrastructure. For precipitation totals under approximately 1.75 inches of rain, green infrastructure tends to be effective at mitigating some local damage. For rain totals over two inches, most stormwater systems will be temporarily overwhelmed. While any single smaller event rarely carries memorable impact, the cumulative cost over time is substantial.

For events that have occurred once every five years (3.6 inches of rain in 24 hours), more significant but manageable impacts are common. Flooding in basements, severe erosion, sewage overflows, and damage to less-fortified or degrading infrastructure is typical.

Regionally, events in this category have become 5-10% larger and 33% more frequent, though there is large variability from place-to-place. Some nearby locations have seen enormous

changes in frequency, while others have seen far less. Overall, the observed trend of increasing frequency is expected to continue or accelerate.

High Wind

Like most of Lake County, Gary is susceptible to straight-line wind events associated with thunderstorms. Its location on Lake Michigan elevates this susceptibility. In May 2007, National Climatic Data Center (NCDC) information provided in the 2010 Lake County Hazard Mitigation Plan shows that Gary had a thunderstorm wind event that caused $60,000 in damage. In addition, more severe wind events, including derechos and tornadoes, may become more common. For extremely strong and random wind events, such as tornadoes, it is generally not cost-effective to protect buildings to these wind speeds. It is more common to create protected areas (i.e., safe rooms) to protect occupants during high level wind events. For lesser wind events still capable of damage to buildings and infrastructure, measures typically undertaken involve tying down/securing exterior equipment, windows, doors and thin walls; "hardening" or relocating vulnerable structures; and employing protective devices such as window shutters. All facilities in Gary are susceptible to straight-line wind, tornadoes and derechos.

Winter Storms

Severe winter storms pose a relatively uniform risk to infrastructure, facilities, structures and sites in Gary. Parcel-specific vulnerability will depend on the nature of the development including utility connections, roof loading capacity, and proximity to trees and other objects that may be brought down by snow, ice and high wind.

Extreme Heat

Gary could be subject to the same weather patterns that resulted in the deadly 1995 Chicago heat wave. While Chicago has many unique characteristics that complicate emergency response and amplify local temperatures, Gary has a similar urban environment where most people are not accustomed to extended periods of extreme heat. While historical records show the days over 90° and 95°F per year have remained relatively stable over time, the number of multi-day, sustained heat waves has increased. Climate models project that extreme heat waves and hot days will increase in the future, increasing heat vulnerability.

Gary is a USEPA non-attainment area for 8-hour ozone, which means it exceeds recommended levels of ground-level ozone, a harmful pollutant to human health as well as plant and animal life. Ozone pollution is of particular concern during the summer and extreme heat events because

strong sunlight and hot weather deteriorates air quality even more. USEPA describes the impacts of ground-level ozone as follows:

> "Breathing ozone can trigger a variety of health problems including chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis, emphysema, and asthma. "Bad" ozone also can reduce lung function and inflame the linings of the lungs. Repeated exposure may permanently scar lung tissue… Ground-level or "bad" ozone also damages vegetation and ecosystems. It leads to reduced agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased susceptibility to diseases, pests and other stresses such as harsh weather. In the United States alone, ground-level ozone is responsible for an estimated $500 million in reduced crop production each year. Ground-level ozone also damages the foliage of trees and other plants, affecting the landscape of cities, national parks and forests, and recreation area."[19]

Availability of data and other relevant information

The production of revised flood maps based upon new climate data is a time-consuming, resource-intensive and expensive undertaking. While such maps would add value to planning efforts, however, they are not essential to achieving a basic understanding of increased risk due to climate change. In general terms (as previously noted), larger events such as the 100-year storm become more frequent when climate change impacts are considered.

Infrastructures/Sites at risk

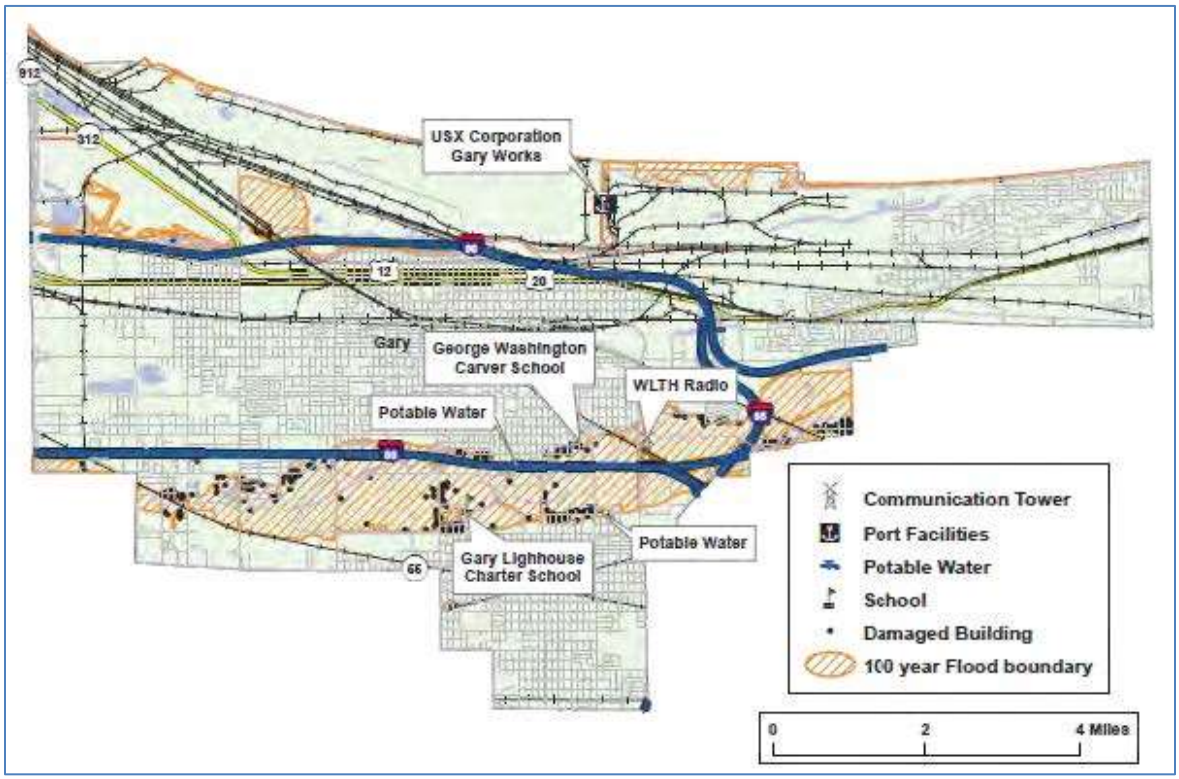
With its urban setting on Lake Michigan, Gary is likely to be vulnerable to hazard event scenarios described in Section III. As noted previously, it has experienced extreme flooding events in the last decade that damaged and/or disrupted critical infrastructure. The balance of this section describes, in additional detail, the critical infrastructure and strategic sites most vulnerable to extreme weather impacts.

Critical Infrastructure

Though much of past flood-related damages in Gary were amplified by aging infrastructure and other local factors, it is likely that the city could experience similar flooding events in the future. Areas of particular vulnerability include structures near both the Grand and Little Calumet Rivers. Figure 7 shows critical facilities in the floodplain that are projected to flood during a 100-year flood event.

[19] From EPA website at http://www.epa.gov/oaqps001/gooduphigh/bad.html, accessed May 2015

Figure 7 - Gary Critical Facilities in the 100-year floodplain



Source: Lake County Hazard Mitigation Plan, 2010 (figure 5-23)

Listed below are many of the critical infrastructure facilities in Gary. Instances are noted where there is a flooding history or risk from flood analysis (e.g., as identified in the 2010 Lake County Mitigation Plan). All of these facilities are expected to have some risk from high wind, winter storms, and extreme heat, except for the levee system which has low damage potential from these hazards. Any known past damage from extreme weather events is listed below as well.

- **Department of Parks and Recreation** – Gleason Park Athletic Complex
- **Gary WWTP -** Located at 3600 West Third Avenue, close to the Grand Calumet River.
    - Gary has a combined sewer overflow system (CSO) that is subject to overflowing raw sewage into the Grand and Little Calumet Rivers during flood events. The sewage will eventually flow into Lake Michigan, causing water quality degradation for lakefront communities' drinking water supply and for recreational uses.
- **Indiana American Water** – treatment facility/distribution. The 2010 Lake County Hazard Mitigation Plan shows that potable water facilities at 28th & Madison and 3212 Georgia Street were damaged from the 100-year flood.

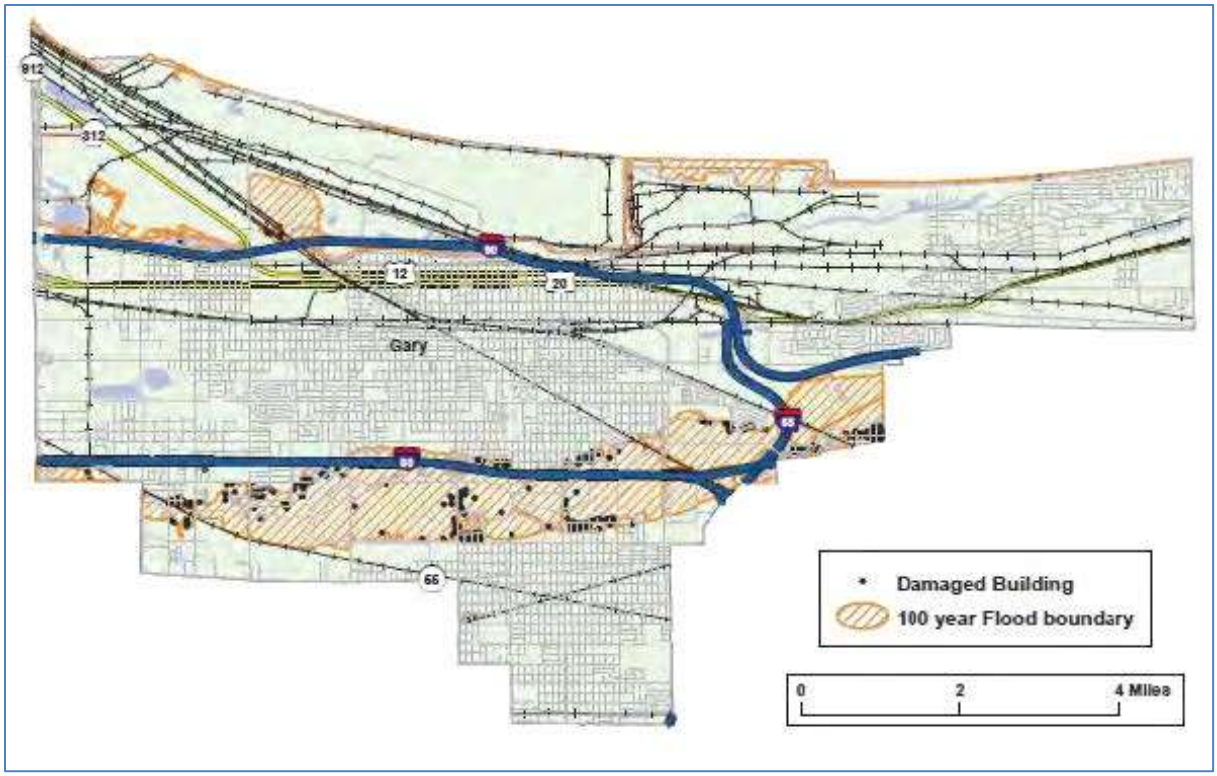
- **NIPSCO Power substations**
- **Little Calumet River, Indiana Flood Control and Recreation Project (Levee system)** – Due to Gary's location near the Little Calumet River, levee failure poses a significant threat. The Little Calumet River project addresses this threat by reducing the likelihood of a levee break and, more generally, by reducing the likelihood of flooding in the community.
- **Gary-Chicago International Airport –** Located near the Grand Calumet River
- **Natural gas facilities** - NIPSCO
- **Communication facilities** - Gary WLTH (listed as vulnerable in 2010 Lake County Mitigation Plan)
- **Port of Gary Harbor**
- **City Hall**
- **Freeways** – Borman Expressway (I-94)
- **Other principal arterials** – U.S. Highway 12 and 20, State Route 53 (Broadway), Ridge Road, Grant Street, Lake Street and Clay Street
- **Rail** – South Shore Line; Freight Rail (Norfolk Southern & CSX)
- **Genesis Convention Center**
- **Indiana University –Northwest (IUN)**
- **Methodist Hospital (Northlake Campus) –** near the Grand Calumet River
- **US Steel Gary Works** – The 2010 Lake County Hazard Mitigation Plan shows both the East and West Dock of the US Steel Facility would be subject to flooding from a 100-year event (shown in Figure 8)
- **Ivy Tech Community College**
- **Gary Area Career Center** (includes 88.7 FM WGVE, an NPR radio station broadcast here)

Other facilities include the George Washington Carver Elementary School (closed in 2006) and the Gary Lighthouse Charter School.

Figure 8 shows many properties in the Little Calumet River floodplain that are vulnerable to future flooding. The Grand Calumet, while in a flood zone, has water levels controlled by industrial users. It is part of the Chicago Area Waterway System, a modified system.

The Little Calumet River flows through Gary and then into the Deep River-Portage Burns Waterway that flows into Lake Michigan. If water levels increase in Lake Michigan, flows from the waterway could be blocked and result in a backup of water in the Little Calumet, thereby contributing to flooding.

Figure 8 - Gary 100-year floodplain showing projected damaged buildings from 100-year flood



Source – 2010 Lake County Hazard Mitigation Plan (Figure 5-22)

The 2010 Lake County Mitigation Plan also identifies the following areas with historical flooding:

- 25th Street and Clay to State Street, Black Oak, East Glen Park
- West 25th Street
- IUN Dormitory
- I-80 and I-94 – the Grant and Broadway exits
- 15th and Cline; 5th and Marshall
- Combined sewer problems

Lakefront Area

In reviewing the NOAA Lake Level viewer for Gary and applying the viewer's maximum increases over the long-term average lake level, it appears that even a six foot increase would only impact a few facilities on the lakeshore, primarily near the U.S. Steel Plant. In addition, the FEMA flood maps show a narrow

A Zone in this area, suggesting that the lakeshore would be severely affected by a surge from lake storms. In addition to the U.S. Steel plant, higher lake levels would impact recreational areas (e.g., beach loss, structure damage) in the Gary area including Lake Street Beach, Marquette Park, and Indiana Dunes National Lakeshore. Higher lake levels would also likely reduce the drainage outfall capacity of the Portage-Burns Waterway, causing some back-up into the Little Calumet River watershed and attendant flooding. Lower lake levels will have adverse impacts on water intakes. A site for viewing Lake Michigan levels is http://coast.noaa.gov/llv/#/lake/michigan.

Strategic Sites

Due to its location near water bodies, as well as its status as an historically important industrial city, Gary has many strategic sites, some of which include industrial waste sites. Below are listings of the various strategic sites in Gary by category.

Wetlands

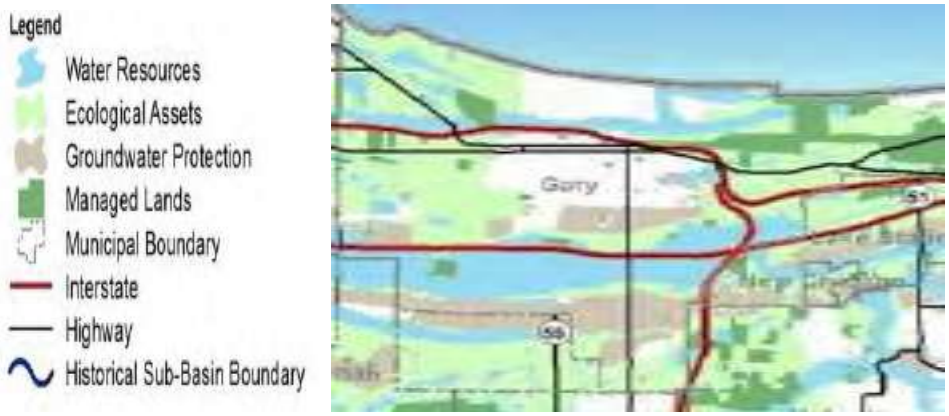
Even though Gary is a heavily developed area, it has many water and ecological resources. Included in this mix are several wetlands, rivers, and ecological areas (as defined by NIRPC). A review of the USFWS National Wetlands Inventory Mapper for Gary identifies several wetland areas including locations along the Grand Calumet and Little Calumet Rivers. Please see Figure 9 below.

Figure 9 – Screen shot of National Wetlands Inventory web page for Gary

Source: USFWS NWI Data Mapper at http://www.fws.gov/wetlands/Data/Mapper.html

In NIRPC's Plan 2040 for Northwest Indiana, water resources, ecological assets, groundwater protection areas and managed lands have been mapped as shown in Figure 10.

Figure 10 – NIRPC Plan 2040 Map



Source: NIRPC Plan 2040 for Northwest Indiana

Superfund Sites and Brownfields

Gary, given its industrial past, has several superfund cleanup sites[20]:

- Gary Development Landfill
- Lake Sandy Jo (M&M Landfill)
- Midco I and II
- Ninth Avenue Dump
- U.S. Steel (RCRA Corrective Action Site)

These areas should be evaluated for their risk to flooding. A flood event has the potential to disperse contaminants widely and impact human and ecosystem health. The Grand Calumet (90% of discharge is municipal or industrial), which includes a designated USEAPA Area of Concern as an impaired water body, is also a trouble spot in the event of a flood.

Other Strategic Sites

These historic areas may be subject to flooding or resulting water quality issues from severe flooding with a sewer overflow event:

- Miller Neighborhood and Marquette Park
- Downtown City Center Historic District
- South Broadway and Historic Midtown - Near Westside Historic Sites

[20] From EPA at http://www.epa.gov/region5/cleanup/index.htm#IN

- Indiana Dunes National Lakeshore

Implications for City of Gary, stakeholders and next steps

Gary has made progress toward risk reduction, including several activities following the 2008 floods. Extreme weather poses additional risks that must be addressed. Gary has several stakeholders that have been extensively involved with past hazard mitigation efforts. The key to future mitigation efforts will be to build on past progress and undertake an on-going, comprehensive effort that features inter-agency coordination, technical and financial resources, programmatic knowledge, and the political will to ensure success. The stakeholders in Gary include:

City of Gary

- Mayor's Office
- City Council
- Sanitary District and Stormwater Management District
- Department of Green Urbanism
- Department of Parks and Recreation
- Building Department
- Department of Environmental Affairs and Green Urbanism
- Public Works Department
    - 22 public works facilities
- Redevelopment Department
- Planning Division
- Zoning Division
- Insurance Department (part of Human Resources)

Important city plans and ordinances include the Long Term Control Plan, Floodplain and Stormwater Management ordinances, and the Parks Master Plan.

Lake County

- Leads development of hazard mitigation plan, provides the services of the Public Works and Highway Departments, and administers the Drainage Board and the Local Emergency Planning Committee.

Little Calumet River Basin Development Commission

The Little Calumet River Basin Development Commission was established in 1980 by the Indiana General Assembly. Its purpose is to serve as the required local sponsor for a federal project called the Little Calumet River, Indiana Flood Control and Recreation Project. This project was authorized for construction in the 1986 USACE Water Resources Development Act. The project is designed to provide structural flood protection up to the 200-year level along the main channel of the Little Calumet River from the Illinois State Line to Martin Luther King Drive in Gary. The construction of the project was divided into eight geographic stages. Overall the project includes:

- Construction of over 9.7 miles of set-back levees in Gary and Griffith.
- Construction of 12.2 miles of levees and floodwalls in Hammond, Highland, and Munster.
- Installation of a flow diversion structure at the Hart Ditch confluence in Hammond/Munster.
- Modification of four major highway bridges along the river corridor to permit better flow.
- Creation of 16.8 miles of hiking/biking trails connecting recreational developments.

Direct project benefits include:

- Protection of 3,500 acres of existing residential, commercial, industrial and transportation, uses from flooding.
- Protection of over 9,500 structures from flooding including 8,755 residences.
- Creation of a 2,000 acre river/recreation corridor system
- Protection of major public/state investments such as Indiana University Northwest Campus and I-80/94 (Borman Expressway) from costly flooding damages.
- Reclamation of over 1,500 acres of presently marginal land along the urbanized Borman Expressway corridor to be reclaimed for economic development uses.

The more recent stages in Gary were completed after the historic 2008 floods. In addition, the Little Calumet River Basin Commission organizes flood fighting drills along the Little Calumet. The Commission maintains a series of gages along the river to monitor river levels including one in Gary on Burr Street. For more information, go to http://littlecalriverbasin.org/. The Commission also completed a comprehensive watershed study which can be accessed at http://littlecalriverbasin.org/pdf/WatershedStudy.pdf.

Northwestern Indiana Regional Planning Commission (NIRPC)

NIRPC is a regional council of local governments serving the citizens of Lake, Porter, and LaPorte counties in Northwest Indiana. NIRPC helps address regional issues relating to transportation, the environment and community, and economic development. For more information, go to http://www.nirpc.org/.

NIRPC has prepared a comprehensive plan for its region entitled *2040 Comprehensive Regional Plan (A Vision for Northwest Indiana)* which can be accessed at http://www.nirpc.org/land-use/publications/2040-crp-full-document.aspx. This plan includes the following sections related to hazard mitigation efforts:

- Regional Growth and Conservation Chapter (1)
- Environment and Green Infrastructure (3)
- Northwestern Indiana Green Infrastructure Network

NIRPC also oversees the NWI Partnership for Clean Water to manage storm water. This partnership is a public education and involvement program that helps communities meet the requirements of the Indiana Department of Environmental Management's (IDEM) Rule 13.

Others

- Indiana University – Northwest
- Purdue University – Calumet (the Center for Innovation through Visualization and Simulation)
- Other Regional Organizations:
    - NIPSCO
    - Northwest Indiana Regional Development Authority (RDA) – does transportation (TODs), shoreline development, and economic development (leveraging the Lake Michigan shoreline)
        - In neighboring Hammond and Whiting, RDA is creating more connectivity through bike and walking trails that could also connect to Gary
        - In Gary, they have helped revitalize Marquette Park and extending the runway at the Gary- Chicago International Airport and a business strategic plan for the airport (at http://www.rdatransformation.com/blog/rda-transformations-the-movie/)
    - Friends of the Little Calumet River

Building on lessons learned from the 2008 floods and looking for opportunities to transform the city, Gary and its partners like the Little Calumet River Basin Development Commission have continued to address hazard risk reduction. The first part of this section will describe proposed and implemented mitigation actions and some description of them. The second part of the section will describe what was included in the 2010 Lake County Hazard Mitigation Plan and the last part are recommendations that resulted from the discussions and ideas generated in preparing this technical paper. Many of these recommendations are to continue building on previous efforts.

Previous and Current Mitigation Efforts

As described earlier, Gary and its partners have implemented several mitigation measures, many in the aftermath of the 2008 Floods. In 2009, the Little Calumet River Basin Development Commission broke ground on the final stage of the project:

> "The final stage of the Little Cal River project includes about 8,600 lineal feet of earthen level [levee], 780 feet of sheet pile wall, 7,762 feet of concrete and sheet pile floodwall and other features. The Little Calumet River Basin Development Commission and Army Corps of Engineers are overseeing the work. The project is designed to provide 200-year flood protection to about 9,500 residences and homes in the Northwest Indiana communities of Gary, Griffith, Hammond, Highland and Munster."[21]

The Commission stated in some of its recent meeting reports that the maintenance funding has been secured for the $275 million project[22]. The Commission has already completed some of the needed maintenance of the levee system in Gary including the Gary South Levee rehabilitation project; the Gary North Levee rehabilitation project will be completed soon (as of May 2015). Gary, in coordination with the Little Calumet River Basin Development Commission, has completed several flood-fighting drills and has increased its supplies of sandbags. For example, on April 12, 2013, the Commission completed a flood fighting drill in Gary along Harrison Avenue. Officials practiced getting flood barriers like inflatable bladder system ready[23].

[21] From IN.gov article dated September 29, 2009 found at http://www.in.gov/activecalendar/EventList.aspx?view=EventDetails&eventidn=61934&information_id=124943&type=&syndicate=syndicate, accessed May 2015

[22] From Little Calumet River Basin Development Commission website at http://littlecalriverbasin.org/docs.html

[23] From the Time of Northwest Indiana article dated March 17, 2013 found at http://www.nwitimes.com/news/local/lake/gary/flood-fighting-drill-set-for-kennedy-avenue-this-week/article_b03faec4-6d67-5fc2-84cd-944f05e95962.html, accessed May 2015

Figure 11- Stage VI of the Little Calumet Federal Project (Kennedy Ave to Cline Avenue on north side)

Source: USACE and found in Lake County 2010 HMP

In addition, the Gary Department of Green Urbanism and Stormwater, part of Environmental Affairs, is undertaking a robust effort to convert several vacant parcels into green infrastructure. In the initial part of this effort, called the "Grey to Green: Vacant to Vibrant Initiative", the city will select 15 city-owned parking lots and transform them into green infrastructure to absorb stormwater.

This effort will help improve water quality by using green infrastructure projects like rain gardens that absorb excess stormwater and capture contaminants. It will also reduce the volume of stormwater flow into the combined sewer/stormwater system and decrease the chances of sewage spills due to excess stormwater. The city will spend $500,000 on the project, which is supported by a $250,000 EPA grant. It will also train and employ 10 Gary residents to install and maintain parts of the project[24].

2010 Lake County Plan

The following are hazard mitigation measures proposed for Gary (from the 2010 Lake County Mitigation Plan) that are most relevant to addressing impacts of extreme weather:

Project	Purpose	Hazard	Status as of 2010	Comments and

[24] From the Times of Northwest Indiana, March 3, 2015 article entitled "Gary launching green infrastructure initiative" found at http://www.nwitimes.com/news/local/lake/gary/gary-launching-green-infrastructure-initiative/article_210e0f46-cbc6-5828-af40-78e460a5f0bd.html, accessed May 2015

		Addressed and Priority	Plan	Status in 2015
Conduct a sewer upgrade to separate stormwater and sanitary sewer lines	Lessen the impacts of hazards to new and existing infrastructure	Flood High	As of 2010, not yet funded but seeking funding sources	Looking for funding sources
Secure funding to complete construction of the levees	Lessen the impacts of hazards to new and existing infrastructure	Flood **High**	Funding need to complete the Little Cal project which can drastically reduce flooding	Completed
Retrofit critical facilities with backflow valves and inertial valves	Retrofit critical facilities and structures with structural design practices and equipment that will withstand natural disasters	Flood & EQ **High**	Seeking funding (City EMA and City Planners)	
Purchase generator/transfer switch for Gary Sanitary District	Improve emergency sheltering in community.	Multiple hazards including flood, tornado and winter storm **High**	Seeking funding (City EMA)	
Procure 4WD emergency vehicles for rescue and recovery	Improve emergency service transportation capabilities	Multiple hazards including flood, tornado and winter storm **Low**	Seeking funding (City EMA)	
Update the evacuation plan for hazardous materials spills	Review and update existing community plans and ordinances to support hazard mitigation.	Hazardous materials event which could be caused by events like flooding **Medium**	Updating to occur in five years (from 2010)	
Harden and flood-proof the Cal Township Multi-Purpose Center, Genesis Center, courthouse, critical facilities, and other public buildings	Retrofit critical facilities with structural design practices and equipment that will withstand natural disasters and offer weather-proofing.	Multiple hazards including flood, tornado and winter storm **Medium**	Seeking funding (City EMA)	Genesis Center could also be upgrade to serve as shelter (from 2010 Plan)
Assess and upgrade drainage systems along I-65 exit, Clay Ave, 15th Ave, 5th Ave, I-80/94	Minimize the amount of infrastructure exposed to hazards.	Flood **High**	The City received a $500K grant to survey areas of concern but needs funding to implement improvements. (City EMA)	

Other extreme weather-related risk reduction priorities or needs listed for Gary in the 2010 Lake County Mitigation Plan include:

- Hazardous material training and equipment
- Hardening of fire stations
- Need for warning sirens
- Burying power lines
- Flow allocation study
- Revising mutual aid agreements

Recommendations for Gary

- Have all major Gary departments go through CRISSP to determine their greatest vulnerabilities; some of the resulting actions could be part of the Lake County Hazard Mitigation Plan update
- Incorporate CRISSP principles and subsequent implementation activities into the city's MS4 Program
- Work with Data Driven Gary to use CRISSP principles in help determine the repurposing of vacant parcels (e.g., green infrastructure, greenways).
- Incorporate resilience into the City departments' capital improvement programs, particularly those that fund major development/redevelopment and infrastructure investments
- Consider partnerships with Chicago Wilderness to connect Gary's greenways to those in neighboring jurisdictions
- Consider partnerships with major industry, especially those on lakefront and along the Grand and Little Calumet Rivers
- Engage the Commerce Team and make climate resilience a part of future economic development and redevelopment projects
- Work with partners like Purdue University-Calumet to develop innovative tools that help communicate the risk and issues to city officials and the general public
- Update building codes to account for extreme weather
- Incorporate more frequent dredging of channels and harbors, dock modifications, and water intake pipe modifications to account for lower levels in Lake Michigan
- Promote green urbanism efforts to public in Gary and creating more awareness of existing social media sites like the Gary Department of Green Urbanism and Stormwater Facebook page at https://www.facebook.com/revitalizegary

- Update emergency response plans, including public health, to account for extreme weather events. If needed, plan more exercises to increase flood response capability and verify mutual aid with surrounding cities and county.
- Monitor mitigation grant and technical assistance opportunities from FEMA, NOAA and USACE
- Protect existing wetlands – either through acquisition of these areas, education to property owners on why they should be preserved and/or adopting higher buffer standards for wetlands and streams (NIRPC Comprehensive Plan recommends buffers of 25 feet for wetlands and 100 feet for streams[25])
    - Concentrate new development and redevelopment away from wetlands and floodprone areas
    - Help facilitate the implementation of 2040 NIRPC Comprehensive Plan

VII. CONCLUSIONS

Many of the lessons learned during the CRISSP development process are captured in the CRISSP White Paper. Outreach efforts for the CRISSP included a webinar for the City of Gary, a panel presentation at the Cities' 2015 Annual Conference, and the September 2015 Technical Workshop. The following discussion narrative focus on replicability of this effort and how to advance it forward.

Replicability and Next Steps

Following development of CRISSP, priority actions include making other cities aware of the process, encouraging use of the protocol, and developing a network of resources to ensure that CRISSP is broadly applied and refined over time throughout the Great Lakes St. Lawrence Region. In so doing, NOAA and GLISA serve as excellent resources that can be leveraged to enhance use of the CRISSP.

To assist in future enhancements of CRISSP, tools should be developed that assist cities assess risk and track mitigation measures. Existing tools, such as NOAA's Environmental Response Management Application (ERMA), could be modified to be applicable for CRISSP.

REFERENCES

[25] NIRPC "Plan 2040 for Northwest Indiana" (p. 1-40)

- ***IBM/AECOM Disaster Resilience Scorecard (at http://www.unisdr.org/2014/campaign-cities/Resilience%20Scorecard%20V1.5.pdf)***
- ***NOAA-NWS-NCEP Storm Prediction Center web site (at http://www.spc.noaa.gov/misc/AbtDerechos/derechofacts.htm#climatechange)***
- ***2014 National Climate Assessment Report (at http://nca2014.globalchange.gov/)***
- ***Union of Concerned Scientists "Confronting Climate Change in the Great Lakes" (at http://www.ucsusa.org/greatlakes/glchallengereport.html#.VRa837HD-pr)***
- ***NOAA Lake Level Viewer***
- ***2013 CRS Coordinator's Manual***
- ***U.S. Fish and Wildfire Service National Wetlands Inventory Wetlands Mapper (at http://www.fws.gov/wetlands/Data/Mapper.html)***
- ***FEMA/DHS Critical Infrastructure Protection and Resilience Toolkit website at http://emilms.fema.gov/IS921/921_Toolkit/index.htm***
- ***Climate Central's "Blackout: Extreme Weather, Climate Change and Power Outages".***
- ***"Understanding the Geologic Background for the September, 2008 Flooding Event that Led to the Temporary Closure of IU Northwest"*** by Erin P. Argyilan, PhD, Indiana University Northwest Department of Geosciences
- ***"Economic Assessment of Green Infrastructure Strategies for Climate Change Adaptation: Pilot Studies in The Great Lakes Region"*** by Eastern Research Group, Inc. Written under contract for NOAA Coastal Services Center (May 2014)

REFERENCES SPECIFIC TO GARY PILOT EFFORT

- ***Gary Comprehensive Plan***
- ***2010 Lake County Hazard Mitigation Plan***
- ***Little Calumet River Basin Development Commission (at http://littlecalriverbasin.org/)***
- ***Little Calumet River Basin Watershed Study***
- ***2040 Comprehensive Plan by the Northwestern Indiana Regional Planning Commission (at http://www.nirpc.org/)***