Climate Adaptation Planning in Great Lakes Cities

Regional Overview and Case Studies

Capstone Project
University of Michigan
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Executive Summary

Climate change will be one of the most challenging problems of this century. Clouded by political controversy over its cause and by scientific variation in future climate prediction, many people opt for inaction. However, within the last thirty years, our communities have experienced more frequent extreme weather events and gradually rising temperatures. While coastal and arid cities have received more attention from the research and planning communities, the Great Lakes Region is significant. This region contains 84% of North America's surface freshwater and supplies 40 million people with drinking water. The Great Lakes' biophysical characteristics create diverse microclimates for cities around its shoreline and these microclimates make climate prediction challenging. The Great Lakes states account for approximately one-third of the U.S. economy, and it is estimated that more than 1.5 million jobs are directly connected to the Great Lakes, generating $62 billion in wages. The region as a whole provides highly diversified industrial offerings and millions of people's livelihoods are directly and indirectly connected to this vast water system. The focus of this study is to identify the anticipated climate impacts for cities within the Great Lakes Region and recommend appropriate adaptation strategies for two case study cities, Marquette, Michigan and Benton Harbor, Michigan.

The Great Lakes' biophysical characteristics make climate prediction challenging. Most communities are expected to experience warmer annual average temperatures, more frequent flooding events, lake level declines, reduced ice cover and increased ice storms. We decided to define the Great Lakes Region by a modified watershed boundary that includes the 150 sub-basins and all counties within it or bisected by the watershed boundary. Within our boundary, we explored methods by which to characterize Great Lakes cities based on demographic information, environmental vulnerability, and social vulnerability. While the Great Lakes Basin as a whole has ample tree canopy cover and an overall low percentage of developed area, land cover types are not evenly distributed across the basin. Based on land cover distribution and change, the southern half is more vulnerable to climate change impacts than the northern half. Particularly in the Erie, Ontario, and Michigan Basins, the southern portion has more developed and impervious area, open cropland, and less forest cover and wetlands, making it more susceptible to flooding, poor water quality, and rising temperatures. Further, land cover change from 2001-2006 shows a general trend of forest and wetland loss accompanied by an increase in developed area in the Great Lakes Basin as a whole. This trend is also more pronounced in the southern portion of the basin.

From the case studies, we determined that the prioritization of climate adaptation strategies for Great Lakes cities must consider unique microclimates, infrastructure and development patterns, and the socio-economic vitality of each city. For example, Marquette, Michigan currently experiences high amounts of snowfall and longer winters. Climate change will reduce the length of the winter seasons but is expected to produce more intense rain and snow events, lower lake levels, and increase the damage from freeze/thaw conditions on infrastructure. These changes will have significant effects on the important maritime transportation and tourism industries. Marquette, Michigan, is a well-managed and financially stable community. The city will be the likely instigator of a climate action plan and the city's prominence in the Upper Peninsula will ensure knowledge transfer to adjacent municipalities. In Benton Harbor, Michigan, the most significant climate impacts concern increased summer temperatures and extreme heat events and more frequent winter ice storms. In residential neighborhoods, the electrical power-grid is fragile and increased demands and more ice storms could exacerbate the frequency of power outages. In addition, this city has a large percentage of lower-income residents who are less able to resist or recover from negative climate impacts. Benton Harbor, Michigan is currently experiencing extreme financial difficulties and leadership around climate adaptation may have to come from Berrien County or regional efforts.

Section 1 The Great Lakes

Overview
Biophysical Characteristics
Water Quantity
Water Quality
Summary of Key Issues

Overview

The Great Lakes are a striking feature of North America. And although the “Great Inland Seas” are known by many simply for their prominence on world maps and satellite images, their history, unique nature, and importance to American and Canadian citizens is often overlooked. The Great Lakes occupy a region scarred by glaciers. Each year, trillions of gallons of fresh water flow through the 150 watersheds that occupy the glacial landscape. The cultures, weather, industries, and cities found throughout the Great Lakes Region vary from watershed to watershed, yet all are tied to the system in a host of ways. The Great Lakes provide drinking water, employment opportunities, and recreational activities to millions of people. Dependence on and respect for the Great Lakes has lead to the creation of protective state, federal, and international legislation, yet human use of the region continues to threaten the system in the form of invasive species, pollution, and climate change. Section 1 provides an overview of the Great Lakes’ biophysical characteristics, the quantity of water found in the Great Lakes, and water quality throughout the Great Lakes Region.

1.1 Biophysical Characteristics

Biophysical characteristics describe the water system, hydrological divides, geology, individual lake profiles, and microclimates of the Great Lakes Region. In the following section, we describe how water volumes, annual average temperatures, type of precipitation, and distribution of precipitation vary greatly among Great Lakes watersheds.

Water System Dynamics

The Great Lakes include Lakes Superior, Michigan, Huron, Erie, and Ontario; water flows through the lakes in that order (See Figure 1). The system also includes the St. Mary's River, which flows from Lake Superior to Lake Huron, and the St. Clair and Detroit Rivers, which carry water from Lakes Michigan and Huron, respectively, to Lake Erie. Water eventually flows through the Niagara River and Niagara Falls before entering Lake Ontario. From Lake Ontario, water flows into the St. Lawrence River and the St. Lawrence Seaway, eventually entering the Atlantic Ocean.

The Great Lakes contain six quadrillion gallons of fresh water, one-fifth of the world's surface freshwater. The lakes have a surface area of

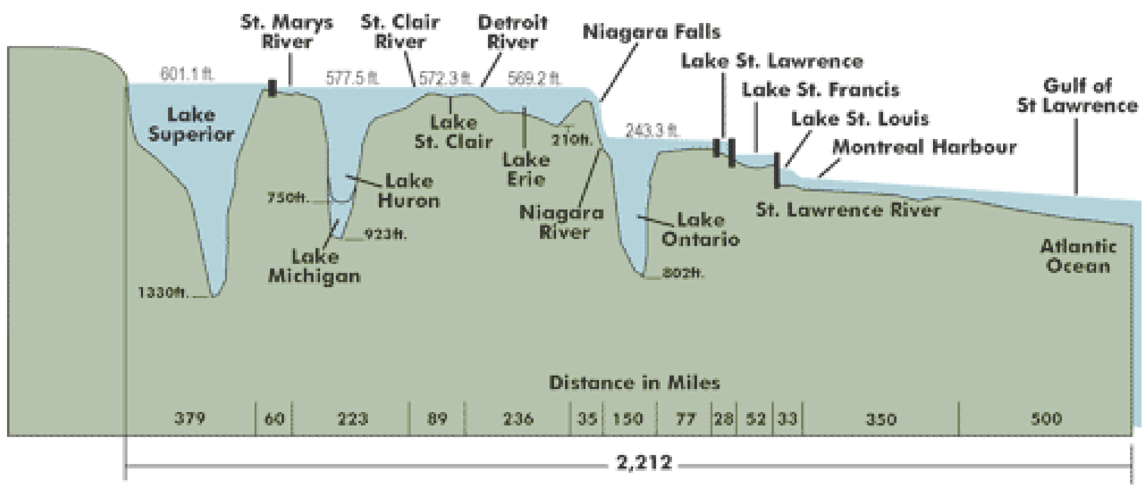


Figure 1. Great Lakes System Profile

(Source: U.S. Army Corps of Engineers, Detroit District.Wikipedia, the free encyclopedia, http://en.wikipedia.org/wiki/The_great_lakes)

94,000 square miles, 10,900 miles of coast line (Great Lakes Facts, 2/10/2011), and approximately 35,000 islands (Great Lakes Shipwreck Facts 2/10/2011). Spread evenly, there is enough water in the Great Lakes to submerge the continental United States in almost ten feet of water. The Great Lakes contain 84% of the U.S. supply of surface freshwater and provide 40 million people with drinking water (Our Lakes Facts 2/10/2011).

A watershed is "an area of land that drains water, sediment, and dissolved materials to a common outlet at some point along a stream channel" (Dunne and Leopold 1978). The Great Lakes watershed is approximately 295,000 square miles in size, about three times larger than the lakes themselves. The watershed includes eight states (Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania and New York) and two Canadian Provinces (Ontario and Quebec). Water that falls within the watershed either flows through the Great Lakes system and into the Atlantic Ocean or evaporates into the atmosphere. The watershed is divided into 150 sub-watersheds that are each associated with rivers or creeks that flow into the Great Lakes system.

Geological Context

Fluctuations of water levels within the Great Lakes are a common phenomenon throughout geologic history. Past records have shown that the average variability range during a millennium is seven feet. The most recent major drop in water level occurred 8,800 to 8,300 years ago under a cool and dry climate setting. Due to a considerable drop in precipitation, lake levels dropped 66 feet (20 meters) from today's levels and disconnected the major lakes from one another (Sohn n.d.). While the Great Lakes system is large, it is sensitive to climate shifts, as illustrated by this example.

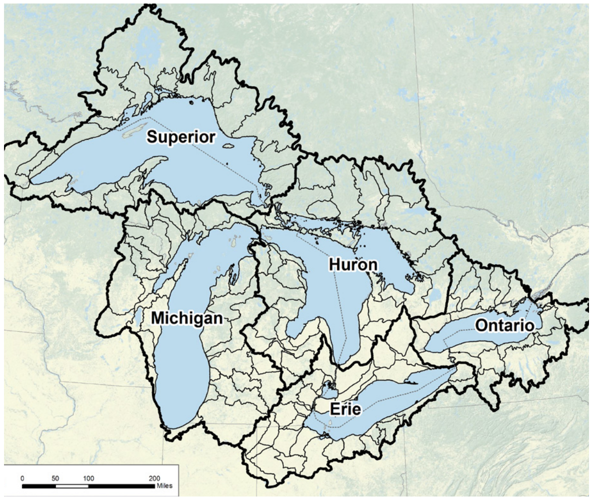


Figure 2 Great Lakes Watersheds

Figure 3 The Principal Hydrological Divides of North America

(Source: Wikipedia, the free encyclopedia, http://en.wikipedia.org/wiki/Continental_Divide_of_the_Americas)

Figure 5 Normal water levels (Seiches of the Great Lakes 2/19/2011)

(Source: Minnesota Sea Grant-NOAA-Great Lakes Environmental Research Laboratory. Sieches on the Great Lakes, http://www.geo.msu.edu/geogmich/seiches.htm)

Figure 6 Inundation from a seiche (Seiches of the Great Lakes 2/19/2011)

(Source: Minnesota Sea Grant-NOAA-Great Lakes Environmental Research Laboratory. Sieches on the Great Lakes, http://www.geo.msu.edu/geogmich/seiches.htm)

Seiches

Lunar tides do not significantly affect the Great Lakes, with the largest spring tides raising lake levels by no more than two inches (Seiches of the Great Lakes 2/19/2011). The Great Lakes do, however, experience "seiches." Seiche is a French word meaning "to sway back and forth." Seiches are water level rises created by weather and barometric pressure changes. These changes cause water to shift and accumulate along one coastline, raising water levels as much as 16 feet on one side of the lake relative to the other side. Figure 4 demonstrates how strong winds can raise water levels in the form of seiches.

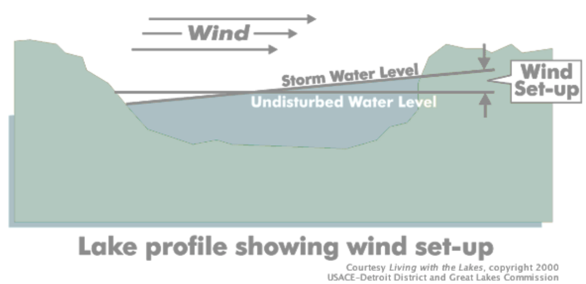


Figure 4 Seiches of the Great Lakes 2/19/2011

(Source: Great Lakes Commission. Seiches on the Great Lakes, http://www.geo.msu.edu/geogmich/seiches.htm)

Seiches are largest on Lake Erie because of its long east-west axis and its shallow depth. However, seiches are dangerous on all of the Great Lakes. Lake Michigan has experienced some of the most deadly seiches in history, including a seiche that killed ten people on July 4, 1929 on a pier in Grand Haven, MI. In 1938, a seiche killed five people in Holland, MI. Figures 5 and 6, taken minutes apart in Canal Park, Duluth, MN, demonstrate the speed and impact of a seiche (Seiches of the Great Lakes 2/19/2011).

Lake Profiles and Watersheds

Figure 7 describes the physical features of the Great Lakes. Lake Superior is 350 miles long at its longest point, while Lake Huron is the widest Great Lake with a breadth of 183 miles. Lake Ontario has the smallest dimensions of the Great Lakes, at 193 miles x 53 miles. With an average depth of 489 feet, Lake Superior is the deepest Great Lake; it also has the deepest point of all the Great Lakes, at 1,333 ft. Superior also holds the most water with almost 3,000 cubic miles of fresh water. Similarly, Superior has the greatest surface area of the Great Lakes. Despite holding more water than Lake Erie, Lake Ontario has the smallest surface area of the Great Lakes. Lake Erie is well-known for being warm and shallow; the lake has a maximum depth of 210 feet but averages a depth of only 62 feet. As one might expect, Erie holds the least amount of water, at 116 cubic miles.

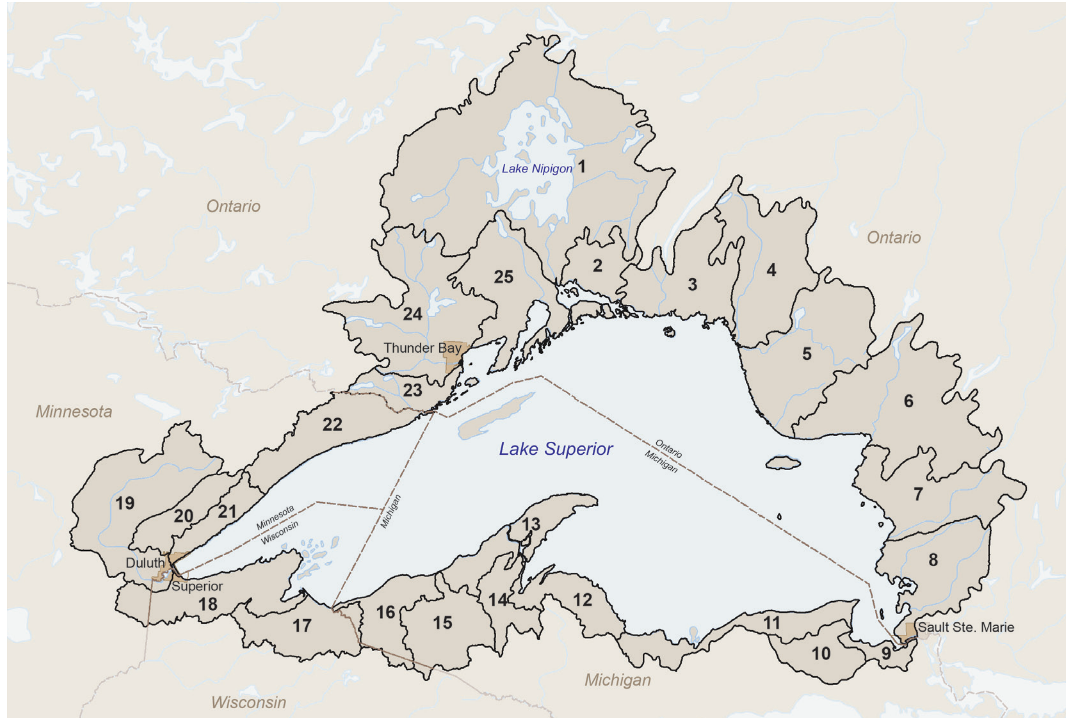
	Superior	Michigan	Huron	Erie	Ontario
Length	350 mi.	307 mi.	206 mi.	241 mi.	193 mi.
Breadth	160 mi.	118 mi.	183 mi.	57 mi.	53 mi.
Depth [ft.] (avg. / max.)	489 / 1,333	279 / 923	195 / 750	62 / 210	283 / 802
Shoreline	2,370 miles	1, 640 mi.	3, 830 mi.	871 mi.	712 mi.
Volume	2, 935 cu. mi.	1, 180 cu. mi.	849 cu. mi.	116 cu. mi.	393 cu. mi.
Surface Area	31, 700 sq. mi.	22, 300 sq. mi.	23,000 sq. mi.	9,910 sq. mi.	7,340 sq. mi.
Retention Time	191 years	99 years	22 years	2.6 years	6 years
Outlet	St. Mary's River / Lake Huron	Lake Huron & Chicago Canal	St. Clair River / Lake St. Clair	Niagara River / Welland Canal	St. Lawrence River / Atlantic Ocean
Discharge Rate	2,297 m^3/s	98 m^3/s Chicago Canal (6.75%) 1352 m^3/s Lake Huron (93.25%) 1,450 m^3/s Total	5,150 m^3/s into the St. Clair River 5,380 m^3/s into the Detroit River (additional flow is picked up in Lake St. Clair)	5760 m^3/s	6430 m^3/s

Figure 7 The Great Lakes Profile

Source: Length, breadth, depth, shoreline, volume, surface area, retention time, and outlet data from About Our Great Lakes 06/18/2004; Superior discharge rate from Bennet n.d.; Michigan discharge rate from Mortimer 2004; St.Clair discharge rate from Schatz n.d.;Detroit River discharge rate from Flow Modeling 01/19/1999; Erie and Ontario discharge rates from Ayers n.d.

Figure 8 Lake Superior Watershed

Watershed	Major River/Creek System
1	Nipigon
2	Gravel
3	Aquasabon
4	Pic
5	White
6	Michipicoten
7	Sand
8	Goulais
9	Waiska
10	Tahquamenon
11	Betsy-Choclay
12	Dead-Kelsey
13	Keweenaw
14	Sturgeon
15	Ontonagon
16	Black-Presque Isle
17	Bad-Montreal
18	Beartrap-Nemadji
19	St. Louis
20	Cloquet
21	Beaver-Lester
22	Baptism-Brule
23	Pine
24	Kaministiquia
25	Black Sturgeon



Lake Superior

The Ojibwe, the Native American tribe that inhabited the shores of Lake Superior, called the lake “Gichigami,” or “big water.” The name is appropriate for a lake that contains more water than all the other Great Lakes combined (Great Lakes Facts and Figures 01/21/2010). Lake levels fluctuate seasonally and annually, but gates on the St. Mary’s River ensure that they never exceed 602 feet above sea level (Great Lakes Facts and Figures 01/21/2010). Due to its 350 mile east-west axis, summer visitors on Superior’s eastern shore witness the sunset 35 minutes before visitors on its western shore (Lake Superior Facts n.d.). Major rivers in the Superior watershed include the Baptism-Brule, Kaministiquia, Michipicoten, Nipigon, Pic, St. Louis, and White. The Nipigon and St. Louis are the largest tributaries, accounting for one-quarter of the water that enters Superior annually (Superior Pursuit 11/25/2008).

Figure 9 Lake Michigan Watershed

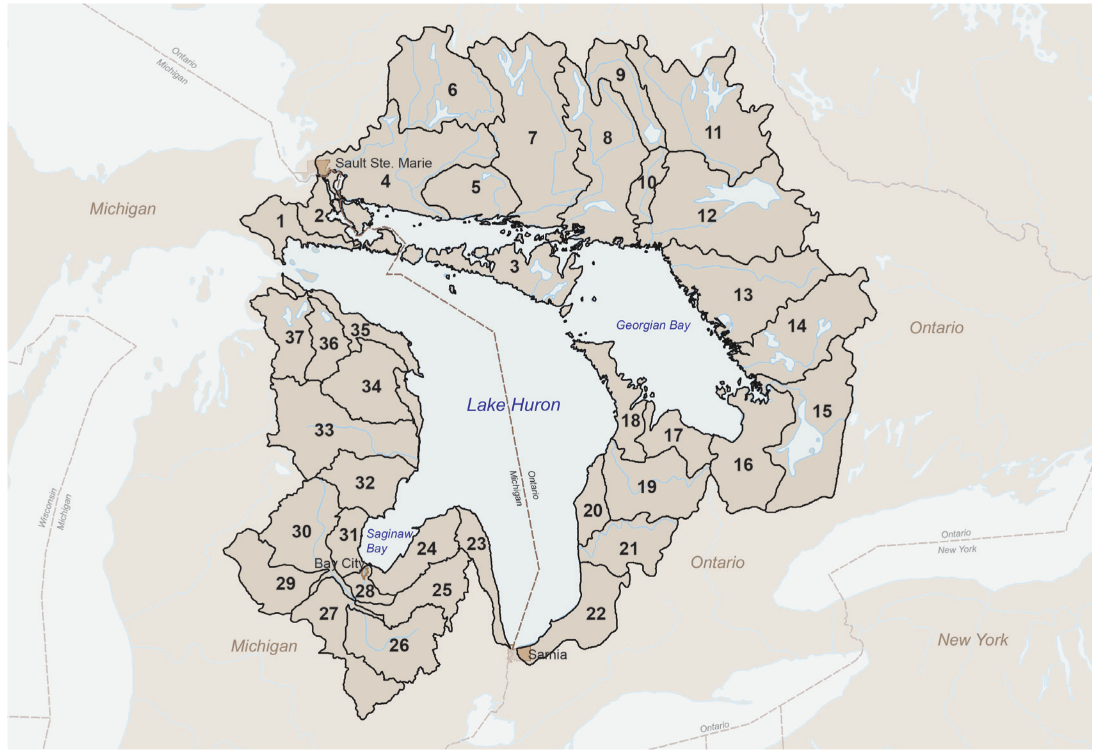
Watershed	Major River/Creek System
1	Brule
2	Michigamme
3	Cedar-Ford
4	Escanaba
5	Tacoosh-Whitefish
6	Fishdam-Sturgeon
7	Manistique
8	Brevoort-Millecoquins
9	Boardman-Charlevoix
10	Betsie-Platte
11	Manistee
12	Muskegon
13	Pere Marquette-White
14	Lower Grand
15	Maple
16	Upper Grand
17	Thornapple
18	Kalamazoo
19	Black-Macatawa
20	St. Joseph
21	Little Calumet-Galien
22	Pike-Root
23	Milwaukee
24	Manitowoc-Sheboygan
25	Fond du Lac
26	Upper Fox
27	Wolf
28	Lower Fox
29	Door-Kewaunee
30	Duck-Pensaukee
31	Oconto
32	Peshtigo
33	Menominee

Lake Michigan

Lake Michigan's name comes from the Ojibwe word "Mishigami," which means "great water" (Projects n.d.). Lake Michigan is the second largest Great Lake by volume and the third largest by surface area (Great Lakes Facts and Figures 01/21/2010). It is the only Great Lake completely within the United States. Historically, Lake Michigan only discharged into Lake Huron through the Mackinaw Straights. However, to prevent municipal water contamination, at the turn of the 20th century the City of Chicago redirected the flow of the Chicago River toward the Mississippi River water basin. Today a small portion of Lake Michigan discharges through the Chicago River (Lee n.d.). Major rivers in the Lake Michigan watershed include the Kalamazoo, Fox-Wolf, Grand, Muskegon, and Menominee (Great Lakes Facts and Figures 01/21/2010).

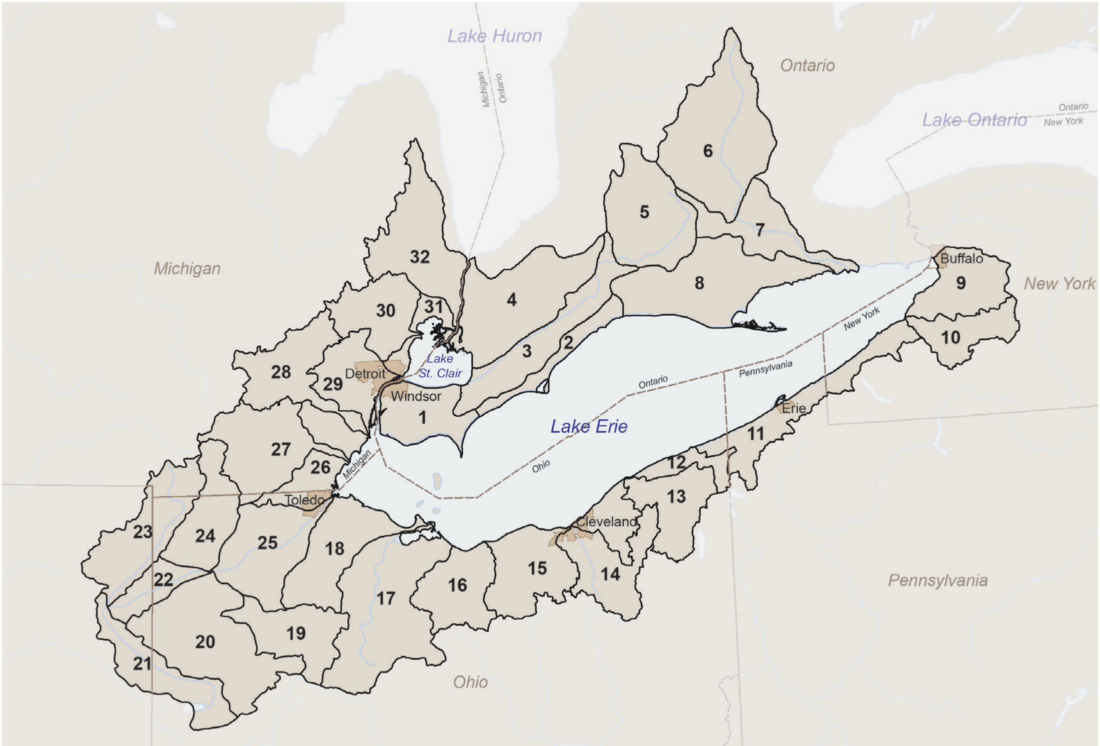
Figure 10 Lake Huron Watershed

Watershed	Major River/Creek System
1	Carp-Pine
2	St. Mary's
3	Manitoulin Island
4	Mississagi
5	Blind
6	Mississagi
7	Wakonassin
8	Whitefish
9	Wanipitai-French
10	Wanipitai-French
11	Marten
12	French
13	Magnetawan
14	Kawpakwakog
15	Severn
16	Nottawasaga
17	Bighead
18	Stokes
19	Saugen
20	Pine
21	Maitland
22	Ausable
23	Birch-Willow
24	Pigeon-Wiscoggin
25	Cass
26	Flint
27	Shiawassee
28	Saginaw
29	Pine
30	Tittabawassee
31	Kawkawlin-Pine
32	Au Gres-Rifle
33	Au Sable
34	Thunder Bay
35	Ocqueoc
36	Black
37	Cheboygan



Lake Huron

Lake Huron is named after the Native American people who occupied the region around the time of European settlement. Lake Huron is the second largest Great Lake by surface area and the third largest by volume (Ayers n.d.). Huron is best known for its two large bays, the Georgian bay on the northeast side and the Saginaw Bay/North Channel on the west side. Huron has the longest coastline of all the Great Lakes and includes many islands within its bays (Lake Huron Info n.d.). The Huron drainage basin is twice the size of the lake itself, making it the largest Great Lakes drainage basin (Great Lakes Facts and Figures 01/21/2010). Major rivers in the Huron watershed include the Au Sable, Birch-Willow, Blind, Cass, French, Magnetawan, Mississaga, Wakonassin, and Whitefish.



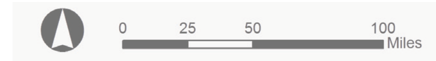


Figure 11 Lake Erie Watershed

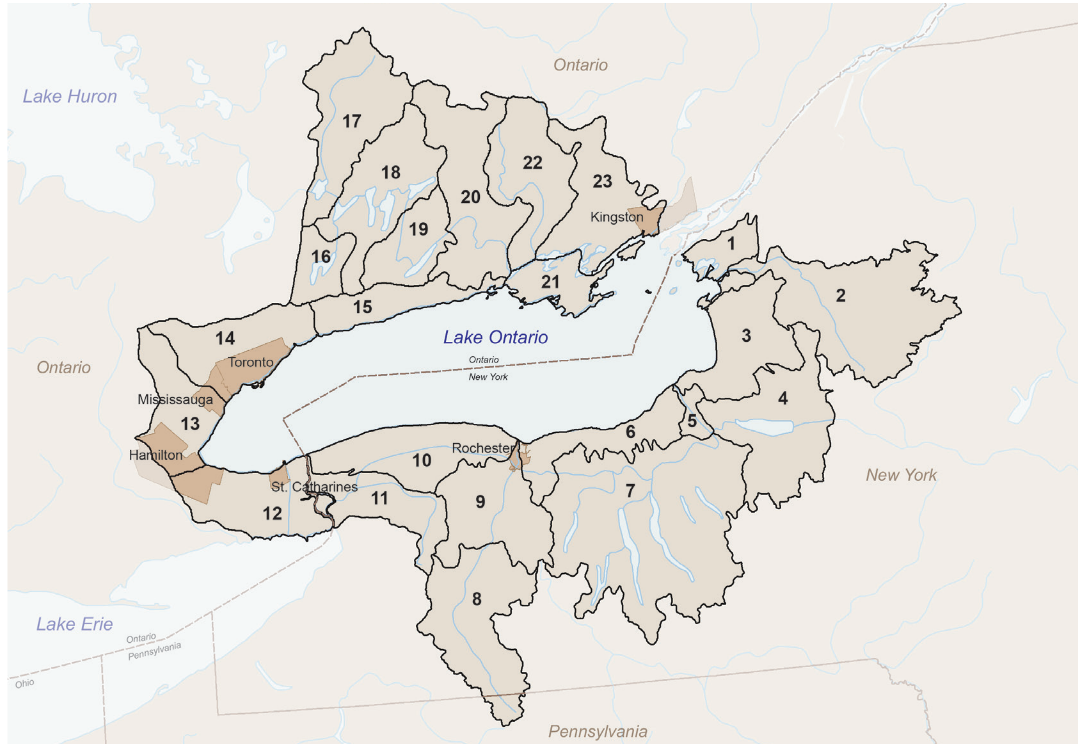
Watershed	Major River/Creek System
1	Canard
2	Sixteenmile
3	Jeannettes
4	Sydenham
5	Thames
6	Grand
7	Grand
8	Big
9	Buffalo-Eighteenmile
10	Cattaraugus
11	Chautauqua-Conneaut
12	Ashtabula-Chagrin
13	Grand
14	Cuyahoga
15	Black-Rocky
16	Huron-Vermilion
17	Sandusky
18	Cedar-Portage
19	Blanchard
20	Auglaize
21	St. Marys
22	Upper Maumee
23	St. Joseph
24	Tiffin
25	Lower Maumee
26	Ottawa-Stony
27	Raisin
28	Huron
29	Detroit
30	Clinton
31	Salt
32	St. Clair

Lake Erie

Lake Erie is named after the Native American tribe that occupied the region around the time of European settlement. Erie is the fourth largest Great Lake by surface area, but contains the least amount of water (About Our Great Lakes 06/18/2004). With major cities such as Cleveland, Toledo, and Buffalo on its shores—and Detroit, MI and Hamilton, Ontario nearby—Erie is the most urbanized Great Lake (Great Lakes Facts and Figures 01/21/2010). As the shallowest Great Lake, Erie cools and freezes quickly in the winter and warms soon after spring arrives (Dennis 2003). As the most southerly Great Lake, Erie is susceptible to fast-forming storms that move quickly along the lake's east-west orientation (Dennis 2003). Major rivers in the Erie watershed include the Canard, Cuyahoga, Grand, Maumee, and Sandusky.

Figure 12 Lake Ontario Watershed

Watershed	Major River/Creek System
1	Chaumont-Perch
2	Black-Ontario
3	Salmon-Sandy
4	Oneida
5	Oswego
6	Irondequoit-Ninemile
7	Seneca
8	Upper Genesee
9	Lower Genesee
10	Oak Orchard-Twelvemile
11	Tonawanda
12	Welland
13	Credit
14	Humber
15	Ganaraska
16	Nonquon
17	Burnt
18	Emily
19	Baxter
20	Trent
21	Moira
22	Otter
23	Napanee



Lake Ontario

The word “Ontario” means “beautiful lake” in Iroquois (Lake Ontario n.d.). Lake Ontario is the smallest Great Lake by surface area and the fourth largest by volume (About Our Great Lakes 06/18/2004). Around 80% of Lake Ontario’s water comes from the other Great Lakes (Great Lakes 02/14/2011). Because Ontario is the final link in the Great Lakes chain, phosphorous pollution and other effects of human activities in the Great Lakes Region are often highly visible in Ontario’s waters (Lake Ontario n.d.). The 5.5 million residents of the greater Toronto area are located on Ontario’s north shore (Toronto’s Racial Diversity n.d.). Major rivers in the Ontario watershed include the Humber, Ganaraska, Napanee, and Salmon-Sandy.

Microclimates

The Great Lakes Region is located in both humid temperate and boreal biomes (Major Biomes Map 10/08/2003). Humid temperate and boreal biomes are characterized by warm summers and cold winters with significant precipitation year round (Sousounis & Albercook n.d.). The presence of large quantities of freshwater in the region supports diverse local and regional weather. For instance, extreme temperature ranges and lower precipitation are found in northwestern Great Lakes communities such as International Falls, Minnesota, while lakeshore communities such as Traverse City, Michigan experience milder annual temperature fluctuations with additional “lake effect” precipitation (Great Lakes 02/28/2011). These localized variations in temperature and precipitation are characteristic of microclimates. Temperature, moisture, wind speed, and light are examples of variables influenced by local topography and proximity to major ecological landmarks such as bodies of water. While microclimates can occur in plots as small as a yard, they’re best understood on a regional scale where climate variations are relatively constant. Combined with highly variable topography and soil types, the presence of the Great Lakes creates a number of distinct microclimates within the Great Lakes Basin.

Figure13 (Great Lakes 02/28/2011) describes some of the microclimates within the Great Lakes Region. Average winter temperatures in the Great Lakes Region hover around freezing along lakeshores and can dip well below 0° F in inland zones; summer highs are equally variable with moderate average highs of around 65° F along lakeshores and warmer temperatures averaging around 80° F further inland. The influence the Great Lakes play in local climate can also be seen in the number of frost-free days and annual precipitation. The number of frost-free days ranges from 80 to 220 within the Great Lakes Region, with high regional variability. For example, Allegheny County, NY has around 80 frost-free days annually, while Buffalo, NY, just 40 miles to the northeast, has over 200. Similarly, microclimates within the region receive between 20-50 inches of precipitation each year.

Gulf of Mexico moisture, Pacific storms, and Arctic air masses often interact over the Great Lakes Region to create unique weather systems that can assemble large thunderstorms, plunge temperatures in Great Lakes communities to -40° F (Great Lakes 2011), or drop over 350 inches of snow in regions in a single season (Snowfall records n.d.). Combined with variable soil types, the unique microclimates of the Great Lakes Region support diverse plant communities ranging from dry savannah and prairie communities in Washtenaw County, MI to moist hardwood forests in Baraga County, MI (Vegetation circa 1800 n.d.). The Great Lakes agricultural community has capitalized on soil and climate variation in order to grow a diverse crop of fruits and vegetables. Michigan alone produces over 200 commercial commodities, making it the second-most agriculturally diverse state behind California (Michigan agriculture 2009). For example, sandy soils and mild winters along Lake Michigan's shores create a microclimate in Traverse City, MI which is suitable for cherry farming (Granja 2010).

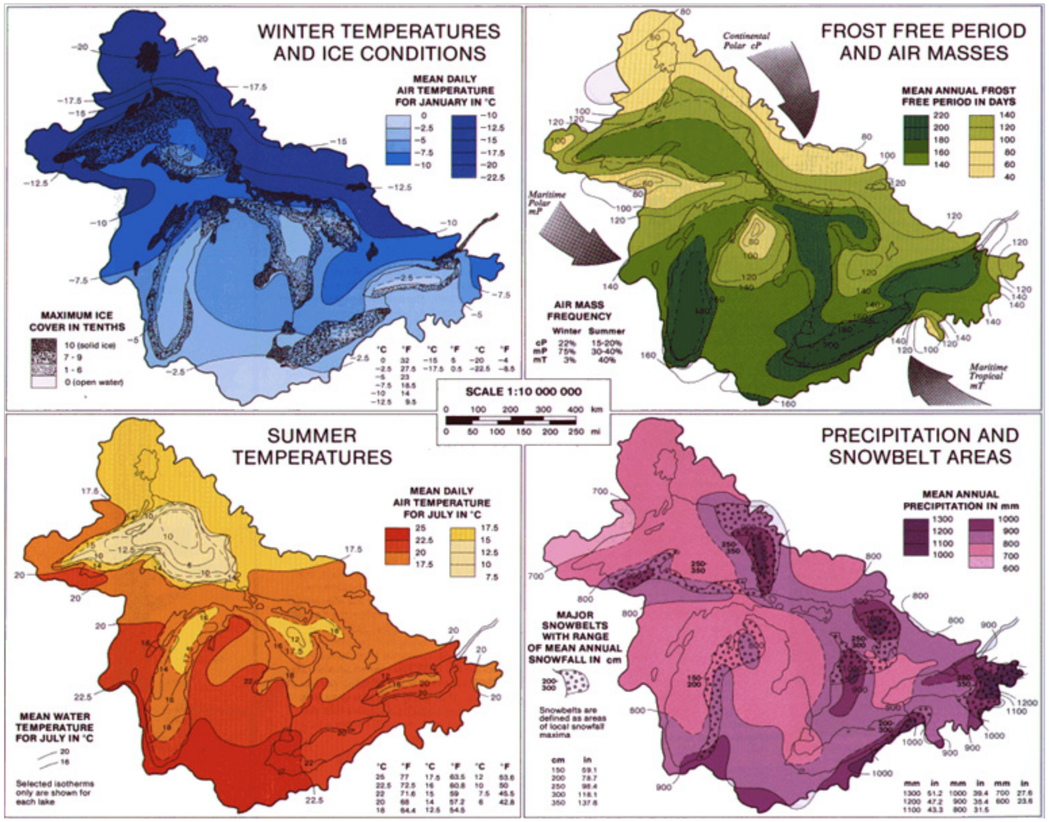


Figure 13 Microclimates of the Great Lakes Region

(Source: The Great Lakes: An Environmental Atlas and Resource Book. http://www.epa.gov.proxy.lib.umich.edu/glnpo/atlas/glat-ch2.html#Climate)

Summary of Biophysical Conditions

The Great Lakes watershed stretches approximately 10° longitudinally with a latitudinal measurement of 20°. The Great Lakes contain 84% of the U.S. surface freshwater supplies and they constitute 1/5th of the world's surface freshwater. They provide drinking water for 40 million people. The five lakes vary in depth, volume and shoreline length. Lake Superior is the largest lake in volume and surface area; it's also the deepest Great Lake. Lake Huron has the longest shoreline, in part because of the many islands found in its waters. Lake Erie is the smallest Great Lake in terms of water volume—4% the size of Superior—and has a retention time of only 2.6 years compared to Lake Superior's 191 years.

Due to varied topography, soil types, proximity to water, and spatial distribution, there is significant microclimate variation in the Great Lakes Region. For example, the number of frost-free days varies from 80 to 220 days. Microclimate variation doesn't reflect a smooth gradient from north to south. Allegheny County, NY has 80 frost-free days and Buffalo NY, which is 40 miles to the NE has 200 frost-free days. Precipitation also varies significantly with Great Lakes communities receiving between 23 and 51 inches per year.

Figure 14 Lake Superior - Grand Sable Dunes, MI

1.2 Water Quantity

Among other things, Great Lakes water is used for drinking water, recreation, manufacturing, and sanitation. The volume of water in the Great Lakes is affected by man-made diversions and legislation that regulates use of the system.

Diversions

Because the Great Lakes contain such an enormous supply of fresh water, use of the lakes is often viewed as a solution to water shortages in other parts of the United States. But even a small disruption to the flow of water through the Great Lakes could have profound impacts on the system as a whole. Since the threat of water diversions—the transfer of water into and out of the basin—is so real, Canadian provinces and U.S. states have taken action to protect the water supply.

Diversions are manmade changes to a water system that direct water away from its natural flow. There are two major types of diversions: inter-basin and intra-basin diversions. Inter-basin diversions move water into or out of the Great Lakes watershed. Inter-basin diversions are the most concerning because they alter the amount of water that is available in the Great Lakes system. Intra-basin diversions remove water from the Great Lakes system in one location and return the water to a different location within the Great Lakes Basin. Theoretically, intra-basin diversions do not change the overall water quantity of the Great Lakes Basin.

Figure 15 Lake Superior - Grand Marais, MI

Historically, water only left the Great Lakes watershed through the St. Lawrence River or through natural evaporation processes. Beginning in the 19th century, diversions for shipping and sanitary purposes altered the system's natural hydrology. Some diversions added water to the Great Lakes watershed from outside sources. Currently, there are three diversions of water into the Great Lakes watershed:

1) Wisconsin's Portage Canal was built in the 1860's in order to connect the Wisconsin and Fox Rivers. The canal allows 64.6 million gallons per day (mg/d) to flow into the Great Lakes watershed.

2) The Ogoki Diversion in Ontario was built during World War II for hydroelectric power generation.

3) Ontario's Long Lac Diversion was built during World War II for hydroelectric power generation. Combined with the Ogaki Diversion, it adds 3,606 mg/d of water to the Great Lakes watershed.

Three diversions remove water from the Great Lakes watershed:

1) The Pleasant Prairie, WI diversion was approved in 1990 to replace the village's radium-contaminated ground water.
The system removes 3.2 mg/d from the watershed. According to the Great Lakes Compact, Pleasant Prairie must reverse the flow of its sanitary system by the year 2010.

2) The diversion of the Chicago River was completed in 1900 amongst sanitary concerns. The flow of the Chicago River was reversed, allowing 2,068 mg/d to flow out of the Great Lakes Basin and into the Mississippi River watershed (Reversal of the Chicago River, 2/19/2011).

3) The Forestport diversion allows 78 mg/d to flow out of the Black River and into the Erie Canal. The diversion was constructed in order to connect New York City ports to the Great Lakes.

Figure 16 Lake Michigan - Grand Haven Pier (winter)

Diversions Within the Great Lakes

Six intra-basin diversions alter the natural flow of the Great Lakes watershed by taking water out of the system at one point and putting it back into the system at a different location.

1)The Raisin River diversion was approved in 1968 and allows 16 mg/d to be diverted away from the St. Lawrence River for 100 days each year. The diversion improves summer flow and is returned to the river further downstream.

2)The New York State Barge Canal was completed in 1918 in order to allow recreational boating around Niagara Falls. The canal removes 450 mg/d from the Niagara River and returns most of the water to Lake Ontario. An additional 20 mg/d is diverted into the Hudson River watershed during the navigational season.

3)In Haldimand, Ontario, a reverse-flow diversion was constructed in 1997 for municipal use. The diversion removes 1.3 mg/d from Lake Ontario and returns the treated water to Lake Erie.

4)The London, Ontario diversion was constructed in 1967 for municipal use. It removes 71 mg/d from Lake Huron and returns the water to Lake St. Clair.

5)The Detroit diversion removes 94 mg/d from Lake Huron for municipal use. Treated water is returned to the Detroit River.

6)The Welland Canal diversion opened in 1829 as a commercial lock. The canal system allows shipping vessels to bypass Niagara Falls. 5,946 mg/d flow between Lake Erie and Lake Ontario, bypassing the Niagara River.

Finally, the City of Akron, Ohio's municipal water system operates a net-neutral diversion. The system removes 32 mg/d from the Cuyahoga River and replaces it with an equal amount of water from the Ohio River watershed.

Figure 17 Lake Superior - Pictured Rocks, MI

Great Lakes Water Protection

Legislation related to Great Lakes diversions began with the 1909 Boundary Water Treaty (BWT). The BWT created the International Joint Commission (IJC), which must approve any obstructions or diversions that alter the natural flow of water in the Great Lakes. The BWT was supplemented in 1967 by the Lake Michigan Diversion Supreme Court Consent Decree. This decree was modified in 1980 to limit the Chicago diversion to its current level of 2,068 mg/d.

With the 1985 Great Lakes Charter, the United States and Canada agreed that diversions greater than five mg/d must be approved by all eight Great Lakes states and both Canadian provinces. The 1986 Federal Water Resources Development Act also requires approval of all Great Lakes governors for any exports or diversions; it also prevents federal agencies other than the IJC from studying possible diversions.

The 2001 Great Lakes Charter Annex established a framework for future agreements for regulations on exports and diversions by the U.S. governors and Canadian premiers. The Charter Annex provided the framework for the most recent and most important legislative action dealing with the Great Lakes, the 2005 Great Lakes Water Resources Compact.

The Great Lakes Water Resources Compact is the most in-depth legislation to date and has legally enforceable regulation for a number of issues. First, new diversions and exports of water out of the basin are limited to communities that straddle the watershed boundary. Even in these cases, diversion rights will only be granted if there are no other viable options for obtaining water. Also, water may only be used for public use, and treated water must be returned to the watershed. In addition, all governors and premiers must approve the diversion. The Great Lakes Compact also has goals for water conservation, sustainable use, and Great Lakes research. Individual states may implement more stringent requirements than those outlined in the Great Lakes Compact.

The Great Lakes Compact also addresses the issue of bottled water. Great Lakes conservationists are concerned that bottling water is used as a method to export water out of the Great Lakes watershed. While the Great Lakes Compact does not ban the bottling of Great Lakes water, it does make it illegal to transport Great Lakes water in any pipeline, canal, or container larger than 5.7 gallons.

Figure 18 Lake Michigan - Saugatuk, MI

The Great Lakes Compact was approved by all eight U.S. states and both Canadian provincial governments; the U.S. and Canadian national governments also approved the legislation. Essentially, it gives legal control of the Great Lakes watershed to the IJC and the state governors and province premiers.

Summary of Water Quantity

Inter-basin water transfers constitute the most significant water diversions. Recorded diversions indicate that 1,521 million gallons per day are added to the Great Lakes watershed. It is noteworthy, however, that this figure does not take into account some intra-basin diversions such as bottled water production. The Great Lakes Compact ensures large-scale diversions won't occur, but withdrawals in containers 5.7 gallons or smaller are unrestricted. Canals, hydroelectric power, and municipal drinking water are common forms of diversion within the Great Lakes. The Boundary Water Treaty of 1909; the 1985 Great Lakes Charter; the 1986 Federal Water Resources Development Act; and the 2001 Great Lakes Charter Annex paved the way for the creation of 2005 Great Lakes Water Resources Compact.

Figure 19 Lake Michigan - Benton Harbor, MI

1.3 Water Quality

Supplying drinking water to 40 million people and innumerable recreational activities to residents and visitors alike, the Great Lakes are recognized as a natural resource worthy of protection. The Clean Water Act in the United States and the Great Lakes Water Quality Agreement between the United States and Canada set minimum water quality standards for the Great Lakes. The Clean Water Act defines the ecological and economic uses that U.S. waterways must support. Waterways that fail to support their designated uses are considered impaired, and states must adopt plans for their remediation. Similarly, the Great Lakes Water Quality Agreement defines beneficial uses that each area of the Great Lakes must support. Areas that do not support their beneficial uses are considered Areas of Concern. In this chapter we survey the quality of Great Lakes waters, map impaired waterways and Areas of Concern, and investigate the most common pollutants found in the Great Lakes.

Common Threats

Total Maximum Daily Load (TMDL) is a measurement that describes the amount of pollution a waterway can receive while still meeting water quality standards. Fecal coliform, total suspended solids, sediment, and phosphorus are among the top five pollutants in both Michigan and Ohio TMDL waters. Polychlorinated biphenyls (PCBs) are the second-most common pollutant in Michigan TMDL waters, but are not among the top five in Ohio. Meanwhile, nitrogen is the fifth-most common pollutant in Ohio, but is not among Michigan's top five (See Figure 20 and 21).

Fecal coliform bacteria, which include E. Coli, are found in human and animal waste, and their presence in the water column is a sign of sewage overflow. Total suspended solids are organic and inorganic particulates suspended in water. They can reduce the sunlight that reaches aquatic plant life, which decreases oxygen levels. They also impact fish directly by clogging gills and smothering eggs. Sediment, like suspended solids, can increase the turbidity of water, thereby reducing the sunlight that reaches aquatic plants. Sediment can also serve as a vector for other forms of contaminants, such as DDT, PCBs, and heavy metals like mercury.

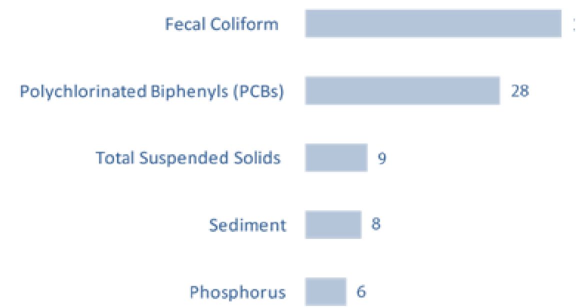


Figure 20 Pollutants Responsible for the Highest Percentage of TMDL Programs in Michigan

(Source: EPA, 2010)

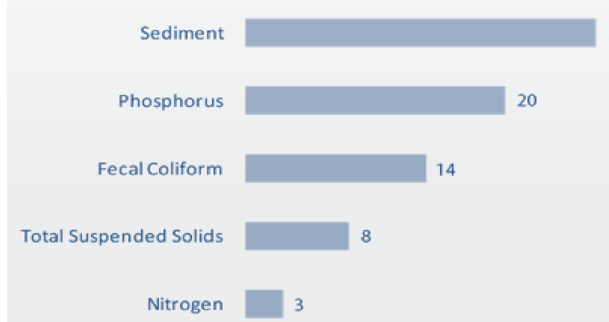


Figure 21 Pollutants Responsible for the Highest Percentage of TMDL Programs in Ohio

(Source: EPA, 2010)

PCBs, the second-most common pollutant in Michigan TMDL waters, have been banned since 1979, but they remain in waterways and the atmosphere due to their chemical stability and low boiling point. They enter waterways primarily through atmospheric depositions such as rain and snowfall. They are carcinogenic to humans and animals; they are also associated with increased rates of Epstein Barr virus, lower birth weights, and learning deficits among children of exposed mothers (EPA 2008).

Nitrogen, the fifth-most common TMDL pollutant in Ohio, can lead to algal blooms and reduced oxygen levels. Nitrogen levels tend to be higher in waters that receive runoff from agricultural land, which often contains fertilizer and animal waste (Dubrovsky and Hamilton 2010).

Great Lakes Areas of Concern

The Great Lakes Water Quality Agreement, signed in 1978 and amended in 1993, is an agreement between the United States and Canada that regulates water quality in the Great Lakes. The agreement calls for the (GLWQA 1993):

- Prohibition of large toxic chemical releases into the Great Lakes
- Elimination of persistent toxic chemical releases into the Great Lakes
- Construction of publicly owned waste water treatment facilities
- Coordination of planning and management among jurisdictions in Canada and the United States.

Areas of Concern (AOC) are Great Lakes waters that fail to meet the water quality standards outlined in the GLWQA. In particular, AOC waters have excessive concentrations of certain critical chemical, physical, biological, and radiological pollutants that prevent them from supporting their designated beneficial uses under the agreement. Similar to designated uses associated with TMDL waters, beneficial uses include fish and wildlife consumption, drinking water, human recreation, and dredging. There are 43 AOCs, 26 in the United States, 12 in Canada, and five that straddle the countries' borders. Figure 22 shows the location of each AOC.

The agreement calls on both countries to devise Remediation Action Plans (RAPs) for each AOC within their borders. Like TMDL programs, RAPs specify the maximum amount of critical pollutants that may be released into an AOC. In addition, they specify remediation strategies to remove toxic pollutants that are already present in AOC waters. To date, RAPs have led to the delisting of two Canadian AOC sites and one U.S. AOC.

Figure 22 Great Lakes Areas of Concern

Source: http://www.ec.gc.ca/raps-pas/default.asp?lang=En&n=96A7D1F1-0

Impaired Waters

Under the Clean Water Act, states must prepare water quality inventories once every two years. In addition to measuring the levels of certain chemical and biological pollutants, inventories must assess the ability of waterways to support aquatic life, human recreation, and industry and their ability to provide drinking water and fish for human consumption. Waters that fail to support these designated uses are included in a list of impaired waters (CWA 1976). The most seriously impaired waters are assigned Total Maximum Daily Loads (TMDLs), which set limits on 176 priority pollutants that may be discharged into the waters and establish remediation programs for each waterway.

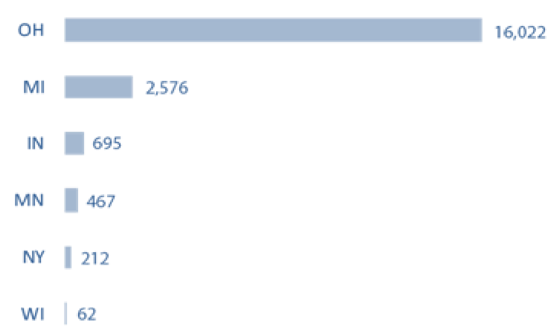


Figure 23 Miles of Impaired Waterways (Source: EPA, 2010)

States have some discretion in preparing water quality inventories. States may categorize water uses in different ways and set different minimum standards for water quality corresponding to each use. Some states may have more vigilant and/or better funded water monitoring programs. However, each state must enforce minimum standards established by the EPA, so comparisons across states are possible. Ohio and Michigan, with 16,022 and 2,576 miles of waterways under TMDLs, respectively, have by far the most miles of waterways subject to TMDLs within the Great Lakes Basin (see Figure 23).

Michigan’s Impaired Waters

Within Michigan, the most extensive TMDL water systems are tributaries of the Pere Marquette River near Lake Michigan, the Saint Joseph River on the southern coast of Lake Michigan, and River Rouge near Detroit. Each of the TMDL programs responds to conditions and uses unique to these water systems.

The Pere Marquette River enjoys special protection as a federally designated Wild and Scenic River and a state Natural River (MIDEQ 2010). It is one of the premier trout rivers in the Midwest, and unlike other large Michigan rivers, has not been dammed. The river is one of two in Michigan that the Nature Conservancy has listed as high priority due to its significant aquatic ecology. In addition, the Pere Marquette has an active watershed council that implements coordinated protection programs. The primary threats to the river are silt deposits and nutrient enrichment from runoff. The inclusion of the Pere Marquette among Michigan’s TMDL waters underscores the fact that a state’s TMDL program prioritizes not only the most threatened, but also the most biologically and economically valuable waterways.

The Saint Joseph River system encompasses six sub-watersheds that include the Paw Paw, Dowagiac, Rocky, Prairie, and Fawn Rivers. The system received a priority TMDL designation due to the ratio of wetland and forest cover within the sub-watersheds, the encroachment of urban development along the watershed’s perimeter, and the potential for regional cooperation to implement protection plans. Like the Pere Marquette, the system includes several important trout streams. In addition to pressure from urban development, channelization and agricultural runoff pose the most serious threats to the system. Along with the Pere Marquette, the Saint Joseph system indicates that TMDL classification is not simply a response to water quality, but also reflects the potential for local institutions to implement restoration plans.

Among Michigan’s TMDL waters, the River Rouge faces some of the most acute water quality problems. Primary threats include impervious surface runoff, sewer outflows during heavy rainfall events, channelization, septic tank seepage, and high nutrient levels that can result in hypoxia, or reduced oxygen levels. Despite these challenges, the river system serves as habitat for brown trout and red side dace, a threatened population. In addition, Friends of the Rouge and the Johnson

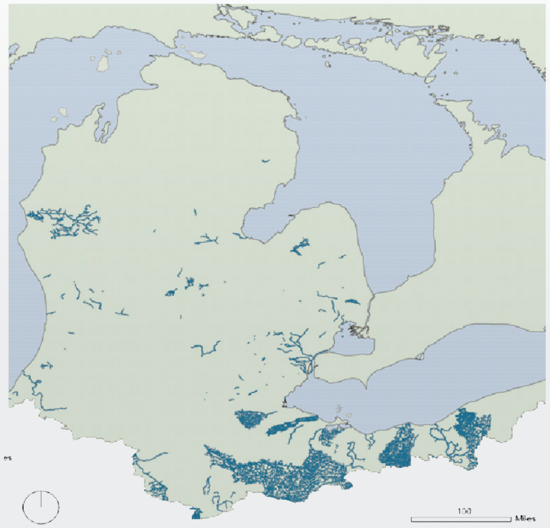


Figure 24 Impaired Waterways

Michigan and Ohio

Creek Protection Group provide grassroots support for restoration efforts (MIDEQ 2010).

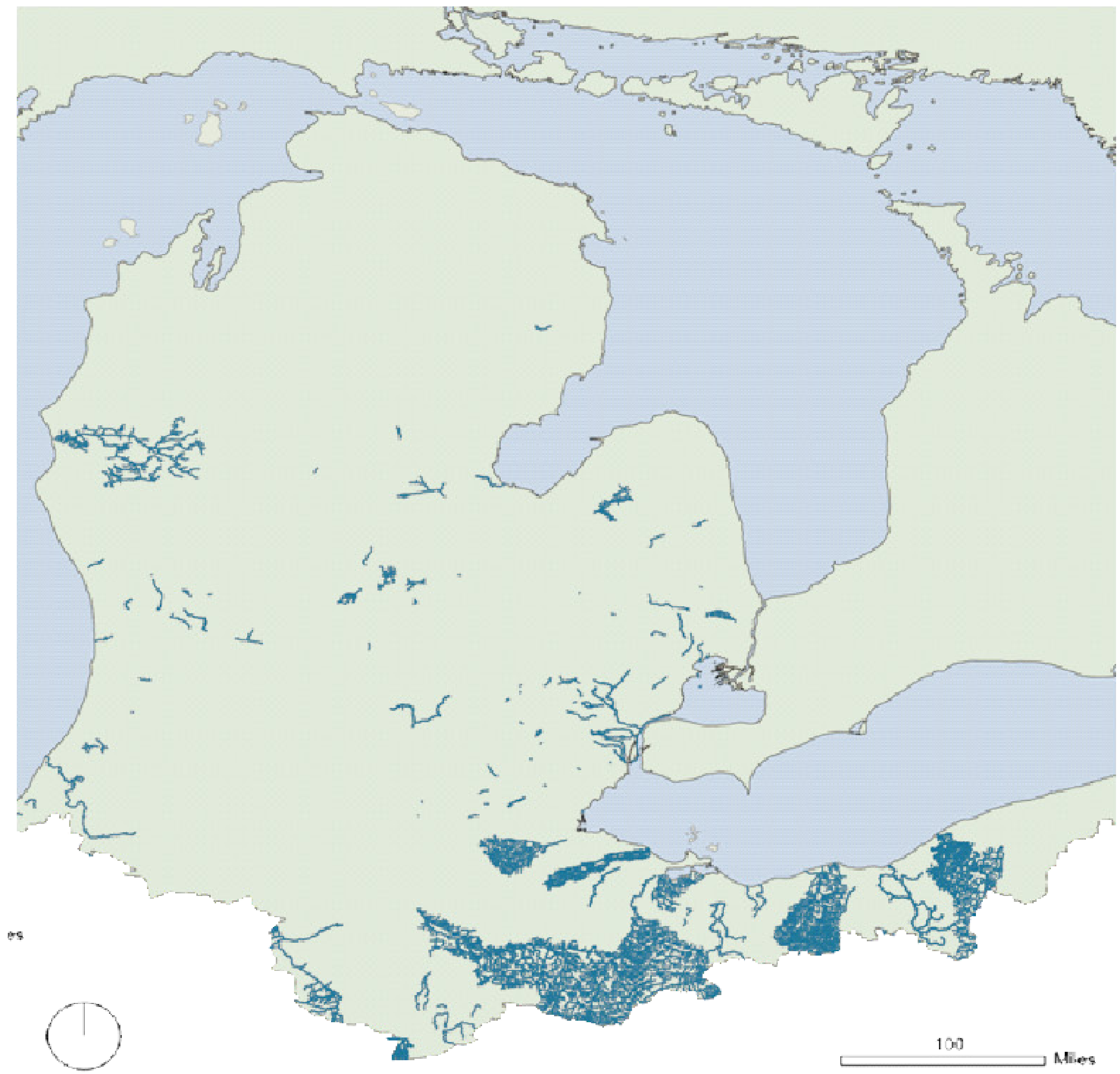


Figure 24 Impaired Waterways

Michigan and Ohio

Ohio's Impaired Waters

A majority of the Ohio TMDL waters in the Great Lakes Basin are located within the Cuyahoga, Sandusky, or Maumee River systems.

The Cuyahoga River basin encompasses 813 square miles and includes 1,220 miles of streams. Southern basin land uses are primarily agricultural, while the northern basin includes Cleveland and other major urban and industrial areas. The diversity of land uses is associated with a mix of threats to the system's water quality. Major sources of contamination include combined sewer overflows (CSOs), nutrient enrichment, impervious surface and agricultural runoff, and industrial discharges. As a result, parts of the system feature high concentrations of nitrogen and phosphorous, dissolved oxygen, and degraded aquatic habitat. Despite these threats, several streams in the system are designated State Resource Waters, and the Cuyahoga itself is an American Heritage River. The TMDL plan for the basin includes CSO mitigation, urban runoff controls, improvements to septic systems, and public education (OH EPA 2003).

The Maumee River system includes the Portage and Ottawa rivers and covers 7,500 square miles of western Ohio and eastern Indiana. Like the Cuyahoga River basin, agriculture dominates the southern Maumee River basin, accounting for 66% of total land use. The northern basin is largely urban and industrial, with the Port of Toledo located at the mouth of the Maumee River. Major threats to the system include CSOs, habitat alteration, industrial outflows, leakage from hazard waste sites, and outdated septic systems. Moreover, agricultural and urban land use conversions threaten the Great Black Swamp, one of the basin's most important aquatic habitats. The Army Corp. of Engineers estimates that restoration costs for the basin could total $2.4 billion (Army Corps 2009).

The Sandusky watershed covers 1,850 square miles of north central Ohio, and includes 2,200 miles of streams. Agriculture accounts for 84% of watershed land, with swamp forest occupying 12.6% and urban development just 1.4%. The majority of agricultural land is dedicated to growing corn, soybeans, and wheat (OH EPA 2004). A 2004 TMDL study by the Ohio EPA found that major threats to aquatic life and human recreation included excessive nutrient concentrations such as nitrogen and phosphorous, sedimentation, habitat degradation, and flow alteration from damming and irrigation.

Figure 25 Lake Superior - Munising, MI

Summary of Water Quality

The most prevalent Great Lakes pollutants are fecal coliform, total suspended solids of organic and inorganic particulates, sediments and phosphorous. Lake Michigan also has a significant concentration of Polychlorinated biphenyls (PCBs). In 1979, legislation made it illegal to release additional PCBs, but their long half-life ensures their presence in the Great Lakes for the foreseeable future.

Ohio and Michigan have the greatest lengths of impaired waterways within the Great Lakes Basin. Ohio lists 16,022 miles of impaired waterways and Michigan lists 2,576 miles. Michigan has ten Areas of Concern (one shared with Wisconsin), more than any other state. Three sources of water pollution have direct links to water treatment and land use practices. Combined Sewer Overflow systems in the Great Lakes release raw effluent and storm water into rivers and streams during intense rain events and are a major source of fecal coliform contamination. Some communities, such as St. Joe and Benton Harbor, are working to replace their combined system with a separated system. Agricultural run-off, particularly from Atrazine, has negative water quality impacts and continues to be a concern in the Great Lakes Region. The pattern of low-density development with increasing amounts of impervious surface also contributes to non-point source pollution problems.

1.4 Summary of Section 1: The Great Lakes

The presence of the Great Lakes in North America has created unique watersheds, microclimates, and development patterns. 84% of the U.S. surface freshwater supply is found in the Great Lakes; the system provides 40 million individuals with drinking water. The five lakes vary in depth, volume and shoreline length. Lake Superior is the largest lake in volume and surface area; it's also the deepest Great Lake. Lake Erie is the smallest Great Lake in terms of water volume—4% the size of Superior—and has a retention time of only 2.6 years compared to Lake Superior's 191 years.

Man-made diversions within the Great Lakes Basin move water in and out of the natural system. Canals, hydroelectric power, and municipal drinking water are common diversions within the Great Lakes. Recorded diversions indicate that 1,521 million gallons per day are added to the Great Lakes watershed. The Great Lakes Compact ensures large-scale diversions won't occur, but withdrawls in containers 5.7 gallons or smaller are unrestricted.

The most prevalent Great Lakes pollutants are fecal coliform, total suspended solids of organic and inorganic particulates, sediments, and phosphorous. Lake Michigan also has a significant concentration of Polychlorinated biphenyls (PCBs). Ohio and Michigan have the greatest lengths of impaired waterways within the Great Lakes Basin. Ohio lists 16,022 miles of impaired waterways and Michigan lists 2,576 miles. Michigan has ten Areas of Concern (one shared with Wisconsin), more than any other state. Combined Sewer Overflow systems in the Great Lakes release raw effluent and storm water into rivers and streams during intense rain events and are a major source of fecal coliform contamination. Some communities, such as St. Joe and Benton Harbor, are working to replace their combined system with a separated system. Agricultural run-off, particularly from Atrazine, has negative water quality impacts and continues to be a concern in the Great Lakes Region. The pattern of low-density development with increasing amounts of impervious surface also contributes to non-point source pollution problems.

Climate Adaptation for The Great Lakes

Vulnerability Assessment of Climate Change

Capstone Project
University of Michigan
April 30, 2011

Section 2 Climate Change Impacts in the Great Lakes Region

Overview

Great Lakes Sensitivity to Climate Change and Recent Climate Trends

Anticipated Impacts

Summary

Overview

Climate change will affect communities worldwide in both subtle and dramatic ways. Most communities are expected to experience warmer annual average temperatures. In semi-arid communities, this will increase the energy demand for cooling purposes. Temperate communities will experience shorter winters and an increase in extreme summer temperatures. Snow packs will melt faster in mountain communities, possibly reducing available drinking water supplies and hydroelectric power. Similarly, watersheds may experience flash-flooding, increased runoff, and increased evaporation. Rivers will flood more often and may experience a decrease in water quality in the form of warmer water and increased pollution. Land use patterns will be forced to change, especially along coastal cities where storm surges are expected to increase. Species distribution will expand and contract depending on regional and local climate changes; farms, fisheries, and tourism that depend on certain species will have to adapt to their changing habitat ranges.

We will begin this chapter by highlighting the effects of climate change within the Great Lakes Region. Through close examination of the region's recent climate trends, a discussion of the anticipated impacts will be included. More specifically, we will look at the likelihood of increased heat waves, climate change and its effects on soil and flora, flooding, changes in lake levels, shifts in hydrologic dynamics and aquatic species, as well as its impacts on stormwater and wastewater management.

2.1 Great Lakes Sensitivity to Climate Change and Recent Climate Trends

Figure 26 Lake Michigan - Grand Haven Pier (winter)

The Great Lakes Region has proven to be more sensitive to global warming than estimates have predicted. From 1895 through 1999, average temperatures in the Great Lakes rose by 1.26 °F (0.7 °C), double the average increase for the continental United States (Hall et al., 2007, p. 7). More recently, from 1970 to 1990, certain regions within the Great Lakes experienced a 2.9 °F (1.6 °C) rise, with average annual evaporation rates increasing by 50% (Hall et al., 2007, p. 7). According to data from the National Climate Data Center (1895 thru 2001) and the Midwest Climate Center (1900 thru 2000), near-shore water temperatures have increased at five of seven sites in the eastern Great Lakes area, causing the period of summer stratification of the lakes to lengthen by one to six days per decade (Kling et al., 2003, p. 14). Winter seasons are starting later and ending earlier. Recent data indicates that freezing occurs 1.5 days later every 10 years, while melting occurs two days earlier every 10 years (Kling et al., 2003, p. 14). Current winters are showing the lowest recorded levels of ice cover for the past 100 to 150 years (Kling et al., 2003, p. 14).

Analysis of climate data over the last century reflects a general warming trend occurring within the Great Lakes Region. Despite a rise in total annual precipitation, rainfall has been unevenly distributed because of the greater frequency of pronounced seasonal extremes along with a growing number of "wet and dry periods." In general, there has been less snowfall in the winter, lakes freeze later in the season, and warmer summers are increasing the Great Lakes' evapotranspiration rates (Hall et al., 2007, p. 7). According to data from the National Climate Data Center (1895 thru 2001) and the Midwest Climate Center (1900 thru 2000), temperatures have increased more than 1 °F (0.5 °C) in the northern hemisphere, and precipitation has increased by 5% to 10% since 1900 (Kling et al., 2003, p. 7). In the past four years, however, average temperatures have been 2 °F to 4 °F (1° to 2 °C) higher than the long-term average and as much as 7 °F (4 °C) warmer than average in winter (Kling et al., 2003, p. 12). In addition, over the last 15 years the Midwest has experienced two record-breaking floods (Karl et al., 2009, p. 117). Moreover, from 1900 to 2000, scientists have observed a rise of 2 to 9 °C in annual average daily maximum temperatures (Wuebbles & Hayhoe, 2004, p. 357). It is evident that for the past 30 years, climate data is showing signs of warming. Along with increased temperatures, the average length of the growing season in the 1990s was one week longer than the season in 1900 (Kling et al., 2003, p. 17).

2.2 Anticipated Impacts

Based upon climate predictions, we anticipate that the Great Lakes Region will be impacted by heatwaves, flooding, decreases in lake levels, and these will have impacts on the area's soil, flora, hydrological system, aquatic species, stormwater systems, and sewer systems. The following text describes these interrelated impacts.

Increased Heat Waves

Given the region's heightened sensitivity to warmer climatic conditions, the latest global circulation climate modeling (GCM) technology (Parallel Climate Model (PCM) and HadCM3) predict hotter and drier summers, warmer winters, and greater frequency and severity of storms by 2100 (Kling et al., 2003, p. 2, 16). With current greenhouse gas emission trends, the continental United States is on track for three major heatwaves by the end of the 21st century (Karl et al., 2009, p. 117). Moreover, by 2100 these models predict an additional 20 to 50 days with temperatures above 90 °F (32 °C), and 40 to 75 additional days with temperatures above freezing (Wuebbles & Hayhoe, 2004, p. 358). The data suggests that daily high temperatures could increase 5.4° to 10.8 °F above the average from 1961 to 1990, with winter temperatures increasing even more dramatically (Dempsey et al., 2008, p. 3).

Figure 27 Presque Isle - Middle Bay

Effects on Soil and Flora

The warming climate in the Great Lakes Region will have profound effects on the health of nearby soils and trees. In the winter season, scientists anticipate an increase in overall soil moisture, with a few spots increasing by as much as 80% (Kling et al., 2003, p. 18). Conversely, drier summers will reduce water content by 30%, leading to an increased risk of forest fires (Kling et al., 2003, p. 2; Dempsey, et al., 2008, p. 19). Although trees and forests can absorb the higher levels of atmospheric nitrogen from greenhouse gas emissions under warmer climatic conditions, studies have shown that excessive nitrogen can pollute water supplies (Kling et al., 2003, p. 3). Additionally, a considerable rise in average temperatures can place native trees under stress. This makes them more susceptible to being overtaken by invasive plants and species of trees in the warmer regions from the south (Karl et al., 2009, p. 121-122). Lastly, warmer winters will enable tree pests such as the Jack pine budworm and gypsy moth to spread easily during the warmer winter months (Dempsey et al., 2008, p. 20).

Flooding

Surprisingly, total precipitation is expected to be the same year-to-year. Climatologists are concerned with the distribution of rainfall because the winter and spring months are expected to have greater precipitation, evaporation, runoff and soil moisture, while the summer months will experience considerably less precipitation and hardened soils due to higher temperatures (Kling et al., 2003, p. 2, 16; Wuebbles & Hayhoe, 2004, p. 358). Such prolonged arid conditions in the summer can destroy sensitive wetlands, small creeks and streams, as well as the plant, aquatic, and animal life that is dependent upon these environments for survival (Karl et al., 2009, p. 121). Excessively dry soil can be problematic for infiltration because of its reduced absorption capacity. In the event of a rainstorm, there is a greater likelihood of flooding and topsoil erosion (Hall et al., 2007, p. 6-7). Although warmer winters extend growing seasons, the impact of seasonal extremities on soil fertility creates numerous land management challenges. Often, the fertile topsoil is too arid from intense summer droughts and is washed away from stormwater runoff (Karl et al., 2009, p. 121). In short, the Midwest and Great Lakes Region will undergo a dramatic shift in overall climate patterns within the next century. Scientists predict that by 2100, the region's climate will be more like Texas and Oklahoma, with twice as many heavy rainfall events (Wuebbles & Hayhoe, 2004, p. 358).

Increasing air temperatures could intensify storm systems considerably (Hall et al., 2007, p. 6). As a result, there will be more lake-effect snow due to less ice formation over lakes, and a possible twofold increase in heavy rainstorm events (Dempsey et al., 2008, p. 3; Kling et al., 2003, p. 18).

Changes in Lake Levels

Generally speaking, the Great Lakes will experience rising water temperatures and a gradual drop in lake levels (Karl et al., 2009, p. 122; Hall et al., 2007, p. 8). Data gathered from Lake Superior for the past three decades support this trend as its summer surface water temperature has increased by 4 °F (2.2 °C) (Hall et al., 2007, p. 8). Although this seems like a negligible increase, the slightest warming of water can disrupt lake turnover and increase the number of oxygen-deprived spots near the lake bottoms, thereby killing off many life forms (Karl et al., 2009, p. 122). Further exacerbating the problem, many scientists agree that within the next hundred years, lake levels will continue to drop. Data indicate that the average annual water level fluctuation of the Great Lakes is approximately six feet, with the recent highest levels recorded in 1973-1975 and 1986-1987. The lowest levels within the past century were observed during 1934-1935 and 1964-1965. As a result, one can reasonably expect minor fluctuations; the key question is whether the lake levels will drop below the six feet range due to an increase in greenhouse gases in the atmosphere. Given uncertainty regarding Earth's sensitivity to greenhouse gases, scientists and scholars are unsure. Further complicating matters, water

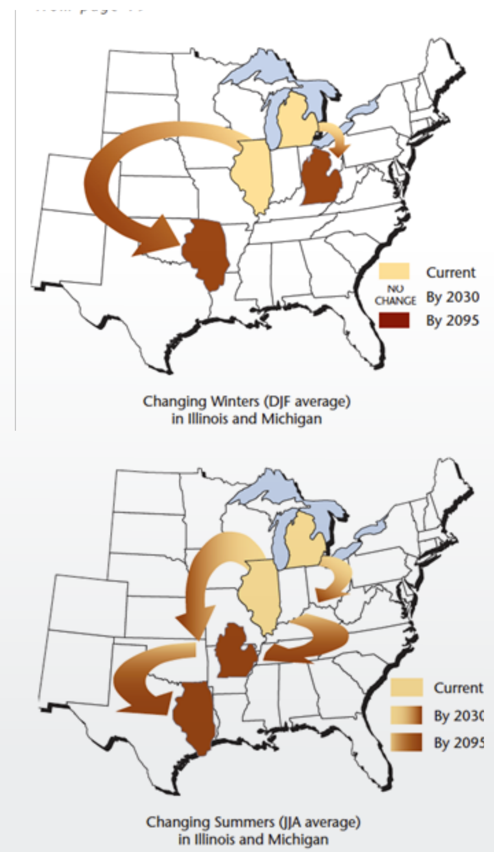


Figure 28 Migrating Climate: Changing Winters and Summers in Illinois and Michigan

(Source: Figure 16 from Kling et al., 2003, p. 42) levels are controlled to optimize cargo shipping and hydroelectric power production, making predictions difficult. Hence the true extent of climate change and its effects on lake levels are hard to determine (Hall et al., 2007, p. 8).

Using simplified models, we can make preliminary predictions of lake levels in 2100. Under the low-emissions scenario, we can expect less than a one-foot drop in lake levels. Under a higher emissions scenario, lake levels may drop between one and two feet (Karl et al., 2009, p. 119). Due to higher temperatures and reduced rain and snowfall, by 2100 Lake Superior is expected to drop one foot, Lakes Michigan and Huron three to 4.5 feet, Erie 2.7 feet, and Lake Ontario 1.7 feet (Dempsey et al., 2008, p. 3; Hall et al., 2007, p. 8). Of all the lakes, Lake Erie is the most vulnerable to climate change because it is the shallowest Great Lake. A 2.7 feet drop can expose 1,500 square miles of land (Dempsey et al., 2008, p. 12). Scientists also expect a dramatic reduction in ice formation over Lake Erie; over the next 80 years, scientist expect it to be ice-free for over 96% of the winter (Hall et al., 2007, p. 8).

Hydrologic Dynamics

Rising water temperatures in the Great Lakes will disrupt seasonal processes that are essential for maintaining good health. In the absence of dramatic climate change, the Great Lakes undergo a biannual lake-turnover process in which oxygen-rich top layers mix with deeper oxygen-deprived bottom layers. This natural phenomenon occurs during the fall and spring seasons and is critical to the health of phytoplankton, zooplankton, as well as all the other species that depend on it for survival. Due to the greater temperature extremes of the summer and winter months, these layers remain stratified.

Warming climates in the future, however, will disrupt this natural process. Current predictions suggest that summers will be longer and hotter, and winters will start later in the season and end earlier. As a result, upper and lower layers will remain stratified longer during the summer season, cutting off the lake bottoms of much needed oxygen. This results in anoxia, or oxygen deprivation, which can wipe out microorganisms and aquatic life. The loss of such life forms can create a ripple effect and compromise the health of all dependent ecosystems (Dempsey et al., 2008, p. 13; Hall et al., 2007, p. 10, 11).

Aquatic Species

The rise in overall water temperatures will enable non-native, invasive species to dominate and take over (Hall et al., 2007, p. 11). As of May 2007, there are 185 invasive species within the Great Lakes. The warmer climate and waters help these species proliferate and wipe out native species. Both the Zebra and Quagga mussels produce a type of bacteria known as Type E botulism that has wreaked havoc on native fish and wildlife. These mussels have also disrupted phosphorous levels in the lake, leading to eutrophication and growth of algal blooms (Dempsey et al., 2008, p. 18). Brook, rainbow, cutthroat, and brown trout fish are expected to see a 25 to 33 % drop within 70 years if temperatures rise by 4.5 °F (Dempsey et al., 2008, p. 19). States such as Pennsylvania, New York, Ohio, Indiana, and Illinois are expected to see an 86% drop in rainbow trout if climate predictions are on track (Dempsey et al., 2008, p. 19). The possible reduction in lake ice formation during the winter months could also compromise whitefish populations, which need ice cover for their spawn to survive. Thin, transparent ice cover enables sunlight to penetrate, allowing algae to grow and microorganisms to flourish (Dempsey et al., 2008, p. 19). Warmer waters will favor smallmouth bass and bluegill populations (Karl et al., 2009, p. 122). Lastly, the duck population in the Great Lakes is expected to drop by up to 39% in the next twenty years with the advance of the warmer climate (Dempsey et al., 2008, p. 19).

Stormwater

In addition to the proliferation of invasive species, a reduction in water quality is to be expected with the warming of the Great Lakes. Reduced oxygen levels and higher rates of evaporation all contribute to higher concentrations of toxins and nutrients in lower water volumes (Hall et al., 2007, p. 9). Making matters worse, longer drought seasons and heavier rainfall during the wet seasons are expected, which will ultimately reduce groundwater recharging capabilities (Hall et al., 2007, p. 9). Such phenomenon will decrease baseflow, or groundwater feeding into local streams, by 20% over the next 20 years. This is critical because healthy streams recharge the Great Lakes with freshwater and approximately 50% of streamflow is supported by groundwater supplies (Hall et al., 2007, p. 9). Lower water levels mean there is less water to dilute pollutants (Hall et al., 2007, p. 11). The retreating lake levels and warmer weather can drive many of the existing wetlands along the shore to extinction and encourage the rapid proliferation of invasive plants. One of the best examples of this can be seen in Long Point, Lake Erie. Between 1995 and 1999, an invasive perennial grass known as Phragmites australis took over the existing wetlands (Hall et al., 2007, p. 11). The loss of wetlands can be devastating because they act as natural water filters and regulators for stormwater before it re-enters the ground to recharge the groundwater tables (Dempsey et al., 2008, p. 3). With many of the wetlands drying out due to retreating lake levels, toxic chemicals such as cadmium, copper, lead, and zinc metals can be released, contaminating beaches and shorelines with “toxic hotspots” as well as fish and other living organisms in the lake (Dempsey et al., 2008, p. 16, 18; Karl et al., 2009, p. 122). Given the greater likelihood of high intensity rainfall events, this lack of proper stormwater infiltration yields greater runoff and can pollute lakes with nonpoint source contaminants such as fertilizers, pesticides, and other chemicals found on impervious surfaces (Dempsey et al., 2008, p. 3). This will ultimately lead to a widespread reduction in the quality of drinking water (Dempsey et al., 2008, p. 16). Higher social and economic costs will result in resolving freshwater taste and odor issues, disruption of natural lake turnover cycles due to a warming climate, and dredging of shallower waters to maintain productive use (Dempsey et al., 2008, p. 16).

Figure 29 Great Lakes Beach

Sewer Systems

The greater frequency of climatic events resulting from a warming climate poses significant challenges to the region's existing sewer infrastructure. In the United States, the most common public sewer systems are combined sewer systems (CSSs) and separated sewer systems (SSSs). In the early 20th century CSSs were an upgrade from cesspools and open sewers as they collected and carried waste and storm water in a single pipe system to a publicly owned treatment plant (POTW). CSSs were designed to divert untreated or only partially treated discharge into local rivers, streams, estuaries, and other designated receiving waters. At a time when population densities and impervious surfaces were low due to less development, CSSs were a cost-effective and reliable solution to dealing with stormwater runoff and sewage. As a result, the majority of older manufacturing communities in New England and the Great Lakes Region utilized CSSs, with Ohio and Michigan having the greatest number amongst the Great Lake states (Burian 2000). (See Figure 30 and 31) As these cities expanded and population densities increased, intense precipitation events overburdened POTW capacity, leading to untreated sewer and stormwater discharge known as combined sewer overflows (CSOs) into local water bodies. The high volume of contaminants found in CSOs posed a serious threat to water quality and public health. As a result, the construction of new CSSs is no longer permitted (Burian 2000). New urban developments are now required to construct separated sewer systems which collect wastewater and storm water in separate systems (EPA 2004).

Figure 30 Great Lakes Watersheds Combined Sewer Overflows by Number of Outflows

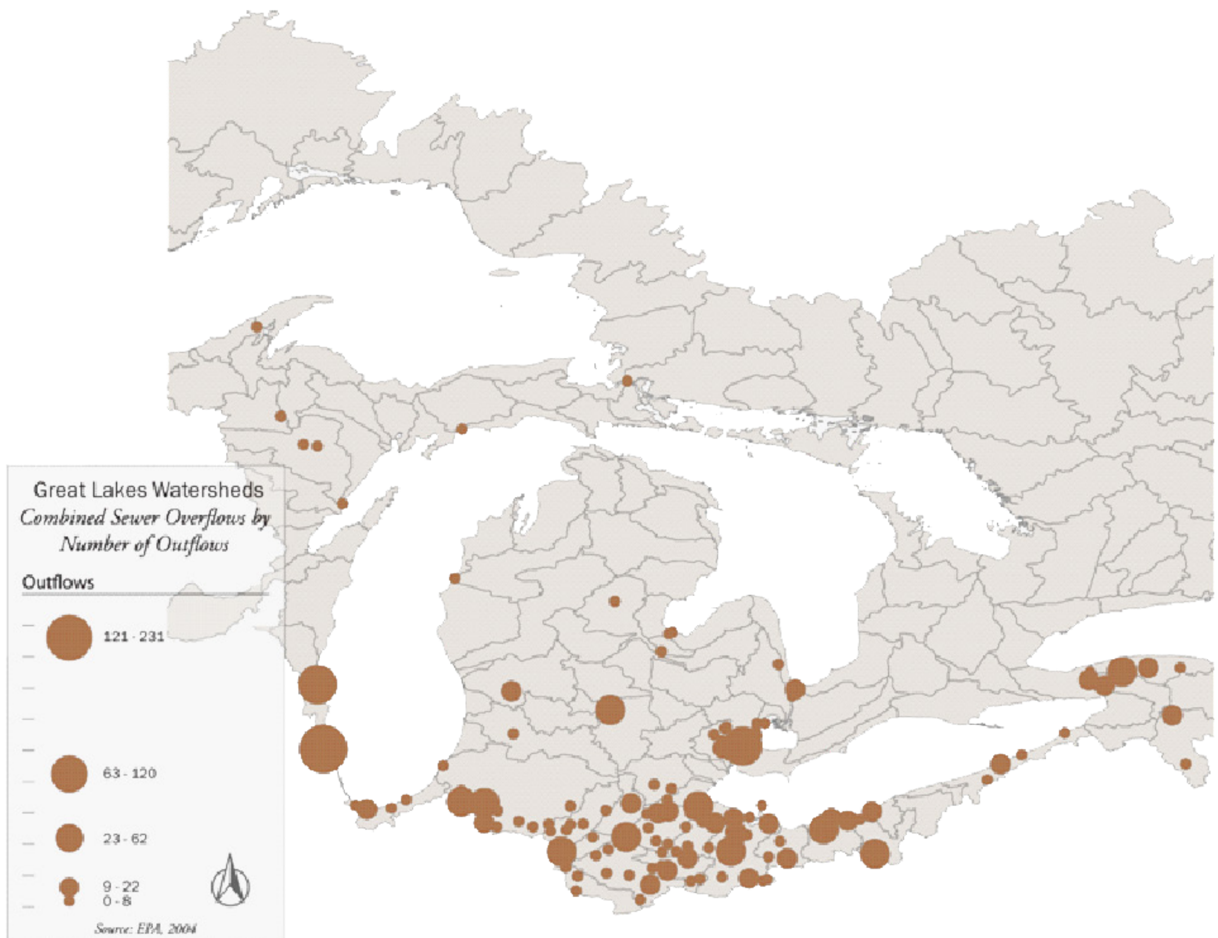


Figure 31 Great Lakes Basin Water Downstreams from Combined Sewer Overflow Events

Despite the initial cost savings, the environmental impacts of outdated CSOs in old cities are considerable. The EPA estimates that 850 billion gallons of overflow are released annually (EPA 2004). The EPA's National Water Quality Index 2000 (NWQI) associated overflows with impaired water quality. According to the NWQI, 75% of waterways within 1 mile downstream of a CSO were impaired, while 25% of all waterways were impaired (EPA 2004).

In an effort to mitigate the impact of combined sewer systems (CSSs), the 1989 EPA National Combined Sewer Overflows (CSO) Control Strategy requires communities with CSSs to adopt nine minimum controls, including minimizing dry weather outflows, notifying the community when CSOs occur, and increasing the volume of water that can be treated in a POTW (EPA 2004). Despite these efforts, the impacts of CSOs could increase as extreme rain events and flooding become more common. One study estimates that if CSS controls in the Great Lakes are engineered based on historical precipitation levels, then CSO events will increase between 14% and 70% (Furlow 2008).

2.3 Summary Of Section 2: Climate Change Impacts

Based upon our review of climate projection reports, we conclude that in the Great Lakes Region, the major climate impacts will be increased precipitation volatility, lower lake levels, increased temperatures with more extreme heat events, less ice cover, more ice storms, and longer summer seasons. These anticipated impacts will alter our environmental systems, shifting species' natural ranges and worsening the problem of invasive species. Within the built environment, these climate impacts will increase stormwater run-off volumes, exacerbate the negative impacts of combined sewer systems on water quality, and require modifications to local building codes.

Climate Adaptation for The Great Lakes

Vulnerability Assessment of Climate Change

Capstone Project
University of Michigan
April 30, 2011

Section 3 Environmental and Social Vulnerability

Overview
Environmental Resilience and Vulnerability
Land Cover Change
Social Vulnerability

Overview

Planners are interested in understanding how climate change will impact their cities and regions so they can prioritize actions to lessen the negative anticipated impacts for residents, the built environment, infrastructure, and natural ecosystems. Therefore, most planners are interested in determining who and what will be 'vulnerable' to negative climate change impacts. Interestingly, the International Panel on Climate Change has opted not to use the term vulnerability in favor of discussing 1) exposure, 2) sensitivity, and 3) resilience. Exposure is an inclusive term while sensitivity recognizes that not all members of a population will be equally impacted. More sensitive residents generally have fewer material resources, such as savings or insurance, to overcome negative impacts. Resilience is the concept that the holistic system (people and place) will return to normal functioning after an extreme event such as a flood or heat wave. The concept of vulnerability is not without its advocates in the scholarly literature related to hazards and environmental and social justice. Vulnerability analysis is a useful tool in addressing anticipated threats associated with climate change and extreme weather events. However, the definition of vulnerability varies. According to Eakin and Luers (2006), there are three main types of vulnerability research: risk/hazard, ecological resilience, and political economy/political ecology, and therefore three slightly differing definitions. Exploring the application of this concept from three different perspectives was helpful in clarifying our own meaning of the term and identifying the strengths and weaknesses of each approach.

The first type of vulnerability focuses on a risk/hazard analysis to determine the impact, location, and timing of the potential hazard (Eakin and Luers, 2006). In a risk/hazard analysis, the exposure sensitivity of places, sectors, activities, landscapes, or regions is the basis for the recommendations. This type of vulnerability concentrates on the biophysical characteristics of the place and the anticipated climate impacts. Generally, efforts to use this method rely on past weather extremes as a proxy for future extreme events. In Great Lakes cities, this approach would involve mapping flood events and identifying where the urban heat island has a disproportionate impact. While this is important, from a planning perspective, this approach doesn't help indicate a method by which to prioritize actions or address social justice concerns.

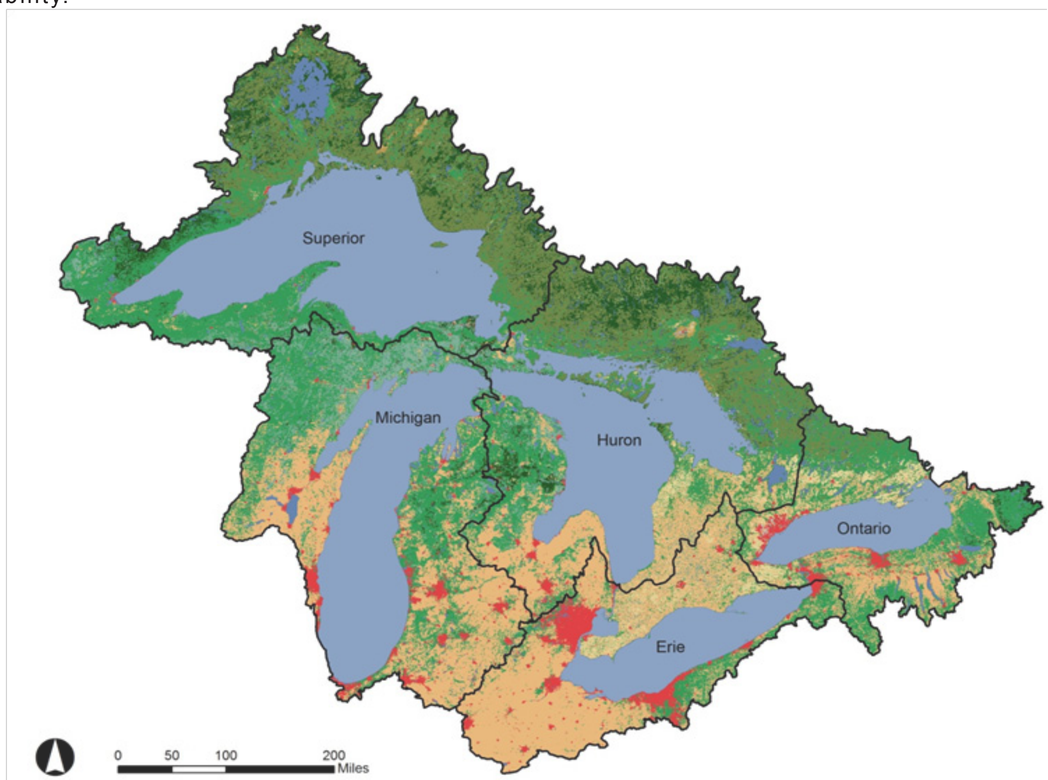
3.1 Environmental Resilience and Vulnerability

A second type of vulnerability analysis focuses on the holistic sense of ecological resilience (Eakin and Luers 2006). These types of analyses look at how ecosystems and coupled human-environmental systems are able to tolerate, or reorganize themselves at a landscape or ecoregion level. In an effort to understand how ecological resilience and vulnerability might be applied to the Great Lakes Region, we examined changes in land cover types within the watershed basins as an effort to assess higher and lower environmental vulnerability.

Figures 32 and 33 show the major land cover classes of the Great Lakes Basin and the 150 lake subbasins from 2005. Forest and cropland are the dominant land covers in the region, with a combined coverage of about 80 %. Broadleaf deciduous forest comprises approximately 30 % and is fairly evenly distributed among the lake basins, except for the Erie basin where forest cover is much lower. Cropland covers approximately 27 % of the Great Lakes Region and is prevalent in the southern half, particularly within the Erie basin. Mixed forest

Figure 32 Land Cover Map, 205

Source: Canada Centre for Remote Sensing (CCRS), Earth Sciences Sector, Natural Resources Canada. (2010). 2005 Land Cover of North America at 250 Meters 1.0



is the third most common land cover, covering 16 %. Mixed forests are particularly prevalent in Ontario, north of Lakes Superior and Huron. Needleleaf forests cover about 8 percent of the basin and are mostly distributed north of the lakes in Ontario and, to a lesser extent in northern Minnesota and Michigan. About 6 % of the region's land cover consists of wetlands, which are most common in the Lake Michigan basin, particularly in Michigan's Upper Peninsula. The urban and built-up category comprises about 5 % of land cover. Similar to cropland, the majority of urban land is concentrated in the southern half of the basin. Excluding the five Great Lakes, water covers about 4 % of the basin area. Large water bodies are more common in the northern part of the region in the Superior and Huron Basins. Less than 3 % of the land cover is grassland, which is most common in the Ontario and Erie Basins.

Land Cover Type	Great Lakes Basin	Sub-basin				
		Superior	Huron	Michigan	Ontario	Erie
Broadleaf Deciduous Forest	30	32	26	36	44	[illegible]
Cropland	27	1	19	39	27	[illegible]
Mixed Forest	16	36	27	0	7	[illegible]
Needleleaf Forest	8	18	12	2	2	[illegible]
Wetland	6	6	5	13	2	[illegible]
Urban & Built-up	5	0	2	6	7	[illegible]
Water	4	7	5	3	4	[illegible]
Grassland	3	0	3	1	8	[illegible]

Figure 33 Primary Land Cover Types as a Percentage of Great Lakes Basin Area*

**Canadian Areas of Five Great Lakes Basins not included in calculations*

3.2 Land Cover Change

The Coastal Change Analysis Program (C-CAP) produces a land cover database for coastal areas in the U.S., including the Great Lakes Region. C-CAP products are updated every five years, with the most recent data available from 2006. This data was used to calculate land cover change from 2001 to 2006 at the watershed level for the U.S. portion of the Great Lakes Basin. Three categories of land cover change were analyzed for this study, including forest, wetland, and developed.

Forest Cover Change

From 2001 to 2006, the U.S. watersheds of the Great Lakes Basin experienced a net reduction of 0.8 % in forest land cover. This amounts to approximately 185,000 acres of forest loss. At the watershed level, the change in forest cover ranged from a low of -4.6 % to a high of 1.0 %. The majority of watersheds, 62, lost less than 1.0 % of their forest cover. Only six lost more than 2.0%, and 23 lost more than 1.0 %. The remaining 14 had net increases up to

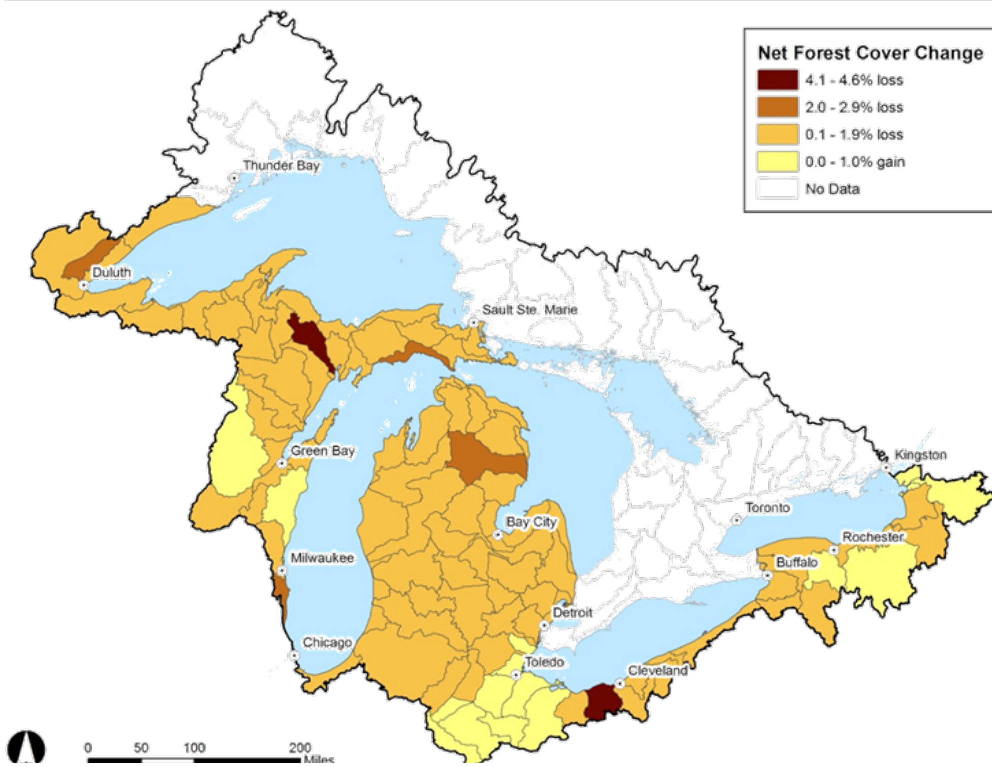


Figure 34 Net Forest Cover Change

1.0 %. The greatest decreases occurred in the Black-Rocky watershed (-4.6 %), which includes a small portion of Cleveland, and the Escanaba watershed (-4.1 %), which is in Michigan's Upper Peninsula. These two watersheds were the only ones to lose more than 3.0 % of forest cover. The Blanchard watershed, at the southern portion of the Lake Erie Basin in northern Ohio, had the greatest net increase in forest cover, and was the only watershed to increase its forest cover by more than 1.0 %.

From 2001 to 2006, an approximate 1.0 % decrease – roughly 12,000 acres in wetland area – occurred in the U.S. watersheds of the Great Lakes Basin. Among the watersheds, wetland change ranged from a low of -5.1 to a high of 1.3 %. The majority of watersheds, 66, experienced losses well below 1.0 %. One watershed lost over five percent of its wetland area. The Ashtabula-Chagrin and Cuyahoga watersheds were the only others to lose more than 1.0 % one percent of their wetland area. These three adjacent watersheds are all located near Cleveland and its hinterlands. Twenty-

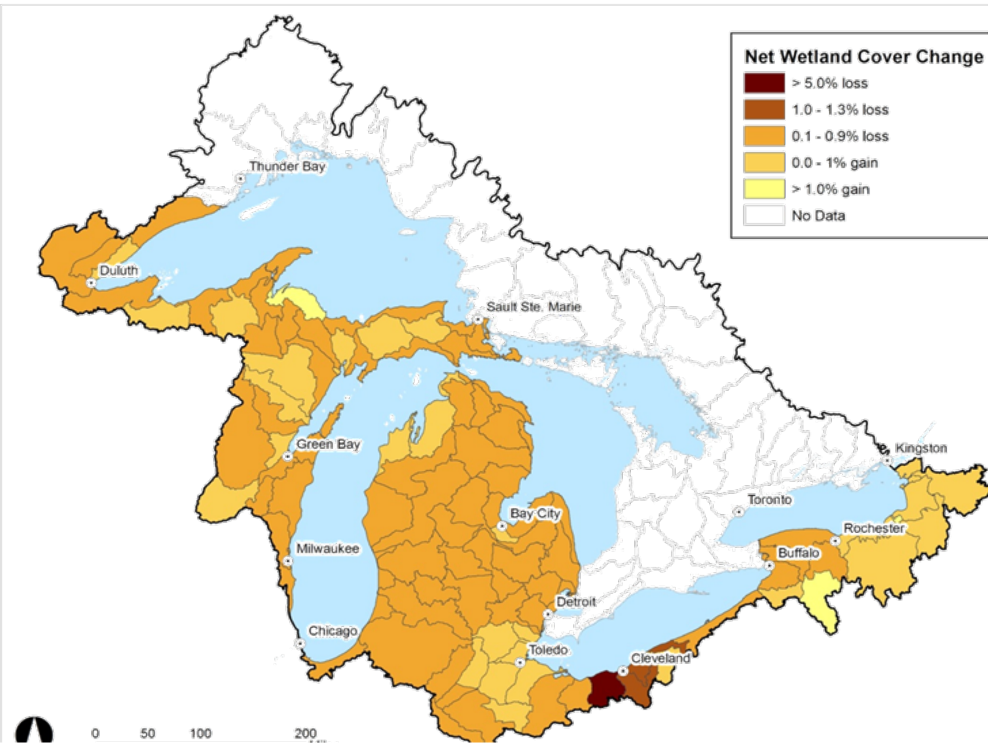
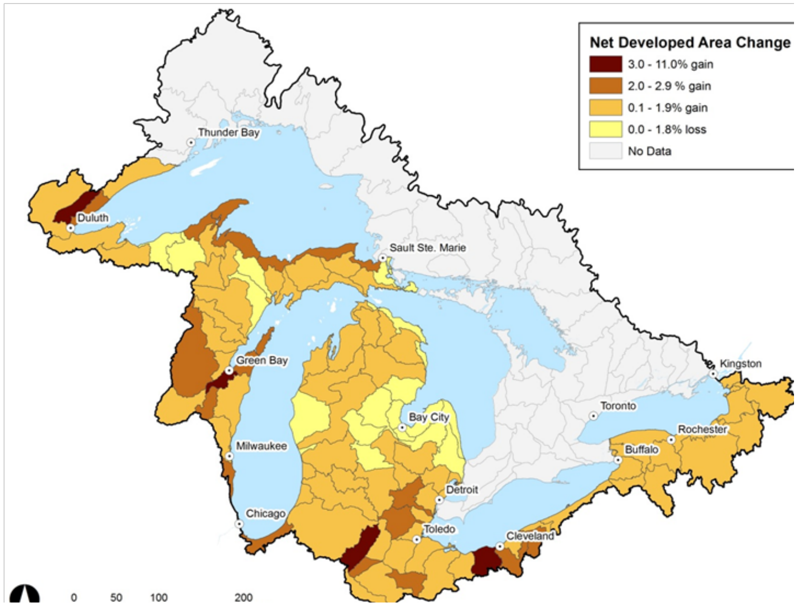


Figure 35 Net Wetland Cover Change

three watersheds experienced a slight increase of less than 1.0 %, and three watersheds saw a 1.0 % increase in wetland area. The three watersheds that gained just over 1.0 % wetland area are the Oswego, Upper Genesee, and Dead-Kelsey watersheds. The Oswego watershed is east of Rochester and north of the Finger Lakes in Upstate New York. The Upper Genesee watershed is located in New York and a small part of Pennsylvania to the southeast of Buffalo and southwest of the Finger Lakes. The Dead-Kelsey watershed is located in Michigan's Upper Peninsula near the city of Marquette.

A net 1.3 % increase, or 70,000 acres, of developed area occurred in the U.S. watersheds of the Great Lakes Basin between 2001 and 2006. Change in developed area ranged from a 1.8 % loss to an 11.0 percent increase. Seventeen watersheds, all located in mid and northern Michigan, had a net loss in developed area. The majority of watersheds, 62, experienced developed area increases of zero to 2.0 %. Sixteen watersheds gained between 2.0 % and 4.0 %. Only four watersheds experienced increases greater than 5.0 %. The Cloquet Watershed in the Lake Superior basin near Duluth, Minnesota gained the most. The other three watersheds with increases

Figure 36 Net Developed Area Change



above 5.0 % are the Black-Rocky near Cleveland, the Lower Fox near Green Bay, and the St. Joseph (Erie basin), which intersects Michigan, Ohio, and Indiana.

Impervious and Tree Canopy Coverage

High levels of impervious area threaten the hydrological cycle and overall ecological health of watersheds. Impervious surfaces, such as roads, sidewalks, roofs, patios, and compacted soil, alter the flow and storage of rainwater. High levels of imperviousness increase the volume and velocity of surface runoff and prevent rainwater from filtering into the soil. As a result, groundwater recharge is reduced and water tables are lowered, which prevents soils from naturally processing pollutants. Increased runoff leads to more severe floods, contributes to erosion of graded construction

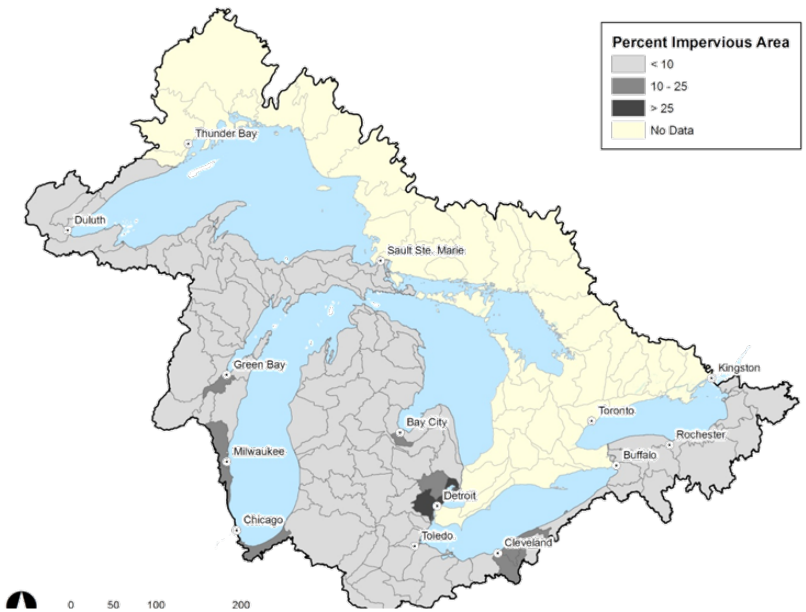


Figure 37 Percent of Impervious Area by Watershed

Source: Derived from NLCD 2006 Percent Developed Imperviousness 1.0

sites and river banks, and transports pollutants, such as pathogens, sediment, toxins, and nutrients into waterways (Arnold, 1996). Increased imperviousness can also intensify the urban heat island effect. Issues related to imperviousness will be exacerbated by rising temperatures and increasingly volatile precipitation patterns as the climate changes.

Percent imperviousness and percent tree canopy data are available for the United States from the U.S. Geological Survey (USGS) National Land Cover Database (NLCD). We assessed imperviousness and tree canopy at the watershed level for the U.S. portion of the Great Lakes Basin using these data and Geographic Information Systems (GIS) software. Researchers have identified thresholds of imperviousness and tree canopy for evaluating the health of watersheds. Generally, watersheds with less than 10 % imperviousness are considered "protected;" those with between 10 % and 25 % are considered “impacted;” and those with greater than 25 % are considered “degraded.” Protected watersheds are generally associated with healthy streams and water bodies while degraded watersheds tend to be characterized by eroding banks, poor biological diversity, and high bacteria levels (Arnold, 1996; Spellman, 2003).

The total imperviousness for the U.S. portion of the Great Lakes Basin is 3.7 %. The Baptism-Brule watershed, north of Duluth in Minnesota, has the lowest level of impervious coverage at only 0.18 %. At 39.3 %, the Detroit River watershed has the highest. The adjacent Lake St. Clair watershed is the only other “degraded” watershed, with an imperviousness of 25.7 %. Eight watersheds in the basin are “impacted,” with imperviousness ranging from 11.4 % to 21.2 % . As expected, these watersheds tend to be located near the region’s large metropolitan areas, including Cleveland, Detroit, Chicago, and Milwaukee. Four watersheds, near the large metropolitan areas of Buffalo, Cleveland, Toledo, and Detroit, are approaching “impacted” status with imperviousness ranging between 7.5 % and 9.0 %. Degraded and impacted watersheds are listed in Figure 38. The majority of these watersheds are contained within the Lake Erie and Michigan basins.

Status	Watershed	Lake Basin	Imperviousness %
Degraded	Detroit	Erie	39.3
Degraded	Lake St. Clair	Erie	25.7
Impacted	Pike-Root	Michigan	21.2
Impacted	Clinton	Erie	19.5
Impacted	Cuyahoga	Erie	14.5
Impacted	Lower Fox	Michigan	13.6
Impacted	Little Calumet-Galien	Michigan	13.1
Impacted	Saginaw	Huron	12.7
Impacted	Ashtabula-Chagrin	Erie	12.2
Impacted	Milwaukee	Michigan	11.4

Figure 38 Degraded and Impacted Watersheds

In contrast to imperviousness, tree canopy contributes to the ecological health of watersheds. Ample tree coverage reduces runoff, provides habitat, stabilizes soil, cools urban areas, and absorbs air pollution. Riparian or streamside forests can reduce pollutants and sediments entering waterways. Inadequate tree cover contributes to greater variability in water temperature, leading to warmer summer and cooler winter water temperatures than some fish species can tolerate (Arnold, 1996).

The adequate level of tree canopy needed to support healthy waterways varies depending on the environment of a particular watershed, and thresholds for assessing watershed health are much less standardized compared to imperviousness. 40 % is a common minimum tree canopy threshold used by urban foresters to evaluate the adequacy of urban forests. For riparian areas, stream health can be compromised with canopies less than 60 %, however; determining the tree cover needed to promote waterway health varies depending on a watershed's imperviousness and the surrounding land cover (Goetz, 2003).

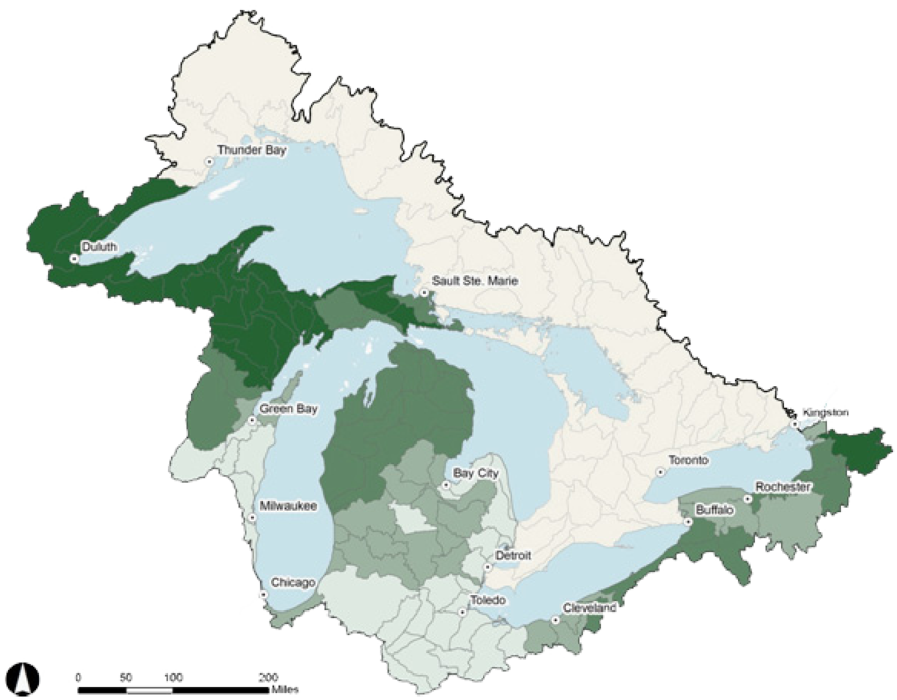
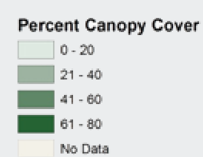


Figure 39 Tree Canopy Coverage by Watershed

Source: Derived from NLCD 2001 Percent Canopy 1.0 and



Watershed	Lake Basin	Imperviousness %
Lake Winnebago	Michigan	3.4
Cedar-Portage	Erie	4.4
Saginaw	Huron	4.7
Lower Fox	Michigan	5.7
Auglaize	Erie	5.8
Blanchard	Erie	5.9
St. Marys	Erie	6.3
Upper Maumee	Erie	6.4
Lower Maumee	Erie	6.9
Pigeon-Wiscoggin	Huron	7.0
Sandusky	Erie	8.1

Figure 40 Watersheds with tree canopies under 10 percent

The most recent percent tree canopy data for the U.S. is available from the USGS NLCD database from 2001. We combined this data with GIS to assess tree cover in the U.S. watersheds of the Great Lakes Basin (see Figure 39S). Tree canopy coverage in the U.S. portion is 38.4 %. Watersheds with the highest percentage of tree canopy coverage are found in northern Michigan, Wisconsin, Minnesota, and Upstate New York. Canopy densities in these watersheds exceed 60 %. At 78.3 %, the Black-Presque Isle Watershed in northern Michigan and Wisconsin has the highest tree canopy density. The Lake Winnebago Watershed has the lowest canopy density at only 3.4 % due to large portions of water, cropland, and urban land cover. Twenty-seven of the ninety-nine U.S. watersheds have tree canopies covering less than 20 %. These watersheds are located in Ohio, Michigan, Indiana, and Wisconsin and generally have large percentages of urban and/or cropland areas. Eleven of these watersheds have tree canopies under 10 %, most of which are located in the Erie basin, which has the highest portion of urban and cropland cover in the Great Lakes Basin. Watersheds with tree canopies under 10 % are listed in Figure 40.

As defined by Carpenter, Walker, Anderies, and Abel (2001) , "[r]esilience has the following characteristics a) the amount of change a system can undergo; b) the degree to which the system is capable of self-organization; c) the degree to which the system can build the capacity to learn and adapt."

Assessing changes in forest, wetland, and developed land cover can help planners understand which direction a watershed is heading in terms of its resiliency to climate change. Decreases in forest and wetland cover and increases in developed area may indicate that a watershed's ability to withstand climate impacts is decreasing. Using percent forest cover change, wetland change, and developed cover change, we used principle component analysis to create an index of watershed land cover change vulnerability. Decreases in forest and wetland cover and increases in developed area are reflected in the index. Figure 40 shows the four watersheds that had the greatest vulnerability increase from 2001 to 2006. These are not necessarily the most vulnerable watersheds in the basin, but they have lost the greatest percentage of valuable land cover over this period. In Figure 42, we see that these watersheds are located near Duluth, MN, Green Bay, WI, Cleveland, OH, and on the border of Michigan, Ohio, and Indiana.

In the exploration of environmental resilience and vulnerability, we saw the strengths and weaknesses of this approach. Adding more dimensions of environmental quality, specifically water quality, would be valuable and could assist watershed-level planners. However, this environmental resilience and vulnerability approach is relatively macro in scale and doesn't incorporate critical social dimensions.

Watershed	Forest Cover Change %	Wetland Cover Change %	Developed Cover Change %	Index
Cloquet	-2.6	-0.4	11.0	11.23
Black-Rocky	-4.6	-5.1	7.5	8.71
Lower Fox	-0.1	-0.1	6.4	6.27
St. Joseph (Erie)	-0.9	-0.1	5.9	5.92

Figure 41 Watersheds with most Land Cover Change Vulnerability

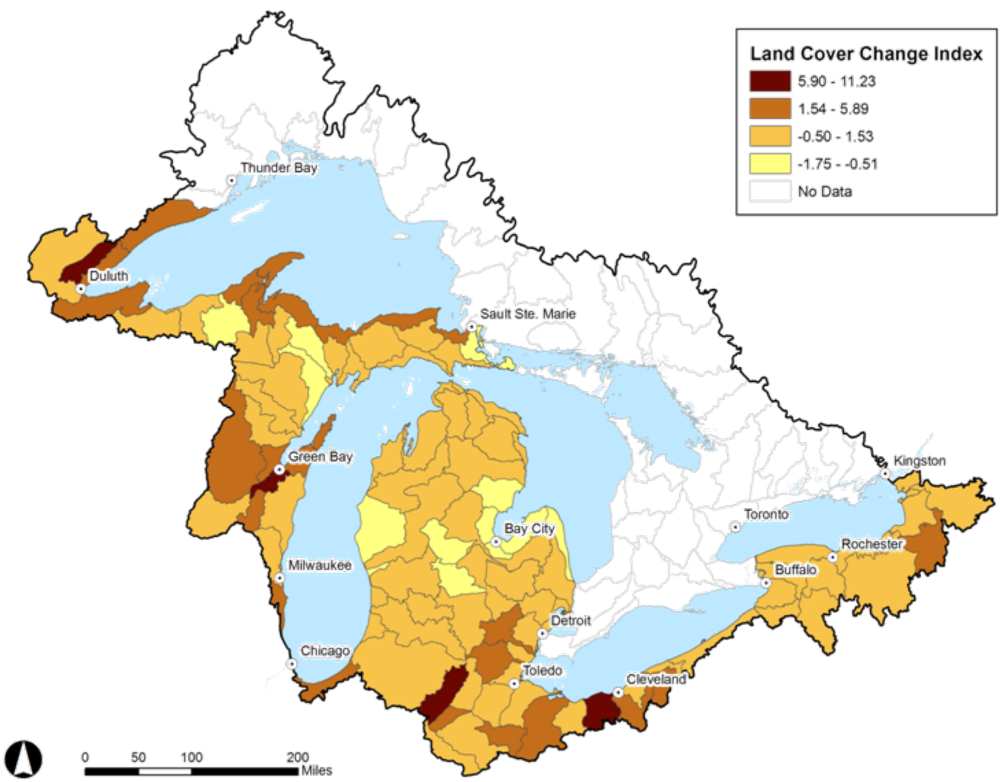


Figure 42 Index of Land Cover Change Vulnerability

3.3 Social Vulnerability

The third approach attempts to anticipate the disproportionate effects natural disasters may have on people, places, and their overall capacity “to cope and adapt” (Eakin and Luers 2006). Eakin and Luers (2006) refer to this as a political economy or political ecology approach to vulnerability, while we have labeled it social vulnerability. This approach highlights individual and group differences that may anticipate who is more or less able to resist or recover from an extreme weather event.

One aspect of social vulnerability that will be important when dealing with climate change is the greater frequency of heat waves resulting from a warming climate. Heat waves can cause serious health concerns for the elderly, the young, and the infirm. The increase in temperatures can also place a tremendous burden on utility companies. With higher energy demands in the summer months, there is an increased likelihood of blackout and brownouts. If electric power is maintained, increasing electricity costs can further reduce the likelihood lower income individuals can afford to mechanically reduce the heat burden. In addition, higher atmospheric temperatures also lead to higher incidences of surface level ozone formation from auto tailpipe emissions; this can cause respiratory problems and further exacerbates the urban heat island effect (Karl et al., 2009, p. 118). So some locations will experience higher temperatures than other locations.

Flooding is another extreme weather event that may produce disproportionate impacts on certain places and people that planners may wish to anticipate. With the increase in the frequency and severity of winter and spring rainfall stormwater systems and wastewater treatment facilities may be overwhelmed. It takes only a moderate rain event to overburden contemporary infrastructure. In large Midwestern cities such as Chicago, peak stormwater capacity is limited to 2.5 inches of rainfall per day. Storm events that are higher in intensity can cause overflows into Lake Michigan. From 1961 to 1990, stormwater overflows have occurred 2.5 times every 10 years. Climate modeling data suggest that by 2100, this frequency is expected to be 5 times every 10 years, and 7.5 times every 10 years for lower and higher emissions scenarios, respectively (Karl et al., 2009, p. 120). Higher risk of flooding, the spread of infectious diseases due to contaminated water sources, and damaged infrastructure are human health impacts linked to increased precipitation events (Karl et al., 2009, p. 120). As well as human health impacts, flooding may cause significant property damage and frequently lower-income individuals lack home or person property insurance and live in lower quality housing structures with less structural resistance.

In looking at vulnerability, we explored academic literature on social vulnerability analysis and found the Cutter, Boruff, and Shirley method to be one of the strongest to date for calculating a Social Vulnerability Index (SVI) for environmental hazards. Cutter, Boruff, and Shirley found over 250 variables that could help delineate vulnerable populations. After testing for multicollinearity they were able to distill those variables down to 85 variables. Once normalized where able to decrease these to 42 independent variables. From these 42 variables, they discovered 11 factors that explain 76.4 % of variance among all counties (their unit of analysis). These 11 factors included personal wealth, age, density of the built environment, single-sector economic dependence, housing stock and tenancy, race-African American, race-Asian, ethnicity-Hispanic, ethnicity-Native American, occupation, and infrastructure dependence (Cutter, Boruff, Shirley 2003).

For this report, we used a modified method of calculating the SVI using an aggregation of five different demographic characteristics from the US Census information. These indices which were taken from a document entitled "Handbook for Conducting a GIS-Based Hazard Assessment at the County Level" written by Cutter, Mitchell, Scott. The five indices were age groups over 65 and under 17, non-white, females, number of housing units, median housing value, and total populations. After creating vulnerability maps using these characteristics to create an index of vulnerability, we discovered that in an urban area median housing value and number of housing units were poor indicators because of the large number of rental properties and the differences in housing density within a urban area.

In order to adapt the Cutter, Mitchell, and Scott method for an urban area, we added information on the percentage of income spent on rent and in combination with housing value. We also substituted population density for housing density in an effort to understand where more people would be vulnerable versus the number of structures. This final list of indices included: minor and senior population (which is defined as persons of 18 years of age and under, and persons of age 65 years and older respectively), percentage of non-white population, percentage of female population, population density, and housing value/rent.

Each index was calculated as a decimal value between 0 through 1. For each demographic characteristic, the calculated value reflects the block group proportion from the total population. This enabled us to rank each block group from smallest to largest. The overall SVI is calculated by obtaining the sum of each demographic characteristic value.
It is important to note that each of these demographic characteristics do not represent absolute vulnerability; it is simply an index for relative comparison. The precise calculations for our SVI index are explained in the appendix.
The efforts of this social vulnerability mapping are contained within the Marquette and Benton Harbor Case Studies. In future research, we would suggest sharing these maps with local planners and community-members to help balance their illustration of vulnerability with local knowledge.

Climate Adaptation for The Great Lakes

Vulnerability Assessment of Climate Change

Capstone Project
University of Michigan
April 30, 2011

Section 4 Economy of the Great Lakes Region

Overview
Background
Economic Importance
Maritime Transportation and Tourism
Summary

Overview

Section 4 focuses on the region's economy and when possible, highlights the Great Lakes' varied economic contributions. The first subsection briefly introduces the Great Lakes' settlement history and explains how the contemporary Great Lakes forms a "Mega-region" of urban and rural areas tied by transportation networks, common industries, and a shared history. The second subsection, entitled Economic Importance, describes how the eight Great Lakes states account for a significant portion of the national economy with their key and emerging industries. The third subsection, entitled Maritime Transportation and Tourism, examines two industries particularly sensitive to the direct impacts of climate change on the Great Lakes. It illustrates how the lower lake levels could decrease profitability of the maritime transportation industry and how the gradual, yet multi-dimensional impacts of climate changes could affect earnings from the tourism industry. The final subsection also identifies "economically vulnerable" places relative to the maritime transportation industry within the Great Lakes Region.

Figure 43 Munising

Figure 44 Negaunee

4.1 Background

Figure 45 Great Lake Settlment

Figure 46 Port of Quebec

Settlement History

The earliest human settlement activities in the Great Lakes Area date back to 9000 B.C., in the Paleo-Indian Settlements Period. At this time, indigenous groups of people lived in concentrated settlements in summer and dispersed in winter. This seasonal migration continued until Europeans arrived in the 1600s. Seeking natural resources such as furs, early European settlers built forts and fought for dominance over the region's favorable places. Early French and English soldiers and settlers fought with the indigenous people and each other in an effort to claim the area and control its resources. In 1759, the British defeated the French. Then in the War of 1812, the British maintained control over the "Dominion of Canada" and the international boundary between the United States and Canada bisected the Great Lakes Region. Many of the significant ports along the Great Lakes' coastlines can be traced to early fortifications and trading posts. Beginning in 1825 with the opening of the Erie Canal, the Great Lakes system of transportation was linked to the Atlantic Ocean. This opened the U.S. Midwest to increased manufacturing and larger cities, such as Detroit, Chicago, Buffalo, Milwaukee, Cleveland, and Pittsburgh, rapidly expanded. In 1959, the opening of the St. Lawrence Seaway marked another significant development in the area's transportation infrastructure by providing another direct connection to the Atlantic Ocean.

9000 Paleo-Indian Settlements (inhabted by band groups assembling at favored hunting sites): Late Paleo-Indian camps may have been located along the shores of the Great Lakes, but higher water levels would have drowned many of these sites.

7000

6000 Early and Middle Archaic settlement: Sites along lake shore may have existed but few traces are preserved. Possible Early and Middle Archaic materials found in the river valleys of the southern Michigan suggest summer camps of groups moving seasonally from south of Michigan.

3000 Late Archaic and Early Woodland settlement: a large scale movement of people occured between the Great Lakes area and the south. It involved winter population concentration and summer population dispersion. This movement happend only during the late high water stages of the prehistoric Great Lakes.

700

100 Middle Woodland settlement: population was concentrated at summer sites; groups dispersed into small family units for winter hunting. During this period, the population seems to have been as large in the northern areas as it was in the southern areas.

0

500 Late Woodland settlement: the summer population concentration and winter dispersal occurred only in the northern Canadian Biotic province. In the Carolinian biotic province, an agricultural base allowed both summer and winter concentrations. In the Carolinian-Canadian transition zone, stable villages occupied on a year-round basis primarily by women, while men spent the summer trading, hunting, and fishing in the coastal area and near river mouths, and the winter hunting in the interior. “The interaction of these adaptations, stimulated by a possible demand for goods from the region in an outside area, lead to the maximum population density of the prehistoric period”. (James E. Fitting, 1969)

1000

1600 By the early 1600s, the French had explored the forests around the St. Lawrence Valley and had begun to exploit the area for furs.

1615 In 1615, Georgian Bay was visited by Europeans, reached via the Ottawa River and Lake Nipissing by the explorer Samuel de Champlain.

1670 In 1670, the French built the first of a chain of Great Lakes forts to protect the fur trade near the Mission of St. Ignace at the Straits of Mackinac.

1673 In 1673, Fort Frontenac, on the present site of Kingston, Ontario, became the first fort on the lower lakes.

1700 Through the 17th century, precious furs were transported to Hochelaga (Montreal) on the Great Lakes routes, but no permanent European settlements were maintained except at Forts Frontenac, Michilimackinac and Niagara

1727 In 1727, Fort Oswego was established on the south shore of Lake Ontario by the British; then settlement was encouraged in the Mohawk and other valleys leading toward the lakes.

1759 In 1759, the British captured Quebec, ending a showdown between the British and the French for control of the Great Lakes. The British’s dominance maintains during the American Revolution. At the end, the Great Lakes became the boundary between the new U.S. and the remained British North America. “The British granted land to the Loyalists who fled the former New England colonies to
1792 Upper and Lower Canada, now the southern regions of the provinces of Ontario and Quebec, respectively”. (Government of Canada, United States Environmental Protection Agency, 1995)

1800 Between 1792 and 1800, the population of Upper Canada increased from 20,000 to 60,000. The new US government started to develop the Great Lakes region with the passage by Congress of the Ordinance of 1787. This legislation covered the area between the Great Lakes and the Ohio River west of Pennsylvania.

1812 The War of 1812 brought the final military challenge for the Great Lakes region. At the end, both the U.S and the British claimed victory. “Canada had survived invasion and was set on an inevitable course to nationhood. The new American nation had gained needed national confidence and prestige”. (Government of Canada, US Environmental Protection Agency, 1995)The only loser was the Native people, who had been involved only to secure their homeland.

Mega-region

The Great Lakes Mega-region is defined by a set of characteristics that tie together cities, suburbs, and rural areas across state lines and even national borders (Delgado et al. 2006, Dewar & Epstein 2007). The following factors were considered critical:

- A shared history that continues to influence development and identity
- A common set of assets and challenges
- Economic and environmental connections that suggest interdependency.

According to the report, Through a Wider Lens: Re-envisioning the Great Lakes Mega-region (Delgado et al., 2006), the region faces formidable challenges. Racial and economic divisions plague many of the region's major cities and suburbs. The region's share of national gross domestic product and population has fallen since the 1960s. College graduates are leaving the region. Manufacturing, once the bulwark of the regional economy, is in decline. In addition, the area's high quality farmland is being converted to low density, sprawling development at a rate that exceeds population growth.

However, from a different perspective, many of the region's current challenges are also important assets. Slow population growth allows for better management of development, land use and public services. An extensive transportation system is emerging to satisfy the growing transit needs of its historic industrial centers. And even though many graduates are leaving, the region still features many excellent institutions of higher education learning in the United States. Furthermore, the region also enjoys the country's largest fresh water source.

Figure 47 Great Lakes Mega-region

(Source: Delgado et al., 2006b)

4.2 Economic Importance

The eight Great Lakes states account for approximately one-third of the U.S. economy. Ontario and Quebec contribute an even greater proportion to the Canadian economy. Taken as a whole, the Great Lakes states and two Canadian Provinces are the second-largest economy on earth, behind only the United States (Austin, Dezenski, & Affolter-Caine, 2008).

The trade relationship between the United States and Canada is very strong. Canada is the leading market for 39 of the 50 U.S. states, and the United States is Canada's largest foreign investor; Canada is the seventh-largest foreign investor in the United States (Austin, Dezenski, & Affolter-Caine, 2008).

Cities within the Great Lakes Basin have translated their proximity to the Great Lakes into economic growth. Some cities, such as Detroit, emerged as manufacturing hubs or trading outposts, utilizing their competitive locational advantages. Since the economic downturn in 2008, however, manufacturing in the region has declined. According to a Michigan Sea Grant report (based on 2009 employment data), more than 1.5 million jobs are directly connected to the Great Lakes, generating $62 billion in wages (Vaccaro & Read, 2011).

Key Industries

The Great Lakes states are home to 38% of Fortune 500 companies' head offices, and the region as a whole provides highly diversified industrial offerings, including several global manufacturing companies, such as Ford Motor Co. (motor vehicles) in MI, IBM Corp. (computers & other electronic products) in NY, Proctor & Gamble Co. (chemicals) in OH, and many more (Fortune Magazine, April 2010).

Manufacturing

Historically, Great Lakes waterways have facilitated not only human settlements but also business establishments, particularly manufacturing industries. As of 2009, 994,879 jobs were connected to the Great Lakes (Vaccaro & Read, 2010).

Tourism and Recreation

Michigan Sea Grant estimates that 217,635 tourism and recreation jobs are connected to the Great Lakes (Vaccaro & Read, 2010). Approximately half a million vessels are registered in the region, and it is estimated that people spend nearly $16 billion annually on boating trips and equipment (Great Lakes Commission, 2008).

Figure 48 Great Lakes Region: Home to business sectors with critical mass and global reach

*Bubble size is proportional to the size of the corresponding industry.

Source: Cluster analysis by James Milway, Executive Director, Institute for Competitiveness and Prosperity, utilizing data from StatCan, U.S. Census Bureau of Economic Analysis, U.S. Department of Labor Statistics.

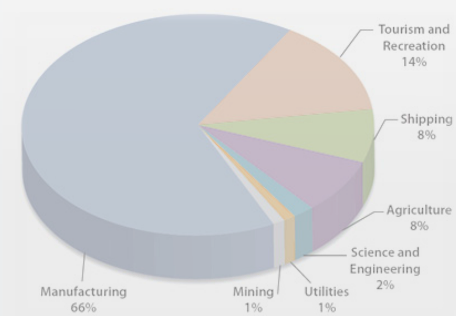


Figure 49 Percentage of Great Lakes Jobs by Industry in 2009

(Source: Michigan Sea Grant)

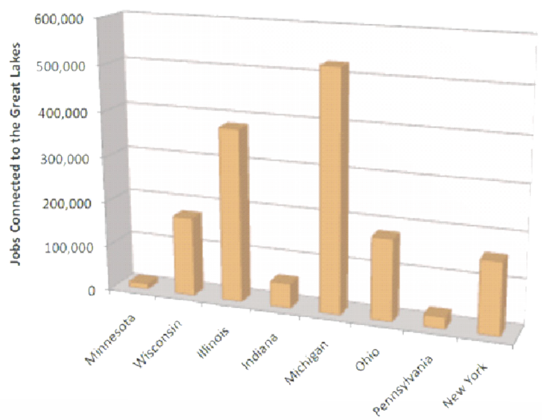


Figure 50 Number of jobs connected to the Great Lakes by state (2009)

Industry	Great Lakes Jobs
Manufacturing	994,879
Tourism and Recreation	217,635
Shipping	118,550
Agriculture	118,430
Science and Engineering	38,085
Utilities	10,980
Mining	10,003
Total	1.51 Million

Figure 51 Number of jobs connected to the Great Lakes by state and industry (2009)

Source: Michigan Sea Grant

Shipping (including Freight Transport and Warehousing)

The maritime transportation system of the Great Lakes is highly cost-efficient compared to other modes of ground transportation. Michigan Sea Grant estimates that 118,550 shipping jobs are connected to the Great Lakes, including freight transport and warehousing jobs (Vaccaro & Read, 2010). On average, Great Lakes vessels transport 160 million tons of cargo each year, mostly from mining, manufacturing, and agriculture in the region (Lake Carriers' Association, 2009).

Agriculture, Fishing and Food Production

An estimated 118,430 jobs in the Great Lakes are related to agriculture, fishing, and food production (Vaccaro & Read, 2010). The commercial and recreational fishing industry is very active, and the lakes create ideal microclimates for certain produce such as cherries and wine grapes (Vaccaro & Read, 2010).

Science and Engineering

Colleges and universities in Great Lakes States award 32% of advanced science and engineering degrees in the United States (NSF Science and Engineering Indicators, 2006). Approximately twenty science, engineering and conservation-oriented occupations are connected to the Great Lakes, and the total estimated number of Great Lakes-related jobs is 38,085 (Vaccaro & Read, 2010).

Utilities

Many power plants and utilities are located along the Great Lakes shorelines in order to access water for cooling. An estimated 10,980 jobs related to utilities are directly tied to the Great Lakes, including jobs from hydro-electricity production on Sault Ste. Marie, Niagara Falls, and the Upper St. Lawrence River (Vaccaro & Read, 2010).

Mining

There are an estimated 10,003 mining-related jobs in the Great Lakes (Vaccaro & Read, 2010). Several cities in Michigan supply raw materials to manufacturing facilities, leveraging the cost-efficient Great Lakes waterways.

Emerging Industries

In addition to these key industrial sectors, the Brookings Institution identified five emerging industries within the Great Lakes Region (Austin, Dezenski, & Affolter-Caine, 2008) They are:

•Advanced Manufacturing: Manufacturers have become increasingly sophisticated in developing and using new technologies in their operations and products (Austin, Dezenski, & Affolter-Caine, 2008).

•Energy: Energy production research across a range of technologies, such as bio-fuel, wind, hydrogen, fuel-cell, battery, clean-coal, and nuclear is significant and diverse across the Great Lakes Region (Austin, Dezenski, & Affolter-Caine, 2008).

•Freshwater Research, Education, and Technology Development: Freshwater technology development offers unique economic opportunities for the Great Lakes Region (Austin, Dezenski, & Affolter-Caine, 2008). Research centers such as the National Oceanic and Atmospheric Administration's (NOAA) Great Lakes Environmental Research Center serve a vital role in this area.

•Health and bio-sciences: The Great Lakes Region, with its extensive research facilities and R&D centers, has significant capacity to apply biotechnology to both medical and agricultural processes and products (Austin, Dezenski, & Affolter-Caine, 2008).

•Information and Communications Technology (ICT): The Great Lakes Region has potential to become a pioneer in advancing ICTs, by inventing and developing hardware and software, training IT scientists and engineers, and forming organizations and policies (Austin, Dezenski, & Affolter-Caine, 2008).

Despite these prospects, many cities in the Great Lakes Region have inefficient, sprawling development patterns and blighted urban cores. In addition, energy-intensive industries in the Great Lakes Region still rely on the extensive use of fossil fuels (Vey, Austin, & Bradley, 2010). Furthermore, seven large metropolitan areas in the Great Lakes states have been among the nation's worst economic performers since the beginning of the recent recession (Bradley & Shearer, 2011). The cities of Detroit, Grand Rapids, Youngstown, and Toledo had the nation's largest unemployment increases from 2009 to 2010 (Bradley & Shearer, 2011).

4.3 Maritime Transportation and Tourism

Maritime Transportation

The Great Lakes navigation system is 1,600 miles long and travels through Lakes Superior, Michigan, Huron, Erie, and Ontario. In effect, this system connects Duluth, Minnesota on the west to Ogdensburg, New York on the east. While it contains 25 of the nation's largest 100 harbors by tonnage, the ports in the system compete against other modes of transportation, such as trails and trucks (US Army Corps of Engineers, 2009). (For more information on the Great Lakes ports, please refer to the appendix.)

Table 3 in the appendix illustrates how the annual shipping tonnages by the Great Lakes U.S.-Flag cargo carriage gradually decreased from 1996 to 2008 and abruptly dropped with the economic recession after 2008. This drop is due to the decline in iron ore, which makes up almost half of the total shipments. Iron ore shipments have declined throughout the years because of the gradual, global economic slowdown of the key markets for the steel industry, such as construction, automobiles, and industrial equipment.

Several facts about the Great Lakes navigation system include (US Army Corps of Engineers, 2009):

•In 2006, approximately 173 million tons of commodities were transported to and from U.S. ports in the Great Lakes system, including more than 80% of the iron ore used in the U.S. steel industry.

•There are 44,000 jobs directly related to maritime transport, and over 54,000 jobs in the mining industry are dependent on the system (Another estimation from the Michigan Sea Grant Report is that 118,550 jobs are related to Great Lakes shipping - freight transport and warehousing).

•The fuel efficiency of maritime transportation is higher than ground transportation; a Great Lakes carrier travels 607 miles on one gallon of fuel per ton of cargo, while a freight train travels 202 miles per ton of cargo and a truck travels 59 miles.

•Cargo transported by a Great Lakes carrier produces 70 % less carbon dioxide as compared to the same cargo transported by rail and 90% less than the same cargo transported by truck.

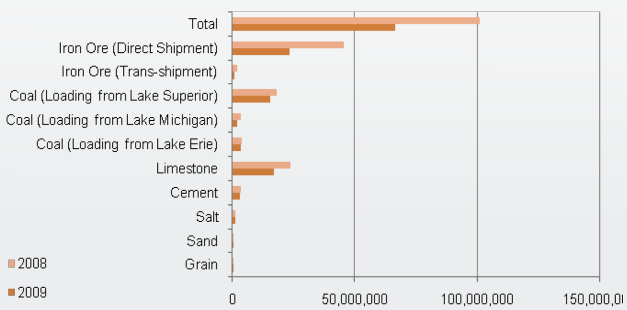


Figure 52 Relative Importance of Each Commodity in 2008 and 2009 (total amount of U.S. Cargo annual shipments through the Great Lakes, net tons)

Source: modified data from the Annual Statistics Reports 2002-2009, Lake Carriers' Association

- The increasing dredging backlog, especially with low water levels over the past 10 years, increases costs to shippers and industry; the Lake Carriers' Association (LCA) reports that for every one foot in lost draft, the Great Lakes fleet forfeits more than 200,000 tons of cargo each trip, and this equates to over 16 million lost tons per year foot of lost draft.

The Lake Carriers' Association also estimated that three of every four LCA-member ships carried less than full loads in the last five years (Lake Carriers' Association, 2009). In February 2011, the U.S. Maritime Administration held a public outreach meeting in Cleveland, Ohio, to get stakeholders' input on their study, The U.S.-Flag Great Lakes Fleet Revitalization. The participants raised the 'dredging crises' as crucial for the success of this industry. Due to the system's interdependence – the loss of outbound or inbound tonnage not only affects one port; it also is a loss at its interdependent port. Therefore, the loss or decrease of any single shipment project in the long-term affects the viability of the whole transportation system (US Army Corps of Engineers, 2009).

Economically Vulnerable Places

Several studies have focused on the potential impacts of climate change on the Great Lakes maritime transportation system. Quinn (2002) expects that the impacts of global climate change, when translated to the Great Lakes Basin, are significant in terms of lake levels and waterborne transportation. Millerd (2011) concurs, finding that higher temperatures associated with climate change may result in a decrease in Great Lakes water levels, and this will lead to restrictions on vessel drafts and reductions in vessel cargos, thereby increasing the number of trips and the cost of moving cargo.

Based on Quinn's research (2002), the Great Lakes maritime transportation system is very sensitive to changes in both economic conditions and to climate change issues such as lower water levels and reduced ice cover. Studies conducted in the U.S. and Canada since the early 1980s show an increased probability of lake level decline due to global warming (Quinn, 2002). Declining water levels in the Great Lakes impact major industries. In the year 2000, lake carriers were forced into "light loading," carrying 5-8% less goods due to lower lake levels (Quinn, 2002). Millerd indicates that average annual costs for

Industry Ratios	2002	2007	% Change
Total revenue (Mil $)	5,066	8,280	63.4
Revenue per establishment ($000)	7,723	15,713	103.5
Revenue per employee ($)	237,648	360,194	51.6
Revenue per $ of payroll ($)	4.7	4.97	5.7
Annual payroll per employee ($)	50,548	72,492	43.4
Employees per [illegible]	[illegible]	[illegible]	[illegible]

Figure 53 Industry Overview: Coastal and Great Lakes Freight Transportation – National Level

Source: U.S. Census

Canadian Great Lakes shipping were estimated to increase by 5% (with no change in tonnages shipped or in the composition of the fleet), and higher cost increases (up to 33%) were found when larger vessels were used (Millerd, 2011).

According to Quinn, there are two counteracting impacts. While lower water levels lead to reduced draft and increased trips with lighter shipments, reduced ice cover and duration also lead to a greatly extended navigation system (Quinn, 2002). Lower lake-level conditions are generally lessened by dredging the harbors to maintain adequate depths for the ships to come in. Conversely, through the extension of the length of the navigation season (perhaps year-round), climate change will permit more shipping (Quinn, 2002).

As the report from U.S. Army Corps of Engineers also emphasizes, the persistent low water levels, constrained budgets (causing a dredging backlog), and need for the expansion and construction of more dredged material disposal facilities (US Army Corps of Engineers, 2009) are priorities for the continuation of the Great Lakes maritime transportation industry, particularly in light of climate change.

Based on these facts and findings, the following subsections estimate what Great Lake places - cities, counties, and states in the Great Lakes Basin - are economically more vulnerable should climate change reduce the amount of Great Lakes shipping. With U.S. Census 2000 data, some "places" (U.S. Census definition equivalent to city or township) in the Great Lakes Basin are identified as relatively more dependent upon the transportation and warehousing industry, based on number of employees relative to the total population. From the U.S. Census 2008 County Business Patterns data, Location Quotients (LQs) from Economic Base Analysis classifies some of the most economically vulnerable counties within the Great Lakes Basin.

U.S. Maritime Transportation Industry Overview

From U.S. Economic Census data (2002 and 2007) at the national level, the coastal and Great Lakes freight transportation (NAICS: 483113) industry has grown in terms of revenue, payroll (per employee), and number of employees, from 2002 to 2007 (Table below). However, the apparent growth should be interpreted with caution because the NAICS categorization combines coastal and Great Lakes data.

The maritime transportation industry at the state (/province) and county level

Using the U.S. Census 2008 County Business Patterns data, some U.S. states and counties in the Great Lakes Basin are identified as more dependent on the Great Lakes freight transportation industries than others (Figure 55). Based on number of employees and number of establishments, the freight transportation industry is most important for New York, followed by Pennsylvania, Ohio, Minnesota, Michigan, Illinois, Indiana, and Wisconsin. Again, the ranks should be interpreted with caution because of the NAICS categorization that combines coastal and Great Lakes data together.

Statistics Canada categorizes Ontario's industry data as the number of employees in "deep sea, coastal and Great Lakes water transportation." (Statistics Canada, 2006). Based on this information, the ten-year average (1991-2002) of 1,720 people is significantly larger than in the U.S. states. However, this figure is not directly comparable with the U.S. data because of the different levels of industry categorization.

The following is a list of the most likely effected counties by state, based on the amount of employees in freight transportation establishments (NAICS: 483113).

Format: State – County (number of employees | number of establishments)

- •Illinois – Cook (52 | 6)
- •Indiana – Lake (0-19 | 1)
- •Michigan – Muskegon (100-249 | 2), Delta (20-99 | 3), and Wayne (20-99 | 2)
- •Minnesota – St. Louis (250-499 | 2)
- •New York – Erie (100-249 | 4)
- •Ohio – Summit (250-499 | 2), Lorain (100-249 | 2), and Cuyahoga (20-99 | 2)
- •Pennsylvania (no counties in the basin have freight transportation business.)
- •Wisconsin – Door (0-19 | 1)

Source: Modified data from the U.S. Census 2008 County Business Patterns

Figure54 Lake Michigan - Near Holland

The water transportation industry at the city and township level

At the city and township level, a number of places in the Great Lakes Basin are identified as relatively more dependent upon the transportation and warehousing industry, based on number of employees relative to the total population. This is the most specific industry categorization available from the U.S. Census 2000 at the city level, from which results should again be interpreted with caution because of its inclusion of many other industries.

Assessing the economic vulnerability of Great Lake places using Location Quotient method

Location Quotient (LQ) from Economic Base Analysis is a method to classify economically vulnerable places. Because of the difference in industry categorization among the geographic levels (national, state, county, and place), the LQs are calculated from the county level data that has the most specific industry categorization at the smallest geographic level. To determine the more vulnerable places, a simple calculation of LQ is required, which is based on the following set of assumptions:

-Activities in a place are divided into two categories – basic and non-basic. Basic industries are those that export their products/services from the place and bring wealth into the place from outside. Non-basic industries are those that support the basic industries.

-Due to the limitation of data available to track industry output and trade flows to and from a region, the basic and non-basic concepts are operationalized using employment data.

The formula to compute LQ can be written as:

$$LQ=(e_i/e)/(E_i/E)$$

Where:

e_i = Local employment in industry i

e = Total local employment

E_i = Reference area employment in industry

E = Total reference area employment

(It is assumed that the base year is identical in all of the above variables.)

The higher the value of the LQ the more the place is dependent on an industry compared to its reference (usually national) area. Figure 55 illustrates the counties that list coastal and Great Lakes freight transportation as a basic industry. These include three counties in Michigan, two in Ohio, and one in Minnesota, Wisconsin, and New York. Among these counties, Delta (MI), St. Louis (MN), and Muskegon (MI) have a concentration that is about ten times the national average. As each state serves as a reference area (with the exception of Cook County, Illinois), 14 counties have this field as their basic industry, showing some of the extreme concentrations in Door (WI), Delta (MI), and Muskegon (MI). The case of Door County (with a LQ of 2.6 as national reference and 227.0 as state reference) might suggest that the state of Wisconsin does not have much of this industry. Michigan, on the other hand, has three counties in the top eight (both as national reference and state reference). These counties are Delta (#1), Mason (#6), and Muskegon (#3). This analysis reveals that Michigan would be the most economically vulnerable state in the Great Lakes Basin to the impact of climate change and the economic difficulties affecting the water transportation industry. In conclusion, Delta County (MI), St. Louis County (MN), Muskegon County (MI), and Lorain County (OH) (with national referenced LQs greater than 5), are the most economically vulnerable to reductions in Great Lakes shipping.

County (Vulnerability Ranking)	**State**	**LQ** (Reference: National)	**LQ** (Reference: State)
1. Delta	Michigan	12.9	56.6
2. St. Louis	Minnesota	12.3	29.3
3. Muskegon	Michigan	9.4	41.0
4. Lorain	Ohio	5.6	25.1
5. Summit	Ohio	4.3	19.2
6. Mason	Michigan	3.2	13.8
7. Door	Wisconsin	2.6	227.0
8. Erie	New York	1.2	1.9
9. Bay City	Michigan	0.9	4.0
10. Saginaw	Michigan	0.4	1.6
11. Wayne	Michigan	0.3	1.2
12. Cuyahoga	Ohio	0.2	1.1
13. Lake (IL)	Illinois	0.2	1.6
14. Lake (IN)	Indiana	0.2	14.9
15. Cook	Illinois	0.1	0.6

Figure 55 LQ Comparison: Coastal and Great Lakes Freight Transportation – County Level

Source: modified data from the U.S. Census 2008 County Business Patterns

Figure 56 Great Lakes States

Percentage of Expenditures by Activity

Tourism

The Great Lakes attract tourists throughout the year. During the winter months, downhill and cross-country skiing, snowmobiling, and ice fishing are popular. In the warmer months, many come to fish, hike, hunt and boat. Regardless of the season, the region's landscape and resources draw many tourists and provide a much-needed source of revenue for those directly and indirectly connected to the tourism industry. For this subsection, tourism statistics are calculated by state, and some tourism included in these calculations may occur outside the Great Lakes Basin.

The impact of recreation and tourism on the region's economy is tremendous. More than the aggregate sum of recreation activities and attractions, tourism is an economic driver with spillover effects in many other industries. An estimated 217,635 jobs are tied to the Great Lakes tourism economy. Boating alone generates $16 billion on trips and equipment, with over four million recreational vessels registered within the region. Other specific activities such as bird watching, hunting, and angling attract millions of visitors annually (Michigan Seagrant).

Winter tourism in the Great Lakes is vulnerable to unseasonably warm winter weather. For example, Cadillac, MI, a popular destination for winter sports such as skiing, has seen winter tourism drop by 54% from 50,000 in the 1980's, to 23,000 in 2008. In addition, Michigan snowmobile sales have also decreased by 47% from 27,000 in 1995 to 14,353 in 2004.

Figure 57 2007 Economic Generation of Tourism in the Great Lakes States

Source: The Impact of Travel by State

State	Expenditures	Travel Generated Employment	Percent of Total Jobs	Tax Revenue Federal	Tax Revenue State	Tax Revenue Local
Illinois	$29,909,300,000	305,400	5.1%	$3,360,400,000	$1,397,200,000	$708,100,000
Indiana	$8,794,800,000	90,000	3.3%	$666,400,000	$411,700,000	$165,700,000
Michigan	$15,252,800,000	148,700	3.5%	$1,481,100,000	$767,400,000	$165,100,000
Minnesota	$10,324,500,000	140,400	5.1%	$1,903,000,000	$820,900,000	$266,900,000
New York	$51,264,700,000	419,300	4.8%	$4,634,300,000	$1,968,100,000	$3,284,300,000
Ohio	$15,809,300,000	168,200	3.1%	$1,480,200,000	$685,300,000	$344,300,000
Pennsylvania	$20,272,200,000	214,400	3.7%	$1,797,000,000	$858,600,000	$341,900,000
Wisconsin	$9,120,000,000	115,500	4.0%	$765,100,000	$521,700,000	$161,100,000

In Wisconsin the decrease in winter sports has led the Chamber of Commerce to look to other areas such as conventions to replace lost tourism revenue. In 2007, the National Park Service predicted that winter recreational seasons will shorten, leading to further declines (Dempsey).

During the summer months, the Great Lakes Region thrives on recreational activities such as charter fishing and beach outings. A recent study of Michigan charter fishing highlights the significant economic impact in direct dollars and its multiplier for other economic activity. In 2009, Lake Michigan charter fishing generated over $11 million in revenue for Michigan communities in direct sales in addition to hotel bookings, restaurant tabs, and other gross sales for local businesses. Summer tourism related to charter fishing is vulnerable to changes in the Great Lakes' ecosystems. From 2002 to 2009, declines in Chinook Salmon populations in Lake Huron contributed to a 49% decline in fishing trips. The estimated impact was a $1.46 million decline in economic output and 51,429 fewer labor hours in 2009 alone (Skinner).

According to Figure 56, hunting, viewing wildlife, and angling alone form a multi-billion dollar industry. Figure 58 shows that Great Lakes tourism industry is a major economic driver.

State	Wild Life Watching Participants	Wildlife Watching Expenditures	Hunting Participants	Hunting Expenditures	Angler Participants	Angler Expenditures
Illinois	2,566,000	$1,133,863,000	316,000	$381,937,000	873,000	$774,319,000
Indiana	2,042,000	$933,920,000	272,000	$223,023,000	768,000	$627,167,000
Michigan	3,227,000	$1,622,521,000	753,000	$915,884,000	1,394,000	$1,671,114,000
Minnesota	2,093,000	$698,889,000	535,000	$494,149,000	1,427,000	$2,725,366,000
New York	3,852,000	$1,567,643,000	566,000	$715,707,000	1,153,000	$925,701,000
Ohio	3,489,000	$1,187,703,000	500,000	$841,556,000	1,256,000	$1,062,036,000
Pennsylvania	3,947,000	$1,442,582,000	1,044,000	$1,609,045,000	994,000	$1,291,211,000
Wisconsin	2,039,000	$744,689,000	697,000	$1,312,128,000	1,394,000	$1,647,035,000

Figure 58 2006 Economic Impact of Hunting, Wildlife, and Angling in the Great Lakes States

Source: The Impact of Travel on State Economies 2009 Research Report

4.4 Summary of Section 4: Economy of the Great Lakes Region

Today the Great Lakes Mega-region is defined by a set of characteristics that tie together cities, suburbs, and rural areas across the state lines and even national borders. The Great Lakes states (8 U.S. states – IL, IN, MN, MI, NY, OH, PA, and WI) account for approximately one-third of the U.S. economy; Ontario and Quebec contribute an even greater proportion to the Canadian economy. It is estimated that more than 1.5 million jobs are directly connected to the Great Lakes, generating $62 billion in wages. Also, the region as a whole provides highly diversified industrial offerings, including manufacturing, tourism and recreation, shipping, agriculture, fishing and production, science and engineering, utilities, and mining. Furthermore, economic experts identify advanced manufacturing, energy, freshwater research, education and technology development, health and bio-sciences, and information/communications technologies as emerging industries in the region.

The Great Lakes contains 25 of the nation's largest 100 harbors by shipment (tonnage). Every year, approximately 160 million tons of commodities are transported in the Great Lakes system, and it transports more than 80% of the iron ore used in the U.S. steel industry. The Great Lakes maritime transportation system is very sensitive to both changes in economic low lake level conditions are generally lessened by dredging the harbors to maintain adequate depths for the ships to come in, the shippers and the industry are concerned that more frequent dredging will significantly increase operational costs. In this section, we assessed economic vulnerability of Great Lakes counties by using the Location Quotients method. From this analysis, we determined that Delta County (MI), St. Louis County (MN), and Muskegon County (MI) are the most vulnerable places should the amount of Great Lakes shipping significantly decline.

Tourism is another economic sector of importance as recreation activities and attractions produce spillover effects to many other industries. The tourism industry has already witnessed the impact that ecosystem changes can have as seen in the example of economic decline in MI due to declines in charter fishing. Furthermore, due to popularity of winter activities, the Great Lakes Region is particularly vulnerable to unseasonably warm winter weather. In general, while increasing temperatures initially appear positive, a closer examination of the climate impacts on the tourism industry is warranted. Anticipating these impacts may be one of the most challenging dimensions of climate change because the ecological functions of the current conditions are intimately tied to many of the recreation pursuits.

Climate Adaptation for The Great Lakes

Vulnerability Assessment of Climate Change

Capstone Project
University of Michigan
April 30, 2011

Section 5 Great Lakes Boundary and City Selection

Overview
Boundary Definition
City Selection Within the Boundary
Summary

Overview

The focus of this study is to identify the anticipated climate impacts for cities within the Great Lake Region and recommend appropriate adaptation strategies. This requires that we define the geography of our Great Lakes Region in a way that is 1) meaningful in relation to the anticipated biophysical impacts of climate change as well as 2) recognizes that political jurisdictions delineate the extent of local climate adaptation planning efforts. This section explains the logic behind our decision to select cities using a modified watershed boundary. In this section, we further discuss some of the demographic characteristics that might be used to sort cities into clusters that have common capabilities or face common climate impacts.

5.1 Boundary Definition

Figure 59 Chicago

The Great Lakes Region can be defined in several ways. As a Mega-region, as defined in Section 4, the Great Lakes encompass urban and rural areas that are tied together through transportation networks, common industries, and a shared history. This approach does not include significant areas of the Great Lakes Region, particularly many smaller Ontario cities. Therefore it would omit many cities in need of climate adaptation planning, and we discarded this method of boundary definition.

When considering significant political boundaries, the Great Lakes Region includes eight U.S. states and two Canadian provinces. These U.S. states are Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin, and the Canadian provinces are Ontario and Quebec. According to the U.S. and Canadian Census, there are 7,546 places within the U.S. states and 1,875 equivalent subdivisions within the Canadian provinces. Figure 60 shows the number of cities in each state or province.

There are several drawbacks to including the entirety of each state and province in our study area. First, there are too many cities within this study area to analyze given our limited time and resources. Second, a number of cities have very low populations and correspondingly lower climate adaptation planning capacities.

As a water system, the Great Lakes Basin covers almost 300,000 square miles that include the lakes themselves as well as all land that drains into the lakes. When considering climate impacts, using the Great Lakes Basin as a boundary definition has many compelling strengths. This boundary definition incorporates the water system dynamics and provides complete coverage of the area. While watersheds do not comply with political boundaries, many watersheds have regional watershed authorities that influence land management and infrastructure decisions. Therefore, we selected a modified watershed area definition. It is modified because we included all counties that were either wholly

Figure 60 The number of cities in the Great Lakes states and provinces

	The United States								Canada	
State or Province	IL	IN	MI	MN	NY	OH	PA	WI	ON	QC
Number of Cities	1,313	601	630	867	1,050	1,054	1,401	630	581	1,294

	The United States								Canada
State or Province	IL	IN	MI	MN	NY	OH	PA	WI	ON
Number of Counties or Division	2	13	83	7	29	35	3	37	40

Figure 61. The number of counties and divisions within the Great Lakes Basin

or partially contained within the Great Lakes Basin. We also excluded the St. Lawrence basin in order to focus on the five Great Lakes. As a result, cities in Quebec, Canada were excluded from our study area. Our boundary definition includes 209 U.S. counties and 40 equivalent Canadian divisions. Figure 61 shows the number of counties and divisions by state or province and by size.

Within our boundary definition, we then selected cities that had a population of at least 23,000 according to the 2000 U.S. and 2006 Canadian census. We used this cutoff in anticipation that the 2010 census may include some smaller cities that had been below 25,000 in 2000 but had now grown beyond this population size. Future work can revisit these selections based on the newest census information. Figure 63 shows the number of cities by state and province.

Figure 62 Grand Rapids

	The United States								Canada
State or Province	IL	IN	MI	MN	NY	OH	PA	WI	ON
Number of cities	47	16	55	1	17	35	1	23	62

Figure 63 The number of places and subdivisions within the Great Lakes Basin

5.2 City Selection within the Boundary

Figure 64 Detroit

Size

Each state or province within the Great Lakes Basin has a variety of cities based on different size categories. Some of the largest cities are well-known and define wider metropolitan regions. These include Chicago, IL, Detroit, MI, Cleveland, OH, Milwaukee, WI, and Toronto, ON. In addition, Fort Wayne, IN, Duluth City, MN, Buffalo City, NY, and Erie City, PA are major urban centers. Chicago grew by 4.03% from 1990 to 2000. Over the same period, Detroit shrank by 7.40%. Buffalo, Cleveland, and Milwaukee also lost population over this period. In Ontario, Toronto's population declined by 0.90% from 2001 to 2006. However, city size has relevance to a city's political structure, amount and type of infrastructure, and planning capacity. In an effort to reflect some of these scale-related differences, we created a table that illustrates the number of cities in each state and province within these different size categories. Future selections should consider the merits of these category break points but they were helpful for our conceptualization of the variation at this time. Figure 65 illustrates the number of cities by the size of population as well as by state or province.

Tables 1 and 2 in Appendix C list all cities with populations over 23,000 within the Great Lakes Basin.

Figure 65 Number of Cities by Population size and by state

Number of Cities by the Size of Population

State / Province	Less than 25,000	25,000 to 99,999	100,000 to 249,999	250,000 or more	Total
Illinois	5	41	-	1	47
Indiana	2	11	3	-	16
Michigan	2	45	7	1	55
Minnesota	-	1	-	-	1
New York	-	14	2	1	17
Ohio	2	30	1	2	35
Pennsylvania	-	-	1	-	1
Wisconsin	2	19	1	1	23
Ontario	4	36	16	6	62

Population Growth and Decline

Another issue for consideration in the selection of cities involves population growth and decline. In the Midwestern United States, most cities were not growing. However, in Canadian cities within Southwestern Ontario, growth was more common.

Figures 66 through 69 show the pattern of population change from 1990 to 2000 and 2001 to 2006 in the United States and Canada, respectively.

Figure 66 shows the 113 U.S. cities that gained population from 1990 to 2000. Chicago, IL, with 2,896,016 residents, is the largest such city, while Roselle Village, IL, with 23,115 residents, is the smallest. Farmington Hills, MI experienced the highest growth rate, from 74,652 to 82,111 residents. The average rate of growth was 3.70%.

Figure 67 shows the 81 places that lost population over the same period. Detroit, MI, with 951,270 residents, is the largest shrinking city, while Alliance, OH, with 23,253 residents, is the smallest. Wyandotte, MI experienced the highest rate of population decline, going from 30,938 to 28,006. The average population decrease was 4.44%.

As seen in Figures 66 and 67, cities that gained population from 1990 to 2000 are clustered around Lake Michigan and Lake Huron, while cities around Lake Erie and Lake Ontario lost population during the same time period.

Figure 68 shows the 61 Canadian cities that gained population from 2001 to 2006. The largest city to gain population was Toronto, ON with 2,503,281 residents. Milton in Southern Ontario experienced the most dramatic increase, from 31,471 to 53,939 residents. Hamilton, ON grew moderately, going from 490,268 to 504,559. Tecumseh,ON, was the only city to lose population, falling from 24,289 to 24,224 residents.

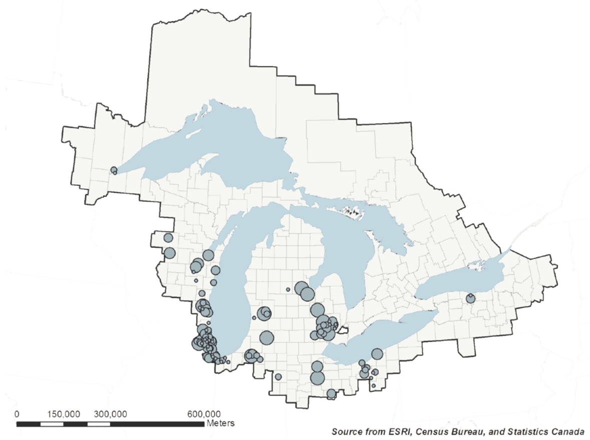


Figure 66 Places with population increase

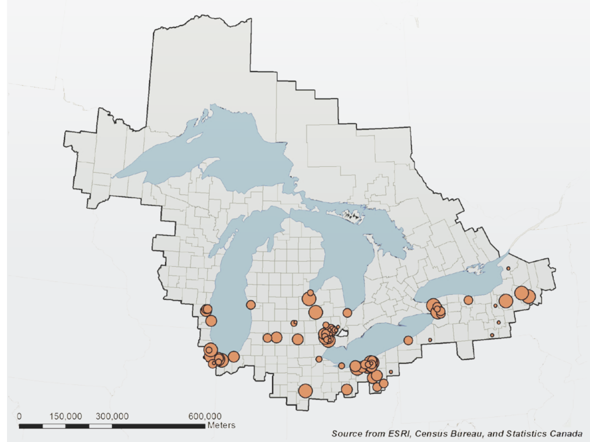


Figure 67 Places with population decrease

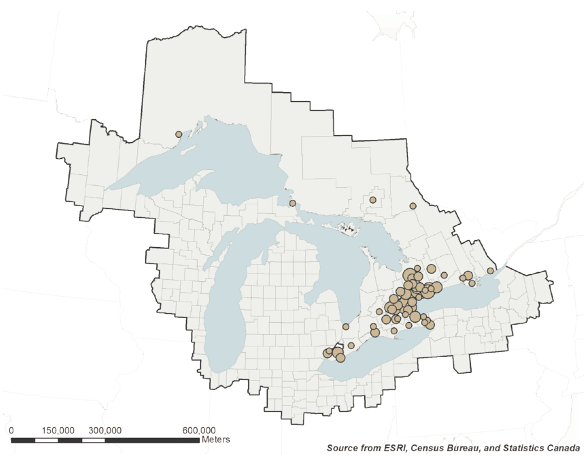


Figure 68 Subdivisions with population increase

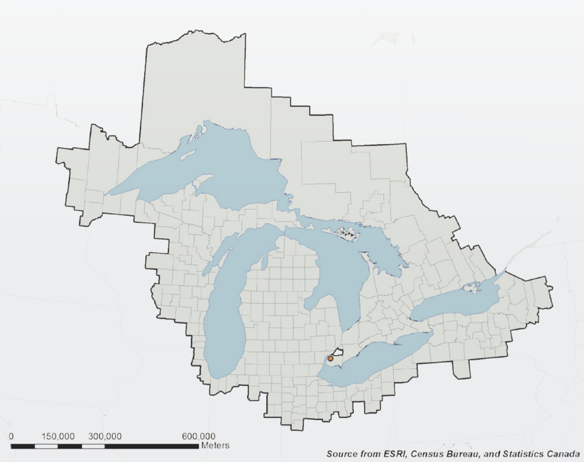


Figure 69 Subdivisions with population decrease

Between 1990 and 2000, the U.S. population grew from 248,709,873 to 281,421,906, an increase of 13.2%. Figure 70 summarizes population changes by state during this period.

From 2001 to 2006, Canada's population increased 5.4%. Ontario grew by 6.6% over the same period, going from 11,410,046 to 12,160,282 residents. Figure 71 summarizes poplulation changes by province during this period.

	Population		Change, 1990-2000	
Area	1990	2000	Number	%
United States	248,709,873	281,421,906	32,712,033	13.2
Illinois	11,430,602	12,419,293	988,691	8.6
Indiana	5,544,159	6,080,485	536,326	9.7
Michigan	9,295,297	9,938,444	643,147	6.9
Minnesota	4,375,099	4,919,479	544,380	12.4
New York	17,990,455	18,976,457	986,002	5.5
Ohio	10,847,115	11,353,140	506,025	4.7
Pennsylvania	11,881,643	12,281,054	399,411	3.4
Wisconsin	4,891,769	5,363,675	471,906	9.6

Figure 70 Population Change by State during 1990 and 2000

Sources: Census 2000, 1990 census, Population and Housing Unit Counts, United States, (1990 CPH-2-1)

While growth can be an indicator of change and increasing tax base, from a climate adaptation planning perspective we decided against the relevance of this method of categorization.

	Population		Change, 2001-2006	
Area	2001	2006	Number	%
Canada	30,007,094	31,612,897	1,605,803	5.4
Ontario	11,410,046	12,160,282	750,236	6.6

Figure 71 Population Change by Province during 2001 and 2006

Source: 2001, 2006 Census, Population and Dwelling Count Highlight Tables, Statistics Canada

Wealth and Poverty

Generally, from a planning perspective, we consider cities with lower poverty levels to have greater access to resources and to have greater planning capacity. However, the social capital literature does show many limitations in this assumption. Overall, the poverty rate in the United States in 2000 was 12.38% for individuals and 11.75% for households. New York is the only Great Lakes state with a higher poverty rate than the national average (Figure 72).

According to Statistics Canada, the overall poverty rates for Canada and Ontario in 2006 were 11.4 and 11.1%, respectively (Figure 73).

Table 1 and 2 in the appendix have more detailed information regarding each place or subdivision.

However, as with growth and decline, while measures of wealth and poverty are informative, they don't directly identify which cities should aggressively engage in climate adaptation planning and therefore, they were secondary considerations in our case study selections.

Area	Population Poverty Status determined	Below Poverty	%	Household	Below Poverty	%
United States	273,882,232	33,899,812	12.38	105,539,122	12,404,237	11.75
Illinois	12,095,961	1,291,958	10.68	4,592,740	465,376	10.13
Indiana	5,894,295	559,484	9.49	2,337,229	221,437	9.47
Michigan	9,700,622	1,021,605	10.53	3,788,780	383,871	10.13
Minnesota	4,794,144	380,476	7.94	1,896,209	150,024	7.91
New York	18,449,899	2,692,202	14.59	7,060,595	982,266	13.91
Ohio	11,046,987	1,170,698	10.60	4,446,621	474,607	10.67
Pennsylvania	11,879,950	1,304,117	10.98	4,779,186	525,388	10.99
Wisconsin	5,211,603	451,538	8.66	2,086,304	174,845	8.38

Figure 72 Poverty Rate by Population and Household by State in the U.S.

Area	Population in Private Household	Population in Low Income after Tax	Percentage of Poverty (%)
Canada	30,628,935	3,484,625	11.4
Ontario	11,926,140	1,324,490	11.1

Figure 73 Poverty Rate by Population by province in Canada

Summary of Section 5 : Great Lakes Boundary and City Selection

In this section, we defined our boundary for the Great Lakes Region and discussed criteria for the selection of cities. These criteria included size, population change, and poverty status. Former manufacturing centers tended to lose population, while other cities, such as Chicago, have grown considerably. Overall, the population growth rates of cities in the Great Lakes states and province are below national averages. Poverty rates of the Great Lakes states and province, meanwhile, are generally lower than the national average. The future selection of additional cities for investigation should revisit these criteria for their relevance.

Figure 74 City of Ann Arbor

Michigan Stadium

Climate Adaptation for The Great Lakes

Vulnerability Assessment of Climate Change

Capstone Project
University of Michigan
April 30, 2011

Section 6 Case Studies and Lessons Learned

Marquette

Benton Harbor/St. Joseph

Figure 75 Marquette County, MI, Watershed

Location

Marquette, Michigan is located on the south shore of Lake Superior in the central Upper Peninsula (U.P.). The city is the county seat of Marquette County, the largest (in land area) of all of Michigan's counties. Marquette has an area of 19.4 sq. mi. (City of Marquette). The city of Marquette has a current population of 21,335 while Marquette County has a population of 67,077. The city of Marquette accounts for about 7% of the U.P.'s population, while Marquette County accounts for 21.5% of the U.P.'s population. While the U.P.'s overall population has declined from 317,000 to 311,361 between 2000 and 2010, population has increased within the city and county by 3.8% and 3% respectively (Census: U.P. 2010). In part, this population is attributed to retirees moving to the area (Census: U.P. 2010). Because of its population density, location, and economic importance, the City of Marquette is often referred to as the "Capital of the Upper Peninsula" (Marquette Master Plan 2004). The mining towns of Ishpeming and Negaunee lie southwest of the City of Marquette and feed into the Marquette region's economic and cultural importance to the U.P.

Ecology

Marquette County is located at the intersection of the Physiographic Regions of the Canadian Shield and Interior Plains (Marsh, 2005). The county contains 250 different types of soils, 18% of which are poorly drained mineral soils and poorly drained organic soils (Soil Survey n.d.). Marquette has rolling topography dominated by Precambrian bedrock, sandstone and granite. The county has a rich geologic history as evidenced by the quartzite, iron, gneiss, sandstone, greenstone, and slate that are found near local beaches, waterfalls, cliffs, and hilltops (Soil Survey n.d.). Additionally, soil and water in the region often have a red tint due to naturally-high iron contents. Much of Marquette's beauty is derived from exposed bedrock formations and the environments they create. Exposed bedrock creates unique elements along city beaches, adds a striking background to the city, and influences water flow and plant communities in the region.

Marquette is located in USDA plant hardiness zone 5b. A mix of aspen, birch, beech, sugar maple, jack pine, red pine, white pine, hemlock, and sand dune communities can be found in the Marquette region (MI Natural Features Inventory n.d.). These ecosystems are also tied to the areas varied topography; much of the city lies between 600-800 feet above sea level (0-200 feet above Lake Superior) while the south side of the city rises as high as 1200 feet above sea level (Marquette Master Plan 2004). Most water in the city of Marquette flows north and east through the Dead-Kelsey and Betsy-Chocolay watersheds before entering Lake Superior; however, water in southern Marquette County flows thorough the Michigamme, Escanaba, Cedar-Ford, and Tacoosh-Whitefish watersheds into Lake Michigan.

Climate

Marquette is characterized by a rather long winter from November-March and relatively short, cool summers. The average first frost day is October 11 – 20 and the average last frost day is May 11 – 20 (PlantMaps.com n.d.). Marquette on average receives 36.32 inches of precipitation and 184.7 inches of snow annually (National Weather Service 2010). October receives the highest amount of precipitation, averaging 3.66 inches of rain, while January receives the most snowfall, averaging 42.5 inches (National Weather Service 2010).

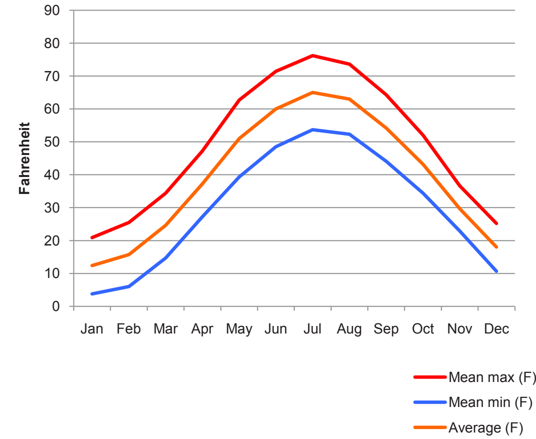


Figure 76 Marquette Temperature 1971-2001

*1971-2000 averages

Data source: National Weather Service

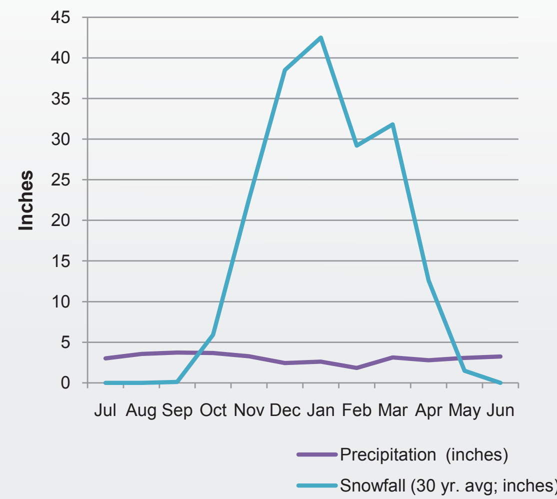


Figure 77 Marquette Annual Snowfall / Precipitation, 1971-2001

*1971-2000 averages

Data source: National Weather Service

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean max (F)	20.9	25.5	34.4	47.2	62.7	71.4	76.2	73.6	64.3	52	36.6	25.2
Mean min (F)	3.8	6	14.7	27.2	39.3	48.5	53.7	52.3	44.1	34.4	22.9	10.7
Average (F)	12.4	15.7	24.6	37.2	51	60	65	63	54.2	43.2	29.7	18
Precipitation (inches)	2.61	1.83	3.13	2.79	3.07	3.23	3.01	3.55	3.74	3.66	3.27	2.43
Snowfall (30 yr. avg; inches)	42.5	29.2	31.8	12.6	1.5	trace	none	none	0.1	5.9	22.6	38.5

Figure 78 Marquette Temperature 2010

Source: National Weather Service

History

Human occupation of the Marquette region can be traced back 9,000 years. Archeologists have found proof of hunter camps near Deer Lake in Marquette County. Native Americans in the area called themselves “Anishinabeg,” meaning “original people,” and evidence has shown they engaged in primitive mining in the region. Archeological remains found in a quarry within Marquette City limits dates back 5,000 years. The decedents of these people are part of the Ojibway Nation and the Ottawa, Potawatomi, and Chippewa tribes. In 1830, the census listed 81 members of the Chippewa Tribe living along the lower Chocolay River in Marquette County south of present day Marquette City (Marquette Master Plan 2004).

Figure 79 Downtown Marquette

French missionaries and fur traders arrived in the Marquette region in the early 17th century. In 1622 Etiennee Brulle was the first white settler to discover Lake Superior and the area’s plentiful furs (Marquette Master Plan 2004). The region remained undeveloped by European settlers until 1844 when iron deposits were discovered by William Burt and Jacob Houghton near Teal Lake, west of present day Marquette (Bishop 2000). Mineral discoveries in the region attracted hopeful settlers who began establishing villages.

The village of Marquette was established on September 14, 1849 under the name New Worcester. On August 21, 1850 the name was changed to Marquette in honor of Jacques Marquette, a French Jesuit missionary who had explored the region (Walter 1986). The village was platted in 1854. Marquette was incorporated as a Village in 1859 and as a city in 1871 (Beattie 2007).

Iron mining was an important early industry and contributed to Marquette’s growth as a rail and shipping hub. The Jackson Mining Company, which was established in 1845, was followed by the founding of the Marquette Iron Company, and the Cleveland Iron Mining Company. Marquette became a booming shipping community for iron and was linked by rail to numerous regional mines. In 1855 a 25-ton American Standard locomotive named Sebastopol began transporting iron ore from Negaunee to Marquette along a 12-mile stretch of track called the Iron Mountain Railroad. This led to the construction of the world’s first pocket ore dock in 1857 along the harbor, thereby eliminating the labor-intensive process of hand loading iron ore on the ships (Marquette Master Plan 2004). While iron mining operations expanded, Marquette also became a nationally known summer haven; visitors often traveled to the city on passenger boats from throughout the Great Lakes (Beattie 2007). Rail lines continued to expand south over the years reaching Bay de Noque and Menominee, finally reaching an existing rail line in eastern Wisconsin.

Marquette suffered a major setback on June 11, 1868 when a railroad fire burned over 100 buildings and left forty families homeless. After this fire, an ordinance was passed banning wood frame construction in the central business district. In February, 1870, Citizens established the community waterworks which distributed water from Lake Superior throughout the city (Marquette Master Plan 2004).

Northern Michigan University—one of the largest employers in Marquette—was founded in 1899 as a State Normal School for educating teachers for the Upper Peninsula. The first class had thirty-two students and was taught by six faculty members. In 1918 the first four-year degree program was started and in 1920 the first Bachelor of Arts degree was awarded (Marquette Master Plan 2004).

Another local institution of note is the K. I. Sawyer Air Force Base. Located south of the City of Marquette, the base was established on January 24, 1955 with a 99-year lease between the Air Force and Marquette County. The base became operational on May 8, 1959. During the Cold War K.I. Sawyer functioned as a station for fighter-interceptor defense against enemy bombers over the North Pole. Later, K.I. Sawyer hosted B-52 bombers as part of the strategic nuclear deterrent. The air force base closed in 1995 and is now maintained as the county's Sawyer International Airport (Maurer 1983).

Figure 80 K.I. Sawyer Airport

Land Use Planning

The City of Marquette worked with Beckett and Raeder to develop a new Master Plan in 2004. The Master Plan looks to build on Marquette's recognition as one of America's "Most Livable Communities," a Michigan "Cool City," and an "All American City." The Master Plan highlights land use, traffic control, walkability, economic diversity, and the protection of natural resources as the city's main concerns. Through an extensive information gathering process, the vision for the Master Plan became "Marquette – the premier livable/walkable winter city in North America." The plan outlines seven goals:

- Create and Preserve Viable and Livable Neighborhoods
- Develop a Historic and Diverse Downtown
- Create an Efficient, Functional and Connected Transportation System
- Make Marquette a Walkable Community
- Foster Economic Diversity and a Family Sustainable Workplace
- Promote Marquette's all Season Quality of Life as a Premier Winter City
- Protect Marquette's Natural Resources

The Marquette Master Plan also has subsection plans for parts of the city. Both the South Marquette Waterfront and the Marquette Downtown Waterfront have specific master plans and form based zoning standards.

South Marquette Waterfront Form Based Code

The purpose of the South Marquette Waterfront Form Based Code is to establish parameters for the area's future development. The goal of the code is to "retain distinctive traditional form, reduce negative environmental impact, support transit and pedestrian environments, reduce auto dependence, encourage adaptive reuse and investment, ensure compatibility of development between use and sub-districts, and create more affordable and sustainable neighborhoods"(South Marquette Waterfront Form Based Code 2004).

The code has 6 sub-districts with unique codes. These sub-districts are:

- Traditional Neighborhood-Residential – based on "traditional neighborhood" development with small lots located close to the road with pedestrian sidewalks and front porches.

•Traditional Neighborhood-Commercial Residential – small scale commercial/retail compatible with surrounding residential neighborhoods and designed to be pedestrian friendly.

•Gateway Corridor-Mixed Use – an aesthetically pleasing commercial strip along the main arterial road leading to the downtown, combining commercial/retail space with pedestrian and auto friendly street design.

•Waterfront-Mixed Use – an extension of downtown with compact, environmentally friendly development similar in size to that found in the downtown.

•Waterfront-Recreation Conservation – land along the waterfront and shoreline preserved for community recreational use.

•Power Plant Special District – property currently owned by the Board of Light and Power to be used as needed under the approval of the planning commission and city council.

The form based code also has specific site planning principles to deal with Marquette's unique weather. These include:

•Designing landscapes and buildings to buffer public and pedestrian spaces from wind

•Avoidance of winter shading in outdoor public space

•Designing transitional spaces at building entrances to shed snow

•Use of numerous small snow pile storage areas to facilitate faster snow melt

•Limiting snow shedding and rain runoff onto pedestrian spaces

•Reducing exterior reflective materials of buildings in order to diminish winter reflectivity

Marquette Downtown Waterfront District

Like the South Marquette Waterfront Form Based Code, the Marquette Downtown Waterfront District is a subsection to the Marquette Master Plan. The intent of the Marquette Downtown Waterfront District is "to foster redevelopment in a sustainable mixed-use pattern as part of a vibrant, diverse urban and working waterfront district." The code encourages traditional urban forms that

Figure 81 Marquette Lighthouse

highlight shop fronts, wide sidewalks, upper story residences and offices, and canopy shade trees. Additionally, the code encourages physical access and a sense of connection to Lake Superior (Marquette Downtown Waterfront District 2004). Like the South Marquette Waterfront Form Based Code, the Marquette Downtown Waterfront District is divided into sub-districts. These sub-districts are:

- •General 3 – two-three story buildings with commercial or residential allowed on all floors

- •General 5 – two-five story buildings with commercial or residential allowed on all floors

- •North Lakeshore Frontages – one-three story buildings with residential or home office allowed on all floors (restrictions on size of home office)

- •Working Waterfront Zone – one and two story buildings with commercial, residential or light industrial use on the first floor and residential or commercial use on the second floor

- •Workshop Flex – one story max with commercial, residential or light industrial uses allowed

- •Founders 5 – two-five story buildings with commercial or residential allowed on all floors.

The South Marquette Waterfront and Marquette Downtown Waterfront form based codes do an excellent job of furthering the goals of the Master Plan. Compliance with the codes will help restore the connection between the city and waterfront that was lost during industrialization. Additionally, the form based codes show a commitment by Marquette to promote sustainable growth of the city. Many of the ideas and plans listed are quite unique and show the city is thinking about how best to situate itself for the future. Such a progressive mindset is essential to larger goals such as the creation of a climate action plan.

Figure 82 Negaunee Houses

Economics

Although long-running economic drivers such as mining and the transportation of goods continue to be important to both the City of Marquette and Marquette County, the region has diversified its economy during the last century. Today, the county's largest employers include service industries such as Northern Michigan University and Marquette General Hospital. While these institutions serve as strong employment centers in the area, there is a growing desire within the community to diversify the local economy (City of Marquette, 2011).

The largest employers in Marquette are Northern Michigan University (NMU), the Marquette Public School System, and Marquette General Hospital (MGH). NMU is a four-year, public, coeducational university that offers 180 degree programs to nearly 9,400 undergraduate and graduate students. MGH has been a major employer in the region since it was designated a "regional medical center" in 1985 by the Federal Health Care Financing Administration; total employment by MGH is 2,900 people, with 1,800 employees based in the City of Marquette (City of Marquette, 2011).

Based on the number of employees and establishments, the largest industries in Marquette County are health care and social assistance with a total of 5,723 employees and 228 establishments. Retail trade employs 3,688 individuals in a total of 299 establishments. Mining, quarrying, and oil / gas extraction employ between 1,000-2,499 employees in only three establishments (US Census County Business Pattern 2008).

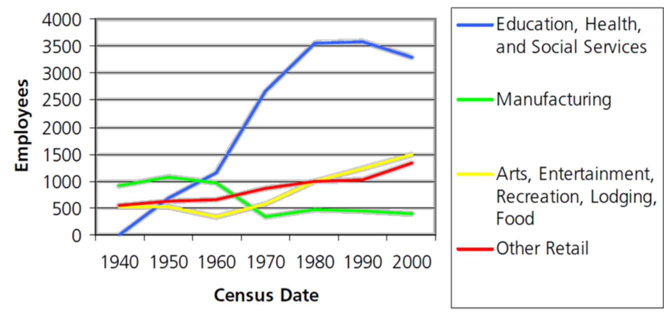


Figure 83 Trends in Employment by Industry, City of Marquette

Source: City of Marquette, 2011

(Employed persons 16 years and over)	**City of Marquette**	
Occupation	**Nbr.**	**%**
Management, Professional and Related Occupations	3,376	33.8%
Service Occupations	2,340	23.4%
Sales and Office Occupations	2,834	28.4%
Farming, Fishing and Forestry Occupations	3	0.0%
Construction, Extraction & Maintenance Occupations	683	6.8%
Production, Transportation & Material Moving Occupations	759	7.6%

Figure 84 Marquette's Employment by Occupation (2000)

Source: City of Marquette

The largest sector in the transportation and warehousing industry is truck transportation with 70 employees and 18 establishments (US Census County Business Patterns 2008). However, there is no data for Great Lakes freight and passenger transportation for Marquette County.

Marquette Harbor is located in Marquette Bay on the south shore of Lake Superior, 160 miles west of Sault Ste. Marie, MI and 265 miles east of Duluth, MN. It is a deep draft commercial harbor and a major regional receiving port on Lake Superior. In 2008, the harbor shipped and received over 1.2 million tons of material.

Figure 85 Industry Composition for Marquette County

Source: 2008 US Census County Business Patterns

Industry code description	Paid employees for paid period including March 12 (number)	Total establishments
Total for all sectors	**21716**	**1726**
Forestry, fishing, hunting, and Agriculture Support	119	19
Mining, quarrying, and oil and gas extraction	1000-2499	3
Utilities	267	5
Construction	1132	196
Manufacturing	1057	49
Wholesale trade	421	56
Retail trade	3688	299
Transportation and warehousing	250-499	37
Information	453	30
Finance and insurance	887	104
Real estate and rental and leasing	284	70
Professional, scientific, and technical services	787	131
Management of companies and enterprises	34	10
Administrative and Support and Waste Mang. and Remediation Srvs.	613	62
Educational services	124	19
Health care and social assistance	5723	228
Arts, entertainment, and recreation	282	33
Accommodation and food services	3007	181
Other services (except public administration)	1099	192
Industries not classified	0-19	2

Commodities received at Marquette Harbor include limestone, coal, and iron ore. The Detroit District of the US Army Corps of Engineers estimates that bulk commodities that pass through Marquette Harbor generate over $15M annually in direct revenue which supports over 200 jobs, and these jobs generate nearly $7.5M per year in personal income (U.S. Army Corps of Engineers, 2010). Dredging of the Marquette Harbor ensures vessels will continue to have access to the docks. The harbor was last dredged in 1978 and a required maintenance dredging will be performed in 2012. "Light loading"—placing less cargo on a vessel when channel depth decreases—would be required if the harbor was not dredged and would likely result in increased shipping costs.

Tourism in Marquette

Although the iron ore mines are an important industry in Marquette County, shipping activities rarely generate economic multiplier activities such as restaurant and lodging expenditures. According to city officials' estimates, residual income from shipping activities is limited. Tourism expenditures account for more direct spending in the city.

Shipping, however, is still an important piece in Marquette's effort to diversify its local economy and tourist attractions. The city has been working with Customs and Border Protection to upgrade Marquette's port facility to a Class A Harbor. Great Lakes cruise ships are unable to stop in Marquette as the facility is rated only for commercial shipping (Class C). If the harbor is upgraded to a Class A facility, federal customs agents can inspect ships and visitors as they arrive. Visitors can exit ships in Class A facilities and enjoy local tourism and recreational activities. According to the city officials, a Class A facility would fit nicely in the lower harbor as cruise ships would have direct access to downtown Marquette.

Figure 86 Lower Harbor Panorama

The city has also amended the master plan and the zoning code for downtown in order to preserve as much of the working waterfront as possible. City officials believe some of the vacant waterfront docks could be used once again as merchant docks. Likewise, the city has also preserved rail corridors connecting to the waterfront.

Although an expansion of boat-oriented tourism is desired by the City of Marquette, other recreational activities attract thousands of visitors to the region each year. Marquette County is home to over 4,000 second homes (Holecek, et al. 2001) but the region also has campgrounds and hotels to accommodate many visitors. While tourism peaks during the summer months, visitors are attracted to Marquette year-round for the diverse activities the county offers. In 2000, tourist spending in the county was $85 million and supported 1,761 jobs; the industry was responsible for 17% of Marquette's economy in 1998 (Stynes 2001). Tourist attractions in Marquette County include (Holecek, et al. 2001):

•Nearly 300,000 acres of public recreation land

•79 Miles of Lake Superior shoreline

•30,000 inland lakes (>50 acres in size)

•5 Great Lake marinas

•6 licensed charter boats

•Three 18-hole golf courses

•795 campsites

•52 miles of "scenic highway"

•191 miles of state-funded snowmobile trails

•164 miles of hiking/skiing/mountain biking trails

•49 miles of off-road vehicle trails

•5 museums

Transportation

Marquette is a popular destination for tourists during all seasons. The city is serviced by K.I. Sawyer International Airport, but most visitors access the city via US-41 and M-28. 2005 traffic counts reveal a steady increase of traffic on these thoroughfares during summer and fall months before tapering off in the winter.

The City of Marquette is also serviced by MarqTran, a limited-access bus service with routes to the airport, Ishpeming, and Negaunee.

Existing Infrastructure

Storm Water System

Marquette is implementing strategies to reduce storm water flow into the municipal system and to improve local water quality. First, Marquette has begun to implement low-impact development techniques into road projects. Center medians and blind catch basins have been installed on some roads in order to allow overflow into the median; water is retained in the median and permeates into the soil.

The city is also using onsite cleaning points in the storm water system. The systems use a vortex method to remove most sediment particulates and oil from storm water before discharging it into creeks, rivers, and Lake Superior. Similarly, Marquette has begun to implement storm water management into its development codes. The code will offer density incentives for developments that reduce storm water inputs through the implementation of green technologies such green roofs and on site detention (Clemo and Ho 2011).

Sanitary System

Marquette has done an excellent job of keeping up with demand with the city's sanitary system,

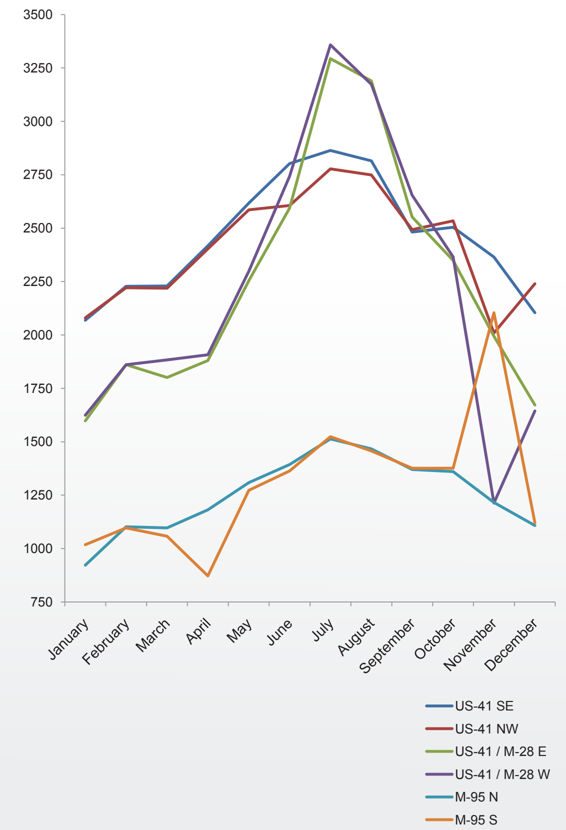


Figure 87 Marquette County Traffic Counts, 2005

Source: Superior Region, MDOT

especially over the last 5 years. During 2007-2008, the city's sanitary system was completely rebuilt with monies from a municipal bond. A full biological process system was installed with a draw-flow capacity of 12 million gallons and an average flow of 6.2 million gallons. The system was de-rated from the state's requirements and draws an average of 3.85 million gallons per day with a peak of 9.8 million gallons. The system was built based on 20 year flow projections and is expected to easily handle projected flow increases. Marquette also treats both Marquette Township and Chocolay Township's sanitary water (Clemo and Ho 2011).

Water System

Marquette's water system infrastructure requires little improvement. Currently, the system draws its water from a Lake Superior intake pipe 600 feet out at a depth of 28 feet. Marquette Township is the only other local municipality that receives its water from the City of Marquette. Chocolay Township draws its water from wells but may need to be connected to Marquette's water supply after the MDEQ raised concerns over infiltration of septic system sewage and petroleum tank leaks from gas stations. Should such an addition to the system take place, the City of Marquette is confident the additional capacity will be met (Clemo and Ho 2011).

Road Infrastructure

The City of Marquette has adopted a 1-5 rating of their 90 mile road system. In this system, a "1" represents a low quality road that needs major work and a "5" represents a road in excellent condition with little need of repair. Currently, about 30% of the roads are in need of some amount of repair and the majority of the roads are ranked a "4" or "5". The city is focused on maintaining a sustainable road budget by concentrating on short-term upkeep rather than massive, long-term projects (Clemo and Ho 2011).

Medical Facilities

The Marquette General Hospital is a regional facility that provides emergency and long-term care to residents from the western and central Upper Peninsula as well as other Midwestern states. The medical campus is located north of downtown Marquette near the campus of Northern Michigan University. An overlay zoning district covers the hospital area and leaves ample room for future medical campus expansions (Marquette Master Plan 2004).

Budget

Marquette's recent budget plans highlight a desire for sustainable growth. The City outlines the following as major line items in the 2010-2011 budget:

- •General Fund
- •Special Revenue Funds
- •Debt Service Funds
- •Enterprise Funds
- •Internal Service Funds

From FY 2007-2008 to the FY 2010-2011 the City of Marquette has reduced the size of its budget. The total amount of revenues/ expenditures has decreased by 22.5% from $70,511,010 in FY 2007-2008 to $54,625,388 in FY 2010-2011. The revenues and expenditures for the General Fund have decreased by 14.5%, and Enterprise Funds have decreased by 31.1%. On the other hand, Special Revenue Funds have increased by 29.1%, and Internal Service Funds have increased by 48.9%. Debt Service Funds have remained constant during the same period. From 2007-2011, "other revenues" in the General Fund have seen a significant decrease of 47.9%, while tax revenues have increased by 6.7%. General Fund financing of Social Services that existed in the 2007-2008 budget are not present in the 2010-2011 budget.

Although the decrease in budget revenues and expenditures might indicate the city government's fiscal condition is constrained by the economic recession in 2009, the city has been relatively active in designating social/ public service funds such as the Sanitation Fund, PEG Fund, Senior Service Fund, and Tourist Park Fund. Such expenditures may reflect the city's effort to serve basic community needs. Furthermore, the city has increased its investment on their infrastructure maintenance and has managed a mid- to long-term (6 to 20 years) plan for infrastructure projects using the state revolving fund and the drinking water fund. Marquette's ability to maintain infrastructure over long periods will make future investments in climate adaptation and mitigation infrastructure much simpler. Figures 88 and 89 highlight the changes in Marquette's funding from 2007-2011. A breakdown of Marquette's 2010-2011 budget can be found in Appendix C.

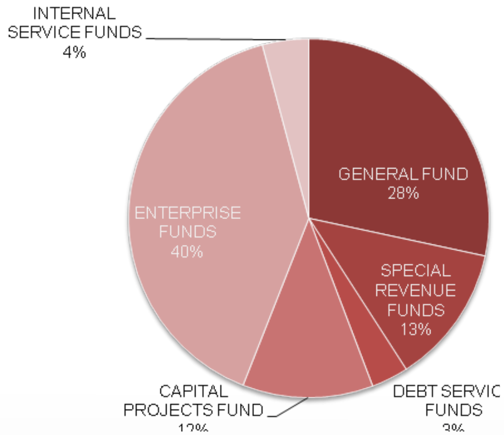


Figure 88 Budget Category, City of Marquette (FY 2007-2008)

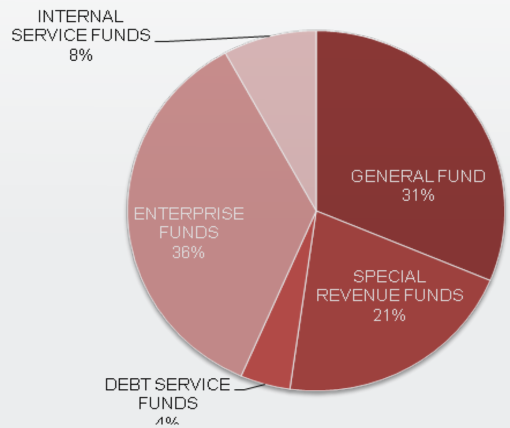


Figure 89 Budget Category, City of Marquette (FY 2010-2011)

Year	Lake Superior
1996	183.6
1997	183.6
1998	183.3
1999	183.3
2000	183.2
2001	183.2
2002	183.3
2003	183.2
2004	183.3
2005	183.3
2006	183.2
2007	183.0
2008	183.2
Record High	183.8
Record Low	182.9
Long Term Average	183.4

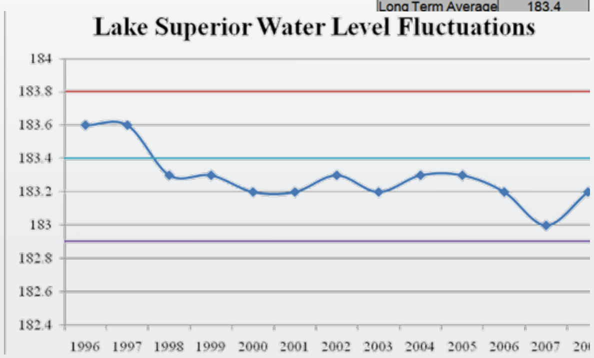


Figure 90 Lake Superior Annual Average Water Levels (1996-2008), in meters

Source: data modified from the Detroit District, U.S. Army Corps of Engineers Impacts to

Recent Extreme Climate Events

In 2003, Marquette experienced devastating spring floods when an excessive amount of rain fell while much of the ground was still frozen. Runoff from the storm event overwhelmed several major pieces of infrastructure. Along the Dead River, both the Silver Lake Dam and an earthen dam at Tourist Park failed. The Tourist Park Basin emptied and washed out a road bridge while cutting off utilities to the northwest section of the city. A culvert along the Carp River also washed out, cutting off one of the main southwestern access points to the city (2004 Marquette Master Plan, Clemo and Ho 2011). As of 2011, the Silver Lake Dam has not been fully repaired. Both the culvert and the washed-out bridge have been replaced with infrastructure capable of handling larger storm events. Infrastructure upgrades were financed with FEMA and local funds (Clemo and Ho 2011).

Anticipated Climate Change

As shown in Figure 90, Lake Superior's water level has consistently decreased during the last decade. Climate models predict a continued decrease in Superior's water level. Several studies have focused on the potential impacts of climate change on the Great Lakes maritime transportation system. Quinn expects that the impacts of global climate change, when translated to the Great Lakes Basin, are significant in terms of lake levels and waterborne transportation (Quinn, 2002). Millerd concurs finding that the higher temperature of climate change may result in a decrease in Great Lakes water levels, and this will lead to restrictions on vessel drafts and reductions in vessel cargos, thereby increasing the number of trips and the cost of moving cargo (Millerd, 2011). Marquette will also experience warmer annual temperatures and an increase in extreme precipitation events. While total annual precipitation is unlikely to change, rain events are likely to occur more regularly in the spring, a time when flooding is already a risk. Flood events similar to the one experienced in 2003 can be expected.

Tourism

Tourism figures fluctuate from year to year depending on economic trends, fuel prices, weather patterns, and other variables. But regional climate models for Marquette predict a significant shift in climate between 2041-2070 that may alter the tourism industry in Marquette. Perhaps most importantly, the NARCCAP model predicts a shift in precipitation events. Winter precipitation may drop 1-2 inches (which translates into approximately 10-20 inches less snow); spring and summer may see an increase in precipitation of 1-2 inches; and fall months may receive 1-2 fewer inches of precipitation (NARCCAP 2041-2070). Similarly, seasonal temperatures are expected to increase between 3°-5°F from 2041-2070 (NARCCAP 2041-2070).

Predicting the impacts of precipitation shifts and temperature increases on Marquette County tourism is a difficult process that warrants further study. Certain industries, like camping, may benefit from the addition of warmer days to each season; however, the industry may also suffer if the number and intensity of precipitation events increases during popular camping months. Winter industries such as skiing and snowmobiling —and the lodging sector that benefits from them—may have to adapt to shorter seasons. Industries such as golf and museums may see an extension of their seasonal traffic as warmer temperatures attract people earlier and later in the season, though their clients may be unable to capitalize on longer seasons due to work and school commitments. The impacts of climate change on tourism are far-reaching. The effects of climate change will benefit some industries and compromise others; whether or not Marquette County tourism can adapt to a changing climate is an important consideration as further studies are initiated.

Municipal Infrastructure

The greatest threat to Marquette's storm water, sanitary, and road infrastructure will be the anticipated precipitation increases during the months of June, July and August. The NARCCAP projections expect an average increase of about two inches of rain during these three months. The additional precipitation events are expected to take place in the form of severe weather events and may overwhelm existing infrastructure. Additionally, Marquette is situated in a bowl with urbanized areas such as Marquette Township located at higher elevations. Flow rates in upstream communities may increase if sustainable storm water management practices are not put in place. Although Marquette's sewer and water systems are currently well under capacity, the systems may need to be upgraded to handle the increased runoff from surrounding communities and spring storm events.

Warmer annual temperatures associated with climate change may also bring new threats to Marquette in the form of invasive species. Due to much lower annual water temperatures, communities around Lake Superior have previously had to deal with fewer invasives than the other Great Lakes. But invasive species such as zebra mussels may colonize warmer waters around Marquette and infiltrate the water intake system. Regular removal of zebra mussel colonies from Marquette's water system infrastructure may be a costly effect of climate change.

Marquette's road infrastructure may also require significant investments in order to keep up with climate change. With increased spring precipitation, low-impact development standards will require large capital improvements in order to upgrade entire infrastructure systems. Such upgrades require long-term capital improvement planning. Similarly, warmer annual temperatures may lengthen the spring freeze/thaw cycle. Due to its far northern longitude, Marquette currently endures fewer freeze/thaw cycles than other Great Lakes communities. Additional degradation of road surfaces may require added municipal investments as Marquette's average annual temperature increases.

Marquette Harbor

Climate change is expected to continue lowering Great Lakes water levels. The Lake Carriers' Association (LCA) continues to monitor the increasing dredging backlog, especially with low water levels over the past 10 years. Costs to the shipping industry rise with every one foot in lost draft. Lower lake levels have required the Great Lakes fleet to forfeit more than 200,000 tons of cargo each trip; this equates to over 16 million lost tons per year (Lake Carriers' Association, 2009). Given the decreasing water level of Lake Superior and the fact that Marquette Harbor is a major regional receiving port on the lake, to prevent potential economic loss—bulk commodities passing through the Harbor generate over $15M annually in direct revenue which supports over 200 jobs (U.S. Army Corps of Engineers, 2010)—more regular dredging may be necessary. The harbor was last dredged in 1978 and required maintenance dredging is planned for 2012 (U.S. Army Corps of Engineers, 2010).

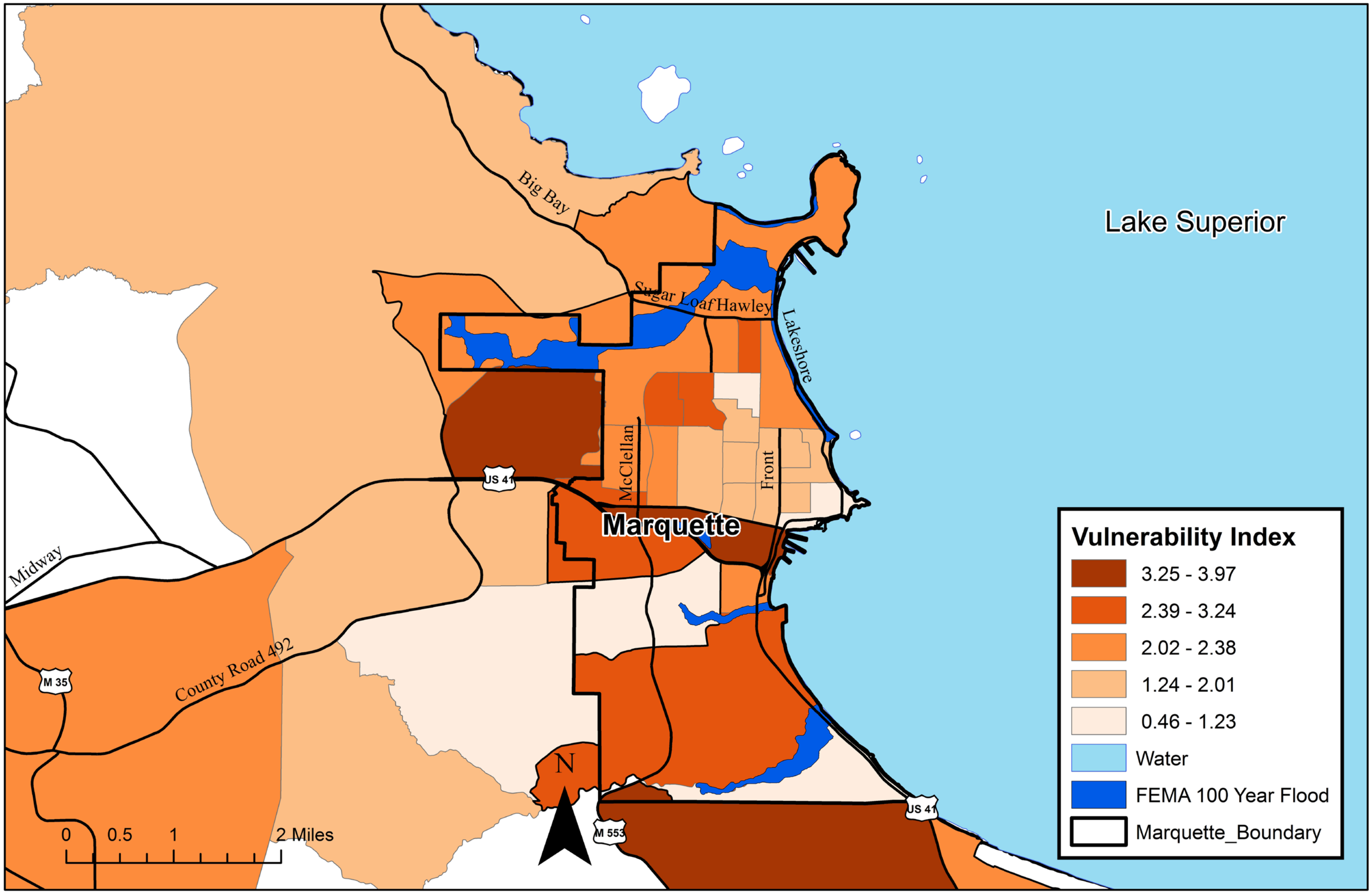
Vulnerable Populations

In order to better understand how the citizens of Marquette may be affected by climate change, a political economy/political ecology vulnerability assessment was completed. The assessment seeks to understand how people and places are affected differently by events such as flooding. Five demographic indices were used to establish a Social Vulnerability Index (SVI): age (under 18, over 65); non-white; female; population density; and housing/rent value. Overlaying the FEMA floodplain maps on a map of SVI in Marquette census block groups reveals the potential vulnerability of populations in the City of Marquette (see figure 92). In general, Marquette's vulnerability is low, with most census blocks scoring between 0-2.5 on the 5 point scale. The four most vulnerable census block groups have populations with high index numbers for age, female population and population density. With the exception of the census block next to Trowbridge Park, the most vulnerable populations are located away from the FEMA floodplains. For more information on vulnerability mapping in Marquette, visit Appendix D.

Figure 91 U.S. Army Corps of Engineers dredge Nicolet.

Photo Courtesy of Great Lakes & Seaway Shipping Online (www.boatnerd.com)

Figure 92 100 Year Flood Impacts on Vulnerable Populations, City of Marquette, MI Urbanized Area by census block group (2000)



Source: Census 2000, ESRI Tiger Line Data

Prioritized Climate Adaptation Efforts

Ecology

Higher average seasonal temperatures and a shift in precipitation events may significantly alter Marquette's local ecology. Plant groups may sequester additional carbon while benefiting from a longer growing season, though the climate changes may also create a habitable environment for invasive species that are normally found farther south. Organizations and municipal departments should seek to:

- Avoid fragmentation of natural areas in order to facilitate the migration of species in response to climate change
- Prepare for extended drought scenarios, especially in zones with sandy or rocky soil
- Monitor the presence and range of invasive species
- Educate the public on their role in ecological preservation

Tourism

A shift in precipitation events and warmer seasonal temperatures has the potential to change the length and practicality of several popular seasonal activities in the Marquette region. Less snow may shorten the snowmobiling and skiing seasons and additional spring rains may discourage camping and hiking activities. Although it's difficult to predict the extent to which Marquette's tourism industry will be influenced by climate change, the city should work with local industries to:

- Establish which activities will benefit or suffer from climate change
- Invest in “climate safe” infrastructure such as multi-use trails
- Continue efforts to diversify the tourist industries

Infrastructure

The City of Marquette has already invested a great deal into non-motorized transportation, walkable urbanism, and low-impact development. As climate change impacts become more apparent, additional infrastructure investments will be required.

Marquette should:

- Invest in greenhouse gas mitigation through continued investments in bicycle lanes, multi-use trails, and walkable urbanism

- Reduce storm water flows from existing and new developments in both the city and surrounding communities

- Consider building mass transit to accompany projected population growth

- Encourage natural buffers along floodplains

For additional adaptation and mitigation plans, see Appendix A for “place investigations” from around the world.

6.2 St. Joseph/Benton Harbor Case Study

Introduction and Context

St. Joseph and Benton Harbor are located at the confluence of the St. Joseph and Paw Paw Rivers in Berrien County in southwest Michigan. Halfway between Chicago and Detroit, Berrien County borders Lake Michigan to the west and Indiana to the south. With a population of 160,472 and a land area of 571 square miles, Berrien County is almost 1.5 times more densely populated than Michigan as a whole (Census 2009). Despite this, 85% of the county is agricultural or vacant land.

The St. Joseph-Benton Harbor region is rich in water resources. Dunes along the Lake Michigan shoreline attract tourists to the area, and local rivers are vital to the region's agricultural and industrial economies. As a result, protecting local water supplies is important to ensuring job opportunities and a sustained quality of life for residents.

In this case study, we investigate the impact that climate change could have on both local water quality and quantity. Higher temperatures may reduce lake levels and stream flows. Severe precipitation events may exacerbate soil erosion and run-off from agricultural and urbanized areas. Heat waves may strain the electricity grid during summer months. While these impacts will affect all St. Joseph and Benton Harbor residents, we will focus on the most vulnerable populations, particularly the elderly, the young, and the socio-economically marginalized. After providing an overview of the area's ecology, economy, and demographics, we will consider how land use decisions, infrastructure investments, and community outreach can mitigate these climate-related impacts.

Figure 93 Benton Harbor

Ecology

Terrain & Soils

The terrain of Berrien County is the result of glacial activity from the Wisconsin Glacial Period, which ended nearly 12,000 years ago. The county's terrain is characterized by mostly flat lake and outwash plains, gently sloping moraines, and entrenched river channels, with modest changes in elevation (Larson, 1980). Elevation at the Lake Michigan shore is about 500 feet, and the highest point in the county is just over 900 feet. Sand dunes are present along much of the lakeshore, rising over 200 feet at some points. The average elevation of Benton Harbor-St. Joseph is about 600 feet.

According to the Soil Survey of Berrien County, there are 42 different soil types in Berrien County, ranging broadly in texture, drainage, and slope. Due to wetness, many of the soils are poorly suited for most land uses other than agriculture. The county's sloping soils are well to moderately-well drained, and range widely in texture. Severe erosion is a concern, and measures are needed to control erosion and reduce sedimentation in streams. If managed well, the soils are suited to field crops, pasture, orchard crops, and vineyards. About half of the county is suited for urban development (Larson, 1980).

Vegetation

Around 1800, oak and hickory forests were the primary land cover in present-day Benton Harbor-St. Joseph. Shrub swampland and emergent marshland dominated near the confluence of the St. Joseph and Paw Paw Rivers. Mixed-hardwood swampland lined the Paw Paw River, and sand dunes lined the shores of Lake Michigan where the two cities are located (Michigan Resource Information System, 1978).

Ecosystems

The dune areas along the Lake Michigan shoreline near Benton Harbor-St. Joseph are home to some of the world's most unique ecosystems. Dune formation and vegetation patterns are driven largely by the lake-influenced prevailing southwest winds. Periods of high water levels between 3,000 and 11,000 years ago have also influenced the formation of the dunes. Most of the dunes along Lake Michigan's eastern shoreline, including those of Warren Dunes State Park, are parabolic. These U-shaped dunes consist of several zones, including beach, open dune, sandy foredune, interdunal wetland, and elevated, forested backdunes. Parabolic dunes support open, herb- and shrub-dominated plant communities and a variety of forest types depending on slope, aspect, and location. Oaks and pines are well adapted to the open, dry environment of the dunes, and establish themselves in backdune areas (Kost et al., 2007; Michigan Department of Natural Resources, n.d.).

The dunes in Berrien County provide habitat to a diverse range of plant and animal species, many of which are threatened or endangered. Endangered or threatened bird species include the piping plover, prairie warbler, and Caspian tern. Dozens of endangered or threatened plant species live in the dunes, including Pitcher's thistle, prairie moonwort, calypso, and sedge (Kost et al., 2007; Michigan Department of Natural Resources, n.d.).

Interdunal wetlands are found in troughs or swales between dune ridges and in wind-formed depressions. They are dominated by rush, sedge, and shrub vegetation, and have water tables that fluctuate seasonally or annually with the Great Lakes. These wetlands provide feeding areas for migrating shorebirds, waterfowl, and songbirds. They also provide habitat for a number of endangered or threatened animal species, including the great blue heron and the spotted turtle (Kost et al., 2007).

Backdune forests can be found at Warren Dunes State Park and on private lands along the Lake Michigan coast. These forests tend to grow on the leeward side of the dunes, and are mostly comprised of bigtooth aspens, sassafrases, oaks, and white pines. The forests help stabilize the dunes and slow the erosion process. They serve as sanctuaries and feeding areas for migrating species such as monarch butterflies, songbirds, and hawks. A variety of spring wildflowers, including trillium and bunchberry, can also be found in backdune forests (Michigan Department of Natural Resources, n.d.).

Dune ecosystems are fragile and face a number of threats, including sand mining, recreation, development, and invasive species (Michigan Department of Natural Resources, n.d.). The State of Michigan's Critical Dune Program was designed to protect the dunes by regulating excavation, vegetation removal, and construction in critical dune areas through a permitting process. Berrien County has approximately 4,000 acres of critical dune areas, 1,200 of which are in state and local parks (Berrien County Office of Emergency Management, 2005).

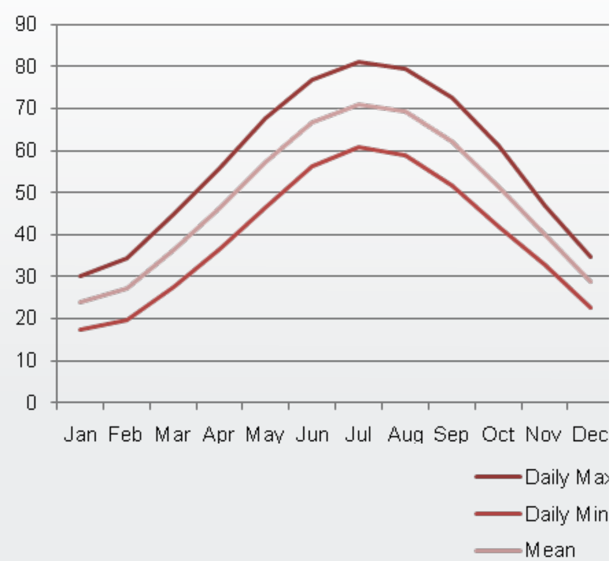


Figure 94 Daily Mean Temperature (°F) Source: National Climatic Data Center. (n.d.). Climatography of United States No. 20 1971-2000: Benton Harbor AP, MI Station.

Watershed

Benton Harbor and St. Joseph are located within the St. Joseph River Watershed, which is the third-largest river basin in Michigan. The watershed intersects 15 counties in Michigan and Indiana and covers 4,685 square miles. The St. Joseph River's main branch is approximately 210 miles long, and there is approximately 600 feet of elevation change from the headwaters in Hillsdale County, Michigan to the river’s mouth at Lake Michigan in Benton Harbor-St. Joseph. Agriculture accounts for 70 % of the landcover within the watershed. Fifty percent of the watershed’s historic wetlands have been lost (Friends of St. Joe River Association, 2005). The Paw Paw River, which is one of the watershed's main tributaries, converges with the St. Joseph River in Benton Harbor. Water quality in the watershed is a concern due to crop and livestock production, as well as urbanization.

Current Climate

Benton Harbor-St. Joseph is located in a humid continental climate region, characterized by warm summers and cold winters. The temperatures around Benton Harbor-St. Joseph are usually milder than inland areas of the region due to prevailing winds from Lake Michigan. Moderate air temperatures near the lake create favorable conditions for orchard crops and vineyards, which are important to the local economy (Larson, 1980).

Based on the National Climatic Data Center’s 1971-2000 monthly climate summaries for the Benton Harbor station (n.d.), the mean January temperature in Benton Harbor-St. Joseph is 23.8° F, with a daily average high and low of 30.2° F and 17.4° F, respectively. The lowest temperature recorded at Benton Harbor was -19° F on November 25, 1950. The mean July temperature is 71.0° F, with a daily average high and low of 81.0° F and 60.9° F, respectively. The highest recorded temperature at the Benton Harbor station from 1971-2000 was 104° F on July 30, 1999.

In Benton Harbor-St. Joseph, the average annual freeze-free period is 149 days. The average last frost day of spring and first frost day of fall are May 13 and October 9, respectively. Average annual precipitation is approximately 37 inches, and is spread relatively evenly throughout the year except during the winter months when precipitation is lower. The heaviest recorded daily rainfall was four inches on April 24, 1950, and September 1986 was the rainiest month with 9.92 inches of precipitation.

On average, 56 inches of snow falls annually on Benton Harbor-St. Joseph. Significant snowfall generally occurs between the months of November and March. The months of April and October average less than one inch, but on occasion can experience significant snowfalls. January is typically Benton Harbor-St. Joseph's snowiest month, with an average of 20 inches. The highest recorded daily snowfall – 20 inches – fell on January 27, 1986. The highest total monthly snowfall – 38.4 inches – occurred in January 1997. The one-day record for snow depth occurred on February 15, 1985, when 80 inches of snow covered the ground.

Settlement History

City of St. Joseph

St. Joseph's recorded history began in 1679 when the explorer LaSalle and his men constructed a fort on the bluff above the St. Joseph River. LaSalle's stay was not long, and the area remained unsettled until 1785 when William Burnett established a trading post and became the first permanent settler. The Carey Mission Treaty of 1828 opened this area, and in 1891 it officially became the City of St. Joseph.

St. Joseph became the county seat in 1894. By the 1890s the city had become a popular destination for tourists. Hotels were erected and the Silver Beach Amusement Park opened (City of St. Joseph Community Profile, 2008). Industries also prospered. Steamers, freighters, and pleasure boats found the St. Joseph River to be an ideal port on Lake Michigan. The city encouraged a balanced mixture of industrial, commercial, and residential development.

City of Benton Harbor

Benton Harbor began with the purchase of 160 acres of land by Eleazar Morton in what is today Benton Township. To establish a market for farmers on the east side of the St.

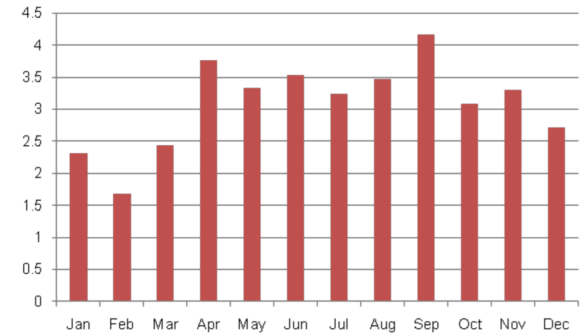


Figure 95 Monthly Mean Precipitation (inches)
Source: National Climatic Data Center. (n.d.). Climatography of United States No. 20 1971-2000: Benton Harbor AP, MI Station.

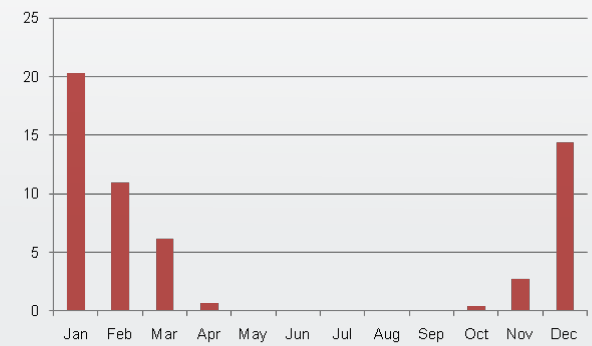


Figure 96 Monthly Mean Snowfall (inches)
Source: National Climatic Data Center. (n.d.). Climatography of United States No. 20 1971-2000: Benton Harbor AP, MI Station.

Joseph River, a canal was built through the wetlands between the river and the city. Shortly afterwards, the town was founded as Brunson Harbor in 1860. The name was changed to Benton Harbor in 1865.

The canal made Benton Harbor a lake port, and by the 1870s ships were loading more than 300,000 packages of fruit per year. Sawmills and basket factories lined the canal. After rapid growth between 1872 and 1888, Benton Harbor was incorporated as a city and a charter was granted by the state legislature in 1891 (The City of Benton Harbor Community Profile, 2008).

In the 1890s, huge numbers of tourists frequented the area. Hotels offered mineral baths for health benefits. In 1905, the Benton Harbor Development Company was founded to attract industries. Land grants and financial aid brought economic prosperity during the Roaring Twenties.

Benton Harbor's economic decline began in the 1960s and continued to escalate through the late 1980s. In 1986, Benton Harbor became the focus of state government attention and was designated as an Enterprise Zone. This program provided substantial incentives for business location and became the basis for the renewal of Benton Harbor. Benton Harbor also received one of four Michigan Renaissance Zone designations in 1997.

Land Use Planning

Berrien County is predominantly agricultural, with 84% of the county classified as Agriculture/Vacant, 9.4% as residential, 3.5% public/semi-public, 1.5% industrial, and 1.3% commercial (Berrien County Master Plan 2010). The U.S. Department of Agriculture has classified large areas of the county as Prime Agriculture Land, and agribusiness is a major contributor to the local economy (USDA Ag Census n.d.). To protect this resource, the county has used various tools such as conservation easements and the purchase of development rights to prevent various developments from encroaching on valuable land. Furthermore, as the local economy continues to turn away from industries such as manufacturing, many feel that business such as agri-tourism is key to supplementing the loss.

The predominant residential development pattern in Berrien County is low-density, single-family detached housing. In addition, from 2009-2010 there was a 21% jump in soil erosion permits issued in the county, from 177 to 225. State law requires soil erosion permits for construction within 500 feet of a water body or wetland, including county drains. Furthermore, according to County Drain Commissioner Roger Zilke, permits issued in recent years have been more spread out, indicating that development is increasing in rural areas.

Considerable controversy has surrounded the Harbor Shores development. Designed as a high-end golf course and condo development along the Paw Paw River and Lake Michigan, Harbor Shores has drawn criticism for its location in a floodplain and wetland. Carol Drake of the organization Friends of Jean Klock Park has expressed concern that construction could exacerbate soil erosion and water contamination. Kameron Jordan, district supervisor of the DEQ's Land and Water Management Division, has defended the development on the grounds that it is not unusual for parks and recreation areas to be located in floodplains.

Overall, Berrien County is considering many key environmental issues in its long-term planning efforts. Throughout the county's master plan, land use issues are addressed through goals and objectives. The plan makes a point of highlighting strategies which include low impact development, watershed plans, storm water system retrofits, and reduction in impervious surfaces, among others.

Figure 97 Benton Harbor Development

Figure 98 Benton Harbor Transportation

Economics

Commercial shipping

Benton Harbor and St. Joseph share the same waterfront access point and are considered one port. The port is named the Consumers International Terminal Company and is under the operation of the St. Joseph River Board of Harbor Commissioners. The commercial port is located on the St. Joseph River.

Benton Harbor is a center for intermodal transportation that offers shipping access to Lake Michigan and beyond. The Southwestern Michigan Regional Airport is a general aviation facility with commercial passenger service. Commercial passenger service is also available at South Bend, Kalamazoo and Chicago. Benton Harbor is halfway between Detroit and Chicago, with Interstates 94 and 196 providing convenient access to more than 50% of the nation's major markets. A CSX rail line and Amtrak also run through the city.

Major Employers

The largest employer in Berrien County is Whirlpool Corporation, which has 3,482 local employees (Berrien Community Profile 2008). Whirlpool manufactures home appliances, including washing machines, stoves, refrigerators, dishwashers, countertop appliances, and water filtration units. In addition, Lakeland Regional Health System, Four Winds Casino, Indiana Michigan Power/ Cook Nuclear Plant, and Andrew's University are other major employers in Berrien County.

Figure 99 Top Employers (Berrien County Community Profile 2008)

Employer	Number of Employees
Whirlpool Corporation	**3,482**
Lakeland Regional Health System	**3,300**
Four Winds Casino	1,800
Indiana Michigan Power / Cook Nuclear Plant (Generation)	1,400
Andrew's University	1,396
Wal-Mart (Benton Harbor & Niles)	**740**
Lake Michigan College	**706**
Berrien County Government	**693**
Leco Coporation	652
Benton Harbor Area Schools	602

Figure 100 Benton Harbor Wirlpool

Industry and Employment

Manufacturing is a major industry throughout Berrien County, including Benton Harbor and St. Joseph. A total of 18,825 Berrien County residents, or one-quarter of workers 16 and over, engage in manufacturing and related work (Census 2000). Benton Harbor and St. Joseph have a similar industrial composition, with manufacturing jobs accounting for 28% and 23% of all employment in Benton Harbor and St. Joseph, respectively. Education, health, and social services is the second largest industry in Berrien County, employing 20% of county workers.

Approximately 30% of Berrien County workers and 40% of St. Joseph workers are engaged in managerial, professional, and related white collar jobs (Census 2000). In Benton Harbor, 33% of jobs are related to production, transportation, and material moving occupations (Census 2000).

Figure 101 Major industries in Berrien County (Census 2000)

	Berrien County		Benton Harbor		St. Joseph	
Category	Total	%	Total	%	Total	%
Agriculture; Forestry; Fishing and Hunting; and Mining	1,462	1.91%	10	0.28%	17	0.39%
Construction	4,601	6.01%	136	3.82%	207	4.70%
Manufacturing	**18,825**	**24.59%**	**1,013**	**28.48%**	**992**	**22.52%**
Wholesale trade	2,229	2.91%	37	1.04%	90	2.04%
Retail trade	8,254	10.78%	432	12.15%	403	9.15%
Transportation and Warehousing; and Utilities	5,003	6.54%	174	4.89%	337	7.65%
Information	1,285	1.68%	52	1.46%	121	2.75%
Finance; Insurance; Real estate and Rental and Leasing	2,911	3.80%	92	2.59%	167	3.79%
Professional; scientific; management; administrative; and waste management services	4,936	6.45%	138	3.88%	368	8.36%
Educational; health and social services	**15,547**	**20.31%**	**765**	**21.51%**	**982**	**22.30%**
Arts; entertainment; recreation; accommodation and food services	5,690	7.43%	464	13.04%	371	8.42%
Other services	3,784	4.94%	141	3.96%	223	5.06%
Public administration	2,030	2.65%	103	2.90%	126	2.86%
Total	76,557	100.00%	3,557	100.00%	4,404	100.00%

Figure 102 Major occupation categories in Berrien County (Census 2000)

	Berrien County		Benton Harbor		St. Joseph	
Category	Total	%	Total	%	Total	%
Management; professional; and related occupations	**22,415**	**29.28%**	349	9.81%	**1,748**	**39.69%**
Service occupations	11,734	15.33%	982	27.61%	604	13.71%
Sales and office occupations	18,432	24.08%	832	23.39%	1,128	25.61%
Farming; fishing; and forestry occupations	794	1.04%	21	0.59%	10	0.23%
Construction; extraction; and maintenance occupations	6,843	8.94%	187	5.26%	284	6.45%
Production; transportation; and material moving occupations	16,339	21.34%	**1,186**	**33.34%**	630	14.31%
Total	76,557	100.00%	3,557	100.00%	4,404	100.00%

	Berrien County	% Change	Benton Harbor	% Change	St. Joseph	% Change
Census 1990	161,378		12,818		9,214	
Census 2000	162,453	0.67	**11,182**	**-12.76**	8,789	-4.61
2005 – 2009 Estimate	**160,129**	**-1.43**	**10,770**	**-3.68**	**8,508**	**-3.20**

Figure 103 Total Population in Berrien County, Benton Harbor, and St. Joseph (Census 2000)

Demographics

Population

From 1990 to 2000, Berrien County's population increased slightly from 161,378 to 162,453, while Benton Harbor and St. Joseph both lost population. Benton Harbor, in particular, experienced a dramatic 12.76% decrease, from 12,818 to 11,182 (Census 2000). St. Joseph's population declined by 4.61%, from 9,214 to 8,789 residents. According to the American Community Survey 2005 – 2009 estimates, all three geographic areas continued to lose population after 2000.

Median Age

The median age in Berrien County and St. Joseph is approximately 40. Benton Harbor is younger, with a median age of 31. Roughly 36% of Benton Harbor is 18 or younger.

Race

Berrien County and St. Joseph are approximately 80% and 90% white, respectively. Benton Harbor, on the contrary, is over 90% nonwhite.

	Berrien County	%	Benton Harbor	%	St. Joseph	%
Median Age	**40.0**		**30.8**		**40.7**	
Under 5	10,522	6.57	992	9.21	304	3.57
5 - 19	32,776	20.47	**2,908**	**27.00**	1,204	14.15
20 - 34	26,667	16.65	2,017	18.73	1,862	21.89
35 - 54	**45,703**	**28.54**	**2,966**	**27.54**	**2,735**	**32.15**
55 - 64	19,929	12.45	915	8.50	909	10.68
65 Over	24,532	15.32	972	9.03	1,494	17.56

Figure 104 Age Distribution in Berrien County, Benton Harbor, and St. Joseph (Census 2000)

Median Income and Poverty

The median family income of Benton Harbor is $23,579, only slightly above the national poverty threshold, and significantly below median income levels in St. Joseph and Berrien County as a whole. Nearly half of Benton Harbor residents live in poverty (ACS 2009).

Figure 105 Median household, family, and per capita incomes, dollars (Census 2000)

	Berrien County	**Benton Harbor City**	St. Joseph City	The United States
Median Household Income	42,481	**17,491**	49,250	51,425
Median Family Income	54,608	**23,579**	72,958	62,363
Average per Capita	24,028	**10,235**	33,034	

Tourism

Berrien County is located in Michigan's 6th congressional district, where travel spending contributes $968.3 million and 9,400 jobs to the local economy (poweroftravel.org). Tourism is thus a major generator of economic activity.

Southwest Michigan is particularly popular during the summer months, when tourists flock to local beaches and farms. There are 18 charter fishing operations in St. Joseph and Benton Harbor, which host walleye, perch, salmon, trout, and steelhead fishing tours. In addition, St. Joseph hosts the Southwest Michigan Steelheaders Summer Challenge fishing tournament (great-lakes.org). In a region known as the Fruit Belt, marketing campaigns have also generated interest in agri-tourism (Berrien County 2010).

With its proximity to Chicago and Indiana, St. Joseph draws seasonal visitors who own summer homes. In 2005, there were 5,259 seasonal homes in Berrien County, which represents 7.2% of the local housing stock (MSU Extention/Micgigan). Over the years that number has increased with expansions in waterfront and resort housing. Residents have noticed the change in the local economy. A 2009 survey revealed that 81% of respondents

	Berrien County	%	Benton Harbor City	%	St. Joseph City	%
Population for whom poverty status is determined	157,246		10,770		7,934	
Income in the past 12 months below poverty level	26,307	16.73	**5,175**	**48.05**	722	9.10
Civilian Labor Force	75,836		N/A		N/A	
Employed	66,976		N/A		N/A	
Unemployed	8,860	**11.68%**	N/A		N/A	

Figure 106 Poverty and unemployment rates (Census 2000)

felt tourism has increased as the county's economic base has shifted away from manufacturing.

Water Systems and Infrastructure

Water Systems

Berrien County lies on the east coast of Lake Michigan. St. Joseph, the county seat, and Benton Harbor, are located at the confluence of the Paw Paw and St. Joseph River. As a result, the quality of local rivers, wetlands, and dunes play an important role in promoting tourism, agriculture, and industry, as well as maintaining the quality of life of local residents. This section provides an overview of Berrien County's water systems, and looks at potential challenges to maintaining water quality in the future.

The majority of Berrien County is located in the Lower St. Joseph Watershed (LSJ); parts of southern Berrien, including the town of New Buffalo, lie within the Galien River Watershed (GRW). In addition, the county is within the Lake Michigan coastal drainage area. The St. Joseph River forms the main stem of the St. Joseph River Watershed, the third-largest watershed in Michigan. The watershed covers 4,685 square miles and spans 15 counties in Michigan and Indiana. Major rivers include the Paw Paw, Prairie, Elkhart, and Dowagiac. Over half of all riparian land is agricultural or urban, and more than a quarter is forested (WMP

2007).

Lower St. Joseph and Galien River Watersheds Health

According to Michigan Public Act 451 (1994), all waterways within Michigan must meet designated uses. These include agriculture, public water supply, navigation, warmwater fisheries, coldwater fisheries, indigenous aquatic habitat, human body contact recreation, and industrial water supply (WMP 2007). Figure 107 and 108 summarize the extent to which the LSJ and GRW support each of these designated uses.

To ensure that the LSJ and GRW comply with federal and state water quality standards, two major initiatives are underway in Berrien County. The first is a Michigan Department of Environmental Quality Total Maximum Daily Load plan for the Lower St. Joseph River.

Designated Use	Status
Agriculture	Threatened in Dowagiac River
Navigation	Threatened at mouth of Saint Joseph River
Warmwater fisheries	Threatened at mouth of Saint Joseph River
Coldwater fisheries	Impaired in Dowagiac and McKinzie and Juday Creeks
Indigenous Aquatic Habitat	Impaired in Dowagiac
Human Body Contact Recreation	Partial contact impaired in Dowagiac and Saint Joseph Rivers
Industrial Water Supply	Threatened in Dowagiac

Figure 107 Status of designated uses in the Lower St. Joseph River Watershed (WMP (2007)

Designated Use	Status
Agriculture	Impaired by E. coli in Deer Creek and the Galien River
Navigation	Impaired in Galien
Warmwater fishers	Impaired by high sediment and nutrient levels
Coldwater fisheries	Impaired by increased temperatures
Indigenous Aquatic Habitat	Impaired by nutrient levels and invasive species
Human Body Contact Recreation	Impaired by E. coli in Deer Creek and Galien Rivers
Industrial Water Supply	Met

Figure 108 Status of designated uses in the Galien River Watershed (WMP (2007)

The second is the Lower St. Joseph/Galien River Watershed Management Plan. Both of these plans focus on raising the quality of waterways in Berrien County to levels that comply with the designated uses above. The remainder of this section will focus on the recommendations of each initiative and their implications for infrastructure and development in Berrien County.

Lower St. Joseph TMDL Program: Controlling E. coli

Section 303(d) of the Clean Water Act requires states to implement Total Maximum Daily Load (TMDL) programs for waterways that do not support their designated uses. Among other designated uses, the Lower St. Joseph River is required to support full body contact recreation from May 1 to October 31. The water quality standard (WQS) for full body contact limits E. coli concentrations to no more than 130 per 100 ml as a 30-day geometric mean, and no more than 235 per 100 ml at any single time. The purpose of the Lower St. Joseph TMDL program is to ensure that the St. Joseph River meets this requirement along the 32 miles of river between the city of St. Joseph and the Michigan/Indiana border.

Fecal coliform bacteria, which include E. coli, are found in human and animal waste, and their presence in the water column is a sign of sewerage overflow and agricultural runoff. Water samples taken from the St. Joseph River in 2002 by the Michigan Department of Environmental Quality showed high concentrations of E. coli immediately downstream from the Michigan state line and the town of Buchanan, ten miles southeast of St. Joseph. In addition, in 2001 the Berrien County Health Department found excessive E. coli concentrations in the St. Joseph River following precipitation events, prompting the department to issue a "Rainfall Plus 48-Hour Health Advisory," warning residents to avoid contact with the St. Joseph River within two days of a precipitation event (Berrien 2001).

Elevated E. coli levels in Berrien County are associated with point and non-point source pollution. There are172 point-source discharge permits in Berrien County (NPDES 2010). The majority are storm water discharge permits. Of the remaining, nine cover discharges from wastewater treatment plants (WWTP), and two are for combined-sewer systems (CSSs) in St. Joseph and Niles Township.

Combined sewer overflows (CSOs) are discharges associated with CSSs that result in the release of untreated or only partially treated human waste directly into receiving waters. The

Environmental Protection Agency's National Water Quality Index 2000 associated overflows with impairment rates in downstream waters that were three times the national average (EPA 2004). Within Berrien County, from May 1 to October 31, CSSs in St. Joseph and Niles Township reported a total of 14 discharges that totaled 15 million gallons of partially treated or diluted raw sewerage. These discharge events corresponded with local E. coli levels that exceeded the minimum WQS (Berrien 2001). Both communities have since undertaken projects to eliminate CSO discharges into the St. Joseph River. Niles Township has installed a retention basin to hold and treat sewer overflow prior to release. The city of St. Joseph is in the process of separating its system and eliminating discharges from five outfalls into the St. Joseph River. The Buchanan and Benton Harbor WWTPs have completed upgrades to eliminate separated system outfalls as well.

In addition to CSSs, the St. Joseph TMDL program points to storm water as a principle source of E. coli contamination. As a result, in 2009 the Berrien County Drain Commission published updated guidelines for storm water drainage system design and development. The new guidelines encourage low-impact, on-site storm water management strategies, such as pervious pavement, rain gardens, and green roofs. In addition, the commission encourages investment in regional storm water retention basins (Berrien 2009).

Watershed Management Plan: Improving Water Quality,

Increasing Water Quantity

Urbanized areas within the St. Joseph and Galien River watersheds are required to meet EPA National Pollutant Discharge Elimination System Phase II Municipal Storm Water Discharge Permit requirements. The Lower St. Joseph/Galien River watershed management plan is intended to meet these requirements through coordination among municipalities. The plan has established five long-term goals:

1)To build the financial and institutional capacity of a stakeholder group that will assume responsibility for implementing the management plan

2)Reduce soil erosion through on-site remediation

3)Reduce nutrient loading through on-site remediation and elimination of pathways

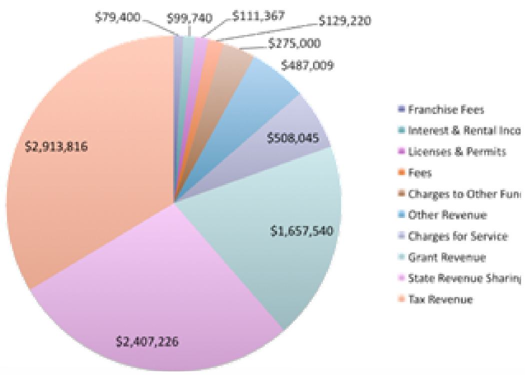


Figure 109 Benton Harbor revenues, 2009 – 2010

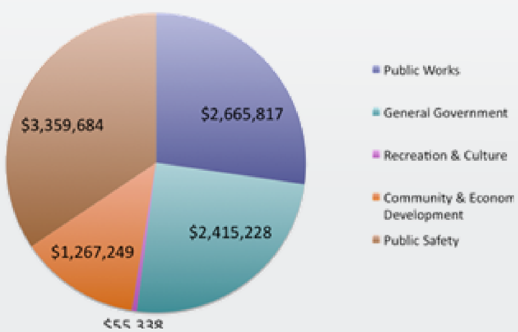


Figure 110 Benton Harbor Expenditures, 2009 – 2010

4)Preserve, restore, and protect open space, coastal zones, and local ecosystems

5)Eliminate pathways for E. coli and other disease-causing pathogens

6)Reduce levels of chemicals, pesticides and other toxins that threaten human and aquatic habitats

To meet these goals, the management plan has identified several best management practices (BMPs) related to treating water prior to discharge, retaining water on-site, creating vegetative buffer zones around vulnerable waterways, and reducing runoff from agricultural land. High priority BMPs include the adoption of an illicit discharge elimination ordinance, increased dumpster use at municipal facilities and construction sites, septic system inspections every five to ten years, coordinated emergency response to spills, and creating a hotline for residents to report pollution hotspots.

Budget

Benton Harbor

The City of Benton Harbor is under considerable financial stress. In a recent presentation to city officials, Emergency Financial Manager Joe Harris reported that the City is $6,082,509 in debt (Lewis n.d.). In recent years city expenditures have outpaced revenues considerably, ranging from $800,000 to $2 million annually, with a $1.1 million shortfall in fiscal year 2009-2010. The general fund deficit currently stands at $4.5 million. Figures 109 and 110 show revenues and expenditures for 2009-2010 (Harris 2011).

Benton Harbor relies heavily on state and federal assistance. In the last fiscal year the state contributed $2,407,226 in shared revenue, making it the second-largest revenue source behind taxes. In addition, the third-largest revenue source was intergovernmental grants, which amounted to $1,657,540. Figure 111 shows the amount of intergovernmental assistance compared to locally-generated revenue (Harris 2011).

In 2009, following a request from the city manager, the state conducted a review of the city's finances. In February 2010, a governor-appointed review team found that the situation was severe enough to warrant a financial emergency and an Emergency Financial Manager (EFM) was appointed.

EFMs have considerable authority to enact reforms in order to restore a city's fiscal solvency. Initially enabled under Michigan Public Act 72 (1990), the mandate of EFMs was recently expanded under Public Act 4 (2011), which forbids a city's chief administrative officer from exercising any powers without the express consent of the EFM (State of Michigan 2011).

As a result of its current status, Benton Harbor faces considerable cuts to its budget. In September 2010, the EFM issued a financial plan for the city that includes consolidation and reduction of services, layoffs, and reductions in city employee benefits. The initial budget for fiscal year 2010-2011 totaled $5.7 million for police, fire, and public works, leaving only $200,000 for the remaining city departments (Harris 2011). Under the status quo, employee wages, salaries, and benefits account for 75% of general fund expenditures, leaving only a small portion for operating expenses. As a result, the financial plan has scheduled layoffs in several departments including police, code enforcement, the city manager's office, finance, public works, the mayor's office, and human resources. Figure 112 displays the extent of cost reductions.

In an attempt to expand its tax base, the city has sought the development of a high-end golf course, condo and seasonal housing complex. In addition, Whirlpool has broken ground on a massive office park development within the city (Colclough 2011). Despite the positive impacts that these developments may have for the tax base, it is not clear how much they will benefit the typical Benton Harbor resident. In the coming months Whirlpool will phase out the last of its remaining manufacturing jobs in the area.

St. Joseph

St. Joseph's finances are more stable. The city enjoys relatively high home values and its citizens earn considerably higher incomes than residents in Benton Harbor. Moreover, the city's general fund operated with a surplus of $1,327,717 in fiscal year 2009-2010 (City of St. Joseph 2011).

While the city has faced some fiscal challenges, its broad tax base has led to a relatively stable budget. It relies significantly less on state assistance than Benton Harbor. Figure 113 shows that 92% of St. Joseph's budget is

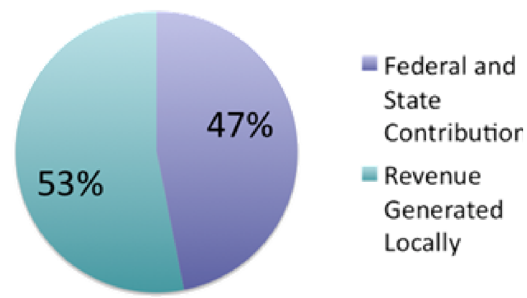


Figure 111 Local versus non-local revenue sources, Benton Harbor, 2009 - 2010

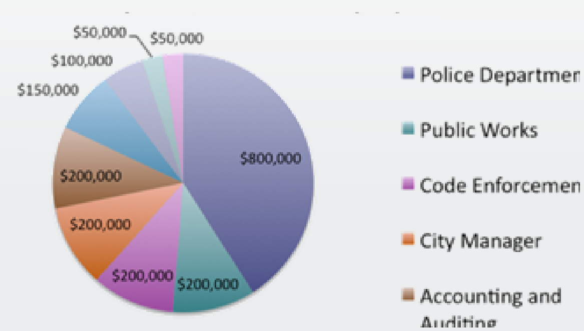


Figure 112. Projected budget cuts, Benton Harbor, 2010 – 2011

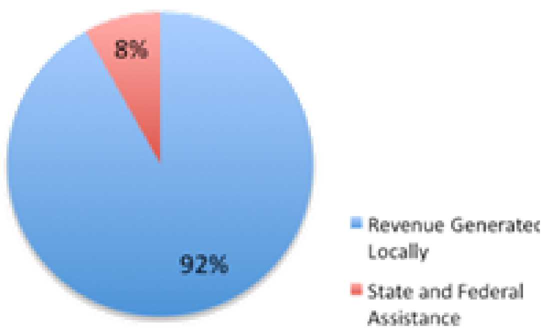


Figure 113 Local versus non-local revenue sources, St. Joseph, 2009 - 2010

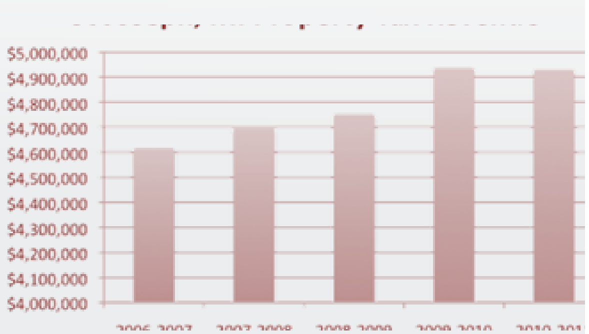


Figure 114 Local versus non-local revenue sources, St. Joseph, 2009 - 2010

financed through local revenues. Furthermore, as figure 114 shows, property taxes have remained stable over time.

Anticipated Climate Impacts

Lake Level Declines

Lake levels are affected by precipitation, runoff from tributaries, evaporation, and the rate of water use. Lower precipitation leads to lower runoff, and higher temperatures lead to higher evaporation rates. Together, they cause lake levels to decline. Water levels in Lake Michigan dropped from 1997 to 1999 and have remained at relatively low levels since then. In 2010, the water level dropped again after slight increases in 2008 and 2009.

NOAA Great Lakes Environmental Research Laboratory's Advanced Hydrologic Prediction System (AHPS) indicates that water levels in Lake Michigan and its linked waterways will likely be 8 to 10 inches lower than 2010 levels for the next 6 months, which is only ten inches above historic lows recorded in 1964. Under the influence of global warming, water levels may fall even further.

Declining water levels will affect many industries, including commercial shipping, recreational boating, marinas, beaches, fishing, cottage and homeowners, and aquatic ecosystems. Lake carriers that transport iron ore, coal, grain, and other raw materials will be forced to carry less, and millions will need to be spent to dredge the St. Joseph River and the waterfront harbor.

Dredging

St. Joseph harbor requires annual dredging. The St. Joseph River carries a significant amount of sediment which over time creates shoals throughout the inner and outer harbor. Decreased water levels could exacerbate the deposits, while silt removal from the river bottom could range from 60,000 to 113,000 cubic yards. This could leave the St. Joseph River's inner harbor too shallow for large commercial ships to turn around, limiting the harbor's commercial capacity.

St. Joseph has been striving to raise funds for dredging for years, with most funding coming from the state and the Army Corps of Engineers. However, St. Joseph is cut off from the 2012 dredging list due to proposed budget cuts. Michigan legislators, however, are dedicated to solving the dredging problem long-term. Senator Carl Levin initiated bill S. 412 to require the Harbor Maintenance Trust Fund to spend $1.6 billion annually. A companion bill, H.R. 104, has been introduced in the House (Great Lakes Maritime Task Force, 2011).

Severe Precipitation

Severe precipitation events can compromise water infrastructure and natural water systems. In Berrien County, the impact on sewerage systems and agriculture runoff may be especially severe. Municipalities in Berrien County have made significant progress in updating their sewerage infrastructure. Niles has separated its system, and St. Joseph is in the process of doing so, as discussed above. Nonetheless, the capacity of these systems may be exceeded if the intensity of storms increases as predicted.

The leading cause of water impairment in the United States is nonpoint source pollution. Runoff from agricultural land is the leading nonpoint source, impacting 50% to 70% of impaired waters. (EPA 1993) Soil erosion from farms increases the turbidity of waters, reducing sunlight and disrupting fish food supplies. Runoff of fertilizers and manure feeds algae, leading to oxygen depletion in receiving streams. Runoff from level farmland with uniformly exposed soil is particularly susceptible to severe precipitation events. With 70% of its land classified as agricultural or vacant, Berrien County is particularly susceptible to agricultural runoff.

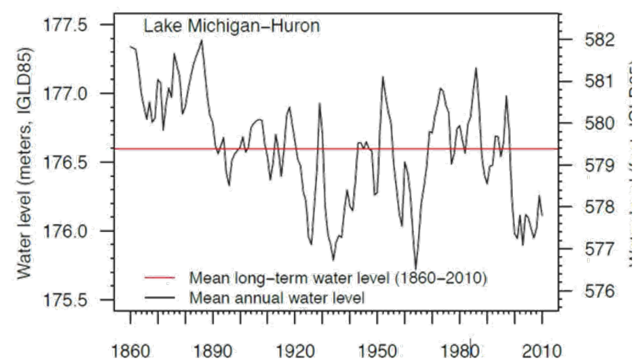


Figure 115 Lake Michigan Yearly Average Water Levels 1860-2010

(Source: NOAA Great Lakes Environmental Research Laboratory, 2011)

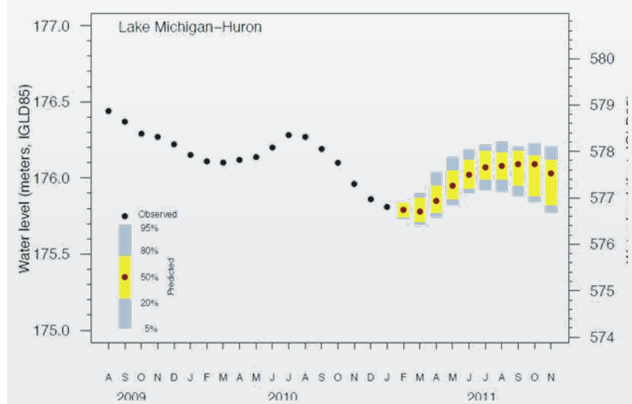


Figure 116 Lake Michigan Forecasting Water Levels for 2011

(Source: NOAA Great Lakes Environmental Research Laboratory, 2011)

Prioritized Climate Adaptation Efforts

To mitigate anticipated climate impacts, St. Joseph, Benton Harbor, and Berrien County should focus on land use planning and infrastructure investments. Local planning documents, such as the Berrien County Master Plan, the County Drain Commission Report, and the Watershed Management Plan have already identified several promising mitigation strategies. Therefore, mitigation may hinge on maintaining the funding and political will necessary to implement mitigation strategies.

Berrien County's Watershed Management Plan identified several Best Management Practices to reduce soil erosion and stormwater runoff. Green roofs, rain gardens, and retention basins can improve onsite stormwater management. Wetlands restoration can help remove suspended solids, chemical and bacterial pollutants, and improve hydrologic flow. In addition, vegetative buffers around vulnerable rivers and lakes can reduce impervious surface runoff and nutrient loading, and prevent soil erosion. Regular inspections of septic tanks can help reduce groundwater contamination. Public education and the creation of a community hotline could aid in the identification and prosecution of illicit discharges of untreated water.

The reduction of nonpoint source pollution, particularly from agriculture, will be particularly important to ensuring regional water quality. Several strategies should be considered. Animal waste, particularly from cattle and pigs, has contributed to elevated E. coli levels in the St. Joseph River. Fencing around nearby water bodies could not only reduce animal waste pollution, but also protect river banks and vegetative buffers from trampling. Manure can be stored in agriculture waste storage facilities before it is applied to fields. In addition, native grasses and legumes can be planted around crops to prevent pesticides and fertilizers from leaching into nearby streams.

Vulnerable Populations

To determine the distribution of vulnerable populations in St. Joseph and Benton Harbor, we mapped each city at the block group-level according to the following criteria:

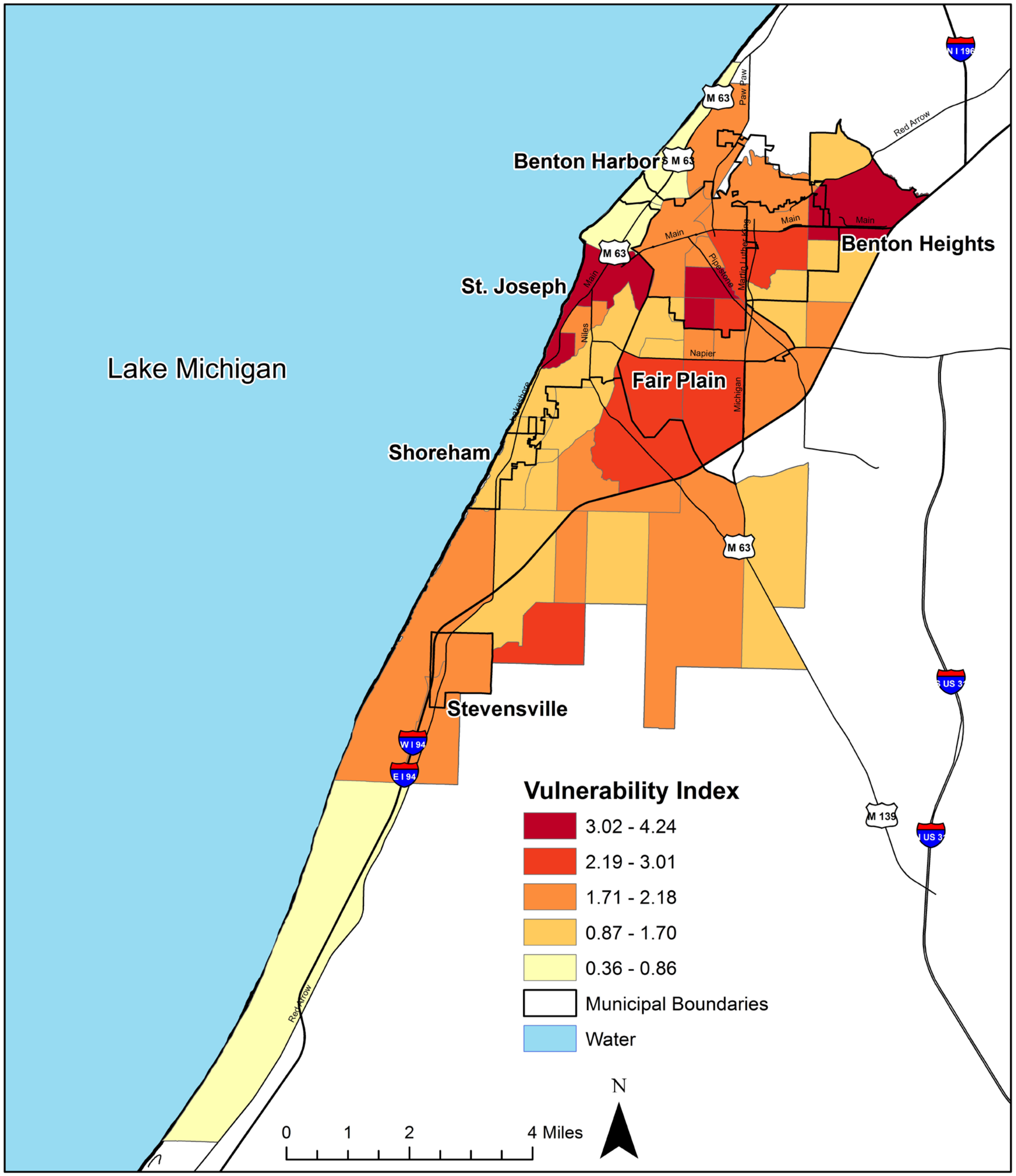
- •Percent of population under 18 or over 65
- •Percent owner-occupied housing
- •Median housing value
- •Population density
- •Percent female
- •Percent nonwhite

We then overlaid a FEMA flood map to assess how flooding may affect each city's most vulnerable populations. For a further discussion of the methodology that we used to construct this index, see Appendix E.

While vulnerable populations are located throughout St. Joseph and Benton Harbor, the largest clusters of vulnerable groups are in downtown St. Joseph and in Benton Harbor/ Benton Heights (Figure 117). These clusters are vulnerable for different reasons. In Benton Harbor, vulnerability is related to low housing values, a large non-white population, and a high percentage of residents under 18. In St. Joseph, vulnerability is related to high population density, high female population, and a high percentage of residents over 65. In Benton Harbor, vulnerable populations are generally not located in high-risk flood zones. In St. Joseph however, there is an elderly, largely female population that is exposed to flooding risk.

While flooding and other natural disasters are not limited to areas that rate highly on the vulnerability index, it is important to give special attention to those areas that are socially vulnerable. These populations are likely to have fewer resources available to respond to extreme climate-related events. It is important to identify the most vulnerable areas with at-risk populations and ensure that they have proper infrastructure and support to cope and adapt to a changing climate and related weather conditions.

Figure 117 Distribution of Vulnerable Population, St. Joseph/Benton Harbor, MI Area by Census Block Group (2000)



Source: Census 2000, ESRI Tiger Line Data

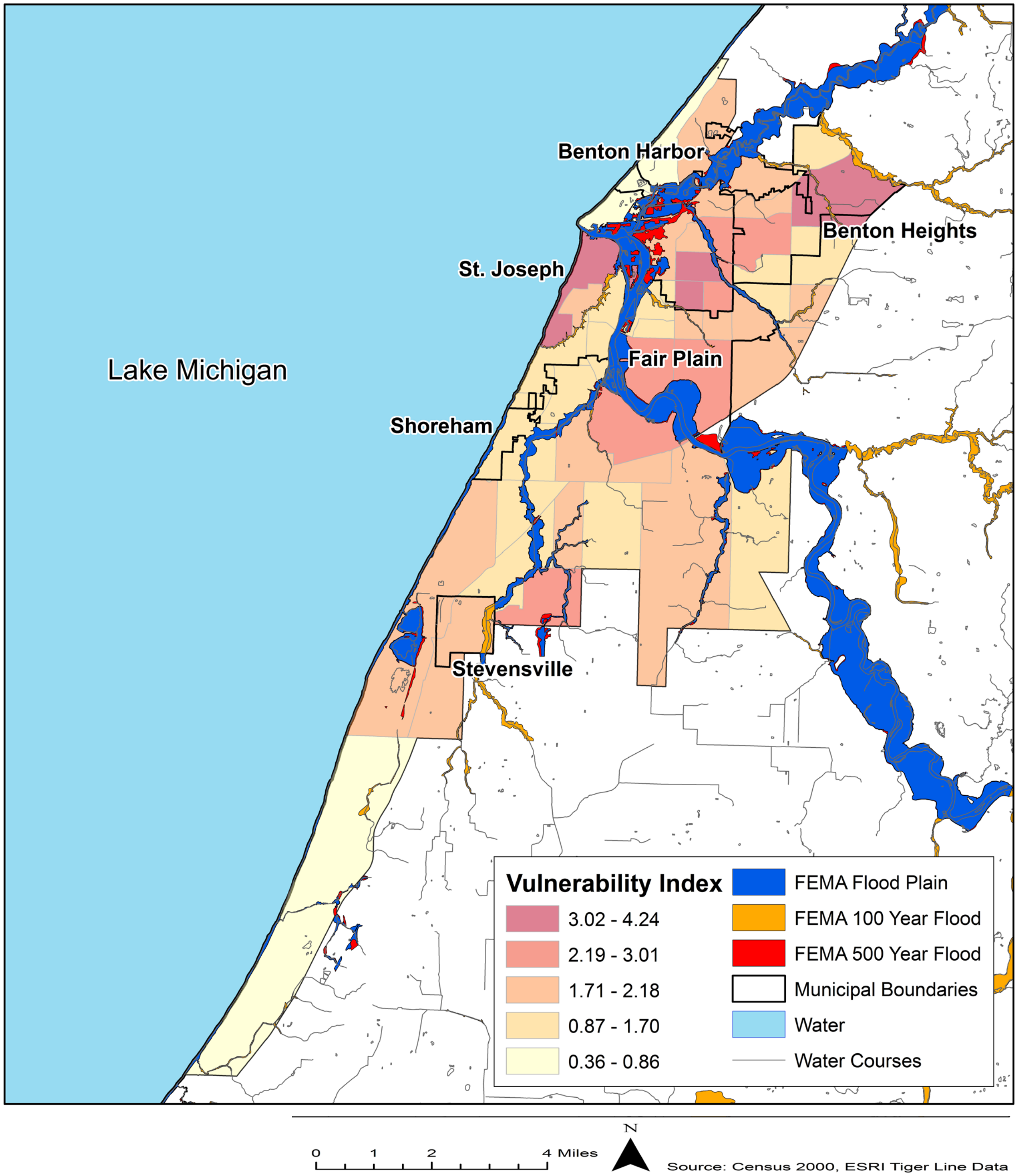


Figure 118 500 Year Flood Impacts on Vulnerable Populations, St. Joseph/Benton Harbor, MI Area by Census Block Group (2000)

6.3 Case Study Comparison

We chose Marquette and St. Joseph-Benton Harbor as our case study cities because they face disparate economic, demographic, and ecological challenges. In this section, we review these differences and how they affect each city's response to the common challenge of a changing climate.

As discussed in section 2, the Great Lakes region includes widely varying ecological and climatic zones. Marquette and St. Joseph-Benton Harbor, located in the Upper Peninsula and far southwest Michigan, respectively, represent this diversity. Marquette features long winters with significant snowfall. Its topography is rolling with widely varying soil types. Winters in St. Joe-Benton Harbor are milder and the topography is generally flat.

Marquette is a demographically homogenous community, with a population that is over 90% white. From 2000 to 2010 it grew by 3%. It is also relatively prosperous, with significant institutional and financial capacity to implement adaptation strategies. St. Joseph and Benton Harbor are more heterogenous. Located on either side of the St. Joseph River, the cities are divided along racial and economic lines, with St. Joseph overwhelming white and middle class, and Benton Harbor over 90% nonwhite and poor. Benton Harbor is under emergency financial management, making it difficult for the city to maintain existing infrastructure, let alone invest in climate adaptation projects. As a result, adaptation in St. Joseph-Benton Harbor will need to occur through regional, or at least county-wide cooperation.

Despite these differences, Marquette and St. Joseph-Benton Harbor face common climate-related challenges. Stormwater runoff from impervious surfaces is a concern in both communities, especially near sensitive waterways and wetlands. Planning documents in both communities acknowledge the need to reign in low-density, car-dependent development in favor of more compact development that puts less pressure on surrounding ecosystems. In addition, both communities recognize the impact that climate change could have on local industries such as tourism.

6.4 Lessons Learned

The Great Lakes are a tremendous presence in North America. While each community is tied to the Great Lakes system, the region contains unique climates, waterways, development patterns, and threats that must be addressed by local climate action plans. Climate models must be instituted on a regional scale in order to reflect the diversity of Great Lakes microclimates, cultures, and development patterns.

Great Lakes cities will likely experience an increase in annual average temperatures and a shift in precipitation events due to climate change. To better understand potential climate impacts and their vulnerability to changes, Great Lakes communities must study their local ecology and utilize down-scaled climate models. Some cities have more than enough infrastructure capacity to handle additional storm events, while others are already operating over capacity. Increasing summer temperatures may also place stress on energy grids ill-equipped to handle cooling demands. Climate change impacts and urban vulnerabilities must be studied from a local perspective.

Climate change will exacerbate current environmental problems such as the spread of invasive species and storm water runoff. Wetlands and other land uses will shift, altering the value and importance of land types to certain industries as well as the natural range of flora and fauna. Cities and regions must avoid the fragmentation of natural habitats as floodplains and land cover typologies continue to transform. Similarly, increasing temperatures and powerful storm events will place additional stress on citizens who are unable to adapt to climate change. When identifying vulnerable populations, a number of indices can be used; studies should be performed using a diverse set of indices in order to account for local demographic character. When cities are unable to provide the infrastructure improvements, educational programs, and mitigation techniques necessary to address climate change, they must provide emergency services to the populations affected by flooding, heat stress, and other climate change-related events.

The Great Lakes Mega-region represents an extraordinarily diverse, international economy. Each year, Great Lakes industries and services generate billions of dollars and sustain millions of jobs. Many of the products and jobs of the Great Lakes Region are sensitive to climate changes. Great Lakes communities should further study their relationship with the Great Lakes in order to prepare for climate changes that will affect maritime transportation, tourism, agriculture, manufacturing, and other industries that are dependent on the Great Lakes.

The Great Lakes Region is home to cities of various sizes, demographics, and climates. It is important to consider population projections, financial health, economic strength, and physical boundaries when developing climate mitigation and adaptation plans. Such approaches are often best addressed by cities, although counties or regions may find it beneficial to work with them.

Future Directions

With this project we have provided an overview of the ecology, hydrology, and climate of the Great Lakes. In addition, we have mapped cities, populations, and watersheds that are particularly vulnerable to the impacts of climate change. Due to time and resource limitations, however, we were unable to address several issues related to climate change in the Great Lakes. The following is a list of recommendations for future work, addressed to planners who want to prepare their communities for the impacts of climate change.

Climate

- Assess past extreme weather events in your area. Consider how the distribution of severe rain and snowfall has changed over time.

- Update flood zoning maps to reflect how the frequency of extreme weather events has changed.

- Model future weather events using localized climate models.

Population

- Identify vulnerable populations in your community. Our vulnerability index considered dependent populations, gender, race, and economic factors, but alternative indicators may be more appropriate in your community. Additional indicators may reflect populations with disabilities, and populations that do not have access to a vehicle.

- Develop emergency response plan to protect vulnerable populations in case of severe weather.

Infrastructure

- Indentify infrastructure that is vulnerable to climate change, such as combined sewer systems, dams, bridges, culverts, and the power grid, and incorporate this information into your capital improvement plan.

- Consider how climate adaptation can reinforce other sustainable development practices, such as compact development and green infrastructure.

Climate Adaptation for The Great Lakes

Vulnerability Assessment of Climate Change

Capstone Project
University of Michigan
April 17, 2011

APPENDIX-A Case Studies

Climate Adaptation and Mitigation in Chicago, IL
Climate Adaptation and Mitigation in New York City
Climate Adaptation and Mitigation in New York City
Climate Adaptation and Mitigation in London, UK
Climate Adaptation and Mitigation in Victoria, Austrailia
Climate Change Adaptation Planning in Toronto
Climate Adaptation and Mitigation in Seoul, South Korea

APPENDIX A - CASE STUDIES

Climate Adaptation and Mitigation in Chicago, IL

Overview

Chicago's adaptation plan is called the Chicago Climate Action Plan (CCAP) "Our City, Our Future." It was released in 2008 and was developed by a task force which was appointed by Mayor Richard Daley. The plan determined the challenges, described the sources or greenhouse gas emissions, set goals to reduce emissions and adapt to changes, identified ways to leverage knowledge to improve the economy and quality of life, and outlined concrete achievable goals.

Context

The CCAP plan only briefly mentions the history of Chicago. In its introduction to the report, it mentions the Great Chicago Fire of 1871 and the Great Chicago Fire of 1871 and the Burnham "City Beautiful" plan. The report does not contain information on the biophysical conditions. Omitting the biophysical characteristics of the Chicago region seems to downplay the constructed history of the Lake Michigan shore which was historical a swampy area. Further, the coast was considerably farther inland than the present day location. Perhaps, as they look to "green the future," they prefer to downplay the historical development of the city and the surrounding areas and the way these changes so drastically changed the city's biophysical conditions.

According to the CCAP, in 2005, 36.2 million metric tons of greenhouse gasses in carbon dioxide equivalent units were emitted in Chicago, this was equivalent to 12.7 tons per resident annually. The baseline according to the Kyoto Protocol is 32.3 million metric tons of

Figure 119 Chicago, U.S. Geology.com

Figure 120 Chicago, Illinoi County
Bookatiket.net

greenhouse gasses in carbon dioxide equivalent units. If Chicago's emissions continued in a linear progression, by 2020 the emissions will reach 39.3 million metric tons of greenhouse. If unchecked, Chicago's greenhouse gas emission could increase 35% by 2050.

Anticipated Climate Impacts

The CCAP's states a number of anticipated impacts through 2050. The main concern is temperature rise of 1-1.5 degrees Fahrenheit over the next few decades Also, there is concern over increased "extremely hot days" (temperatures over 100 degrees Fahrenheit) from the average of 2 days in 2008 to as many as 31 days in 2050. This increase in warming would decrease the number of extremely cold days. However, the amount and severity of rain events would increase. Finally, Chicago's native ecosystems are expected to change in the future. Chicago's hardiness zone has already shifted to conditions formally found in central Illinois in 1990.

Impetus for Climate Planning

By implementing recommendations put forth in the CCAP Chicago hopes to be the leader in municipal efforts to curb climate change. As stated numerous times in the report, Chicago hope to lead by example both by making changes at the government level to push private development in the city to follow, and also at the national and world level by showing other cities what is possible. With the ability to control transit infrastructure as well as city codes and ordinances in new construction and land use planning, and higher property values creating smaller dwelling, along with purchasing power, and creation of news, cities are in a unique position to force the adaptation of green technologies.

Plans, Programs, and Partnerships

The CCAP calls for a decrease in CO2 by 80% below the 1990 level by 2050 with the sharpest reductions occurring in the next 12 years. To hit the 80% benchmark, the CCAP aims to have a 25% reduction below 1990 levels by 2020. It aims to reach these goals through changes in the electrical grid, implementation of new development standards, reworking of water collection and reuse, increased recycling, and improvements to the transportation network.

The CCAP sets out a list of ways in which they feel they can meet their goals though a mixture of action, incentives, and regulations. The CCAP plan includes recommendations that transcend the public realm into private businesses and household actions. It sees itself as a city (in total), that together, between the private and public sector, can lead the country and world by example on how others should address climate and CO_2 problems. By doing this, the changes it suggests aren't just changes that a government is able to carry out, but also ideas for how commercial, industrial, and residential parts of the city can help the city as a whole.

Because Chicago does not own/run its own electrical company, the city must work with ComEd to implement incentive and regulation programs to decrease electrical consumption. Specifically, Chicago wants to increase renewable sources and decrease or remove reliance of coal power plants, replacing them with more natural gas plants.

The CCAP has a goal for more LEED certified buildings along with more energy efficient buildings through retrofitting and new construction. Chicago offers a number of incentives for renovations and new buildings and offers appliance trade-ins. Chicago also plans to update the energy code and create new guidelines for renovations that promote energy efficiently when renovating a building. Further, in building construction and renovations, Chicago has made a major push for green roofs to decrease the urban heat island effect. All of the changes they are incentivizing and implementing through regulations are extended to municipal buildings. The CCAP sees the green building movement as a great creator of economic expansion and job creation. The plan looks toward the colleges and trade schools to expand curriculum in green building to educate a workforce able to develop and implement the technologies.

The CCAP calls for more recycling as well as reuse and reduction of waste. Chicago is currently expanding their roadside pickup because recycling doesn't reach all residents. Chicago does look toward recycling or removal of Hydroflourocarbons (HFCs) used in refrigerant units. In their report they claim one ton of HFC release equals 1300 tons of CO2 in atmospheric damage.

The report looks to decrease per capita levels of water use, and also looks toward standards for capturing stormwater runoff onsite in rain gardens or for irrigation, using grey water in buildings for toilet flushing, and creating better systems for dealing with storm water. The city passed a stormwater ordinance requiring large developments to capture the first half-inch of rain on-site. Chicago is trying to keep as much rainwater on site as possible through the use of Green Roofs, permeable pavement, and green alleys. The Cities Green Alley Program had installed 30 at the time of the report with 30 more planned. In the 2010 update, it claimed a 20 percent increase in permeable areas per site on new developments, increasing permeable surface area in the city by 55 acres. Also, it claimed the installation of 120 green alleys resulting in the transformation of 32,000 square feet of impermeable area into permeable. The plan asks homeowners to do their part as well by utilizing rain barrels and installing backup power for sump pumps.

The CCAP has strong outlines for continued improvements, and increased use, of their transportation network as a way that they can impact the amount of CO2 emissions by vehicles. Chicago has seen increased use of their current system and wants to expand the system. Also, it wants to work with surrounding communities to create intercity rail connections. The plan also suggests more bicycle transit as well as creating transit oriented development. Transit oriented development integrates residential and commercial development around rail and public transit hubs to decrease dependency on private vehicles.

Finally, the CCAP looks toward the future, looking to find ways to help the city adapt and work with the climate changes that will happen. The CCAP foresees a time when the plants and animals, currently residing in the city, will no longer be able to survive because the hardiness levels for plants have changed. To deal with this, Chicago is, and wants to continue to, update its plant selection list to keep it up to date with the expected warming temperatures. Chicago also foresees more droughts as well and more intense weather systems and recognizes the need to maintain a stormwater system with sufficient hydraulic capacity to provide effective service.

Much of the CCAP is dependent on outside entities like ComEd, and private building and business owners. Because of this, it looks to regulations and incentives. Major regulations talked about include changing building codes to require better practices for both new construction and renovation. Incentives are a major focus of the Chicago plan. First, because it does not own ComEd, the plan has to use incentives to upgrade the plants they currently run and build renewable electricity. Part of the partnership with ComEd also includes working with them to create incentives for the city as well which includes an appliance trade-in program to provide energy efficient appliances to residents. Other Incentives the city offers are for green roof installation, personal power generation (including wind turbines), retrofitting commercial, industrial and residential buildings with energy efficient updates, promoting green urban development for new construction, and financial/physical help for private owners to install storm water saving devises like rain gardens and rain barrels.

Public Engagement

The Chicago plan is a bottom-up approach where they used city input to create it. A number of times the plan mentions committees and discussion groups that were created to develop the plan and many private and public institutions will need to be involved to implement the plan which would suggest that those institutions participated in the planning process. The CCAP also talks of the need for support from a multitude of groups including religious groups to implement the plan.

Lessons Learned

The CCAP is asking a lot from its residents in implementing the plan. It is questionable if the goals they are looking for will ever be reached. An 80% decrease in emissions by 2050 is important, and calling for most of those changed by 2012 is a great start but there is no requirement, only goals, for achieving those levels. Also, for each section, it lists the possible decrease that will be created; but it gives no solid evidence on how those numbers were calculated. The scientific community is asking for much greater reduction goals for the world as a whole, and cities like Chicago will most likely have to do more than their fair share to reach them. Due to this, the CCAP may not go far enough to create a truly obtainable and meaningful goal to help future climate change.

References

Chicago Context Image One, http://geology.com/satellite/cities/chicago-satellite-image.shtml (March 30, 2011)

Chicago Context Image Two, http://www.bookaticket.net/holidays/chicago.html (March 30, 2011)

Chicago Climate Action Plan: Our City. Our Future, http://www.chicagoclimateaction.org/ (March 30, 2011)

Chicago Climate Action Plant: Our City. Our Future, Progress Report: First Two Years, http://www.chicagoclimateaction.org/ (March 30, 2011)

Additional Chart

The Following chart gives a synopsis of the Chicago Climate Action Plan. It breaks the plan into the five strategies the plan addresses. In the first column you will see the list of actions proposed for that strategy. In the second column is the Initiatives laid out in the original (2008) plan. Finally, in the third column are the initiatives which are stated in the Two Year Progress Report which was published in 2010. The new initiatives (not in the 2008 report) in the 2010 report are shown in bold.

Figure 121 Chicago Climate Action Plan

Chicago Climate Action Plan		
CCAP Strategies	**2008 Initiatives (original plan)**	**2010 Initiatives (two year update)**
Energy Efficient Buildings		
1) Retrofit Commercial and Industrial Buildings	Saving Energy from bungalow to skyscraper – provides financing for retrofitting building and homes	Residential retrofits – 12 fold growth in residential energy efficient solutions
2) Retrofit Residential Buildings	Making appliances work for use – ComEd funded new appliance trade-in program.	Richard J Daley Center – retrofit the building to become eligible for EnergyStar certification
3) Trade in Appliances	Using water wisely – water main replacement effort my city	Making appliances work for us – ComEd and City initiated Smart Ideas for Your Home Program
4) Conserve Water	Streamline resources – making technical help and financing easier to access	**Phase two of the project – teaming with the Clinton Climate Initiative**
5) Update City Energy Code	Policies that promise change – simplifying code, requiring renovations to meet standards in green building	Using water wisely – making water saving changes to city owned buildings
6) Establish New Guidelines for Renovations	Green roofs, green streets – increase green roof installations and plant one million trees by 2020	**MeterSave program – helps homeowners track water use**
7) Cool with Trees and Green Roofs	Small steps, big gains – working with homeowners for small changes, installing CFLs and limiting water use	**Policies that promote change – All municipal building must meet LEED silver certification, new building code requiring more efficient building and expedited permits for sustainable projects**
8) Take Easy Steps		

Clean and Renewable Energy Sources		
1) Upgrade Power Plants	New ways to power the city – replace four coal power plants with renewable energy	**New ways to power the city – 14 wind companies have setup headquarters in Chicago**
2) Improve Power Plant Efficiency	Distributed solutions – replacing large coal power plants with high efficiency onsite power plants	Chicago Park District – now uses 25% renewable energy resources, installed solar wind lighting
3) Build Renewable Electricity	Household-scale solutions – installation of small scale power production systems at the homeowner level	Rosa Parks Apartments – geothermal heating and cooling, sloar thermal water heaters, renewable water resources, energy saving measures, bamboo flooring all installed in all apartments
4) Increase Distributed Generation		Exelon City Solar Plant – photovoltaic power plant installed on 41 acre brownfield site
5) Promote Household Renewable Power		**Smaller Scale pilots to test large scale implementation – Chicago Public Schools purchasing 20% of electricity from renewable systems**
		Distributed solutions – grants for installation of ground source heat pumps

Improve Transportation Options		
1) Invest More in Transit	Public transit solutions – increase ridership by 30% by infrastructure investment	**CTA Hybrid Bus Fleet – introduction of 228 hybrid buses into fleet**
2) Expand Transit Incentives	Developing communities around a hub – promote transit oriented development	**CTA Bus Tracker – installation of GPS tracking software and internet based mapping for ease of service**
3) Promote Transit Oriented Development	Walking, biking, and car sharing boost walking and biking trips to one million a year through implementation of Bike 2015 Plan and Chicago Pedestrian Plan	Regional transportation – continuous implementation of CREATE plan
4) Make Walking and Biking Easier	Fuel the future – efficiently – support municipal vehicle transition to biofuels and hybrids	**Fueling the future efficiently – use $15 million grant to implement alternative fuel infrastructure**
5) Car Share and Carpool	Regional transportation – implement the Chicago Region Environmental and Transportation Efficiency(CREATE) plan to promote energy efficient regional transportation, altering airport systems and limiting bottlenecks in transportation system	Municipal Alternative Fuel Use – 240,000 gallons of biodiesel used in municipal vehicles in 2009
6) Improve Fleet Efficiency		**Pedestrian Program – work with the City Safe Streets for Chicago program and Mayor's Pedestrian Advisory Council continuing to build public awareness to increase walking**
7) Achieve Higher Fuel Efficiency Standards		Biking – continuous implementation of Bike 2015 Plan
8) Switch to Cleaner Fuels		
9) Support Intercity Rail		
10) Improve Freight Movement		

Reduce Waste & Industrial Pollution		
1) Reduce, Reuse, and Recycle	HFCs: Recovering a potent greenhouse gas – The city will work to create a program to deter and recycle HFC emitting appliances	**Reducing waste through policy – intergovernmental agreement with the Illinois Environmental Protection Agency to reuse soil and rubble**
2) Shift to Alternative Refrigerants	Using green infrastructure – capture and reuse of stormwater in sites	
3) Capture Storm Water on Site		

Adaptation		
1) Manage Heat	Update the emergency response plan	Managing Stormwater – development of a stormwater management ordinance has resulted in 20% increase in permeable pavement, installation of 120 green alleys
2) Pursue Innovative Cooling	Create new flood zone maps - take into consideration expect climate changes	Managing Heat – develop more green roofs and plant more trees
3) Protect Air Quality	Implement the Green Urban Design – actions include capturing as much rain as possible where it falls, developing green allies, promoting pervious paving and green roofs	**Beyond energy efficiency: trees and green roofs – launched Urban Forest Agenda in 2009, teamed with Chicago Trees Initiative to expand urban forest**
4) Manage Storm Water	Chicago Plant Nursery Stock – update landscape ordinance to accommodate plant that can tolerate the altered climate	**Green urban design implementation – Chicago Plan Commission adopted the Adding Green the Urban Design: A City for Us and Future Generations comprehensive plan to promote green infrastructure**
5) Implement Green Urban Development	Planning Ahead – the city has formed a Green Steering Committee to plan for the possibility of extreme heat and storm events	Planning ahead – created an comprehensive Extreme Weather Operations Plan
6) Preserve our Plants and Trees		**Sewer model – developed a comprehensive trunk sewer model for over 775 miles of combined sewer pipes**
7) Engage the Public		**Sustainable airports – implement the Chicago Department of Aviation's green initiatives and polices**
8) Engage Businesses		
9) Plan for the Future		

Climate Adaptation and Mitigation in New York City

Overview

In April 2007, the New York City Office of Long-Term Planning and Sustainability released PlaNYC, a comprehensive plan to guide the city's growth through 2030. Central components of the plan include immediate steps the city can take to mitigate climate change through reductions in green house gas (GHG) emissions, and long-term planning and development strategies that will enable the city to adapt to a changing climate. After a brief look at New York's demographics and geography, this memo will discuss how New York is planning for climate change through both mitigation and adaptation strategies.

Context

With 19 million residents spread over five boroughs, New York is the largest U.S. city. (U.S. Census 2009). With a GDP of $1.13 trillion in 2005, it is also the richest. (Forbes 2010) And New York is growing. By 2030, the city anticipates that 265,000 additional housing units will be needed to accommodate new residents. (PlaNYC 2007, p. 18)

New York is also a coastal city. The Atlantic Ocean borders Brooklyn and Staten Island to the east. Manhattan and the Bronx are surrounded by the Hudson River to the west and Long Island Sound to the east. Queens is bordered on the north by Long Island Sound and on the south by Rockaway Inlet. Elevations range from zero to 410 feet above sea level. (USGS 2001) As a result, critical city infrastructure such as subway lines, water treatment facilities, energy production and distribution systems, and telecommunication networks are vulnerable to rising sea levels and storm surges. (Map ###)

structure such as subway lines, water treatment facilities, energy production and distribution systems, and telecommunication networks are vulnerable to rising sea levels and storm surges. (Map ###)

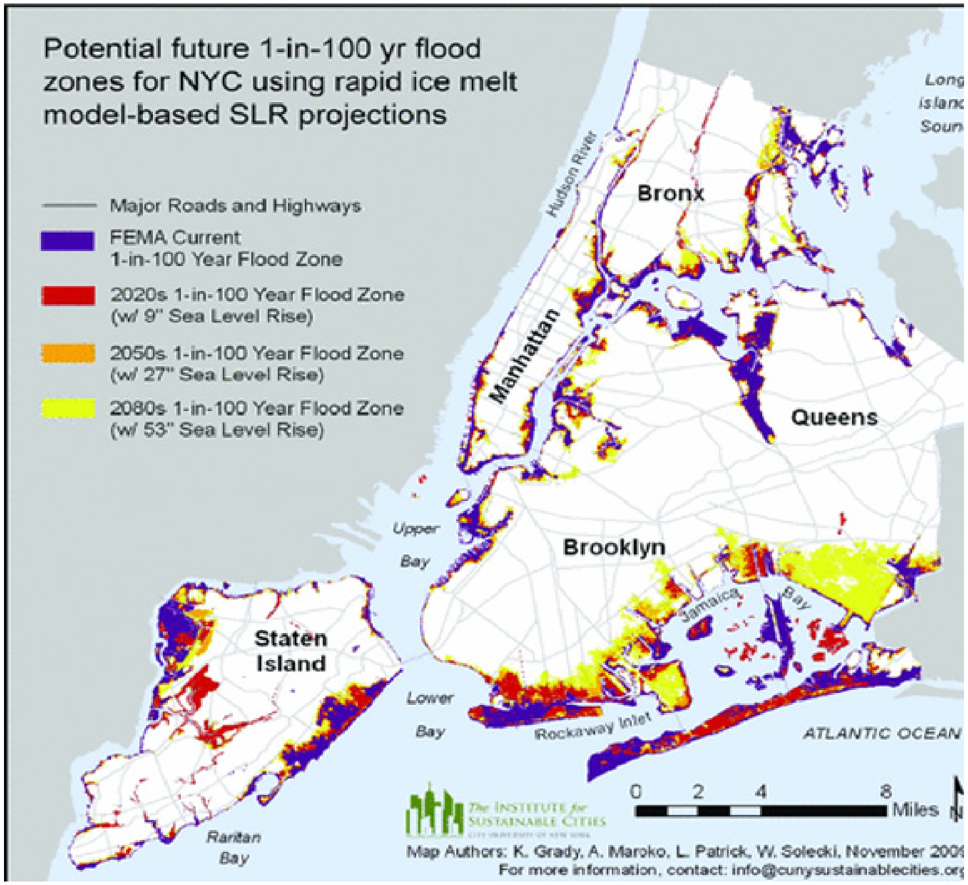


Figure 122 Projected flood plans assuming 9, 27, and 53 inch sea level rises.

As Figure ### shows, average monthly precipitation totals in New York range from 3.23 inches in February to 4.7 inches in May. Average monthly temperatures range from 32.1 °F (0°C) in January to 76.5 °F (24.7°C) in August. (NOAA 2001)

Recent severe weather events have underscored the city's vulnerability. A nor'easter in December 1992 flooded lower Manhattan and severely disrupted the city's transportation infrastructure. On August 8, 2007, flash flooding during the morning commute disrupted service on most of the city's subway lines. And on August 14, 2003, blackouts disrupted the transportation and water supply system for several days. (Rosenzweig and Solecki 2010) These examples underscore not only how an increase in severe weather associated with climate change may threaten individual infrastructure systems in the city, but also how impacts on one system can have a cascading effect on systems throughout the city.

Mitigation

The major mitigation strategy in PlaNYC is to reduce citywide GHG emissions by 30% by 2030. (PlaNYC 2007, p. 136) To meet this goal, the city is targeting emission reductions from new and existing buildings, power generation and distribution facilities, and transportation systems.

Buildings account for 69% of New York City's GHG emissions, compared to 39% nationally (PlaNYC 2007, p. 135) As a result, half of the city's emission reduction, 16.5 million metric tons of GHGs, will come from increased efficiencies in buildings. The plan calls for stricter building codes that require lighter materials, improved insulation, and more efficient heating and cooling systems. The plan also emphasizes that targeting new construction is not enough, because existing buildings will make up 85% of New York's building stock in 2030. Therefore existing building will need to be retrofitted to improve efficiencies.

Improved power generation and distribution will account for 32% of New York's GHG emission reductions. Existing infrastructure upgrades will include more efficient transmission lines and GHG sequestration. In addition, the city plans to diversify its energy system by investing in

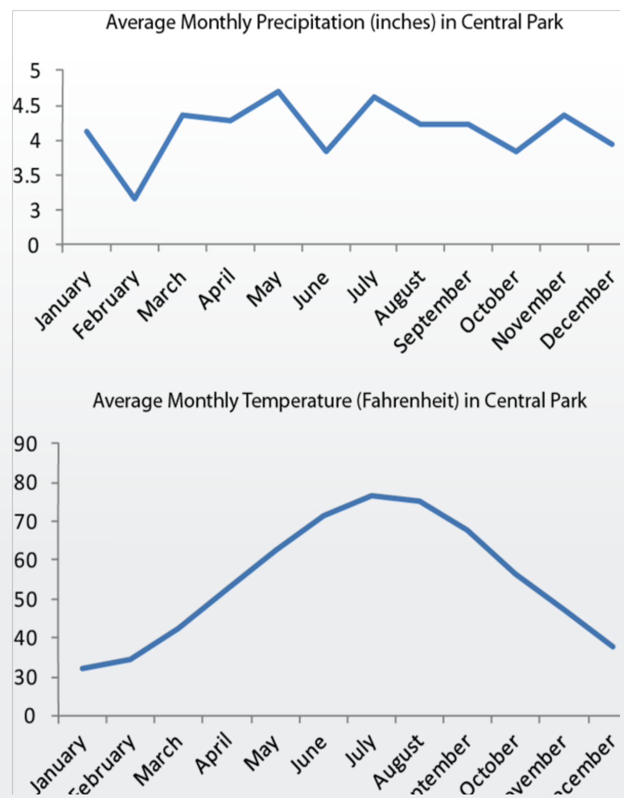


Figure 123 Average Percipitation and Average Temperature in Central Park

sustainable energy technologies, such as wind turbines and solar panels. It estimates that once solar panel technology becomes cost-competitive with competing energy sources, the city can generate 18% of its daytime energy needs through rooftop panels.

Transportation is expected to account for 18% of the city's emission reductions. The main strategy is to reduce car trips in favor of mass transportation. Currently, private vehicles are responsible for 70% of New York's transportation-related GHG emissions, even though they make up only 55% of trips. Meanwhile, mass transit accounts for only 11.5% of emissions. In addition to expanding the transit system, the city aims to improve the efficiency of automobiles themselves by sourcing more efficient vehicles for city-owned fleets. (PlaNYC 2007, p. 136)

Adaptation

In August 2008 Mayor Bloomberg established the New York City Climate Change Adaptation Task Force to assess the risks that climate change poses to the city's major infrastructure systems. The city also partnered with Columbia University and the Sunset Park neighborhood to create a standard process to engage vulnerable waterfront neighborhoods.

In 2010 the Task Force published a comprehensive review of the impacts that increases in temperature, precipitation, sea levels, and wind speeds would likely have on New York's energy, transportation, water/waste treatment, and communication infrastructure. Among the Task Force's recommendations was the adoption of Climate Protection Levels (CPLs), or design standards, land use regulations, and best practices that reflect the impact that climate change will have on critical infrastructure. To identify areas in need of CPLs, the Task Force

1) Developed regional climate models

2) Identified potential hazards, such as flooding or increased temperatures

3) Interviewed the operators and regulators of infrastructure to identify potential climate

change impacts

4) Reviewed existing design standards and regulations in light of climate projections

5) Recommended the implementation of CPLs as needed. (NPCC 2010, p. 297)

This memo can only briefly summarize the CPL recommendations as they relate to New York's three major climate-related impacts: flooding, heat waves, and high wind conditions. (NPCC Appendix C)

Flooding

The main flooding performance standards are the FEMA-designated 1-in-100-year flood maps and the New York State Department of Environmental Conservation 100-year flood control requirements. Both standards will need to be revised and updated to reflect rising sea levels. Additional modifications to design standards include

• Street grades that accommodate increased storm water conveyance

• Impervious surface regulations for new developments that reflect increased flooding risks

• Possible restrictions on the use of basement and ground floor space, including the location of generators and mechanical and safety equipment

Heat Waves

The NPCC defines heat waves as three consecutive days with maximum temperatures above 90° F. Under the NPCC regional climate models, heat waves in New York will increase in frequency and duration as a result of climate change. To adapt, the Task Force recommends that the city

- Increase the interior air cooling standards for residential buildings
- Assess the reliability of back-up power supply systems
- Update the Office of Emergency Management's Heat Wave Action Plan
- Assess the integrity of building materials under prolonged heat exposure.

Extreme Wind Speeds

As nor'easters and thunderstorms increase in frequency and intensity, so will extreme wind events. New York building codes were updated in 2007 to require new building to withstand a three second wind gust of up to 98 mph. Certain structures, such as radio and cellular transmission towers, have special standards. The Task Force believes these regulations are adequate, but that buildings built under previous codes will need to be retrofitted, if possible, to withstand higher expected wind speeds.

Conclusion

New York City is addressing climate change through both mitigation and adaptation. Reducing GHG emissions is the city's major mitigation strategy. Meanwhile, adaptation planning has proceeded in several steps. The first step involves calculating regional climate models. The second step requires the assessment of vulnerable infrastructure and the review of applicable regulations. Finally, design guidelines and land use policies will need to be updated to reflect projected climate impacts. While PlaNYC also mentions the importance of identifying and engaging vulnerable waterfront neighborhoods and populations, this aspect of the plan was cursory, more aspiration than accomplished fact.

References

NOAA 2001. National Oceanic and Atmospheric Administration. Monthly figures can be accessed at

http://www.erh.noaa.gov/okx/

PlaNYC (2007) A Greener, Greater New York. Can be accessed at http://www.nyc.gov/html/planyc2030/html/home/home.shtml

USGS (2001) Elevations and Distances in the United States. Can be access at

http://egsc.usgs.gov/isb/pubs/booklets/elvadist/elvadist.html

Zumbrun, Joshua (2008) World's Most Economically Powerful Cities in Forbes. Can be access at

http://www.forbes.com/2008/07/15/economic-growth-gdp-biz-cx_jz_0715powercities.html

Rosenzweig, Cynthia and William Solecki (2010) New York City adaptation in context. Annals of the New York Academy of Sciences, Volume 1196.

NPCC (2010) New York Panel on Climate Change. Annals of the New York Academy of Sciences, Volume 1196.

Climate Adaptation and Mitigation in Seattle, WA

Overview

King County and Seattle, WA have begun researching and instituting climate adaptation strategies. The King County Climate Guide and the Seattle Climate Action Plan offer complimentary strategies for addressing rising water levels, reduced snowpack, increased precipitation events, and other potential effects of climate change. Collaboration between county and local officials has been instrumental in the implementation of climate adaptation strategies.

Context

Seattle is located in King County, Washington. King County is 2,134 sq. mi. in area and has a population of 1.93 million, an increase of 11.2% since 2000 (U.S. Census 1). Seattle has a population of 608,660, an increase of 8% since 2000 (U.S. Census 1) and accounts for 31% of King County's population. The county has a wide range of landforms with farmland and the Cascade Mountains to the east and urban coastline found to the west (Climate Impacts Group 10). Downtown Seattle is located at sea level on the shores of the Puget Sound and is connected to the Pacific Ocean by the Strait of Juan de Fuca.

Anticipated Climate Impacts

King County and Seattle lie in a "convergence zone" where hilly terrain meets the Puget Sound. This zone is characterized by steady, misty rainfall. Seattle receives around 37 inches of precipitation each year, with most of the rainfall occurring during winter months (Local Weather 1). Seattle's climate is quite mild, with winter and summer temperatures only occasionally reaching the extremes characteristic of other U.S. cities (Local Weather 1). King County anticipates temperature increases of 1.4F – 4.6F by 2040. Summers will experience slightly more warming than winters. Additionally, there will likely be a slight increase in precipitation of between -4 – 9% by 2040. Slightly more precipitation is expected to fall in the winter while less will fall in the summer (Climate Impacts Group 38). Additional precipitation in the winter may cause flood events, while drier summers could produce extended droughts. Mountain snowpack will be reduced while coastal and freshwater river systems will experience increased flooding (Climate Impacts Group v).

Loss of snow pack may adversely affect drinking water supplies and hydroelectricity operations. 88% of Seattle's electricity is produced by

Figure 124 Location of Seattle and King County, Washington

Figure 125 Shorelines being studied as part of Seattle's Shoreline Master Program

hydroelectric dams (Lange 1). Seattle Public Utilities anticipates a 9-21% reduction in water supply by 2050 and a 2-7% increase in peak demand as the city's population grows (Climate Change Impacts). While local sea level changes are difficult to predict, it's anticipated that Seattle will experience a sea level rise of up to 1.3 ft. by 2050 (Seattle Climate Action Plan 33).

Impetus for Climate Planning

The King County climate guide references internationally recognized data that establishes climate change as a real threat already in motion. Although significant reduction in greenhouse gases is possible through a number of processes, stabilization or reversal of climate change is unlikely in the near future. Greenhouse Gas concentrations and average temperatures are expected to rise for the foreseeable future and will have largely negative economic consequences (Climate Impacts Group 25). Given these predictions, King County and Seattle recognize the need for adaptation and mitigation strategies to be established as soon as possible.

Plans, Programs, and Partnerships

The King County climate guide recommends a proactive approach to climate adaptation. Localities, regions, and states can be more proactive than the federal government because climate adaptation requires a thorough understanding of local risks and needs. While federal assistance is beneficial, it is not always efficient or precise. Additionally, proactive policies are more effective and prevent the human and ecological crises that climate change will induce. The International Council on Local Environmental Initiatives (AKA Local Governments for Sustainability – ICLEI) collaborated with The University of Washington and King County in order to publish the climate guide. (Climate Impacts Group vi). This collaboration was an integral to the emergence of a climate adaptation plan.

The King County climate guide outlines five milestones for climate adaptation (Climate Impacts Group 7):

1) Initiate climate resiliency effort by building support and studying the scope of climate change impacts

2) Perform a climate resiliency study based on vulnerability and risk assessment

3) Set preparedness goals and develop preparedness plans

4) Implement plan

5) Measure progress and update the plan as needed

Similar to the King County climate guide, the Seattle Climate Action Plan (CAP) highlights 18 “action plans” for reducing greenhouse gas emissions in the city. While the CAP deals mostly with emissions reduction and mitigation, it does outline a climate adaptation list focused on Cascade Mountains hydrology predictions. The areas of interest include: hydroelectricity, storm water management, urban forestry, building codes, heat spells, and sea level rise. Research into these areas is on-going and an in-depth analysis has not been released (Seattle Climate Action Plan 33).

In Seattle, land use zoning along flood zones is being altered in order to accommodate rising sea levels. A draft Shoreline Master Program was completed in February, 2011, and is currently available for public review. The Shoreline Master Program outlines preferred shoreline uses such as recreation, port facilities, and single family residences that are consistent with environmental protection regulations (Shoreline Master Program 1). The plan will be likely be approved in the spring or summer of 2011.

Continued research is also being completed by Seattle Public Utilities (SPU). SPU is looking at the potential for an increase in precipitation intensity and the necessary upgrades to sewer and drainage systems such increases would require. Their sea level rise research will be used to inform asset management planning. Additionally, SPU is researching climate change’s effect on drinking water quality, surface water quality, aquatic and terrestrial species, forest health, and the frequency of forest fires in the western Cascades (Climate Change Impacts 1).

Public Engagement

Seattle citizens have been receptive to climate adaptation and are doing their part to reduce carbon emissions. Despite continued population growth, Seattle is actually seeing a decline in total carbon emissions (Climate Change Impacts 2). Perhaps most important is the fact that Seattle has worked with The University of Washington and King County in order to develop carbon emission reduction plans and adaptation guidelines.

Actions and Implementation

SPU anticipates a 24 million gallon/day reduction in water supply by 2040. Despite full confidence in meeting water supply needs at the current growth rate, SPU plans to address the risk of major snow melt loss by reducing water usage by 15 million gallons/day by 2030 (Climate Change Impacts 12). Without investing in infrastructure expansion, adjustment of reservoir levels has helped reach this goal by creating new storage capacity (Silberg 1).

When making capital investments, creating land use policies and plans, or developing new facilities, city departments have begun using sea level rise scenario maps. The maps highlight areas of the city vulnerable to climate change (Climate Change Impacts 12). Unfortunately, these maps are not readily available to the public.

Seattle's Alaskan Way seawall is one example of aging infrastructure that will soon be replaced. The height of the new structure will accommodate at least an 11-inch rise in sea levels and will be based on the best scientific climate data when the wall is built (Young 1). King County has also initiated improvements to infrastructure. The Snoqualmie River Tolt Bridge was replaced with longer spans and an increased capacity for high flows and major flooding events. Additionally, 57 county bridges are planned to be replaced with wider span structures (Flood Protection 1). King County's Wastewater Treatment Division studies potential climate change impacts on county storm and sewer systems but has found a low risk to the systems; in time, extreme storm events may flood some systems (Wolf 2).

In April, 2007, the King County Flood Control District was established. The district captures about $32 million per year from an additional property tax assessment. The fund is used to address a backlog of maintenance and repairs to levees, acquire floodplain properties, and to improve countywide flood warning and flood prediction capacity (Wolf 2). Over ten years, the flood control program will be allocated $335 million. 500 levees will be repaired or upgraded in order to protect 65,000 jobs and a $3.7 billion industry that is vulnerable to increased flood events (Hertsgaard 2). In 2008, the county purchased homes and properties in the Cedar Grove Mobile Home Park along the Snoqualmie River. Residents were relocated away from the property which is subject to extreme flooding events (Flood Protection 1).

Lessons learned

Seattle and King County offer several important lessons in climate change adaptation. First, the city and county have done an excellent job researching the vulnerabilities of the region. While many of the city and county departments are still busy assessing vulnerabilities and developing long-term plans to address the risks, several programs have already been implemented. Second, King County and Seattle have been national leaders in climate adaptation in large part because they've collaborated with each other and with other institutions such as The University of Washington. Climate risks are rarely, if ever, limited to a single municipality. Shared infrastructure and resources are common between cities and counties and are a good starting point for climate adaptation. Cities and counties within the Great Lakes Region will likely face similar risks and would do well to follow the King County and Seattle guides to climate adaptation.

References

Climate change: Impacts assessment (n.d.). In Seattle Public Utilities. Retrieved March 13, 2011, from http://www.seattle.gov/util/About_SPU/Management/SPU_&_the_Environment/ClimateChange/ImpactsAssessment/

Climate Impacts Group, et al. Preparing for climate change: A guidebook for local, regional, and state governments. . Retrieved March 9, 2011

Flood protection capital improvement projects (n.d.). In King County. Retrieved March 15, 2011, from http://green.kingcounty.gov/flood-cip-map/default.aspx

Hertsgaard, M. (2011, January 25). Why Seattle will stay dry when your city floods. Mother Jones. Retrieved March 14, 2011, from http://motherjones.com/environment/2011/01/why-seattle-will-stay-dry-when-your-city-floods?page=2

Lange, L. (2010, January 20). Garbage power: Seattle touts renewable energy source. Seattle Post-Intelligencer. Retrieved April 4, 2011, from http://www.seattlepi.com/local/article/Garbage-power-Seattle-touts-renewable-energy-881941.php

Local weather and climate (n.d.). In City of Seattle. Retrieved April 1, 2011, from http://www.cityofseattle.net/html/visitor/weather.htm

Seattle climate action plan (2006, September). Retrieved March 9, 2011, from http://www.seattle.gov/archive/climate/

Shoreline master program (2011, February 23). Seattle Department of Planning and Development. Retrieved March 14, 2011.

Shoreline master program (2011, February 23). Seattle Department of Planning and Development. Retrieved March 14, 2011.

Silberg, B. (2010, November 16). A tale of two cities. NASA Climate Change. Retrieved March 10, 2011, from http://climate.nasa.gov/news/index.cfm?NewsID=441

"U.S. census bureau delivers Washington's 2010 census population totals, including first look at race and hispanic origin data for legislative redistricting." Census 2010. U.S. Census Bureau, 23 Feb. 2011. Web. 13 Mar. 2011. <http://2010.census.gov/news/releases/operations/cb11-cn45.html>.

Wolf, K. (2009, March). Adapting to climate changes: Strategies from King County, Washington. American Planning Association. Retrieved March 10, 2011, from http://www.nerrs.noaa.gov/doc/pdf/training/strategies_king_county.pdf

Young, K. M. (2008, April 1). Seattle's plans for future shaped by climate change still in infancy. Seattle Post-Intelligencer. Retrieved March 9, 2011, from http://www.seattlepi.com/local/357223_port01.html

Climate Adaptation and Mitigation in London, UK

Overview

To prepare for climate change, the Mayor of London and the Greater London Authority (GLA) began drafting a Climate Change Adaptation Strategy (CCAS) in October 2006. The aim of the Mayor's CCAS is "to assess the consequences of climate change on London and to prepare for the impacts of climate change and extreme weather to protect and enhance the quality of life of Londoners" (CCAS). The CCAS has experienced several revisions and updates. The plan was finalized in 2010, after public consultations.

Figure 126The City of London within the Greater London

Source: from C-Map, http://www.cmap.comersis.com/map-436-greater-london-vector-map-with-

Contex

London has a diverse range of people, cultures and religions. According to the UK National Statistics Office, in 2007, approximately 7,900 residents live in the financial center of the global finance, the City of London; 7,556,900 residents live within the Greater London boundary. And among the 7.5 million inhabitants of London, 69.0% were White; 13.3% are of South Asian descent; 10.6% are Black; 3.5% are of mixed race; 1.5% are Chinese; and 2.0% belong to other ethnic group (Neighborhood Statistics).

London experienced severe climate changes in the past decades. From 1961 to 2006, seasonal rainfall decreased by 16% in summer and increased to 22% in winter. More frequent high temperatures have caused significant decreases in soil moisture content in summer. The annual mean temperature has increased by 35°F (1.7°C). Sea levels near London have been rising at a rate of 1mm per year over the 20th century. In 2006, climate changes peaked in July. The temperature on board buses exceeded 122°F (50°C), threatening the public health; in September, a heavy rainfall caused signal failures, with commuters stranded and roads under water. Meanwhile, London suffered its worst drought in 70 years, which caused millions of economic loss and led to a spate of fires.

According to the place-based vulnerability assessment in the CCSA, London is under high risks of flooding and overheating, and under medium risks of drought. The baseline of flooding is created based on the probability of a flood occurring: more than 1.3% is as significant; between 1.3% and 0.5% is as moderate; 0.5% or less is as low. The maximum baseline of the temperature is 69°F (20.5°C), and the maximum baseline of rainfall between 1961 and 1990 is 55mm/month. The drought is measured by water supply-demand balance. It ranges from the surplus (more than 20MM L/day) to the deficit (less than 20MM L/day). And the balance scope is between 0.99 above the zero point and 0.99 below the zero point. The UK Climate Projections released in 2009 reports that the climate changes will continue.

Anticipated Climate Impacts

The most significant climate change impacts in London will be flooding, drought, overheating and the cross-cutting issues of health, environment, economy and infrastructure. According to the UK Climate Projections 2009, the anticipated impacts on London are described in the following table:

Impetus for Climate Planning

The mission to address the impacts of climate changes in London is urgent. The GLA Act charges the Mayor with a 'climate change duty', which requires him/her to assess the consequences of climate changes and to prepare a CCAS that outlines how to work with partners to manage the impacts. Under the Act, the Mayor must ensure that all GLA plans and strategies consider adapting to, and mitigating further, climate change; they must also prepare a Climate Change Mitigation and Energy Strategy to reduce GHG emissions.

Rising temperatures	• Summers will be warmer, with the average summer day being 37°F (2.7°C) warmer and very hot days 44°F (6.5°C) warmer than the baseline average. By the end of the century the hottest day of the year could be 50°F (10°C) hotter than the hottest day in 2009. • Winters will be warmer, with the average winter day being 36.5°F (2.2°C) warmer and very warm winter day 38°F (3.5°C) above the baseline
More seasonal Rainfall	• Summers will be drier, with the average summer 19 % drier and the driest summer 39 % drier than the baseline average. • Winters will be wetter, with the average winter 14 % wetter and the wettest winter 33 % wetter than the baseline average.
Tidal Surges	• Tidal surges are not projected to increase in frequency, though the height of a one-in-fifty-year tidal surge is projected to increase by up to 70 cms by the end of the century.
Sea level rise	• Sea levels are projected to rise by up to 90cms by the end of the century. An extreme projection of a 2-meter increase has been generated using the latest ice-sheet modeling published after the IPCC (Intergovernmental Panel on Climate Change) Fourth Assessment report.

Figure 127 UK Climate Projections 2009 for London (2050s medium emissions scenario) Source: Draft Climate Change Adaptation Strategy, 2006

Plans, Programs and Partnerships

The first climate adaptation strategy for London was issued in February 2010. The proposed actions identified a need

1) to increase London residents' understanding of the challenges they face

2) to ensure that they do not increase the risks in the future and that they have emergency plans for when extreme weather events occur.

In order to meet these aims, the draft proposes two strategies:

1) to assess the consequences of climate change on London

2) to prepare for the impacts of climate change and extreme weather to protect and enhance the quality of life of Londoners.

The City of London's Climate Change Adaptation Strategy provides a more detailed overall aim, which is to ensure that the City's assets, services and infrastructure continue to function appropriately in the face of climate change ('Building climate-resilience'). The City of London's Adaptation Strategy, the first of its kind by the UK local authority, aims 1) to identify the priority risks associated with climate change and 2) to propose adaptation measures which are designed to ensure that the city's infrastructure and services adapt to a changing climate.

In addition to the efforts the Mayor of London dedicated to the CCSA, many departments contribute as partners, such as the GLA, Department for Environment, Food and Rural Affairs (DEFRA), Drain London, London Water Group, London Climate Change Partnership, London Development Agency, boroughs, etc. The City of London Corporation is working on their adaptation strategy in partnership with utilities and city service providers in the City, city businesses, city residents, and other public sector bodies.

Public Engagement

The CCAS for London seems to use the top-down approach when the Mayor of London and the GLA initiated it and then updated it with public input. In addition to the previously mentioned partnerships, public consultations were held to improve and finalize the CCAS. The key stages in the development of the CCAS are detailed below:

Actions and Implementation

The CCAS for London suggests that a decision-maker should prioritize efforts based on 1) the scale of the risk / opportunity (considering probability and consequence), 2) the level of uncertainty around the prediction of the event, or degree of change, and 3) the risk attitude of the decision maker (how risk averse he or she is).

The CCAS for London suggests a roadmap to resilience. The roadmap is categorized into four expected impacts caused by climate change on London. Several actions, which have their own timeline to be done by, are responding to each possible impact. The following will present actions already implemented as a part of climate change adaptation strategy as well as actions it recommends.

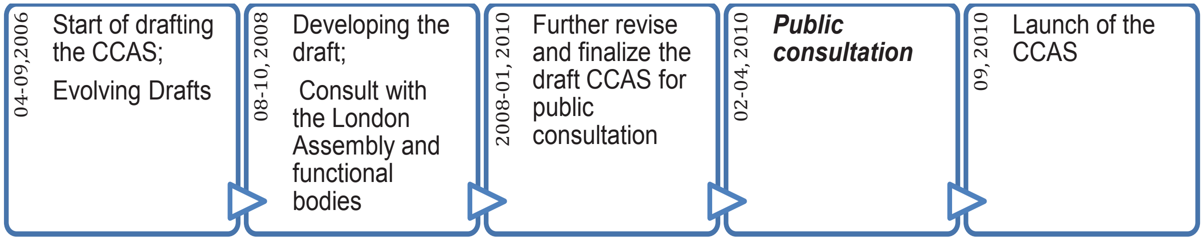


Figure 128 London Climate Adaptation Planning Process

Flooding

The Mayor believes that London should be resilient to all but the most extreme floods and should have robust emergency plans to respond to, and recover quickly from, flooding. In order for London to be resilient to future flooding events, the CCAS established goals, which are

1) to improve their ability to predict and manage flood risk,

2) to prioritize actions to reduce the risk to critical assets and vulnerable communities,

3) to raise individual and community-level awareness and capacity to cope and recover.

To achieve these goals, Drain London Forum plays a significant role in developing a surface water management plan and creating a single flood reporting system with Department for Environment, Food and Rural Affairs (DEFRA). In addition, the city identifies critical assets and vulnerable communities at flood risk and improves drain and gully maintenance program to prioritize actions.

The City of London CCAS addresses some implemented London wide actions, responding to flooding. First of all, the Thames Barrier and associated defenses currently provide a high standard of protection to London and the Thames Estuary, which offer a standard of protection of 0.05% risk of flooding from tidal surge in any one year. The Thames Barrier is a large movable flood barrier, and it is run and maintained by the Environment Agency in UK. The barrier spans 520 meters across the River Thames, and it protects 125 square kilometers of central London from flooding caused by tidal surges. It became operational in 1982 and has 10 steel gates that can be raised into position across the River Thames. When raised, the main gates stand as high as a five-story building and as wide as the opening of Tower Bridge (Environmental Agency, 2011).

In order to cope with storm drainage and surface water flooding, the City of London also requires that new developments demonstrate how they are located, designed and constructed for the climate change expected over their design life. All new developments are set back from flood defenses, such as an embankment or a dike. To help manage sewer overflows as a result of heavy rainfall events, Thames Water is implementing the London Tideway Tunnel project (the Lee and Thames Tunnels), that will substantially reduce the pollution entering the River Thames by capturing sewer overflow before it enters the river and transporting it back to Beckton Sewage Treatment Works for treatment.

The City of London Corporation also provides a practical recommendation to respond to predicted flooding events. These practical actions are 1) to encourage businesses to consider relocating flood-sensitive IT equipment and archives to areas with low risk of flooding, 2) to encourage developers to install sustainable drainage systems and green roofs in targeted flash flood 'hotspots' for new developments, redevelopments or major refurbishments, and 3) to examine a range of incentives to encourage sustainable drainage systems(SuDs) and green roofs.

SuDS have various forms, but most of them resemble nature systems. The primary idea of the system is to imitate natural drainage patterns. Consequently, the system can alleviate surface water runoff, encourage recharge of groundwater, provide amenity and wildlife enhancements, and employpollutant trapping and degradation processes that protect water quality.

Green roofs are also considered a SuDS technique. Vegetated roofs,

1) reduce storm water runoff,

2) reduce urban heat island effect,

3) create natural green spaces in urban areas,

4) reduce energy consumption and fuel costs,

5) benefit biodiversity,

6) reduce air pollution, and

7) extend roof life.

Over recent years the City of London Corporation has encouraged developers to include extensive green roofs in their building designs, and several are now under construction. The City of London Corporation has worked with the British Council for Offices to produce a publication to raise awareness of green roofs.

The mayor promotes the incorporation of SuDS in new developments through plans and policies. The Mayor's Further Alterations to the London Plan states(Policy 4A.5vii) "the use of SuDS should be promoted for development unless there are practical reasons for not doing so..." His Supplementary Planning Guidance on Sustainable Design and Construction considers the use of SuDS measures as the essential standard to reduce water pollution and flooding and gives instructions to approach SuDS. The Checklist for Development requires the developers and their design teams to:

- Carry out a survey to determine which SUDS techniques will be appropriate for use on the site

- Consult with the Environment Agency, that the requirements of the Groundwater Regulations are met

- Demonstrate consideration is given to future maintenance requirements of SUDS including the need, where necessary, for the removal of silt which will be treated as a controlled waste, and that space requirements for this purpose are allowed for in the design

- Ensure that responsibility for maintaining SUDS is clear at the planning application stage

- Consider using permeable paving anywhere that loadings will not cause structural failure

- In developing the drainage plan for the site, ensure that the design standard takes account of climate change and that carriage ways, paths and other features of the site are designed to convey this excess flow safely.

Figure 129 London's Battersea Power Station Green Roof

source: cleanerairforcities.blogspot.com

Drought

The Mayor suggests that London should achieve a sustainable supply and demand balance for water in London by 2030 and should be more robust to drought. In order to meet the Mayor's strategic outcomes, the CCAS established goals, which are

1) to take a strategic view on London's water resources,

2) to reduce the demand for water, and

3) to improve drought response.

Most actions responding to drought events are led by the Mayor of London as well as several agencies, working together around water issues. The primary effort is to reduce the demand for water. To be specific, the Mayor of London will lead an action to improve the energy and water efficiency of up to 1.2 million homes by 2015.

The five-year average of water consumption in London was 161 liters per person per day from 2004/5 to 2008/9. This is a slight decrease from the 163 liters per person per day for the five-year period from 2003/4 to 2007/8. The 2008/9 household water use increased last year from 2006/7 and 2007/8 levels when it was suppressed first by hosepipe restrictions and then by wet weather. In 2008/9, household consumption in London amounts to 1,217 million liters per day or 71% of total consumption. A further 492 million liters per day (29%) is non-household consumption (commercial and industrial water use). However, consumption itself amounts to about 74% of the total 'demand', with 26% leakage (Environmental Agency, 2011)..

The City of London CCAS proposes a water management hierarchy for managing supply and demand in London. From the view of demand, the City pressures on water resources and managing water use through measures such as water metering in homes and flats, reducing the loss of water through better leakage management, and improving the efficiency of water use in residential and commercial properties. In addition, Greywater recycling and rainwater harvesting are also advocated.

From the perspective of supply, developing new water resources for London are under consideration. The UK Government has given Thames Water consent to build a desalinization plant in London. Even though construction of the Upper Thames Reservoir are delayed and reduced in size from 150 million cubic meters to 100 million cubic meters, other resources are also being investigated to secure London's water supply.

The City of London Corporation makes recommendations as practical actions, which are 1) to develop a coordinated and sustained awareness-raising campaign aimed at city businesses, property developers and residents regarding water use and water efficiency, 2) to work with Thames Water Utilities to discuss contingency planning for vital City functions in times of extreme drought, and 3) to encourage developers to design and install drought-resistant landscaping schemes and 'low water gardens' in open spaces that require minimal irrigation.

Overheating

According to the City of London CCAS, increasing temperatures are the most urgent challenge London faces. In response to the issue, the Mayor's vision is to make London a more comfortable city to live, work and play in and to ensure that a robust emergency plan exists for heatwaves. In order to achieve the Mayor's vision, the CCAS for London has goals, which are 1) to improve the understanding of overheating risk and target priority areas, 2) to manage temperatures by increasing green space in the city, 3) to reduce the risk of overheating by providing low-carbon cooling systems, and 4) to ensure that London has a robust heatwave plan. Actions include increasing green space, installing high-end cooling technology, and improving heatwave plans.

The Greater London Authority (GLA) has published research on how to manage the intensification of London's Urban Heat Island and supports the need for more green roofs and street trees. In addition, the Mayor's Air Quality Strategy sets out policies and proposals to reduce air pollution. The London Air Quality Network (LAQN) was formed in 1993 to coordinate and improve air pollution monitoring in London

The City of London Corporation recommends practical actions regarding its residents who might be affected by overheating. In terms of research and monitoring, the actions they recommend are

1) to investigate risks of heat stress to residents of City of London Corporation-owned housing,

2) to identify residents who are most vulnerable to heat stress and ensure that they are regularly visited during heatwaves, and

3) to encourage Open Spaces Department to work with the Emergency Services to undertake an analysis of the relationship between weather conditions and fire risk in open spaces and parks and investigate the prevalence of these conditions now and in the future with climate change.

The City of London Corporation also suggests practical actions, including

1) enhancing biodiversity,

2) requiring Transport for London and tube companies to do everything possible to manage high temperatures on the underground and make the underground environment more comfortable,

3) examining the provision of 'cool' centers during heatwaves and the inclusion of vulnerable people in emergency plans,

4) working with strategic health authorities and primary care trusts to implement the local heatwave plan in the City and to include actions to manage air pollution health risks in these plans, and

5) to build awareness among workers and residents over the wider impacts of high temperatures.

Lessons Learned

Due to many variables of climate change projections, most of the actions that have been implemented contain recognition of uncertainty and an effort to understand risk. Considering the natural variability of the climate and the uncertainty inherent in predictions, decision makers should strongly consider a risk-based approach. The CCAS approach is a good example. It assesses risks by understanding the components of risks, including the probability of an event or change, the consequence of the event or change, and exposure and vulnerability.

The CCAS also says that it is crucial to avoid unsustainable adaptation when creating climate change adaptation strategy. The CCAS states that

> 1) the wider implications of the action should be assessed over the lifetime of the action;
>
> 2) anticipatory adaptation is usually more effective and less costly than retrospective or emergency action.

References

CILT, the National Centre for Language. Retrieved 6 June 2008. Language Spoken in the UK Population.

City of London Corporation. First Published May 2007. Revised and Updated January 2010.Rising to the Challenge - The City of London Climate Change Adaptation Strategy.

City Population. Retrieved 3 March 2009. "The Principal Agglomerations of the World".

Collingwood Environmental Planning, Centre for Research into Environment and Health (CREH). February 2010. Mayor of London's Draft Climate Change Adaptation Strategy Sustainability Appraisal Report.

Demographia. Retrieved 1 April 2009. "Southest England Population by Area from 1891".

Environment Agency. 2011. http://www.environment-agency.gov.uk/homeandleisure/floods/38353.aspx

Greater London Authority. November 2005. "Adapting to climate change: a checklist for development - Guidance on designing developments in a changing climate".

Greater London Authority. May 2006. "Sustainable Design and Construction-The London Plan Supplementary Planning Guidance".

Greater London Authority. September 2006. "Further Alterations to the London Plan (Spatial Development Strategy for Greater London)".

Greater London Authority. February 2010. The draft climate change adaptation strategy for London

Greater London Authority. September 2006. “Further Alterations to the London Plan (Spatial Development Strategy for Greater London)”.

Greater London Authority. February 2010. The draft climate change adaptation strategy for London (Public Consultation Draft).

HM Treasury, 2007. The Stern Review of the economics of climate change.

Neighbourhood Statistics. Office for National Statistics. Retrieved 31 July 2010. "Resident Population Estimates by Ethnic Group (Percentages)"

Office for National Statistics (www.statistics.gov.uk). 21 August 2008. Retrieved 26 January 2009. “T 08: Selected age groups for local authorities in the United Kingdom; estimated resident population; Mid-2007 Population Estimates" (XLS).

Office for National Statistics. Retrieved 6 June 2008. “KS01 Usual resident population: Census 2001, Key Statistics for urban areas"

UK National Statistics Office, 2008

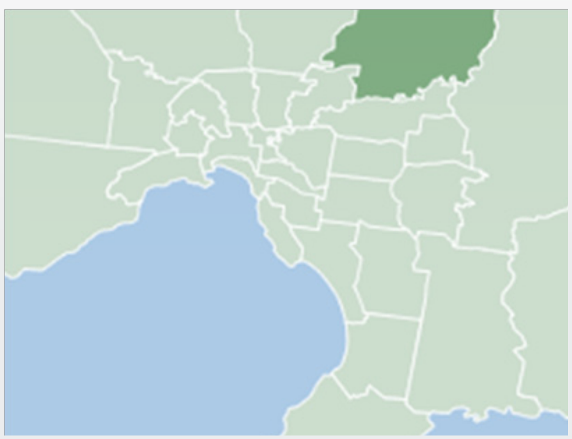


Figure 130 Victoria, Austrailia
Source: Shadbolt

Overview

This report focuses on the Shire of Nillumbik, which is a 431.94 km2 region that is home to approximately 60,623 residents 25 kilometers northeast of Melbourne. It is considered to be a Local Government Area in the state of Victoria (Nillumbik Shire Council, 2011).

Context

The Shire of Nillumbik is home to small and medium sized businesses. Estimates from the Australian Bureau of Statistics indicate that "ninety nine percent of Victoria's business community is made up of small and medium sized businesses (less than 100 employees)" (21). It is comprised of a VERY diverse array of wholesale and retail trade shops with very few manufacturing, and a complete absence of heavy industrial sites (21). Scientists estimate that Nillumbik's industrial and commercial sector accounts for approximately 26.5% of Shire's greenhouse gas emissions. Because most of these are wholesale and retail trade shops, the bulk of the greenhouse gas emissions come from electricity use (21). Although considerable emissions reduction and energy savings can be realized here, "these businesses often don't have the time or skills-set to implement energy efficiencies" (21).

Other major sources of greenhouse gas emissions come from energy use associated with the Shire's residential units and transportation methods. Surprisingly, residential structures relative to other structure types are one of the biggest greenhouse gas emitters within the Shire as it accounts for 41% of the region's total. Space heating, water heating, and use of electric appliances are the most energy intensive activities within the residential sector (25). Transportation accounts for 28% of the region's overall emissions, with 82% of this coming from passenger vehicles (30).

Victoria's dependence on coal power plants for electricity generation is an area of concern. With more stringent greenhouse gas emissions regulations, the state faces serious challenges in meeting future quotas because approximately 70% of the existing plants run on Brown coal, which happen to be the most carbon intensive amongst all of the varieties of coal. Combustion of Brown Coal releases 1.2 tons of CO_2 equivalent per megawatt-hour, while NSW and Queensland

Black Coal release 0.75 tons of CO_2 equivalent per megawatt-hour (28). With a growing population and the ever-increasing reliance on electronics, meeting the state's energy demands while using less carbon intensive sources of fuel to provide power can be an exceedingly difficult goal (28). As a result, 68% of Nillumbik's greenhouse gas emissions in 2006 come from electricity generation and consumption (8).

Anticipated Climate Impacts

Scientific predictions by 2030 for Austrailia

Scientists anticipate a 1^{o}C increase temperature nationwide, leading to "20% more months of drought" and a "25% increase in days of very high or extreme fire danger" (4). Additionally, storm frequency and severity is expected to increase with higher greenhouse gas levels, endangering Australian coastal towns and cities, the Great Barrier Reef, and the Kakadu wetlands. In short, northern Victoria is expected to have a higher likelihood of warming, while Southern Victoria is expecting to see more droughts (4).

Scientific predictions by 2030 for Victoria

For the State of Victoria, scientists anticipate a more arid climate in which average annual temperatures will be 1-2^{o}C higher than averages of 1990. As a result, there will be a greater number of hotter days (35^{o}C and higher), reduced rainfall during the dry seasons, and a drop in surface runoff by 30% or more. Because of excessively dry soils and vegetation, scientists are also expecting a 5% to 40% increase in risk of fire by 2020 relative to 1974 through 2003 rates. In addition, water bodies will experience higher temperatures, altering its natural circulation patterns. Costal regions within Victoria will be subject to higher sea levels. Lastly, there will be greater frequency and severity of storms in the wet season (4-5).

Impetus for Climate Planning

Taking these estimates into account, the Mayor of Nillumbik feels "that it is not what we do tomorrow that counts but what we do today" (3). There is a mounting sense of urgency for action because recent data suggests that the world has met or exceeded the IPCC's worst-case scenario predictions (6). Furthermore, the mayor believes that human activity is highly sensitive to small changes in climate. With major changes anticipated in the near future, the irreversible effects of global warming will ultimately affect everyone and as a result, the need for a collaborated effort at climate stabilization is of top priority (5).

Plans, Programs, and Partnerships

Nillumbik's main goal is to reduce its dependence on fossil fuels and to begin investing further resources into renewable energy programs. By 2015, the Council is expecting a higher percentage of renewable energy options, the establishment of a carbon cap and trade system, and policies that will incentivize research, development and implementation of green technology (9).

In the meantime, the Shire has made efforts at establishing partnerships with like-minded organizations in climate change mitigation. Nillumbik is a part of ICLEI, Cities for Climate Protection (CCP), and the Northern Alliance for Greenhouse Action (NAGA) (7). NAGA also involves neighboring communities such as Banyule, Darebin, Hume, Manningham, Melbourne, Moreland, Whittlesea, and Yarra (8). By 2015, the CCP plan aims to reduce emissions 20% less than those of 1997 levels (7).

Funding for energy efficiency projects will be provided through the Revolving Resource Conservation Fund (RRCF) (7). The following are fundamental principles for the proposed Carbon Management plan (10):

- If emissions can be avoided, then by all means do so
- Make an effort at reducing existing emissions
- Switch to less carbon intensive sources of energy
- Look into carbon offset programs

Proponents of this plan believe that it can be successfully integrated with the existing governmental structure. The new Carbon Management plan should "encourage and inform the community regarding waste minimization, energy reduction and water conservation and reuse through education programs" (12). The new Carbon Management plan ensures greater transparency and community involvement since it calls for annual progress reports, publicly released findings, and mandates public review and input every four years (17). It classifies tasks according to the level of urgency; high priority tasks are to be implemented within 1 to 3 years, medium priority within 3 to 5 years, and low priority measures to be implemented beyond 5 years (18). Oversight of the CCAP will be handled by the Council's environment and planning services group, while the council unit, organization, or consulting agency will have the primary and secondary responsibilities for the Carbon Management plan (13, 18).

Actions and Implementation

On the national level, Australia has made efforts towards environmental protection. In December of 2007, the Australian government incentivized the purchase of solar panels and efficient water tanks by issuing rebates (6). In addition, the Carbon Pollution Reduction Scheme (known as the CPRS) was established to ensure policies and measures were effectively meeting Kyoto requirements (7). Similarly, the state of Victoria has also taken a proactive approach to greenhouse gas mitigation. In 2002, the state of Victoria launched a 3-year program to reduce emissions by looking at numerous sectors and identifying potential areas for improvement (7). By 2006, $200 million was allocated for such measures, which also included various tree planting programs across the region (7).

Dovetailing from the Australian government's goals, the Shire of Nillumbik has taken further steps at climate stabilization. Recently, the community has implemented the highly successful GRO 3-bin waste management system that encourages recycling and proper disposal of various types of waste. Because more trash is being recycled and less is going to the landfills, "Nillumbik residents have decreased their carbon dioxide equivalent greenhouse gas (CO_2-e) emissions by approximately two tonnes per participating household" (3). As a result, Nillumbik has been ranked #1 in waste reduction for the state of Victoria in 2007-2008 (3). Additionally, Council operations have also made dramatic improvements over the past few years. Reports indicate that "greenhouse gas emissions have reduced by approximately 1 per cent since last measured in 1997", with a 44 percent drop in 2008 (7). With such great success, the "Council has committed to reducing energy consumption throughout its operations by 2015" (3).

Future steps

The Shire of Nillumbik has proposed the following action plan that focuses on the following areas for improvement (18):

1. Strategic

   - The Council would like to create greater transparency and ease of access to "community energy data" (20). This should help create a sense of collective ownership and accountability in greenhouse gas mitigation measures.

2. Industrial & Commercial

   - Since Nillumbik is home to many small businesses, the Council would like to establish funding and educational programs to help these enterprises meet emissions standards.

3. Residential

   - Considerable reduction in electricity consumption can be realized through the use of energy efficient appliances and on-site renewable energy sources such as solar panels to help offset usage.

4. Decabonizing energy supply

- Victoria needs to gradually shift away from Brown coal power plants and phase into renewable sources for energy. There are two options available (28):

    i.Coal power plant owners can utilize technological fixes to reduce emissions from their plants. The problem with this approach is that there is no public input, and at the moment plant owners have little incentive to do so.

    ii.Switch over to alternative sources of energy that are more environmentally sustainable. Currently, this is the Council's approach.

5.Transport

- The government is looking at incentives to get private automobile users to switch over to hybrid and electric vehicles, and to invest into renewable fuels R&D and remote connectivity options for work (30).

6.Residual emissions

- The Council would like to purchase carbon offsets through a standardized process such as the Clean Development Mechanism (CDM) (34). The CDM specifies the following conditions:

- 1) Project must be additional, 2) project must be permanent, 3) measurable emission reduction, 4) transparency in information and credit ownership, 5) independent verification of emission;

- Additionally, bioswales, and other vegetative landscapes can be used as a method of biosequestration of carbon (34).

Victoria's adaptation strategies (Department of Sustainability and Environment)

Victoria's Department of Sustainability and Environment along with the Department of Planning and Community Development have allocated $13.5 million dollars to the Future Coast Program. With a growing concern of coastal erosion and flooding, the program focuses "on the physical impacts of sea level rise as a result of climate change" and offers public education on the subject. More importantly, it is intended to provide localities with more effective planning strategies in dealing with flood events. As a result, the state of Victoria is implementing a state-wide assessment throughout its coastal areas. Using digital elevation maps, coastal landform/ geomorphology classification, and sea rise predictions, the most vulnerable places can then be identified and prepared for future flood events.

Additionally, the Department of Sustainability and Environment have also supported the International Tundra Experiment (ITEX). The intention of ITEX is to provide more effective habitat conservation measures in the near future by studying the effects climate change on native flora and fauna in the Victorian alps. Lastly, the Australian government will be allocating a total of $5 million over a five-year timeframe to the Victorian Climate Change Adaptation Research Center (VicCCCAR). VicCCCAR establishes a symbiotic relationship between Australian research universities and the government to address the issues of climate change more effectively.

References

Department of Sustainability and Environment. (2010). Adapting to Climate Change. State Government Victoria: Understanding Climate Change. Retrieved from http://www.climatechange.vic.gov.au/adapting-to-climate-change

Nillumbik Shire Council. (2011). About the Shire of Nillumbik. Retrieved from http://www.nillumbik.vic.gov.au/Page/Page.asp?Page_Id=33

Nillumbik: The Green Wedge Shire. (2010, April). Climate Change Action Plan: 2010-2015. Nillumbik, Victoria, Australia.

Shadbolt, J. (2006). Map of Melbourne's Local Government Areas, Highlighting Shire of Nillumbik [Map]. Retrieved from http://en.wikipedia.org/wiki/File:MelbLGA-Nillumbik.gif

Climate Change Adaptation Planning in Toronto

Overview

The City of Toronto adopted the Climate Change, Clean Air, and Sustainable Energy Action Plan in 2007 to reduce greenhouse gas emissions by 80 percent by 2050. In addition to mitigation strategies, the plan calls on the City to formulate a comprehensive adaptation plan. As a result, the Toronto Environment Office (TEO), a City division, established an Adaptation Steering Group to develop the plan. Ahead of the Storm:

Toronto Environment Office (TEO), a City division, established an Adaptation Steering Group to develop the plan. Ahead of the Storm:

Preparing Toronto for Climate Change, Toronto's guiding document for creating a comprehensive adaptation strategy, was adopted by City Council in 2008 after nearly a year of planning.

Figure 131 Toronto
Source: ESRI Maps & Data

Context

Toronto is situated on Lake Ontario's northwestern shore. The city's humid-continental climate is characterized by warm, humid summers and cold winters. Toronto is generally warmer in the winter and cooler in the summer than surrounding areas due to the moderating effects of Lake Ontario. Annual precipitation and snowfall are about 33 and 52 inches respectively (Environment Canada, 2010).

Toronto is the capital of Ontario and Canada's largest city with more than 2.5 million residents. The metropolitan population exceeds 5 million and is growing rapidly, largely due to immigration. Approximately one-half of the city's residents are immigrants. Toronto is also one of the world's most diverse cities with 1.1 million of its residents belonging to a visible minority population. Statistics Canada projects that by 2017 over 50 percent of the metropolitan area's residents will belong to a visible minority group (Statistics Canada, 2011).

Anticipated climate impacts

Recent years have produced some of Toronto's most severe weather events on record. In 2005, a severe storm resulted in Toronto's most expensive flood, which caused about $500 million in damages to trees, roads, and utilities. Additionally, the storm caused severe erosion of stream banks and flooding in the basements of 4,200 buildings (Toronto Environment Office, 2008; Penney and Dickinson, 2009). The summer of 2005 was also one of the hottest and smoggiest on record, resulting in120 heat-related deaths (Toronto Environment Office, 2008).

Two weeks in January 1999 produced more snowfall than a typical Toronto winter. Snow clearing costs exceeded more than twice the City's yearly snow removal budget. Major snowstorms also occurred in 2001 and 2002, and the winter of 2007-2008 was one of the snowiest on record, causing traffic pile-ups, airport closures, and power outages (Toronto Environment Office, 2008; Penney and Dickinson, 2009).

Due to rising average temperatures, Toronto is expected to experience extreme weather events on a more frequent basis. Toronto will also experience hotter and drier summers, shorter and milder winters, changing precipitation patterns, and declining water levels on Lake

Ontario and other water bodies. Figure ### shows some of the projected climate change impacts for Toronto.

Impetus for Climate Planning

The City of Toronto initiated its adaptation planning strategy out of concern that climate change impacts will threaten its ability to provide effective services. Water supply, stormwater management, transportation, electricity distribution, parks, urban forests, public health, and emergency services are just a few of the systems and programs that likely will be affected. The City is currently investing in a number of expensive capital projects and programs that are expected to endure for the long-term, and is betting that the expense of adaptation planning will be less costly than impacts to systems that have not been adapted to changing conditions. The City is concerned not only with protecting its infrastructure, but also its vulnerable residents, such as homeless people, senior citizens, people with low income, and children.

Plans, Programs, and Partnerships

A number of partners collaborated to develop Toronto's initial adaptation strategy. The process was led by TEO and the Adaptation Steering Committee, which includes representatives from 15 City divisions, the Clean Air Partnership, and the Toronto Regional Conservation Authority. Other non-City entities, including the Institute for Catastrophic Loss Reduction and Pollution Probe, also contributed by pushing to get climate change adaptation on the agenda.

TEO and the steering committee identified several of the City's existing programs that could potentially reduce vulnerability to climate change. These are described in Figure ###. The identified programs provided planners with a foundation on which to build a long-term strategy.

To improve existing programs and develop new ones as part of a comprehensive adaptation plan, the steering committee formulated nine goals. These include:

1) Create internal mechanisms for adaptation process

2) Engage public, business and other stakeholders

Figure 132 Projected Climate Changes and Potential Impacts

Projected Climate	Potential Impacts
Hotter summers	More: - Hot days, nights and heat waves - Smog - Illness and deaths related to heat waves and smog - Demand for electricity and water - Stress on trees, gardens and vegetation - Food-borne illness - Power outages: brownouts and blackouts - Violence and crime
Milder winters	More: - Disease-bearing insects will survive the winter and expand the range of certain infectious diseases - Insects that damage trees - Freeze-thaw cycles which damage roads, other transportation infrastructure and vegetation
Dryer summers	- Increased demand for water - Stress on trees, gardens and vegetation - Reduced electricity generation capacity
More intense precipitation	- Pressure on the stormwater management system - Flooding of basements and low-lying areas - Increased wear and pressure on culverts, bridges and other transportation infrastructure - Contamination of streams and lakes from runoff - Erosion of rivers and streams
More extreme weather, storms and increased wind speeds	Damage to: - Buildings, roads and other infrastructure from high winds, heavy snowfalls and freezing rain - Transmission lines - Trees, parks and natural areas - Beaches, waterfront areas and stream banks -Increased risk of power outages/blackouts
Water level drop in Great Lakes Basin	- Increased concentration of contaminants in Lake Ontario - Reduced capacity for Great Lakes shipping - Loss of wetlands

Source: Toronto Environment Office, Ahead of the Storm: Preparing Toronto for Climate Change - Highlights, 2008

3) Incorporate climate change adaptation into policies and business planning

4) Analyze how Toronto's climate is changing

5) Identify vulnerabilities to climate change

6) Perform a risk assessment to identify impacts requiring priority action

7) Identify and assess adaptation options to reduce risk

8) Develop and implement adaptation strategies

9) Monitor and evaluate adaptation actions and adjust as needed

Public Engagement

In 2008, City Council hosted a large public meeting that featured several climate change experts discussing potential impacts and organizational strategies. TEO is continuing to hold large-scale and neighborhood-level public meetings that focus on presenting main issues, discussing key impacts and identifying potential actions and needed analysis. In addition to meetings, the City plans to regularly engage the public through printed and interactive web material, media coverage and organizations that reach out to Toronto's vulnerable populations, such as homeless and senior residents.

Actions and Implementation

Toronto has already taken a number of actions to begin implementing the plan. In January 2009, the City created an Environmental Protection Reserve Fund to pay for the development of a long-term strategy, and for related infrastructure and special projects. For the 2009 budget year, $500,000 from the fund was committed for climate and risk assessment studies. The City also created the Extreme Weather Reserve group of accounts to offset costs of unexpected severe weather events, such as the 2005 storm and flood. These accounts are funded with end of year surpluses (Penney and Dickinson, 2009).

Figure 133A Toronto city planner shows the new green roof on city hall to students from the University of Michigan's Urban Planning Program.

Figure 134 Existing Programs that Reduce Vulnerability to Climate Change

Heat Alert System and Hot Weather Response Plan: Toronto Public Health issues heat warnings and works with community agencies to prevent illness and death during periods of extreme hot weather. Toronto Public Health has studied climate change and its effects on heat and air pollution in the city to help with planning for the future.

Wet Weather Flow Master Plan: This 25-year implementation plan is designed to reduce flooding from intense rainfall, and water quality and erosion impacts on streams and lake water. Toronto Water is using information from the August 19, 2005 storm to guide its implementation of this plan.

Basement Flooding Protection Subsidy Program: The City is subsidizing the costs of installing back-water valves and sump pumps on household sewer connections in order to provide additional protection against flooding from sanitary sewers.

Flood Warning Forecasting: The Toronto Regional Conservation Authority is improving the existing system to better prepare for flood emergencies and reduce damage to life and property.

Green Roof Pilot Incentive Program: This program provides an incentive for green roofs to be installed on new or renovated Toronto buildings. Green roofs capture and retain stormwater and they cool buildings on which they grow.

Commitment to Double the Tree Canopy: Parks, Forestry and Recreation is undertaking a major study of canopy potential and associated implementation strategy with Planning & Transportation Services. Expanding the tree canopy in Toronto will provide shade, lessen the urban heat island effect, and reduce runoff and other effects of climate change.

Deep Lake Water Cooling, Peaksaver, and Keep Cool Programs: These and several other innovative programs that conserve energy and reduce peak electricity demand on hot summer days also reduce the risk of brownouts and blackouts during heat waves.

Green Development Standard: The standard provides a set of performance targets for the design and construction of new developments in Toronto. The standard will increase energy efficiency of buildings, reduce greenhouse gas emissions, reduce the urban heat island, conserve water, reduce stormwater runoff and enhance neighborhood green space. Many of these features will contribute to reducing the impacts of climate change.

Green Parking Lots: Draft design guidelines for greening surface parking lots have been prepared by City Planning and pilot projects are in progress. Greener parking lots are expected to reduce heat and runoff.

Better Buildings Partnership: This program works with building owners and developers to increase energy efficiency in existing buildings and in new construction, which decreases energy use and peak energy demand, reducing the vulnerability of the grid to brownouts and blackouts during heat waves.

Emergency Plan: Toronto's Emergency Plan prepares the City to protect the health, safety and welfare of the community in the face of a variety of hazards, including several that may occur more frequently as a result of climate change (severe weather, floods, power failures, etc.).

Source: Toronto Environment Office, Ahead of the Storm: Preparing Toronto for Climate Change, 2008

City Planning has been working on specific commitments for climate change adaptation and mitigation to be included in the Official Plan for guiding land use and development. Funds have also been approved for the following initiatives:

- Improving maintenance of city trees and planting new ones

- Identifying areas in the city prone to flooding, and methods of reducing flooding in those areas

- Implementing a water efficiency plan for droughts; collaborating with adjacent municipalities to update storm water standards

- Researching mapping and identifying populations vulnerable to heat waves and developing targeted heat response systems

Figure ### describes some of the other adaptation actions the City has already taken.

Some Toronto programs that have been more fully developed since the City began adaptation planning include a low-income home weatherization program, the Toronto Green Standard (TGS), and the Green Roof Bylaw. The home weatherization program offers weatherization services to low-income residents in the Toronto area through a partnership with the utility provider, Enbridge. After an in-home visit with an energy specialist, improvements, such as draft-proofing and insulation, are provided at no cost to the home owner.

TGS is Toronto's two-tiered development standard for promoting environmentally sustainable site and building design. Tier 1 includes a set of required development standards while Tier 2 consists of optional, incentivized performance measures. Both tiers are based on goals related to air quality; greenhouse gas emissions and energy efficiency; water quality and efficiency; solid waste; and ecology. The required standards in Tier 1 mostly deal with exterior elements, such as landscaping and transportation facilities, but also include energy efficiency requirements. The optional Tier 2 includes performance measures related to interior building elements and a higher energy efficiency target. Incentives, such as a 20 percent rebate of all development fees paid to the City, are available for developers who meet the requirements of both tiers (D'Abramo and Oates, 2010).

Toronto's Green Roof Bylaw, the first of its kind in North America, establishes minimum green roof requirements and mandates green roof construction on new developments. The

Figure 135 Adaptation Actions Under Way in Toronto

New Adaptation Actions	Anticipated Benefit
• Engage Toronto's Neighborhoods and Communities through 'Live Green Toronto'	• To support neighborhoods and communities in greening projects, including initiatives that will reduce climate change impacts.
• Conduct the Don Trunk Sewer and Waterfront Wet Weather Flow Control Projects	• To assess the effects of extreme weather on long-term performance of existing and new wet weather flow facilities and attain water quality goals.
• Complete Flood Warning System Updates • Conduct Lake Ontario Shoreline Planning	• To improve existing systems to prepare for flood emergencies. • Adaptive design for aquatic diversity and flood protection will take into account fluctuations of water level.
• Develop Regional Extreme Precipitation Intensity, Duration and Frequency Curves • Review Urban Flooding Issues	• To improve ability to design storm drainage infrastructure for extreme runoff events. • To identify future policy and program requirements for flood protection.
• Conduct a Scan of Methods used in other Jurisdictions to Assess Vulnerability to Heat • Evaluation of the Air Quality Health Index (AQHI) Pilot	• To create a heat-related vulnerability assessment tool that improves the effectiveness of the City's Hot Weather Response Plan. • Evaluation will help identify behavior changes that citizens are making as a result of the AQHI and identify improvements in education initiatives that can help maximize health benefits when air quality is poor.
• Increase Use of New Winter Weather Technologies to Improve Monitoring for Snow and Freezing Rain Conditions • Begin Using Combination Plowing and Salting Vehicles	• These innovations will: • a) reduce accident claims and service delivery costs during freezing rain episodes which are expected to increase as our climate changes; and • b) result in more effective use of salt.
• Conduct Studies on Potential Regulatory Requirements for Green Roofs	• An increase in green roofs will reduce electricity demand for air conditioning in summer and reduce stormwater runoff.
• Conduct Urban Heat Island Research to Inform Land Use Planning Policy Approaches to "cooling" the city	• Identification of Toronto's "hot spots," what causes them, and implementing strategies to reduce them will help cool the city. This information will be helpful in forming new development standards, e.g. Green Development Standard.
• Reduce Stream Erosion and Increase Stream Restoration	• Coordinate procedures among different levels of government to reduce stream erosion and in the long-term, aid in stream restoration.
• Develop a Live Green Toronto "Climate Change Action Kit"	• Torontonians better informed and engaged in adapting to climate changes.
• Improve Future Climate Change Prediction Capabilities	• Improved information on expected climate changes will permit better decision-making on adaptation planning. Models will help develop watershed plans that will aid adaptive management in the Rouge, Don and Humber River watersheds.
• Participate in the Greater Toronto Incident Management Exchange	• Help the business sector adapt to climate changes including severe weather events.

Source: Toronto Environment Office, Ahead of the Storm: Preparing Toronto for Climate Change - Highlights, 2008 goal of the program is to improve stormwater management, improve air quality, reduce the urban heat island effect, and reduce energy consumption. Green roofs are required on new buildings with more than 2,000 square meters of gross floor area, and the amount of required green roof coverage ranges from 20 to 60 percent depending on the size of the development. The bylaw allows for developers to make cash-in-lieu payments in exchange for reduced green roof area. The payments are used to support the City's Eco-roof Incentive Program, which funds retrofitting existing buildings with green roofs. Currently, the bylaw only applies to residential, commercial, and institutional projects; however, starting in 2011, new industrial developments will also be included (D'Abramo and Oates, 2010).

Lessons Learned

Several lessons can be drawn from Toronto's approach to climate change adaptation planning. The City of Toronto partnered with the Clean Air Partnership and other local organizations to put adaptation planning on the City's agenda. Municipalities working on formulating an adaptation strategy should reach out to local non-profits and other organizations that have an interest in climate change. Non-profit organizations can provide staff resources and serve as champions of climate change planning. The City of Toronto also utilized scientific and technical expertise available at local universities and institutions to inform its planning strategy, and to educate City staff and residents. Utilizing these resources can provide valuable analysis at a far lower cost than hiring consultants, which is extremely difficult for most local governments to afford.

Toronto was also able to establish a team of City staff, from numerous departments, to work on climate change adaptation. These staff members were able to identify a comprehensive inventory of existing programs on which to build and short-term actions that could be taken immediately. Assigning staff from a range of divisions also ensured that climate change adaptation was being considered by policymakers across City divisions.

References

D'Abramo, J. & L. Oates. (2010). Toronto's climate change initiatives: Overview, the Toronto green standard and the green roof bylaw. Plan Canada, Winter 2010.

Environment Canada. (2010). National climate data and information archive. Retrieved from http://www.climate.weatheroffice.gc.ca/

Penney, J. & T. Dickinson. (2009). Climate change adaptation planning in Toronto: Progress and challenges. Fifth Urban Research Symposium.

Statistics Canada. (2011). 2006 Community profiles. Retrieved from http://www12.statcan.ca/census-recensement/2006/dp-pd/prof/92-591/index.cfm?Lang=E

Toronto Environment Office. (2008, April). Ahead of the storm...Preparing for climate change.

Climate Adaptation and Mitigation in Seoul, South Korea

Overview

South Korea, officially the Republic of Korea, is located on the southern portion of the Korean Peninsula in East Asia. The neighboring countries are People's Republic of China to the west, Japan to the east, and North Korea to the north. Seoul, the capital of South Korea and one of the most populous cities in the world (10,314,245 as of February 2011)(Estimation from the Republic of Korea Ministry of Public Administration and Security), is on the northwestern portion of South Korea, adjacent to the Incheon Metropolitan City and Kyonggi Bay-Yellow Sea to its west (Figure #). Seoul is 605.25 km2 in area with a population density of 17,288/km2 (44,775.7/sq mi), and its average elevation is estimated at 50 meters (160 feet). Seoul's High-level Adaptation System is a comprehensive set of approaches to adapt itself to the various impacts of climate change. As the capital city of South Korea, Seoul utilizes its wide range of concentrated human, physical,

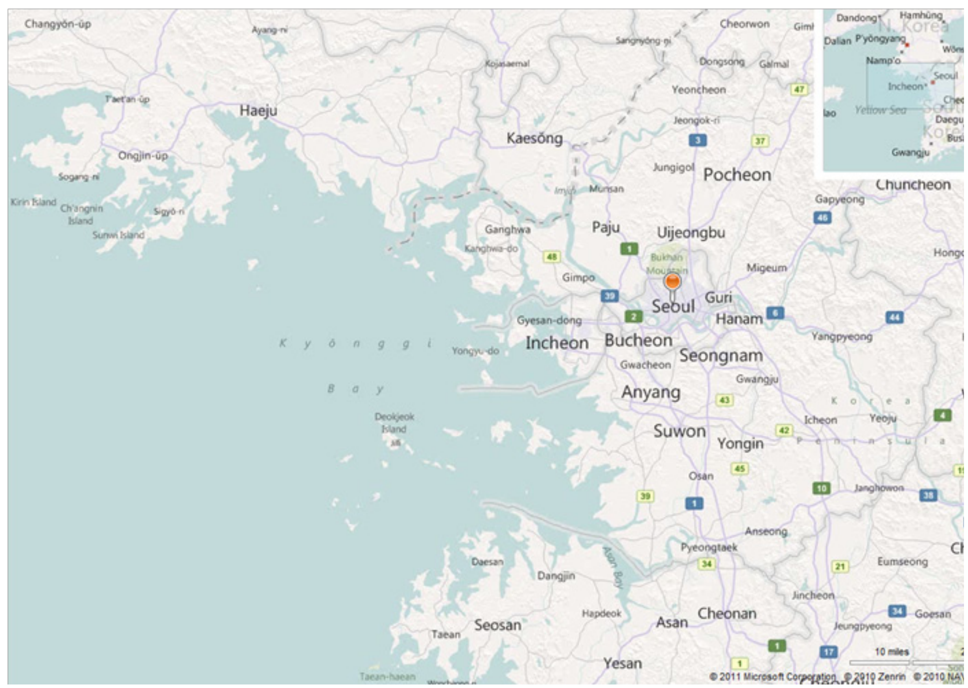


Figure 136 Location Map of Seoul Metropolitan Area

Source: Bing Maps

and technological resources to adapt itself to the climate changes, and this gives a suggestion for the cities in the Great Lakes Region (GLR) in the U.S. and Canada. The cities in GLR have great financial and technological potential to adapt themselves to the impacts of climate change – in addition to the manufacturing industry base; a large number of advanced-technology firms, clusters of R&D facilities, top-notch university-affiliated research institutes, high-quality human capital, and many more. As Seoul just started to develop its own comprehensive adaptation strategies and try to leverage its own strengths, we can learn from Seoul's approach and consider what elements GLR cities might incorporate to improve their climatic adaptation capabilities.

Context

Climate Change

Seoul's temperature has risen 2.4 °C during the last century, which is three-times higher than the world's average, and the Seoul Metropolitan Government (SMG) projects an additional 4 °C increase by 2100 (Seoul Metropolitan Government, 2010). From the health risk point, Seoul's mortality rate drastically increases as the highest temperature reaches around 30-32 °C, and at 36 °C, the rate increases by 50% from the one at 30 °C. Also, the increased temperature would likely to cause increased number of infective mosquitoes carrying diseases and greater risk of food poisoning, etc.

For the last century, the amount of rainfall in Seoul has increased, but its number of days with precipitation has decreased and more precipitation falls during the summer seasons (Seoul Metropolitan Government, 2010). SMG forecasts a 17 % increase of annual precipitation in 2100 (Seoul Metropolitan Government, 2010).

In 1998, ozone warnings were issued in Seoul 17 times for 11 days, but in 2008, they were issued 23 times for just seven days (Kim, Choi, & Kim, 2010). During the 1980s, average number of annual yellow/sandy dust days was 3.9, but in the 1990s, it was increased to 7.7, and it reached at 12 during the 2000s (Kim, Choi, & Kim, 2010). Due to the increased frequency of yellow/sandy dust phenomena and high concentration of fine dust, Seoul's citizens' health is at the risk of heightened threats.

Socio-demography

Seoul occupies less one percent of the total area of South Korea, but its population makes up approximately 25 % of the national population, and it has been growing in last seven years (0.25% annually). In addition, its tourist attractions draw considerable number of foreign visitors every year. These socio-demographic characteristics would make Seoul citizens more vulnerable to infectious diseases. The outbreak ratio of malaria patients per 100,000 people was 3 to 18.5 in 2009, and it has been increasing since 2004 (Kim, Choi, & Kim, 2010). Likewise, the outbreak ratio of tsutsugamushi fever patients per 100,000 populations has increased from 0.1 to 11.2 since 2004 (Kim, Choi, & Kim, 2010).

Seoul's population of residents 65 years and more is increasing. Seoul's population ages 65 and more had increased from 368,000 in 1990 to 936,000 in 2009 (154 % increase), and in 2005, Seoul became an aging society when its percentage of population over 65 reached at 7.2 %, and in 2009, it increased to 8.2 % (Kim, Choi, & Kim, 2010). The SMG expects that Seoul will become an aged-society (reaching at 14 %) in 2019, and then, a super-aged society (reaching at 26 %) by 2026 (Seoul Metropolitan Government, 2010). Also, as of 2008, percentage of senior citizens who live alone among the elderly population reached at 20.7 % (Kim, Choi, & Kim, 2010). Because elderly residents are considered more vulnerable to the negative impacts of climate change, this shifting demographic trend increases the city's need to act. As of 2008, the percentage of 'national basic living subsidy' recipients to the total population in Seoul was 2.0 % (205,059 people), and the percentage of households receiving that subsidy was 2.8 % (115,407); and these imply the necessity for discriminative responses to the adaptation demand of the vulnerable classes in Seoul (Kim, Choi, & Kim, 2010).

Urban Environment

Flooding, though infrequent, is Seoul's more threatening natural disaster. As of 2005, the percentage of impervious surfaces in Seoul was 47.4 % (7.8 % in 1962; before urbanization); in other words, except forest areas (25.4 %), most of the build-up areas in Seoul are covered with impervious surfaces (Seoul Metropolitan Government, 2010). When a localized torrential downpour happens in Seoul, increased peak flows raise the possibility of flood occurrence in the area (Seoul Metropolitan Government, 2010). This large percentage of impervious surface also increases the urban heat island effect. During the summer season, temperature of asphalt-paved surfaces goes up to 70 °C (Seoul Metropolitan Government, 2010).

Plans, Programs, and Partnerships

Policy Measures

In December 2008, the 3rd Committee for the Climate Change Countermeasures, housed at the Republic of Korea Prime Minister's Office (PMO), announced "National Climate Change Adaptation Master Plan." The Green Growth Five-Year Plan (2009 – 2013), also developed by the PMO, adopted "Strengthening the capacity to adapt to climate change (Provision 3)," as one of the "ten policy actions to implement each of ten policy directions" (Cho, 2009). Under Article 48 of the Low-carbon Green Growth Act (enforced since April 2010), the metropolitan governments in Korea must establish their own adaption plans, after evaluating impacts of climate change and assessing vulnerabilities.

In July 2009, Seoul Metropolitan Government announced "Seoul Low-carbon Green Growth Master Plan (2010 – 2030)." This plan envisions: 1) transformation towards a climate-friendly city; 2) achieving the goal of becoming a green growth city; and 3) realization of a high-level adaptation city. However, according to the Seoul Development Institute's (SDI) recent report, examining policy demand necessary to realize the high-level adaptation city and the policy formation process that connects this to the low-

Figure 137 Seoul, South Korea
source: www.tipsfortravellers.com

carbon green growth management policies are considered unsatisfactory, compared with other developed countries' cases (Kim, Choi, & Kim, 2010).

Vulnerability Assessment

To make a comprehensive prognosis of Seoul's vulnerability to the impacts of climate change, SDI, a non-profit and independent research organization established and supported by the SMG, has proposed a set of assessment indices for the Seoul's climate change adaptation vulnerability (Table #).

Seoul's Readiness

Results of a recent survey from the climate change experts in Korea indicate that high temperature (heat wave), urban heat island, and air pollution are the climatic elements of greatest concern for Seoul (Kim, Choi, & Kim, 2010). It also reports that Seoul has been relatively successful in establishing administrative organizations related to climate change adaptation and initiating internal and external cooperation networks around adaption. On the other hand, the degree of implementing the climate change adaptation policies for the vulnerable classes is considered insufficient (Kim, Choi, & Kim, 2010).

In the survey, the anticipated structural/institutional barriers to push ahead the climate change adaption measures were identified as securing manpower and budget, inter-departmental policy integration, and the guidelines and regulations from the upper-level governments; otherwise, barriers within the unstructured systems would be the education and public relations that aim to increase the public and bureaucrats' awareness of the climate change (Kim, Choi, & Kim, 2010). Meanwhile, based on the index classification (Table 1), vulnerability assessment for Seoul to the anticipated impacts of climate change can be summarized as follows (Kim, Choi, & Kim, 2010):

- Climate Exposure (E) – heat wave, flood

- Sensitivity (S) – high population density, increasing percentage of population lacking access to health services, relatively high ratios and percentages of build-up areas, deteriorated structures and impervious surfaces, extreme climate that causes flood, fierce heat and etc.

- Adaptation Capacity (AC) – relatively high adaptation capacity due to the abundant economic resources, high level of physical infrastructure securement (securement rate of medical facilities, accessibility to clean water, means of communications, etc.), industrial structure (high proportion of tertiary industries, low proportions of primary and secondary industries)

• Adaptation Base (AB) – the Climate Change Ordinance issued in 2008, organizational restructuring of the Climate Change Task Force, budget and public relations for the climate change adaptation

While Seoul's climatic antecedents (e.g., localized torrential downpour), socio-demographic factors (e.g., aging/aged society), and urban built environment factors (e.g., high impermeability) have been growing, the city's adaptation preparedness – longer-term, comprehensive management plans – has not been concretized until recently (Kim, Choi, & Kim, 2010). In addition, there is no evidence that the SMG has involved public (residents and stakeholders) participation in developing these plans.

Actions and Implementation

In 2010, the SMG and its independent research institutes, in cooperation with national agencies such as Korea Meteorological Administration (KMA), announced its specific strategies for the Seoul's High-level Adaptation System. This comprehensive set of adaptation strategies would be a main frame of near future additions of climate change adaptation strategies. Its main goals, specific strategies, and programs are as follows:

1) Establishment of an Early Prediction-and-Response System

• Reinforcing climate change monitoring and alert system capacity: construct a comprehensive climate change and air pollution monitoring system, by consolidating data collected from the Automatic Weather Stations (AWSs) in Seoul, to establish databases (2010 – present).

• Establishing a system to assess climate change impact: construct a database of the vulnerable places, classified by each classification (Table 1), and conduct a periodic assessment every five years (the General Assessment, 2011 – 2012,

Figure 138 Seoul Climate Change Adaptation Vulnerability Assessment Index

Classification	Content	Index
Climate Exposure (E)	Torrential Rain	Number of days with 80 mm torrential rain (day)
		Maximum precipitation for one day (mm)
		Precipitation intensity index (mm/day)
	Drought	Average number of continuous days without precipitation (day)
		Maximum number of continuous days without precipitation (day)
	Fierce Heat	Number of days with tropical night (day)
		Number of days with daily maximum temperature greater than 33 °C (day)
		Heat wave continuation index (day)
Sensitivity (S)	Demographic Characteristics	Population density (persons/km^2)
		Percentage of population 65 years and over (%)
		Percentage of senior citizens who live alone (%)
		Percentage of basic living subsidy recipients (%)
		Occurrence rate of Climate-sensitive patients (%)
	Energy Consumption Characteristics	Final energy consumption (1,000 toe)
		Electricity consumption (Gwh)
		Energy consumption per capita (toe/person) (*toe = tonnes of oil equivalent)
	Geographic Characteristics	Area vulnerable to drought (%)
		Area vulnerable to flood (%)
		Percentage of impervious areas (%)
		Percentage of build-up areas (%)
	Ecological System	Percentage of forest areas (%)
		Number of endangered species
	Infrastructure	Percentage of infrastructure establishments (%)
		Percentage of deteriorated structures (%)

Classification	Content		Index
Adaptation Capacity (AC)	Economic Capacity		Gross Regional Domestic Product (billion)
			Financial autonomy ratio (%)
	Environmental Capacity	Green Area	Green area (m^2/person)
		SOx Footprint	SOx Footprint per unit area (kg/m^2)
	Physical Infrastructure	Securement Rate of Medical Facilities	Number of medical establishments per 1,000 people (establishments/1,000 persons)
			Number of medical establishments per capita (establishments/person)
			Number of health care providers per capita (person/1,000 persons)
			Number of community health center manpower per capita (person/1,000 persons)
		Accessibility to Clean Water	Water supply penetration rate (%)
			Sewerage penetration rate (%)
			Rate of underground water utilization to development (%)
		Communications	Personal Computer penetration rate (%)
			Percentage of high-speed Internet service provision (%)
	Industrial Structure		(Primary + Secondary) / (Primary + Secondary + Tertiary) (%)
	Human Resource and Education		Educational expenditure / gross income (%)
	Social Capital		Private partnerships
			Citizen's climate change adaptation capacity and community spirit (conduct survey)
Adaptation Base (AB)	Organization		Organization in charge of climate change adaptation and its number of civil service officials (person/1,000 persons)
	Institutions		Climate change countermeasures and adaptation-related regulations
	Budget		Percentage of climate change adaption-related budget (%)
	Public Relations		Operation of website providing climate change adaptation-related information

Source: Translated from (Kim, Choi, & Kim, 2010) (the General Assessment, 2011 – 2012, periodic assessment, 2010 – present).

2) Reinforcement of Climate Change Adaption Policies and Regulations

• Organizing administrative institutions: create a team in charge of developing adaptation measures within the Division of Climate Change Adaptation (SMG); organize adaption management teams in each department (SMG) responsible for the areas that are identified as vulnerable; strengthen the city-districts adaptation cooperation, through regular meetings and workshops.

• Preparing adaptation-related ordinances and regulations: set responsibilities, emergency measures, and direction ordering systems for SMG, businesses, and schools in the city (2009 – 2010).

• Creating an evaluation system comprehensively diagnosing adaptation management status: annually diagnose SMG's general management status, conducted by an expert evaluation group (more frequent diagnosis for the prioritized, more vulnerable areas and individual projects).

3) Formation of Networks between Government, Citizens, Educational Institutions, and NGOs

• Receiving continuous feedback on implementing adaptation policies: expand and encourage public participation during the processes of creation, execution, and evaluation of the climate change adaptation measures (2010).

• Establishing a social cooperation network for the climate change adaptation: establish a social cooperation network between the vulnerable class protecting facilities (e.g., welfare facilities for the aged, orphanages, etc.) and community organizations; create intercorporate networks for the climate adaptation social cooperation.

• Creating internal and external climate adaptation cooperation networks: share policy information with the international city cooperation organizations, such as C40 and ICLEI, as well as "best-practices" with other cities (2010).

4) Enhancement of Citizen's Climate Adaptation Capacity

• Offering comprehensive climate adaptation information services: construct a climate change information-sharing system with the SMG, local governments, and civic organizations; establish a public open website to facilitate citizen's adaptation education and capacity (2010 – 2011).

• Developing and providing customized climate adaptation manuals: develop a set of strategies to the climate damages by type and level; provide climate change information online and offline, utilizing public service announcements; distribute personal, portable manuals to the vulnerable classes (2010 – 2011).

• Designing and offering target-specified education and training programs: develop and distribute education and training programs by disaster type, situation, and subject, to businesses, schools, and community organizations; operate special education and training programs for the vulnerable classes, such as children and the aged; include these programs in the regular school curriculum.

5) Establishment of a Climate-friendly City Management Base

• Organizing regulations and providing technical supports for sustainable urban management: establish urban design and development principles with regard to climate impacts, by applying the "high-level adaptation standards" (e.g., introduction of climate change and damage impact evaluation system when creating urban development plans, preparation of urban design guidelines considering climate elements, such as wind ways, and increase ratio of green space requirement for public and private development projects); assist R&D for the high performance, cost efficient paving paint enabling temperature reduction, reflection enhancement, and anti-discoloration; conversion of impervious surfaces to permeable areas, to reach the goal of expanding permeable spaces greater than 50 % of the total area (by preparing obligatory standards for the permeable paving ratio through environmental impact assessment for urban development projects).

• Enhancing capacity of urban climate control: expand green spaces (current proportion: 29.3 % to the total area) to reduce temperature and improve air quality (additional expansion of 11.0 kim2 by 2030, which will make up 32 % to the total); promote rooftop gardening as a compulsory, phased regulation for the large downtown buildings and for apartment complexes throughout the region (strengthen incentives by subsidizing the costs for rooftop gardening and designate it as a mandatory element for redevelopment/ reconstruction projects will be done by the SMG); pursue stream restoration projects (13 stream restorations by 2020, utilizing high class treatment water).

•Supporting applications and provisions of cutting-edge adaptation technologies: utilize new technologies (e.g., individual portable devices) to provide climate change-customized (e.g., fierce heat) medical information services; R&D for climate change damage-neutralizing and -mitigating medical protection devices (e.g., special masks to protect from yellow dust); prepare construction standards and models for the climate adaptive (mostly to higher temperature), and high efficiency (e.g., energy saving designs and construction materials) residential and commercial structures.

Lessons Learned

Seoul's (SMG's) climate change adaptation system (i.e., the High-level Adaptation System) carries a multi-dimensional, comprehensive set of approaches to adapt itself to this changing environment. In consideration of Seoul's extremely high population density and massive accumulation of man-made, physical infrastructures, these comprehensive approaches seem to be necessary for its adaptation. Although the city acknowledged its importance and started to deploy these initiatives in recent years, Seoul's sequential and systematic approaches based on short-term and mid-term (10 to 30 years) forecasts particularly stand out. In sum, Seoul attempts to:

1) strengthen its adaptation base by reorganizing its existing climate monitoring systems and by establishing their databases; and based on these,

2) categorize vulnerable elements and select areas by a multi-dimensional assessment; and

3) organize and re-organize a variety of institutions and regulations, establish internal and external cooperation networks, assist and support various strategies for the public adaptation, and manage urban built environment to improve its adaptive capacity.

With all these efforts, while Seoul tries to stretch itself as one of the actively transforming cities in the world around climate adaptation. The most notable adaptation efforts would be the plans of providing Seoul citizens with the ubiquitous climate adaptation information system, utilizing advanced ICT technologies embedded in urban infrastructures and personal portable devices, and the R&D investment to advance technologically the city's adaptation system in general. Additional examples include enterprising and creative goal-setting and policy formulation utilizing the city's urban engineering know-how and capabilities.

References

Cho, W.-D. (2009). Korea's Road to Green Growth: The Green Growth Five-Year Plan (2009 - 2013). Seoul: Republic of Korea Prime Minister's Office.

Kim, W., Choi, Y.-j., & Kim, J. (2010). A Study on Strategies of Climate Change Adaptation in Seoul. Seoul: Seoul Development Institute.

Seoul Metropolitan Government. (2010). Climate Change Adaptation: The Way We Altogether Go. Seoul: Department of Climate and Atmosphere.

APPENDIX-B Sources

Appendix-B Source

About our Great Lakes: Great Lakes Basin facts. (2004, June 18). In National Oceanic and Atmospheric Administration Great Lakes Environmental Research Laboratory. Retrieved January 23, 2011, from http://www.glerl.noaa.gov/pr/ourlakes/facts.html

A history of the cherry industry in Traverse City. (2011). In Traverse City Convention and Visitors Bureau. Retrieved February 20, 2011, from http://www.traversecity.com/cherry-industry-132/

Areas of Concerns. Retrieved January 21, 2011, from http://www.epa.gov/glnpo/aoc/

Army Corps 2009. An Investment Strategy for the Western Lake Erie Basin. US Army Corps of Engineers, 2009.

Assel, R.A. (1991). Implications of CO2 global warming on Great Lakes ice cover. Climate Change 18: 377-395.

Austin, J., Dezenski, E., & Affolter-Caine, B. (2008, March). Brookings Institution Metropolitan Policy Program. Retrieved March 3, 2011, from Brookings: http://www.brookings.edu/metro

Ayers, H. D. (n.d.). Drainage basin. In The Canadian Encyclopedia. Retrieved February 1, 2011, from http://www.thecanadianencyclopedia.com/index.cfm?PgNm=TCE&Params=A1ARTA0002386

Bennett, Edward B., “Water Budget for Lake Superior and Whitefish Bay” Journal of Great Lakes Research Volume 4, Issue 3-4 Pages 331-342.

Berrien County Drain Commission (2009) Requirements and General Compliance Guidelines for Storm Water Drainage System Design for Development and Redevelopment within Berrien County

Berrien County Health Department (2001) Surface Water Monitoring Project

Berrien County Office of Emergency Management. (2005, January). Berrien County Hazard Mitigation Plan.

Botts, L; Krushelnicki, B; Lewandowski, L; etc.(1988). The Great Lakes: An Environmental Atlas and Resource Book. http://www.epa.gov.proxy.lib.umich.edu/glnpo/atlas/index.html

Booth, D. B. and R. Jackson. (1997). Urbanization of aquatic systems: Degradation thresholds, stormwater detection, and the limits of mitigation. Journal of the American Water Resources Association 33: 1077–1090.

Bogue, Margaret Beattie (2007). Around the Shores of Lake Superior: A Guide to Historic Sites, pp. 237–39. University of Wisconsin Press. ISBN 0-299-22174-1.

Brown, R.W., and W.W. Taylor (1993). Factors affecting the rectruitment of Lake Whitefish in two areas of northern Lake Michigan. Journal of Great Lakes Research. 19:418-428.

Burian, S.J., et al. (2000). Urban wastewater management in the United States: Past, Present, and Future. J Urban Tech 7(3):33–62.

Census: U.P. lost 6,000 residents. (2011, March 23). Escanaba Daily Press. Retrieved April 2, 2011, from http://www.dailypress.net/page/content.detail/id/529251/Census--U-P--lost-6-000-residents.html

City of Marquette. (2011, March 28). Planning. Retrieved March 31, 2011, from City of Marquette, MI: http://www.mqtcty.org/plan.html Clemo, Peter, and Billy Ho. Personal interview. 11 Apr. 2011.

City of Benton Harbor. City of Benton Harbor Financial Plan. By Joe Harris. Web. 20 Apr. 2011. <http://www.bentonharborcity.com/CoBH%20Financial%20Plan%202010.pdf>.

City of St Joseph 2010-2011 Fiscal Year Budget. Web. 20 Apr. 2011. <http://sjcity.com/pdfs/2010-2011%20Budget%20as%20approved.pdf>.

Coutant, C.C. Temperature-oxygen habitat for freshwater and coastal striped bass in a changing climate. Transactions of the American Fisheries Society 119:240-253.

CWA 1976. Clean Water Act. United States Environmental Protection Agency.

Delgado, Elizabeth; Epstein, David; etc. 2006. Through a Wider Lens:Re-envisioning the Great Lakes MegaRegion.

Delgado, Elizabeth; Epstein, David; etc. 2006. Methods for Planning the Great Lakes MegaRegion.

Dempsey, D., J. Elder, and D. Scavia, (2008). Great Lakes Restoration & the Threat of Global Warming. Healing Our Waters – Great Lakes Coalition.

Dennis, Jerry. The Living Great Lakes. New York: St. Martin's Griffin, 2003. Print.

Dewar, Margaret and Epstein, David. Planning for "Megaregions" in the United States. Journal of Planning Literature 2007; 22; 108

Dubrovsky, Neil and Pixie Hamiliton 2010 The Quality of Our Nation's Waters: Nutrients in the Nation's Streams and Groundwater: National Findings and Implications. United States Geological Survey

Eckert, Kathryn Bishop (2000). The Sandstone Architecture of the Lake Superior Region, pp. 89–91. Detroit: Wayne State University Press. ISBN 0-8143-2807-5.

EPA (1993) Agriculture and the Environment: The Problem of Nonpoint Source Pollution.

EPA 2008. Health Effects of PCBs. Can be found at: epa.gov/epawaste/hazard/tsd/pcbs/pubs/effects.htm

EPA Report to Congress on the Impact and Control of CSOs and SSOs, 2004, p. 1□2.

ESRI GIS Library, Census 2000 Population Data

Flow modeling study of the St. Clair: Detroit River waterway. (1999, January 19). Retrieved February 1, 2011, from http://mi.water.usgs.gov/progproj/mi08900.html

Friends of the St. Joe River Association. (2005, June). St. Joseph River Watershed

Management Plan. Retrieved from http://www.fotsjr.org/

Furlow, J., et al. (2008). A Screening Assessment of the Potential Impact of Climate Change on Combined Sewer Overflow (CSO) Mitigation in the Great Lakes and New England Regions. EPA/600/R-07/033F.

Holecek, D. F., Herbowicz, T., Nikoloff, A., & Alexander, P. J. (2001, June). Marquette County Tourism Profile. In Michigan State University tourism resource center. Retrieved April 15, 2011, from http://www.jobforce.org/documents/Tourism/F4DMarquette.pdf

GLWQA 1993. Great Lakes Water Quality Agreement.

GLWQA 1993. Great Lakes Water Quality Agreement.

Government of Canada, United States Environmental Protection Agency, Great Lakes National Program Office. 1995. The Great Lakes: An Environmental Atlas and Resource Book

Great Lakes (2011, February 14). In Environmental Protection Agency. Retrieved February 20, 2011, from http://www.epa.gov/greatlakes/

Great Lakes facts. (2007, March 30). In Shipwreck Explorers. Retrieved January 25, 2011, from http://www.shipwreckexplorers.com/great_lakes_facts.php

Great Lakes facts and figures. (2010, January 21). In Great Lakes Information Network. Retrieved January 23, 2011, from http://www.great-lakes.net/lakes/ref/lakefact.html

Great Lakes Regional Assessment Group.2000. Preparing For a Changing Climate: The Potential Consequences of Climate Variability and Change.

Great Lakes Shipwreck Facts. Retrieved January 10, 2011, from http://www.shipwreckexplorers.com/great_lakes_facts.php

Hall, N.D., L. Schweiger, and B.B. Stuntz, (2007). Climate Change and Great Lakes Water Resources. National Wildlife Federation, Ann Arbor, Michigan.

Harris, Joe. (2011) "Benton Harbor PROGRESS REPORT WEEK OF MARCH 14-18, 2011." (14 Mar. 2011). Print.

Hollis, G.E. (1975). The Effects of Urbanization on Floods of Different Recurrence Intervals. Water Resources Research 11:431-435.

"Interview with Marcy Colclough." Personal interview. 11 Apr. 2011.

James E. Fitting. 1969. Settlement Analysis in the Great Lakes Region. Southwetern Journal of Anthropology, Vol.25, No. 4 (Winter, 1969), pp.360-377

Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). (2009). Regional Climate Change Impacts: Midwest. Global Climate Change Impacts in the United States (pp. 117-122). Cambridge, Massachusetts: Cambridge University Press.

Kling, G.W., K. Hayhoe, L.B. Johnson, J.J. Magnuson, S. Polasky, S.K. Robinson, B.J. Shuter, M.M. Wander, D.J. Wuebbles, D.R. Zak, R.L. Lindroth, S.C. Moser, and M.L. Wilson (2003). Confronting Climate Change in the Great Lakes Region: Impacts on our Communities and Ecosystems. Union of Concerned Scientists, Cambridge, Massachusetts, and Ecological Society of America, Washington, D.C.

Kost, M.A., D.A. Albert, J.G. Cohen, B.S. Slaughter, R.K. Schillo, C.R. Weber, and K.A. Chapman.

2007. Natural Communities of Michigan: Classification and Description. Michigan Natural Features Inventory, Report No. 2007-21, Lansing, MI. Retrived from http://web4.msue.msu.edu/mnfi/communities/index.cfm

Lake Carriers' Association. (2009). LCA Annual Reports. Retrieved March 1, 2011, from Lake Carriers' Association: http://www.lcaships.com/

Lake Huron Info. (n.d.). In The Lake Huron Centre for Coastal Conservation. Retrieved February 10, 2011, from http://lakehuron.ca/index.php?page=lake-huron-info

Lake Michigan: History, facts & figures. (n.d.). In Southwest Michigan Business & Tourism Directory. Retrieved January 25, 2011, from http://www.swmidirectory.org/History_of_Lake_Michigan.html

Lake Ontario. (n.d.). In International Lake Environment Committee. Retrieved February 15, 2011, from http://www.ilec.or.jp/database/nam/nam-07.html

Lake Ontario. (n.d.). In World Geography. Retrieved February 13, 2011, from http://world-geography.org/lakes/510-lake-ontario.html

Lake Superior Facts. (n.d.). In The Canadian Encyclopedia. Retrieved February 2, 2011, from http://law2.umkc.edu/faculty/projects/ftrials/superior/superiorfacts.html

Larson, J. D. (1980). Soil survey of Berrien County, Michigan. [Washington, D.C., U.S. Dept. ofAgriculture, Soil Conservation Service.

Lee, S. (n.d.). The reversal of the Chicago River in 1900. In Northern Illionis University Library. Retrieved February 10, 2011, from http://www.lib.niu.edu/2001/ihy010452.html

Lewis, Brandon. "Audit Finds City of Benton Harbor $6 Million in Debt." WNDU - Home. 08 Mar. 2011.<http://www.wndu.com/localnews/headlines/Audit_finds_City_of_Benton_Harbor_6_million_

in_debt_117564384.html>.

Lower St. Joseph/Galien River Watershed Management Plan (2007)

Marquette Downtown Waterfront District http://www.mqtcty.org/Departments/Planning/Files/downtown_waterfront_district_fbc_final_draft.pdf (March 20, 2011)

Marquette Master Plan, City of Marquette, Michigan, Adopted May 4, 2004

Maurer, Maurer. Air Force Combat Units Of World War II. Washington, DC: U.S. Government Printing Office 1961 (republished 1983, Office of Air Force History, ISBN 0-912799-02-1).

Major biomes map. (2003, September 8). In United States Department of Agriculture Natural Resource Conservation Service. Retrieved February 12, 2011, from http://soils.usda.gov/use/worldsoils/mapindex/biomes.html

Michigan Agriculture at a Glance (2009, June 9). Retrieved March 16, 2011, from http://michigan.gov/documents/mda/MDA_at_a_Glance_Booklet_6-17-09_327130_7.pdf

Michigan Department of Environmental Quality (2003) Total Maximum Daily Load for Escherichia coli for the St. Joseph River, Berrien County

Michigan Department of Natural Resources. (n.d.). Coastal Dunes. Retrieved from http://www.michigan.gov/dnr/0,1607,7-153-10370_22664-61314--,00.html

Michigan Resource Information System. (1978). Template – Landuse/Cover Circa 1800 Arc. Lansing, MI. Retrieved from http://www.mcgi.state.mi.us/mgdl/

Michigan Interactive USDA Plant Hardiness Zone Map. Plant Maps.com. Retrieved from http://www.plantmaps.com/interactive-michigan-usda-plant-zone-hardiness-map.php?ZS=49855 iMillerd, F. (2011). The Potential Impact of Climate Change on Great Lakes International Shipping. Climate Change , 629-652.

Millerd, F. (2011). The Potential Impact of Climate Change on Great Lakes International Shipping. Climate Change , 629-652.

Mortimer, Clifford Hiley. Lake Michigan in Motion: Responses of an Inland Sea to Weather, Earth-spin, and Human Activities. University of Wisconsin Press, 2004 pg. 71

National Climatic Data Center. (n.d.). Climatography of United States No. 20 1971-2000: Benton Harbor AP, MI Station. Retrieved from http://hurricane.ncdc.noaa.gov/cgi-bin/climatenormals/climatenormals.pl

National Weather Service. (2010, Feb 11). NWS Marquette, MI. Retreived from http://www.crh.noaa.gov/mqt/normals/marquette.php

State of Michigan. Web. 20. April. 2011 http://www.michigan.gov/documents/treasury/FiscalEmerg_271926_7.pdf

OH EPA 2003. Total Maximum Daily Loads for the Lower Cuyahoga River Final Report. Ohio Environmental Protection Agency Division of Surface Water Quality.

OH EPA 2004. Total Maximum Daily Loads for the Upper Sandsuky River Watershed. Ohio Environmental Protection Agency Division of Surface Water Quality.

Our Lakes Facts. Retrieved February 13, 2011, http://www.glerl.noaa.gov/pr/ourlakes/facts.html (2/10/2011)

Penney, J. & T. Dickinson. (2009). Climate change adaptation planning in Toronto: Progress and challenges. Fifth Urban Research Symposium.

Projects. (n.d.). In Superior Watershed Partnership and Land Trust. Retrieved February 9, 2011, from http://www.superiorwatersheds.org/projects.php?id=6

Quinn, F. H. (2002). The Potential Impacts of Climate Change on Great Lakes Transportation. The Potential Impacts of Climate Change on Transportation (pp. 1-9). Washington D.C.: U.S. Department of Transportation.

Reversal of the Chicago River, Retrieved January 19, 2011, from http://www.lindahall.org/events_exhib/exhibit/exhibits/civil/chicago_river.shtml

Remediation Actions Plans (RAPs) for the Great Lakes Areas of Concern. Retrieved January 21, 2011, from http://www.great-lakes.net/envt/pollution/rap.html

Romig, Walter (1986) [1973]. Michigan Place Names. Detroit, Michigan: Wayne State University Press. ISBN 0-8143-1838-X.

Schatz, Roy. Website link currently broken: http://priorities.ijc.org/stclair-river-flows/en/comments/roy-schatz-toronto-on

Seiches of the Great Lakes. Retrieved February 19, 2011, from http://www.geo.msu.edu/geogmich/seiches.htm

Selbig, J. (n.d.). In Seiches on the Great Lakes. Retrieved January 25, 2011, from http://www.geo.msu.edu/geogmich/seiches.htm

Snowfall records. (n.d.). In Michigan Technological University. Retrieved February 10, 2011, from http://www.mtu.edu/alumni/favorites/snowfall/snowfall.html

"Soil Survey of Marquette County, Michigan." (n.d.) Natural Resources Conservation Service. United States Department of Agriculture, n.d. Web. 17 Apr. 2011. <http://soildatamart.nrcs.usda.gov/Manuscripts/MI103/0/Marquette_MI.pdf>.

Sohn, Emily. "Climate Change Could Drain Great Lakes" Discovery News. 29 Jan 2009. http://dsc.discovery.com/news/2009/01/29/great-lakes-warming.html

Sousounis, P. J., & Albercook, G. M. (n.d.). The Great Lakes Region: Past, present, and future. In Michigan State University Geography. Retrieved February 14, 2011, from http://www.geo.msu.edu/glra/PDF_files/Regional%20Summary/02_Historic_overview.pdf

South Marquette Waterfront Form Based Code, http://www.mqtcty.org/Departments/Planning/Files/south_marquette_district_draft_12.02.08_Final.pdf (march 20, 2011)

Stefan, H.G., et al. (1996). Simulated long-term temperature and dissolved oxygen characteristics of lakes in the north-central US and associated fish habitat limits. Limnology and Oceanography 41: 1124-1135.

Superior pursuit: Facts about the greatest Great Lake. (2008, November 25). In Minnesota Sea Grant. Retrieved February 7, 2011, from http://www.seagrant.umn.edu/superior/facts

Stynes, D. J. (2001, May). Economic importance of tourism to Marquette County, Michigan. In Marquette Satellite. Retrieved April 16, 2011, from web4.canr.msu.edu/mgm2/econ/miteim/satellite/marquettesat.pdf

The Great Lakes Information Network. http://www.great-lakes.net. Accessed on April 24, 2006

Toronto's racial diversity. (n.d.). In City of Toronto. Retrieved February 15, 2011, from http://www.toronto.ca/toronto_facts/diversity.htm

US Army Corps of Engineers. (2009, January). USACE - Detroit District. Retrieved March 1, 2011, from Great Lakes Navigation: http://www.lre.usace.army.mil/greatlakes/navigation/

US Army Corps of Engineers. (2010, April 22). Marquette Harbor, Michigan (Project Overview). Retrieved March 31, 2011, from US Army Corps of Engineers Detroit District: http://www.lre.usace.

army.mil/who/operationsofficehomepage/project_overview/marquette/

US Army Corps of Engineers. (2009, January). USACE - Detroit District. Retrieved March 1, 2011, from Great Lakes Navigation: http://www.lre.usace.army.mil/greatlakes/navigation/

Vaccaro, L., & Read, J. (2011, February). Jobs, Economy and the Great Lakes. Retrieved March 3, 2011, from Michigan Sea Grant: http://www.miseagrant.umich.edu/

Vaccaro, L., Read, J., & Scavia, D. (2009). Economic Vitality and the Great Lakes. Retrieved March 3, 2011, from Michigan Sea Grant: http://www.miseagrant.umich.edu/focus/community-development/jobs.html

Vegetation circa 1800 maps. (n.d.). In Michigan Natural Features Inventory. Retrieved March 3, 2011, from http://web4.msue.msu.edu/mnfi/data/veg1800.cfm

What is a watershed? January 19, 2011, from http://water.epa.gov/type/watersheds/whatis.cfm

“What Was the Last Ice Age Like?” Rice University. Taken from http://earth.rice.edu/mtpe/cryo/cryosphere/topics/ice_age.html

Wuebbles, D.J., & K. Hayhoe (2004). Climate Change Projections for the United States Midwest. Mitigation and Adaptation Strategies for Global Change, 9, 335-363. doi:10.1023/B:MITI.0000038843.73424.de

Yediler, A., and J. Jacobs (1995). Synergistic effects of temperature-oxygen and water-flow on the accumulation and tissue distribution of mercury in carp (Cyprinus carpio L.). Chemosphere 31: 4437-4453.

APPENDIX-C Additional Tables

APPENDIX-C ADDITIONAL TABLES

TABLE 1 - Great Lakes Cities US Census Population Summary

Place	County	State	Population in 1990	Population in 2000	Pop. Change (%)	Pop. Poverty Status Determined	Pop. Below Poverty	Pop. Above Poverty	% of Poverty by Pop.	House holds	HHs Below Poverty	HHs Above Poverty	% of Poverty by HHs
Chicago city	Cook	IL	2,783,726	2,896,016	4.03	2,839,038	556,791	2,282,247	19.61	1,061,964	185,070	876,894	1.74
Elgin city	Cook	IL	77,010	94,487	2.26	91,893	7,414	84,479	8.07	31,563	2,065	29,498	6.54
Waukegan City	Lake	IL	69,392	87,901	2.66	86,713	12,058	74,655	13.91	27,676	3,323	24,353	1.20
Cicero Town	Cook	IL	67,436	85,616	2.69	84,971	13,187	71,784	15.52	23,124	3,160	19,964	1.36
Arlington Heights Village	Cook	IL	75,460	76,031	0.76	75,189	1,878	73,311	2.50	30,844	845	29,999	2.74
Schaumburg Village	Cook	IL	68,586	75,386	9.91	74,011	2,209	71,802	2.98	31,585	1,023	30,562	3.24
Evanston city	Cook	IL	73,233	74,239	1.37	68,020	7,518	60,502	11.05	29,675	3,037	26,638	1.02
Palatine village	Cook	IL	39,253	65,479	6.68	64,907	3,100	61,807	4.78	25,385	1,019	24,366	4.01
Skokie village	Cook	IL	59,432	63,348	6.59	62,294	3,380	58,914	5.43	23,208	1,321	21,887	5.69
Des Plaines city	Cook	IL	53,223	58,720	1.03	57,702	2,646	55,056	4.59	22,369	1,061	21,308	4.74
Mount Prospect village	Cook	IL	53,170	56,265	5.82	56,581	2,614	53,967	4.62	21,648	941	20,707	4.35
Oak Lawn village	Cook	IL	56,182	55,245	-1.60	54,848	2,963	51,885	5.40	22,293	1,208	21,085	5.42
Berwyn city	Cook	IL	45,426	54,016	1.89	53,667	4,223	49,444	7.87	19,707	1,628	18,079	8.26
Oak Park village	Cook	IL	53,648	52,524	-2.00	52,230	2,902	49,328	5.56	23,107	1,453	21,654	6.29
Orland Park village	Cook	IL	35,720	51,077	4.29	50,647	1,562	49,085	3.08	18,657	609	18,048	3.26
Hoffman Estates village	Cook	IL	46,561	49,495	6.30	49,941	2,204	47,737	4.41	17,096	659	16,437	3.85
Tinley Park village	Cook	IL	37,121	48,401	3.03	47,514	1,207	46,307	2.54	17,496	478	17,018	2.73
Buffalo Grove village	Lake	IL	36,427	42,909	1.77	42,278	960	41,318	2.27	15,565	321	15,244	2.06
Glenview village	Cook	IL	37,093	41,847	1.28	41,325	840	40,485	2.03	15,407	355	15,052	2.30
Calumet city	Cook	IL	37,840	39,071	3.25	38,842	4,721	34,121	12.15	15,141	1,699	13,442	1.12
Hanover Park village	Cook	IL	32,895	38,278	1.63	38,194	2,329	35,865	6.10	11,271	569	10,702	5.05

Park Ridge city	Cook	IL	36,175	37,775	4.42	37,200	911	36,289	2.45	14,287	426	13,861	2.98
Bartlett village	Cook	IL	19,373	36,706	8.94	36,739	687	36,052	1.87	12,157	216	11,941	1.78
Streamwood village	Cook	IL	30,987	36,407	1.74	36,468	1,093	35,375	3.00	12,146	282	11,864	2.32
North Chicago city	Lake	IL	34,978	35,918	2.69	23,739	3,596	20,143	15.15	7,723	1,100	6,623	1.42
Elk Grove village	Cook	IL	33,429	34,727	3.88	34,594	684	33,910	1.98	13,271	352	12,919	2.65
Wheeling village	Cook	IL	29,911	34,496	1.53	33,967	1,803	32,164	5.31	13,237	651	12,586	4.92
Northbrook village	Cook	IL	32,308	33,435	3.49	32,821	756	32,065	2.30	12,336	324	12,012	2.63
Chicago Heights city	Cook	IL	33,072	32,776	-8.90	32,603	5,697	26,906	17.47	10,736	1,753	8,983	1.63
Highland Park city	Lake	IL	30,575	31,365	2.58	31,331	1,182	30,149	3.77	11,500	377	11,123	3.28
Mundelein village	Lake	IL	21,215	30,935	4.58	30,364	1,395	28,969	4.59	9,784	352	9,432	3.60
Niles village	Cook	IL	28,284	30,068	6.31	28,920	1,575	27,345	5.45	12,012	607	11,405	5.05
Harvey city	Cook	IL	29,771	30,000	0.77	29,639	6,418	23,221	21.65	9,018	2,000	7,018	2.21
Gurnee village	Lake	IL	13,701	28,834	1.10	28,575	867	27,708	3.03	10,536	357	10,179	3.39
Lansing village	Cook	IL	28,086	28,332	0.88	28,095	1,525	26,570	5.43	11,333	598	10,735	5.28
Oak Forest city	Cook	IL	26,203	28,051	7.05	27,418	998	26,420	3.64	9,722	415	9,307	4.27
Burbank city	Cook	IL	27,600	27,902	1.09	27,686	1,425	26,261	5.15	9,273	477	8,796	5.14
Wilmette village	Cook	IL	26,690	27,651	3.60	27,546	623	26,923	2.26	9,994	259	9,735	2.59
Maywood village	Cook	IL	27,139	26,987	-5.60	26,810	3,582	23,228	13.36	7,934	1,076	6,858	1.35
Round Lake Beach village	Lake	IL	16,434	25,859	5.73	25,342	1,282	24,060	5.06	7,349	364	6,985	4.95
Dolton village	Cook	IL	23,930	25,614	7.04	25,324	2,115	23,209	8.35	8,516	700	7,816	8.22
Elmwood Park village	Cook	IL	23,206	25,405	9.48	25,132	1,312	23,820	5.22	9,852	602	9,250	6.11
Rolling Meadows city	Cook	IL	22,591	24,604	8.91	24,320	1,249	23,071	5.14	9,015	342	8,673	3.79
Blue Island city	Cook	IL	21,203	23,463	1.06	23,212	3,088	20,124	13.30	8,179	994	7,185	1.21
Park Forest village	Cook	IL	24,656	23,462	-4.80	22,677	1,514	21,163	6.68	9,050	567	8,483	6.27
Melrose Park village	Cook	IL	20,859	23,171	1.10	23,169	2,369	20,800	10.22	7,625	821	6,804	1.07
Roselle village	Cook	IL	20,819	23,115	1.10	23,123	463	22,660	2.00	8,408	225	8,183	2.68

Fort Wayne city	Allen	IN	173,072	205,727	1.88	201,459	25,204	176,255	12.51	83,416	9,397	74,019	1.12
South Bend city	St. Joseph	IN	105,511	107,789	2.16	104,706	17,452	87,254	16.67	42,627	6,020	36,607	1.41
Gary city	Lake	IN	116,646	102,746	-1.10	101,273	26,117	75,156	25.79	38,281	9,337	28,944	2.43
Hammond city	Lake	IN	84,236	83,048	-1.40	82,396	11,807	70,589	14.33	31,968	4,360	27,608	1.36
Elkhart city	Elkhart	IN	43,627	51,874	1.89	50,904	6,901	44,003	13.56	20,107	2,449	17,658	1.21
Mishawaka city	St. Joseph	IN	42,608	46,557	9.27	45,493	4,507	40,986	9.91	20,299	2,060	18,239	1.01
Portage city	Porter	IN	29,060	33,496	1.52	33,010	2,471	30,539	7.49	12,756	882	11,874	6.91
Michigan city	LaPorte	IN	33,822	32,900	-2.70	30,052	4,010	26,042	13.34	12,610	1,488	11,122	1.18
East Chicago city	Lake	IN	33,892	32,414	-4.30	32,186	7,845	24,341	24.37	11,689	2,942	8,747	2.51
Merrillville town	Lake	IN	27,257	30,560	1.21	30,229	1,285	28,944	4.25	11,780	578	11,202	4.91
Goshen city	Elkhart	IN	23,797	29,383	2.34	27,705	2,570	25,135	9.28	10,642	759	9,883	7.13
Granger CDP	St. Joseph	IN	20,241	28,284	3.97	28,036	385	27,651	1.37	9,122	114	9,008	1.25
Valparaiso city	Porter	IN	24,414	27,428	1.23	24,884	2,258	22,626	9.07	10,919	1,106	9,813	1.01
Hobart city	Lake	IN	21,822	25,363	1.62	25,098	1,201	23,897	4.79	9,866	461	9,405	4.67
Schererville town	Lake	IN	19,926	24,851	2.47	24,743	779	23,964	3.15	9,627	358	9,269	3.72
Highland town	Lake	IN	23,696	23,546	-6.30	23,484	708	22,776	3.01	9,633	290	9,343	3.01
Detroit city	Wayne	MI	1,027,974	951,270	-7.40	932,512	243,153	689,359	26.08	336,482	81,789	254,693	2.43
Grand Rapids city	Kent	MI	189,126	197,800	4.59	188,785	29,681	159,104	15.72	73,336	10,213	63,123	1.39
Warren city	Macomb	MI	144,864	138,247	-4.50	136,812	10,112	126,700	7.39	55,619	4,002	51,617	7.20
Flint city	Genesee	MI	140,761	124,943	-1.10	122,853	32,440	90,413	26.41	48,818	11,563	37,255	2.36
Sterling Heights city	Macomb	MI	117,810	124,471	5.65	123,568	6,480	117,088	5.24	46,381	2,517	43,864	5.43
Lansing city	Ingham	MI	127,321	119,128	-6.40	117,807	19,866	97,941	16.86	49,458	7,687	41,771	1.55
Ann Arbor city	Washtenaw	MI	109,592	114,024	4.04	102,044	16,922	85,122	16.58	45,744	6,856	38,888	1.49
Livonia city	Wayne	MI	100,850	100,545	-3.00	99,202	3,136	96,066	3.16	38,129	1,237	36,892	3.24
Dearborn city	Wayne	MI	89,286	97,775	9.51	97,367	15,720	81,647	16.15	36,713	4,463	32,250	1.21
Clinton CDP	Macomb	MI	85,866	95,648	1.13	94,897	5,500	89,397	5.80	40,274	2,452	37,822	6.09
Westland city	Wayne	MI	84,724	86,602	2.22	85,532	5,821	79,711	6.81	36,699	2,527	34,172	6.89

Farmington Hills city	Oakland	MI	74,652	82,111	9.99	81,352	3,299	78,053	4.06	33,538	1,399	32,139	4.17
Troy city	Oakland	MI	72,884	80,959	1.10	80,864	2,220	78,644	2.75	30,043	971	29,072	3.23
Southfield city	Oakland	MI	75,728	78,296	3.39	77,102	5,721	71,381	7.42	33,971	2,570	31,401	7.57
Kalamazoo city	Kalamazoo	MI	80,277	77,145	-3.90	68,388	16,641	51,747	24.33	29,415	6,434	22,981	2.18
Canton CDP	Wayne	MI	57,047	76,366	3.38	76,099	2,841	73,258	3.73	27,465	985	26,480	3.59
Waterford CDP	Oakland	MI	66,692	73,150	9.68	71,272	3,658	67,614	5.13	29,457	1,490	27,967	5.06
Wyoming city	Kent	MI	63,891	69,368	8.57	68,832	5,003	63,829	7.27	26,549	1,803	24,746	6.79
Rochester Hills city	Oakland	MI	61,766	68,825	1.14	68,226	2,346	65,880	3.44	26,363	931	25,432	3.53
Pontiac city	Oakland	MI	71,166	66,337	-6.70	65,179	14,375	50,804	22.05	24,274	5,079	19,195	2.09
Taylor city	Wayne	MI	70,811	65,868	-6.90	64,918	7,003	57,915	10.79	24,766	2,555	22,211	1.03
Shelby CDP	Macomb	MI	48,655	65,159	3.39	64,732	2,391	62,341	3.69	24,462	938	23,524	3.83
West Bloomfield Township CDP	Oakland	MI	54,843	64,862	1.82	64,162	1,743	62,419	2.72	23,386	579	22,807	2.48
St. Clair Shores city	Macomb	MI	68,107	63,096	-7.30	62,581	2,332	60,249	3.73	27,495	1,183	26,312	4.30
Saginaw city	Saginaw	MI	69,512	61,799	-1.10	60,945	17,389	43,556	28.53	23,196	5,987	17,209	2.58
Royal Oak city	Oakland	MI	65,410	60,062	-8.10	59,669	2,550	57,119	4.27	28,850	1,331	27,519	4.61
Dearborn Heights city	Wayne	MI	60,838	58,264	-4.20	57,687	3,532	54,155	6.12	23,270	1,242	22,028	5.34
Battle Creek city	Calhoun	MI	53,540	53,364	-3.20	51,876	7,446	44,430	14.35	21,372	2,999	18,373	1.40
Redford CDP	Wayne	MI	54,387	51,622	-5.00	51,166	2,616	48,550	5.11	20,203	1,030	19,173	5.10
Roseville city	Macomb	MI	51,412	48,129	-6.30	47,787	3,781	44,006	7.91	19,999	1,664	18,335	8.32
Novi city	Oakland	MI	32,998	47,386	4.36	47,164	1,054	46,110	2.23	18,710	387	18,323	2.07
East Lansing city	Ingham	MI	50,677	46,525	-8.10	32,477	11,317	21,160	34.85	14,401	4,489	9,912	3.11
Kentwood city	Kent	MI	37,826	45,255	1.96	44,991	2,817	42,174	6.26	18,448	1,122	17,326	6.08
Portage city	Kalamazoo	MI	41,042	44,897	9.39	44,702	2,149	42,553	4.81	18,094	842	17,252	4.65
Bloomfield Township CDP	Oakland	MI	42,137	43,021	2.10	42,783	1,078	41,705	2.52	16,887	344	16,543	2.04
Midland city	Midland	MI	38,053	41,685	9.54	40,416	3,567	36,849	8.83	16,787	1,569	15,218	9.35

Muskegon city	Muskegon	MI	40,283	40,105	-4.40	35,224	7,238	27,986	20.55	14,567	2,811	11,756	1.92
Lincoln Park city	Wayne	MI	41,832	40,008	-4.30	39,649	3,059	36,590	7.72	16,201	1,260	14,941	7.78
Bay city	Bay	MI	38,936	36,817	-5.40	36,518	5,336	31,182	14.61	15,252	2,187	13,065	1.43
Jackson city	Jackson	MI	37,446	36,316	-3.00	35,347	6,944	28,403	19.65	14,215	2,631	11,584	1.85
Holland city	Ottawa	MI	30,745	35,048	1.39	32,254	3,430	28,824	10.63	12,044	1,207	10,837	1.00
Eastpointe city	Macomb	MI	0	34,077	0.00	33,997	2,174	31,823	6.39	13,609	930	12,679	6.83
Port Huron city	St. Clair	MI	33,694	32,338	-4.00	31,623	5,342	26,281	16.89	12,938	2,231	10,707	1.72
Madison Heights city	Oakland	MI	32,196	31,101	-3.40	30,779	2,738	28,041	8.90	13,307	1,119	12,188	8.41
Burton city	Genesee	MI	27,617	30,308	9.74	30,211	2,619	27,592	8.67	11,701	1,098	10,603	9.38
Southgate city	Wayne	MI	30,771	30,136	-2.00	29,880	1,363	28,517	4.56	12,822	791	12,031	6.17
Inkster city	Wayne	MI	30,772	30,115	-2.10	29,777	5,795	23,982	19.46	11,166	2,019	9,147	1.80
Garden city	Wayne	MI	31,846	30,047	-5.60	29,920	1,334	28,586	4.46	11,493	618	10,875	5.38
Oak Park city	Oakland	MI	30,462	29,793	-2.10	29,713	2,789	26,924	9.39	11,091	1,071	10,020	9.66
Allen Park city	Wayne	MI	31,092	29,376	-5.50	29,035	931	28,104	3.21	11,984	426	11,558	3.55
Wyandotte city	Wayne	MI	30,938	28,006	-9.40	27,831	1,726	26,105	6.20	11,818	716	11,102	6.06
Plymouth Township CDP	Wayne	MI	23,646	27,798	1.75	26,719	485	26,234	1.82	10,679	191	10,488	1.79
Mount Pleasant city	Isabella	MI	23,285	25,946	1.14	20,298	7,549	12,749	37.19	8,475	2,929	5,546	3.45
Saginaw Township North CDP	Saginaw	MI	23,018	24,994	8.58	24,686	1,746	22,940	7.07	10,705	838	9,867	7.83
Harrison CDP	Macomb	MI	24,685	24,461	-9.00	24,392	1,396	22,996	5.72	10,707	587	10,120	5.48
Duluth city	St. Louis	MN	85,493	86,918	1.67	81,253	12,627	68,626	15.54	35,547	5,351	30,196	1.50
Buffalo city	Erie	NY	328,123	292,648	-1.00	282,377	75,120	207,257	26.60	122,672	31,165	91,507	2.54
Rochester city	Monroe	NY	231,636	219,773	-5.10	211,273	54,713	156,560	25.90	89,093	20,937	68,156	2.35
Syracuse city	Onondaga	NY	163,860	147,306	-1.00	137,234	37,485	99,749	27.31	59,568	15,425	44,143	2.58
Cheektowaga CDP	Erie	NY	84,387	79,988	-5.20	79,326	5,124	74,202	6.46	34,158	2,390	31,768	7.00
Tonawanda CDP	Erie	NY	65,284	61,729	-5.40	61,077	4,461	56,616	7.30	26,205	2,015	24,190	7.69
Utica city	Oneida	NY	68,637	60,651	-1.10	57,770	14,154	43,616	24.50	25,093	5,863	19,230	2.33

Niagara Falls city	Niagara	NY	61,840	55,593	-1.00	54,973	10,705	44,268	19.47	24,071	4,599	19,472	1.91
Irondequoit CDP	Monroe	NY	52,322	52,354	0.06	51,579	2,794	48,785	5.42	22,276	1,282	20,994	5.76
West Seneca CDP	Erie	NY	47,866	45,943	-4.00	45,785	2,126	43,659	4.64	18,354	809	17,545	4.41
Brighton CDP	Monroe	NY	34,455	35,584	3.28	34,143	2,080	32,063	6.09	15,856	992	14,864	6.26
Rome city	Oneida	NY	44,350	34,950	-2.10	31,544	4,728	26,816	14.99	13,653	1,943	11,710	1.42
North Tonawanda city	Niagara	NY	34,989	33,262	-4.90	33,136	2,374	30,762	7.16	13,681	1,100	12,581	8.04
Jamestown city	Chautauqua	NY	34,681	31,730	-8.50	31,050	6,070	24,980	19.55	13,532	2,403	11,129	1.77
Elmira city	Chemung	NY	33,724	30,940	-8.20	27,237	6,286	20,951	23.08	11,486	2,544	8,942	2.21
Ithaca city	Tompkins	NY	29,541	29,287	-8.50	21,672	8,721	12,951	40.24	10,236	3,761	6,475	3.67
Auburn city	Cayuga	NY	31,258	28,574	-8.50	26,214	4,335	21,879	16.54	11,437	1,819	9,618	1.59
Watertown city	Jefferson	NY	29,429	26,705	-9.20	25,814	4,973	20,841	19.26	11,039	2,135	8,904	1.93
Cleveland city	Cuyahoga	OH	505,616	478,403	-5.30	466,305	122,479	343,826	26.27	190,725	46,892	143,833	2.45
Toledo city	Lucas	OH	332,943	313,619	-5.80	306,933	54,903	252,030	17.89	128,842	21,981	106,861	1.70
Akron city	Summit	OH	223,019	217,074	-2.60	211,891	36,975	174,916	17.45	90,143	14,669	75,474	1.62
Parma city	Cuyahoga	OH	87,876	85,655	-2.50	84,231	4,157	80,074	4.94	35,178	1,743	33,435	4.95
Canton city	Stark	OH	84,161	80,806	-3.90	78,073	14,957	63,116	19.16	32,564	6,141	26,423	1.88
Lorain city	Lorain	OH	71,245	68,652	-3.60	67,784	11,582	56,202	17.09	26,422	4,245	22,177	1.60
Lakewood city	Cuyahoga	OH	59,718	56,646	-5.10	55,939	4,956	50,983	8.86	26,721	2,341	24,380	8.76
Elyria city	Lorain	OH	56,746	55,953	-1.30	54,739	6,393	48,346	11.68	22,462	2,409	20,053	1.07
Euclid city	Cuyahoga	OH	54,875	52,717	-3.90	52,094	5,055	47,039	9.70	24,312	2,598	21,714	1.06
Mentor city	Lake	OH	47,358	50,278	6.17	49,840	1,366	48,474	2.74	18,758	589	18,169	3.14
Cleveland Heights city	Cuyahoga	OH	54,052	49,958	-7.50	49,597	5,276	44,321	10.64	20,932	2,400	18,532	1.14
Cuyahoga Falls city	Summit	OH	48,950	49,374	0.87	48,928	2,991	45,937	6.11	21,706	1,553	20,153	7.15
Mansfield city	Richland	OH	50,627	49,346	-2.50	46,181	7,540	38,641	16.33	20,182	3,044	17,138	1.50
Warren city	Trumbull	OH	50,793	46,832	-7.70	45,658	8,847	36,811	19.38	19,292	3,492	15,800	1.81
Strongsville city	Cuyahoga	OH	35,308	43,858	2.42	43,592	947	42,645	2.17	16,207	436	15,771	2.69
Lima city	Allen	OH	45,549	40,081	-1.20	37,526	8,509	29,017	22.67	15,446	3,384	12,062	2.19
Findlay city	Hancock	OH	35,703	38,967	9.14	37,692	3,444	34,248	9.14	15,998	1,425	14,573	8.91
Marion city	Marion	OH	34,075	35,318	3.65	32,931	4,540	28,391	13.79	13,570	1,764	11,806	1.29

North Olmsted city	Cuyahoga	OH	34,204	34,113	-2.60	33,811	1,376	32,435	4.07	13,574	547	13,027	4.03
Brunswick city	Medina	OH	28,230	33,388	1.82	33,062	1,513	31,549	4.58	11,885	514	11,371	4.32
Stow city	Summit	OH	27,702	32,139	1.60	31,567	1,260	30,307	3.99	12,288	608	11,680	4.95
Westlake city	Cuyahoga	OH	27,018	31,719	1.73	30,730	765	29,965	2.49	12,845	354	12,491	2.76
Massillon city	Stark	OH	31,007	31,325	1.03	30,447	3,249	27,198	10.67	12,720	1,313	11,407	1.03
Garfield Heights city	Cuyahoga	OH	31,739	30,734	-3.10	30,266	2,586	27,680	8.54	12,333	1,037	11,296	8.41
Bowling Green city	Wood	OH	28,176	29,636	5.18	22,796	5,761	17,035	25.27	10,199	2,472	7,727	2.42
Shaker Heights city	Cuyahoga	OH	30,831	29,405	-4.60	29,234	2,004	27,230	6.86	12,266	852	11,414	6.95
North Royalton city	Cuyahoga	OH	23,197	28,648	2.34	28,449	662	27,787	2.33	11,266	371	10,895	3.29
Kent city	Portage	OH	28,835	27,906	-3.20	22,280	5,622	16,658	25.23	9,784	2,491	7,293	2.54
Barberton city	Summit	OH	27,623	27,899	1.00	27,517	3,656	23,861	13.29	11,561	1,500	10,061	1.29
Sandusky city	Erie	OH	29,764	27,844	-6.40	27,503	4,201	23,302	15.27	11,884	1,689	10,195	1.42
East Cleveland city	Cuyahoga	OH	33,096	27,217	-1.70	26,645	8,519	18,126	31.97	11,222	3,433	7,789	3.05
Maple Heights city	Cuyahoga	OH	27,089	26,156	-3.40	25,877	1,531	24,346	5.92	10,493	651	9,842	6.20
Medina city	Medina	OH	19,231	25,139	3.07	24,494	1,408	23,086	5.75	9,377	560	8,817	5.97
South Euclid city	Cuyahoga	OH	23,866	23,537	-1.30	23,383	1,063	22,320	4.55	9,494	509	8,985	5.36
Alliance city	Stark	OH	23,376	23,253	-5.20	21,344	3,835	17,509	17.97	8,932	1,468	7,464	1.64
Erie city	Erie	PA	108,718	103,717	-4.50	98,588	18,549	80,039	18.81	40,908	7,203	33,705	1.76
Milwaukee city	Milwaukee	WI	628,088	596,974	-4.90	579,235	123,664	455,571	21.35	232,312	42,313	189,999	1.82
Green Bay city	Brown	WI	96,466	102,313	6.06	99,725	10,490	89,235	10.52	41,656	4,195	37,461	1.00
Kenosha city	Kenosha	WI	80,352	90,352	1.24	87,760	8,328	79,432	9.49	34,503	3,043	31,460	8.82
Racine city	Racine	WI	84,298	81,855	-2.80	79,806	11,120	68,686	13.93	31,358	3,844	27,514	1.22
Appleton city	Outagamie	WI	65,695	70,087	6.69	67,989	3,714	64,275	5.46	26,899	1,498	25,401	5.57

Waukesha city	Waukesha	WI	56,958	64,825	1.38	62,019	3,323	58,696	5.36	25,624	1,375	24,249	5.37
Oshkosh city	Winnebago	WI	55,006	62,916	1.43	55,565	5,672	49,893	10.21	24,019	2,405	21,614	1.00
West Allis city	Milwaukee	WI	63,221	61,254	-3.10	60,508	3,944	56,564	6.52	27,640	1,813	25,827	6.56
Sheboygan city	Sheboygan	WI	49,676	50,792	2.25	49,651	4,107	45,544	8.27	20,799	1,628	19,171	7.83
Wauwatosa city	Milwaukee	WI	49,366	47,271	-4.20	46,372	1,769	44,603	3.81	20,430	848	19,582	4.15
Fond du Lac city	Fond du Lac	WI	37,757	42,203	1.17	39,854	2,992	36,862	7.51	16,676	1,251	15,425	7.50
Brookfield city	Waukesha	WI	35,184	38,649	9.85	38,258	843	37,415	2.20	13,985	283	13,702	2.02
Wausau city	Marathon	WI	37,060	38,426	3.69	37,234	4,227	33,007	11.35	15,743	1,500	14,243	9.53
New Berlin city	Waukesha	WI	33,592	38,220	1.37	38,071	748	37,323	1.96	14,499	298	14,201	2.06
Greenfield city	Milwaukee	WI	33,403	35,476	6.21	34,773	1,637	33,136	4.71	15,702	662	15,040	4.22
Manitowoc city	Manitowoc	WI	32,520	34,053	4.71	33,175	2,609	30,566	7.86	14,165	1,005	13,160	7.09
Menomonee Falls village	Waukesha	WI	26,840	32,647	2.16	32,418	706	31,712	2.18	12,874	325	12,549	2.52
Franklin city	Milwaukee	WI	21,855	29,494	3.49	27,610	734	26,876	2.66	10,637	289	10,348	2.72
Oak Creek city	Milwaukee	WI	19,513	28,456	4.58	28,395	868	27,527	3.06	11,277	450	10,827	3.99
West Bend city	Washington	WI	23,916	28,152	1.77	27,730	1,374	26,356	4.95	11,366	540	10,826	4.75
Superior city	Douglas	WI	27,134	27,368	0.86	26,261	3,507	22,754	13.35	11,606	1,561	10,045	1.34
Stevens Point city	Portage	WI	23,006	24,551	6.72	21,362	3,687	17,675	17.26	9,276	1,603	7,673	1.72
Neenah city	Winnebago	WI	23,219	24,507	5.55	24,245	1,301	22,944	5.37	9,756	516	9,240	5.29

TABLE 2 - Great Lakes Cities Canada Census Population Summary

Subdivision	Division	Province	Population in 2001	Population in 2006	Pop. Change (%)	Pop. in Private Households	Pop. in Low Income after Tax	Percent of Low Income by Pop.	Housing Units
Toronto	Toronto	Ontario	2,481,494	2,503,281	0.90	2,465,500	478,710	19.42	1,040,597
Mississauga	Peel	Ontario	612,925	668,549	9.10	663,830	80,060	12.06	223,737
Hamilton	Hamilton	Ontario	490,268	504,559	0.00	495,455	69,320	13.99	204,962
Brampton	Peel	Ontario	325,428	433,806	33.30	430,810	44,490	10.33	130,803
London	Middlesex	Ontario	336,539	352,395	4.70	347,390	40,990	11.80	157,436
Markham	York	Ontario	208,615	261,573	25.40	260,420	32,760	12.58	81,181
Vaughan	York	Ontario	182,022	238,866	31.20	237,830	19,200	8.07	71,265
Windsor	Essex	Ontario	209,218	216,473	3.50	213,665	30,400	14.23	95,049
Kitchener	Waterloo	Ontario	190,399	204,668	7.50	201,335	17,605	8.74	82,723
Oakville	Halton	Ontario	144,738	165,613	14.40	163,680	12,590	7.69	58,828
Burlington	Halton	Ontario	150,836	164,415	9.00	162,205	11,555	7.12	65,340
Richmond Hill	York	Ontario	132,030	162,704	23.20	161,555	20,090	12.44	53,028
Greater Sudbury / Grand Sudbury	Greater Sudbury / Grand Sudbury	Ontario	155,219	157,857	1.70	155,120	14,570	9.39	69,430
Oshawa	Durham	Ontario	139,051	141,590	1.80	139,670	13,250	9.49	57,469
St. Catharines	Niagara	Ontario	129,170	131,989	2.20	129,600	13,625	10.51	57,790
Barrie	Simcoe	Ontario	103,710	128,430	23.80	126,290	10,645	8.43	48,196
Cambridge	Waterloo	Ontario	110,372	120,371	9.10	118,730	8,425	7.10	44,589
Kingston	Frontenac	Ontario	114,195	117,207	2.60	113,100	12,545	11.09	53,838
Guelph	Wellington	Ontario	106,170	114,943	8.30	113,505	9,430	8.31	47,969
Whitby	Durham	Ontario	87,413	111,184	27.20	110,155	5,920	5.37	38,129
Thunder Bay	Thunder Bay	Ontario	109,016	109,140	0.10	107,040	10,600	9.90	49,023
Chatham-Kent	Chatham-Kent	Ontario	107,341	108,177	0.80	105,945	8,335	7.87	46,614
Waterloo	Waterloo	Ontario	86,543	97,475	12.60	95,945	7,790	8.12	40,659
Brantford	Brant	Ontario	86,417	90,192	4.40	88,590	8,905	10.05	36,963
Ajax	Durham	Ontario	73,753	90,167	22.30	89,765	7,290	8.12	29,535
Pickering	Durham	Ontario	87,139	87,838	0.80	87,240	6,280	7.20	29,044
Niagara Falls	Niagara	Ontario	78,815	82,184	4.30	80,510	7,700	9.56	33,871
Clarington	Durham	Ontario	69,834	77,820	11.40	77,105	3,510	4.55	27,753
Sault Ste. Marie	Algoma	Ontario	74,566	74,948	0.50	73,690	7,180	9.74	33,378
Peterborough	Peterborough	Ontario	71,446	74,898	4.80	72,750	9,140	12.56	33,042
Kawartha Lakes	Kawartha Lakes	Ontario	69,179	74,561	7.80	73,115	5,065	6.93	37,986

Newmarket	York	Ontario	65,788	74,295	12.90	73,265	5,420	7.40	25,876
Sarnia	Lambton	Ontario	70,876	71,419	0.80	70,035	5,760	8.22	31,610
Norfolk County	Haldimand-Norfolk	Ontario	60,847	62,563	2.80	61,420	3,645	5.93	26,527
Caledon	Peel	Ontario	50,605	57,050	12.70	56,800	1,995	3.51	18,915
Halton Hills	Halton	Ontario	48,184	55,289	14.70	54,290	1,945	3.58	19,265
North Bay	Nipissing	Ontario	52,771	53,966	2.30	52,790	6,355	12.04	23,841
Milton	Halton	Ontario	31,471	53,939	71.40	53,200	1,960	3.68	18,913
Welland	Niagara	Ontario	48,402	50,331	4.00	49,785	5,080	10.20	21,543
Belleville	Hastings	Ontario	46,029	48,821	6.10	47,470	4,875	10.27	21,239
Aurora	York	Ontario	40,167	47,629	18.60	46,870	2,880	6.14	16,032
Haldimand County	Haldimand-Norfolk	Ontario	43,728	45,212	3.40	44,480	2,445	5.50	18,386
Quinte West	Hastings	Ontario	41,366	42,697	3.20	42,240	3,605	8.53	17,612
Georgina	York	Ontario	39,263	42,346	7.90	41,865	3,835	9.16	16,879
St. Thomas	Elgin	Ontario	33,303	36,110	8.40	35,305	3,000	8.50	15,225
Woodstock	Oxford	Ontario	33,269	35,480	6.60	34,730	2,375	6.84	14,960
Brant	Brant	Ontario	31,669	34,415	8.70	33,900	1,435	4.23	12,517
Lakeshore	Essex	Ontario	28,746	33,245	15.70	33,090	1,280	3.87	12,368
Innisfil	Simcoe	Ontario	28,666	31,175	8.80	31,070	2,025	6.52	12,822
Stratford	Perth	Ontario	29,780	30,461	2.30	29,770	2,020	6.79	13,316
Orillia	Simcoe	Ontario	29,121	30,259	3.90	28,930	2,905	10.04	13,013
Fort Erie	Niagara	Ontario	28,143	29,925	6.30	29,345	2,210	7.53	14,251
Leamington	Essex	Ontario	27,138	28,833	6.20	27,055	1,870	6.91	10,465
New Tecumseth	Simcoe	Ontario	26,141	27,701	6.00	27,240	1,090	4.00	10,315
LaSalle	Essex	Ontario	25,285	27,652	9.40	27,530	1,165	4.23	9,537
Orangeville	Dufferin	Ontario	25,248	26,925	6.60	26,515	1,330	5.02	9,636
Centre Wellington	Wellington	Ontario	24,260	26,049	7.40	25,695	1,030	4.01	10,267
Prince Edward	Prince Edward	Ontario	24,901	25,496	2.40	24,755	1,490	6.02	12,055
Whitchurch-Stouffville	York	Ontario	22,008	24,390	10.80	24,060	930	3.87	8,898
Tecumseh	Essex	Ontario	24,289	24,224	-0.30	24,195	920	3.80	8,710
Bradford West Gwillimbury	Simcoe	Ontario	22,228	24,039	8.10	23,815	890	3.74	8,128
Grimsby	Niagara	Ontario	21,297	23,937	12.40	23,505	1,315	5.59	8,944

Talbe 3 Great Lakes Annual U.S.-Flag Cargo Carriage (1996-2009),net tons

	Iron Ore		Coal (by lake of loading)								
Year	Direct Shipment*	Trans-shipment**	Lake Superior	Lake Michigan	Lake Erie	Limestone	Cement	Salt	Sand	Grain	Total
1996	54,663,331	6,741,365	12,926,516	8,129,943		26,137,520	3,734,530	1,149,700	232,010	536,683	114,251,598
1997	56,727,630	6,643,000	13,763,365	9,480,887		28,755,341	4,159,146	1,002,934	272,218	669,741	121,474,262
1998	57,545,538	5,977,686	13,584,279	8,472,940		30,358,476	4,251,903	1,312,157	234,300	352,083	122,089,362
1999	52,160,147	5,523,530	13,353,794	8,279,404		27,310,498	4,417,055	1,309,894	249,238	346,814	112,950,374
2000	54,586,514	5,746,164	12,769,682	2,068,078	5,922,714	27,288,089	4,144,774	838,017	427,070	351,857	114,142,959
2001	43,829,971	3,094,732	13,640,260	2,288,791	6,030,000	26,988,622	4,136,897	876,392	625,094	350,719	101,861,478
2002	45,861,075	2,334,252	13,874,872	2,239,657	5,629,302	26,554,243	3,817,911	587,090	230,095	329,471	101,457,968
2003	41,343,509	1,672,776	14,238,033	2,771,065	4,870,328	24,239,110	3,851,487	945,355	500,456	312,316	94,744,435
2004	48,265,018	2,936,493	15,459,399	3,734,928	5,222,022	29,861,141	3,965,401	1,032,109	489,355	367,785	111,333,651
2005	43,884,572	2,687,547	17,429,479	3,760,477	6,017,394	27,935,513	3,892,822	1,187,777	461,813	403,055	107,660,449
2006	45,850,298	3,121,814	17,180,114	3,161,804	5,018,195	29,489,410	3,997,703	1,126,862	429,411	356,143	109,731,754
2007	45,049,721	2,156,662	16,692,347	2,718,874	5,759,408	25,966,057	3,602,488	1,241,297	449,474	404,923	104,041,251
2008	45,329,607	1,893,887	17,962,580	3,253,001	3,756,042	23,632,070	3,294,071	1,224,769	359,191	247,597	100,952,815
2009	23,271,702	759,385	15,427,708	1,996,793	3,250,387	17,067,232	2,865,323	1,260,901	262,805	304,507	66,466,743

*Direct shipment means that the container does not change the vessel.
**Trans-shipment means that the container actually changes the vessels; usually transported slower with lower costs than direct shipment containers.

Source: modified data from the Annual Statistics Reports 2002-2009, Lake Carriers' Association

Table 4 Comparison: Coastal and Great Lakes Freight Transportation-State Level

State	Paid employees (number)	Total Establishments	'1-4'	'5-9'	'10-19'	'20-49'	'50-99'	'100-249'	'250-499'	'500-999'	'1000 or more'
Illinois	199	13	3	4	4	1	1	0	0	0	0
Indiana	0-19	3	2	0	1	0	0	0	0	0	0
Michigan	295	10	4	0	1	2	3	0	0	0	0
Minnesota	250-499	2	0	0	1	0	0	0	1	0	0
New York	1759	50	21	5	11	6	2	3	2	0	0
Ohio	250-499	8	3	0	3	0	0	1	1	0	0
Pennsylvania	496	7	2	2	0	1	0	1	1	0	0
Wisconsin	0-19	1	0	0	1	0	0	0	0	0	0

Source: modified data from the U.S. Census 2008 County Business Patterns

Talbe 5 Comparison: Transportation and Warehousing – Place Level

Country	State/Province	Place/Subdivision	% (number of industry employees to the total population)
Canada	Ontario	Brampton	6%
U.S.	Illinois	Dolton Village	13.5%
		Maywood Village	12.6%
		Burbank	10%
		Harvey	10%
		Calumet	9.4%
	Indiana	Portage	7.2%
	Michigan	Lincoln Park	8.6%
		Inkster	8.0%
		Southgate	7.9%
		Taylor	7.5%
	Minnesota	Duluth (*only 'place' in the GLB)	5.0%
	Ohio	Cleveland	5.2%
		Strongsville	5%
		Maple Heights	5%
		Brunswick	5%
	New York	Cheektowaga CDP	5.8%
		Buffalo	4.8%
	Pennsylvania	Erie (*only 'place' in the GLB)	2.4%
	Wisconsin	Oak Creek	8.3%
		Franklin	5.9%
		Green Bay	4.5%
		Greenfield	4.5%
		Milwaukee	4.4%

Source: modified data from the U.S. Census 2000

Talbe 6 2007 Economic Generation of Tourism in the Great Lakes States

State	Expenditures	Travel Generated Employment	Percent of Total Jobs	Tax Ravenue Federal	Tax Revenue State	Tax Revenue Local
Illinois	$29,909,300,000	305,400	5.1%	$3,360,400,000	$1,397,200,000	$708,100,000
Indiana	$8,794,800,000	90,000	3.3%	$666,400,000	$411,700,000	$165,700,000
Michigan	$15,252,800,000	148,700	3.5%	$1,481,100,000	$767,400,000	$165,100,000
Minnesota	$10,324,500,000	140,400	5.1%	$1,903,000,000	$820,900,000	$266,900,000
New York	$51,264,700,000	419,300	4.8%	$4,634,300,000	$1,968,100,000	$3,284,300,000
Ohio	$15,809,300,000	168,200	3.1%	$1,480,200,000	$685,300,000	$344,300,000
Pennsylvania	$20,272,200,000	214,400	3.7%	$1,797,000,000	$858,600,000	$341,900,000
Wisconsin	$9,120,000,000	115,500	4.0%	$765,100,000	$521,700,000	$161,100,000

Source: The Impact of Travel on State Economies 2009 Research Report

Table 7 Budget – FY 2010-2011, City of Marquette

*items in blue indicate the funds that did not exist in FY 2007-2008 budget

GENERAL FUND	
General Fund	
Revenues by Source:	
Taxes	8,796,520
Payment in lieu of taxes	2,660,000
State revenue sharing	1,938,000
Other	3,713,845
Total Revenues	17,108,365
Expenditures by Function:	
General government	2,818,565
Public safety	6,249,955
Public works	3,831,050
Recreation & culture	659,115
Transfers out	3,549,680
Total Expenditures	17,108,365
DEBT SERVICE FUNDS	
1998 Building Authority Debt Fund-MSC	
Revenues:	264,945
Expeditures:	264,945
FY 2007 Street Projects Debt Fund	
Revenues:	241,850
Expeditures:	241,850
2006 High Street Debt Fund	
Revenues:	13,230
Expeditures:	13,230
FY 2008 Street Projects Debt Fund	
Revenues:	216,360
Expeditures:	216,360

SPECIAL REVENUE FUNDS	
Major Street and Trunkline Fund	
Revenues:	3,483,955
Expenditures:	3,483,955
Local Street Fund	
Revenues:	2,686,165
Expeditures:	2,686,165
Sanitation Fund	
Revenues:	1,393,000
Expeditures:	1,393,000
Brownfield Fund	
Revenues:	66,040
Expeditures:	66,040
Public Education Government Fund	
Revenues:	12,065
Expeditures:	12,065
Peter White Public Library	
Revenues:	1,640,800
Expeditures:	1,640,800
MSHDA Downtown Development Authority	
Revenues:	800,178
Expeditures:	800,178
Criminal Justice Training Fund	
Revenues:	8,150
Expeditures:	8,150
Senior Services Fund	
Revenues:	477,860

2008 MDOT-Spring Street Debt Fund	
Revenues:	82,875
Expeditures:	82,875
FY 2009 Street Projects Debt Fund	
Revenues:	326,580
Expeditures:	326,580
2008 Founders Landing Debt Fund	
Revenues:	278,825
Expeditures:	278,825
2005 Heartwood Forestland Debt Fund	
Revenues:	566,000
Expeditures:	566,000
1997 Library Improvement Debt Fund	
Revenues:	351,400
Expeditures:	351,400
TOTAL:	2,342,065
INTERNAL SERVICE FUNDS	
Technology Services Fund	
Revenues:	1,061,915
Expeditures:	1,061,915
Municipal Service Center Fund	
Revenues:	604,955
Expeditures:	604,955
Motor Vehicle Equipment Fund	
Revenues:	2,700,000
Expeditures:	2,700,000
TOTAL:	4,366,870

Expeditures:	477,860
Lakeview Arena Fund	
Revenues:	858,350
Expeditures:	858,350
TOTAL:	11,426,563
ENTERPRISE FUNDS	
Tourist Park Fund	
Revenues:	154,250
Expeditures:	154,250
Stormwater Utility Fund	
Revenues:	2,768,446
Expeditures:	2,768,446
Marquette Area Wastewater Treatment Facility Fund	
Revenues:	2,551,060
Expeditures:	2,551,060
Water Fund	
Revenues:	6,504,095
Expeditures:	6,504,095
Sewer Fund	
Revenues:	6,884,455
Expeditures:	6,884,455
Presque Isle Marina Fund	
Revenues:	81,825
Expeditures:	81,825
Cinder Pond Marina Fund	
Revenues:	243,086
Expeditures:	243,086
Concessions Fund	
Revenues:	194,310
Expeditures:	194,310
TOTAL:	[illegible]

Table 8 Ports History

Port of Chicago /Illinois/

1800s Founded by Jean Baptiste Pointe DuSable. Chicago was the distribution point for the products of upper Midwest fur traders, farmers and lumber producers.
1848 Shipping in Chicago expanded due to the construction of the Illinois and Michigan canal, which connected Atlantic Ocean and the Gulf of Mexico inland.
1921 A deep water port was built. The Van Vlissingen plan allowed the Port remains its basic framework for commercial shipping and industrial development.
1935 Regularly scheduled overseas shipping service was established.
1951 The General Assembly created the Chicago Regional Port District to supervise harbor and port development. The district functioned as independent municipal corporation.
1959 The St. Lawrence Seaway was dedicated after the port opened. Deep-draft commercial vessels travelled the Seaway between the Port and the Atlantic Ocean, while barges used the Mississippi and Illinois Rivers to travel between the Port and the Gulf of Mexico.
1978 A second major waterfront site for future development was built at the mouth of the Calumet River, including two new terminal sheds. The site was rechristened "Iroquois Landing".
2000s The Port became a key distribution point for many different types of cargo. Among the cargoes most frequently handled there were steel, grain, scrap metals, graphite, zinc, silicon, stone, coke, lead, ore, cement, sugar, and vegetable oils
(Source: The Illinois Internetional Port District, 2010)

Port of Detroit /Michigan/

1701 Founded by Antoine de La Mothe Cadillac. Located between the upper and lower Great Lakes, as an access to forest, soil and mining materials.
1751 Became an important fur-trading center.
1800s Became a gateway for shipment of timber, wool, and field products from the north and west, as well as manufactured goods from the east. When the ores, limestone and coal were discovered, the Port became more important for trade and transportation. Growing steadily from the 1830s, it was home to industries engaged in shipping, shipbuilding, and manufacturing.
1900s It grew rapidly and achieved its status as one of the leading manufacturing centers.. New residents poured in from the South to find work in the new automobile plants.
2000s Development of the city's riverfront was a top priority. The Detroit/Wayne County Port Authority built a $11 million US Public Dock and Terminal to enhance it as a tourist destination.
(Source: The Detroit/Wayne County Authority, 2011)

Port of Cleveland /Ohio/

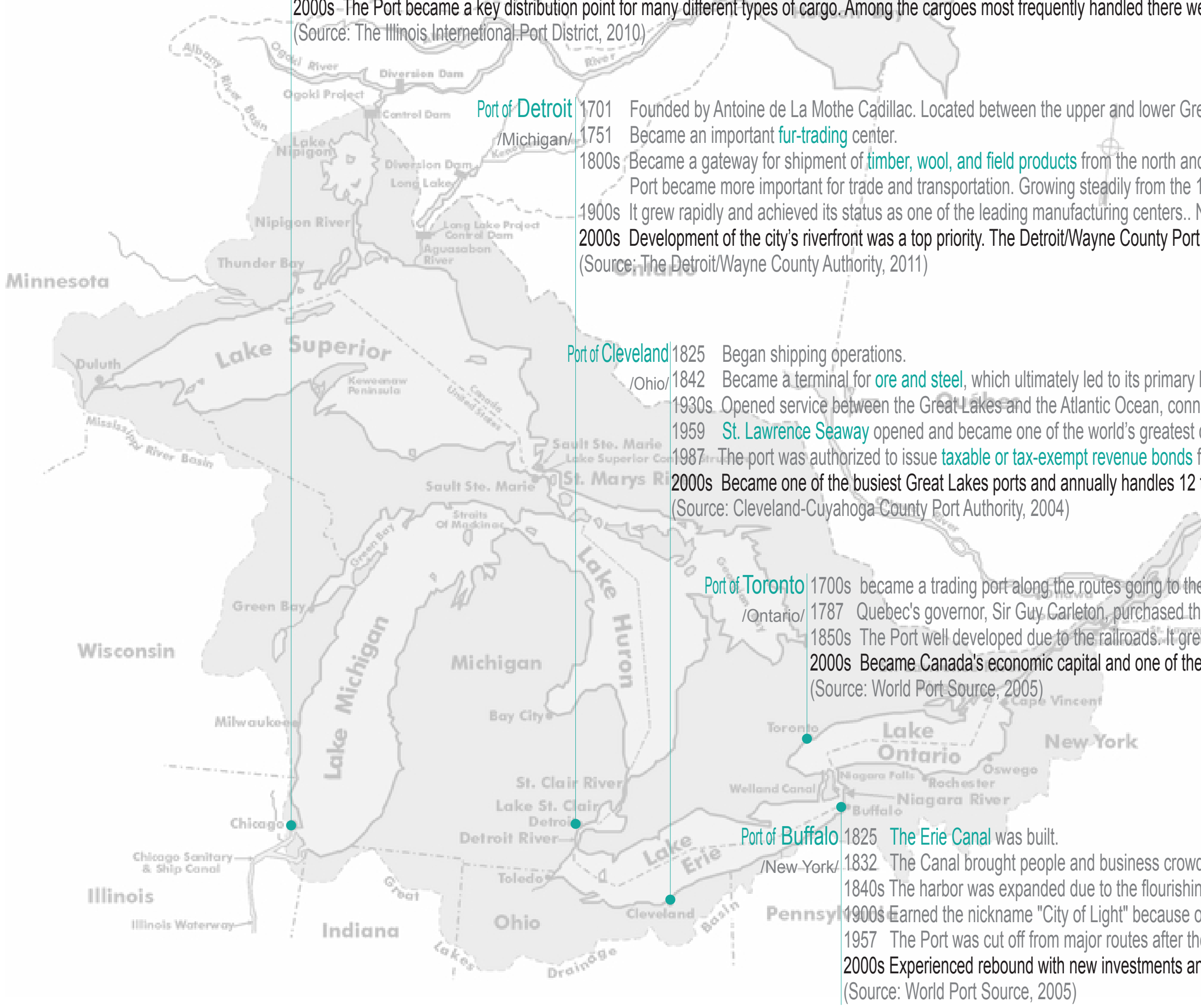
1825 Began shipping operations.
1842 Became a terminal for ore and steel, which ultimately led to its primary business.
1930s Opened service between the Great Lakes and the Atlantic Ocean, connecting the Port to the United Kingdom, continental Europe and Scandinavia.
1959 St. Lawrence Seaway opened and became one of the world's greatest commercial waterways, making it possible for oversea shipping.
1987 The port was authorized to issue taxable or tax-exempt revenue bonds for development initiatives.
2000s Became one of the busiest Great Lakes ports and annually handles 12 to 16 million metric tons of cargo. The shipments were mainly steel and cement.
(Source: Cleveland-Cuyahoga County Port Authority, 2004)

Port of Toronto /Ontario/

1700s became a trading port along the routes going to the Mississippi River to the west and Lake Simcoe to the north, used by fur traders, explorers, and missionaries.
1787 Quebec's governor, Sir Guy Carleton, purchased the site for the Port of Toronto from three tribal Chiefs.
1850s The Port well developed due to the railroads. It grew rapidly as timber was harvested and farms were expanded.
2000s Became Canada's economic capital and one of the world's top financial centers.
(Source: World Port Source, 2005)

Port of Buffalo /New York/

1825 The Erie Canal was built.
1832 The Canal brought people and business crowding into the Port.
1840s The harbor was expanded due to the flourishing grain and commercial shipments.
1900s Earned the nickname "City of Light" because of its widespread electric lighting. Automobile industry thrived.
1957 The Port was cut off from major routes after the openning of the St. Lawrence Seaway. Local economy went downhill.
2000s Experienced rebound with new investments and developments. The port mainly handled bulks of salt, steel and stone.
(Source: World Port Source, 2005)



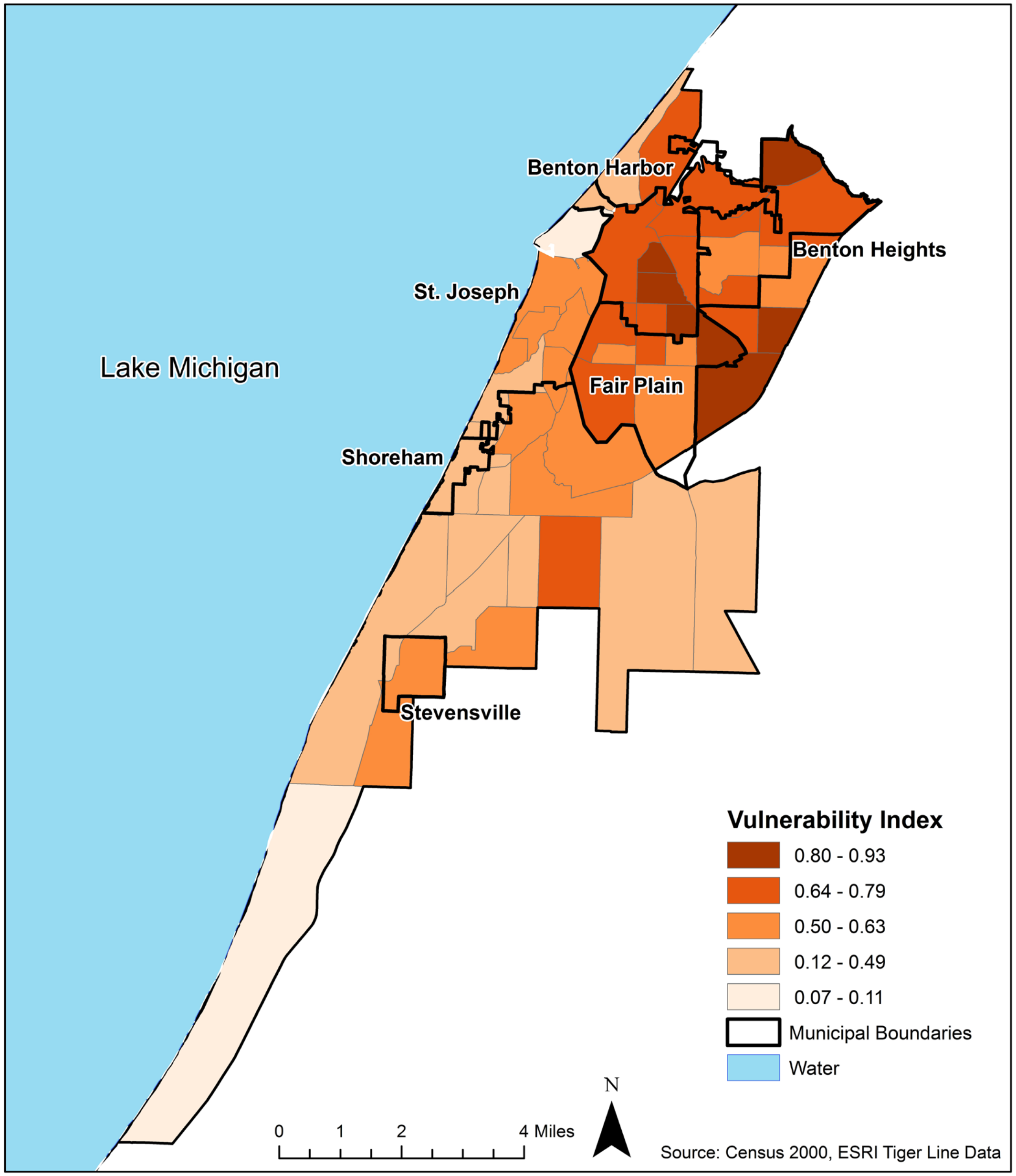
Talbe 9 Ports History II

Port	1700s	1800s	1900s	2000s
Port of Duluth-Superior Minnesota/Wisconsin		1800s The Duluth Ship Canal was developed. Commercial marine traffic Began. 1870s Became a mid-continent transportation hub. The Port has easy access to natural resources. The primary products were grain and eastern coal.	1900s The iron ore shipment via this port made the majority of steel that built America. The closing of the US Steel plant in 1987 due to foreign competition resulted in industrial decline.	2000s Focused on tourism. Duluth's Canal Park is a tourist center, using old warehouses as restaurants, cafes, and shops. (Source: World of Ports, 2005)
Port of Milwaukee Wisconsin		1835 The port was opened. Settlers and traders were attracted to the site because of its proximity to the "western frontier". 1881 Congress made provision to create a Harbor of Refuge in Milwaukee by the extension of a breakwater across the Bay.	1927 Operated dredging and filling on Jones Island in order to develop a car-ferry terminal.	2000s Handled heavy containers; dedicated to cultivating the wind industry. (Source: World of Ports, 2005)
Port of Lorain Ohio			1960s Funded by U.S. Army Corp of Engineers for harbor improvements. Redesign Norfolk Southern Railroad Bridge to accommodate ocean-going vessels. 1980s LTV Steel built the Lorain Pellet Terminal facility for transshipment of ore. Marina International (Spitzer-Lakeside Marina) was constructed.	2000s Transformed from a heavy industrial to a mixed-use waterfront. The primary shipping products are iron ore, coal, limestone, gravel, sand,stone and calcium chloride. (Source: Lorain Port Authority, 2008)
Port of Toledo Ohio		1840s The towns of Port Lawrence and Vistula merged to gain a competitive edge for the Miami and Erie Canal connecting Cincinnati to Lake Erie. The combined city was named Toledo. The Port of Toledo was born, when the canal was finished. 1880 Railroads began to compete with the canals for transportation. The port became the hub for railroads, and an industrial community formed with furniture, carriages, glass, and beer productions.		2000s Became the largest seaport on the Great Lakes. It handled all types of cargo, including bulk, breakbulk, containers, and project cargo. cargos ranged from corn, wheat, and soybeans to coal and metal products. (Source: World of Ports, 2005)
Port of Kingston New York	1700s British Governments, Jamaican Governors, pirates, buccaneers and privateers plundered and brought fortunes to finance imports.	1800s Became one of the principal ports in the Western Hemisphere, and the main source of coins for the British Empire.	1900s Became a primary source of supply of labor for the canals, railways, and the introduction of banana cultivation. 1944 Coastal trade was renewed among Jamaican ports with the closure of the Atlantic merchant shipping lanes; and small boats started trading with other Caribbean ports.	2000s Evolved from a boat yard with a repair facility and a hoist to a picturesque park-like setting, providing park and recreation facilities. (Source: World of Ports, 2005)

Port	1700s 1800s 1900s 2000s	
Port of Oswego, New York	1870s	Became the largest lumber port in the US.The grain trade was born; Salt was shipped from Syracuse west to the Welland Canal and Lake Erie; wheat shipments provided for the flour mills along Oswego's two hydraulic canals.
	1955	Officially commissioned. Known as a ship-building port, populated with the tall masts of schooners and sailing ships.
	2000s	Nearly 120 vessels call on an annual basis. The primary products are cement, corn, salt and windmills.
		(Source: World of Ports, 2005)
Port of Hamilton, Ontario	1815	The original site was purchased by George Hamilton. Port Hamilton soon became a highly-populated industrial area.
	1830	The Burlington Canal connected to Lake Ontario for the landlocked Burlington Bay. The port started to grow as a rail center.
	2000s	Became one of the top ten Canadian ports. Cargoes include raw materials like iron ore and coal, sand, salt, soybeans, grains, jet fuel, and liquid fertilizers.
		(Source: World of Ports, 2005)
Port of Thunder Bay, Ontario	1800s	The area was settled permanently as two towns: Port Arthur and Fort William. They thrived as silver was discovered there and the railroad came. Both cities experienced building boom until the early 20th Century.
	1900s	Manufacturing and shipbuilding industries were recovered during World War I. The Canada Car and Foundry Company re-opened.
	1970	Fort Williams and Port Arthur were combined to create Thunder Bay Port. And it soon became a regional service center for Northwestern Ontario.
	2000s	As the second biggest grain port in Canada, the port handles cargoes like coal, potash, grain, forest products, manufactured goods, sand, salt, stone, limestone, and urea.
		(Source: World of Ports, 2005)
Port of Québec, Québec	1700s	Built by Samuel de Champlain as a colony at the long-abandoned Iroquois village of Stadacona. It soon became an important fur trading center.
	1800s	The city was incorporated. Trinity House was founded in 1805 in charge of dredging the river to make it navigable to larger vessels. Corporations were created to develop port facilities. The Port of Quebec's Estuary Sector, the Bassin Louise, silos at Bunge, and railways were added to the port.
	1900s	After the port diversified it became a vital trans-shipment point on the St. Lawrence Seaway and River.
	2000s	The second busiest port in Canada, its handles cargoes grain, feed grain, industrial and agricultural fertilizers, steel products, ferrous scrap metal, sugar, salt, cement, limestone and dolomite.
	2002	The Port of Quebec's Cruise Terminal at Pointe-a-Carcy opened to offer service to cruise liners and passengers.
		(Source: Port de Québec, 2011)
Port of Montréal, Québec	1760	The fur trade expanded and the first port facilities were built.
	1825	The Lachine Canal opend the way to sail up the St. Lawrence. Later in 1850, the port began to accommodate trans-ocean ships. The railway industry begian to flourish.
	1859	Victoria Bridge was built to allow trains cross the river. Montréal, as the most important grain port in the world, became Canada's primary hub for rail and maritime transport.
	1959	The opening of the St. Lawrence Seaway made it unnecessary for trans-ocean vessels to stop in Montréal. The port went downhill.
	1970s	Lachine Canal was closed. The Port was moved farther east, and port activities in Old Montréal were ended. The new port specialized in handling containers.
	2000s	The Port of Montreal's cargoes included forest products, foodstuffs, metal products, construction materials, iron and steel products, vehicles and accessories, chemicals, textiles, ores, granite and sandstone. It also hosts cruise vessels and passengers.
		(Source: History of the Old Ports, 2008)

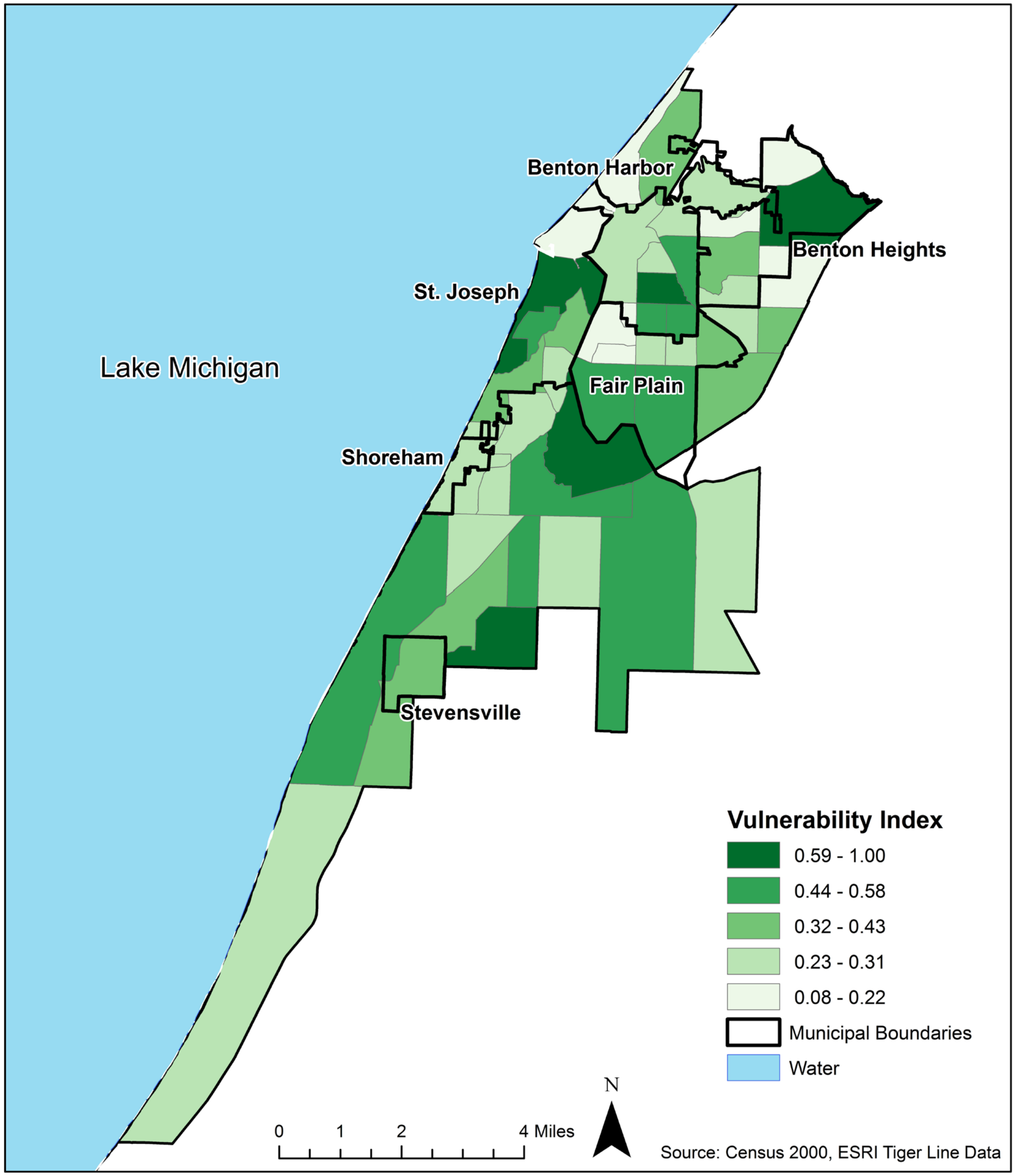
APPENDIX-D Additional Maps

APPENDIX-D ADDITIONAL Maps

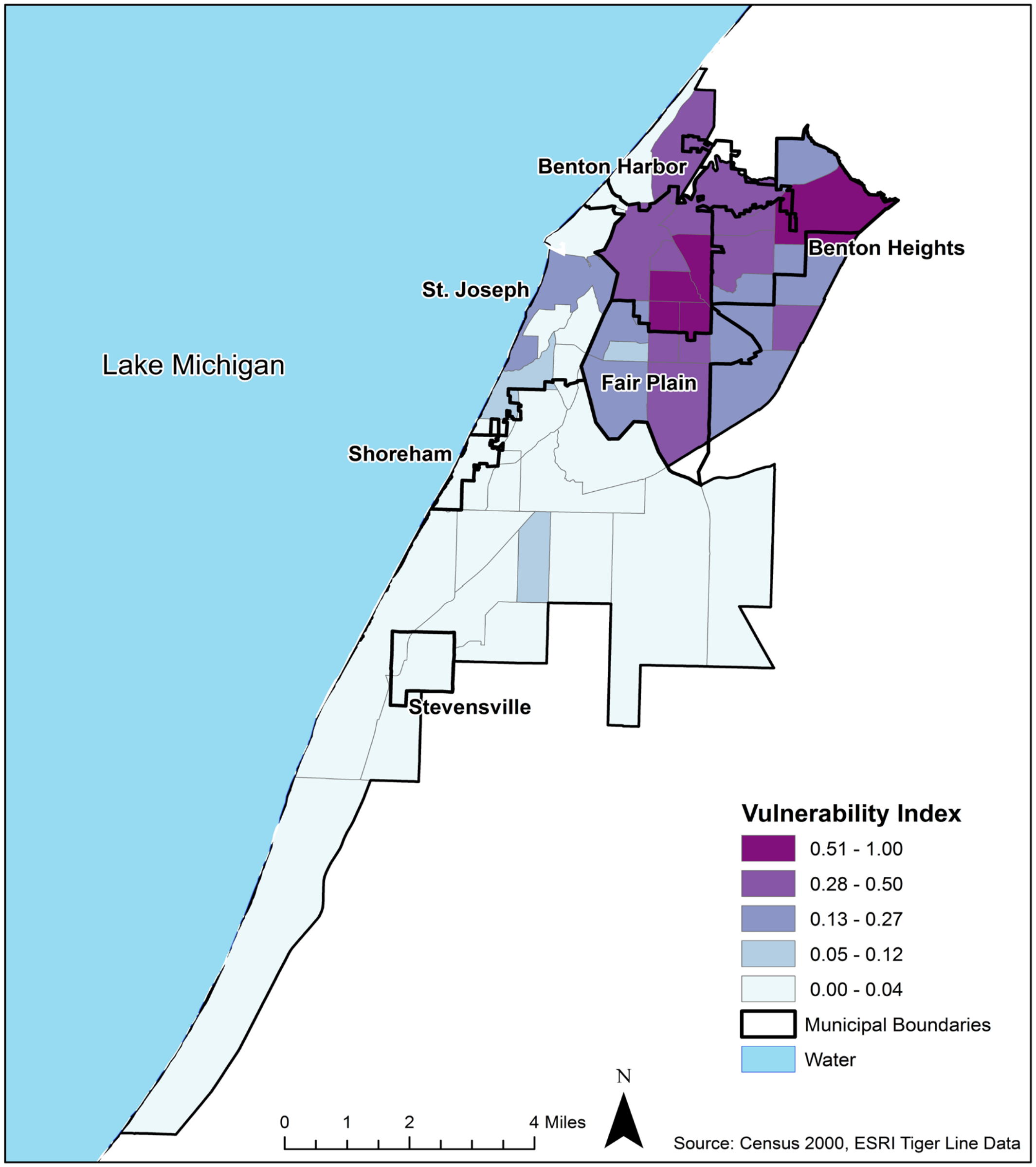


Map 1 Distribution of Dwelling Value Vulnerability, St. Joseph/Benton Harbor, MI Area by Census Block Group (2000)

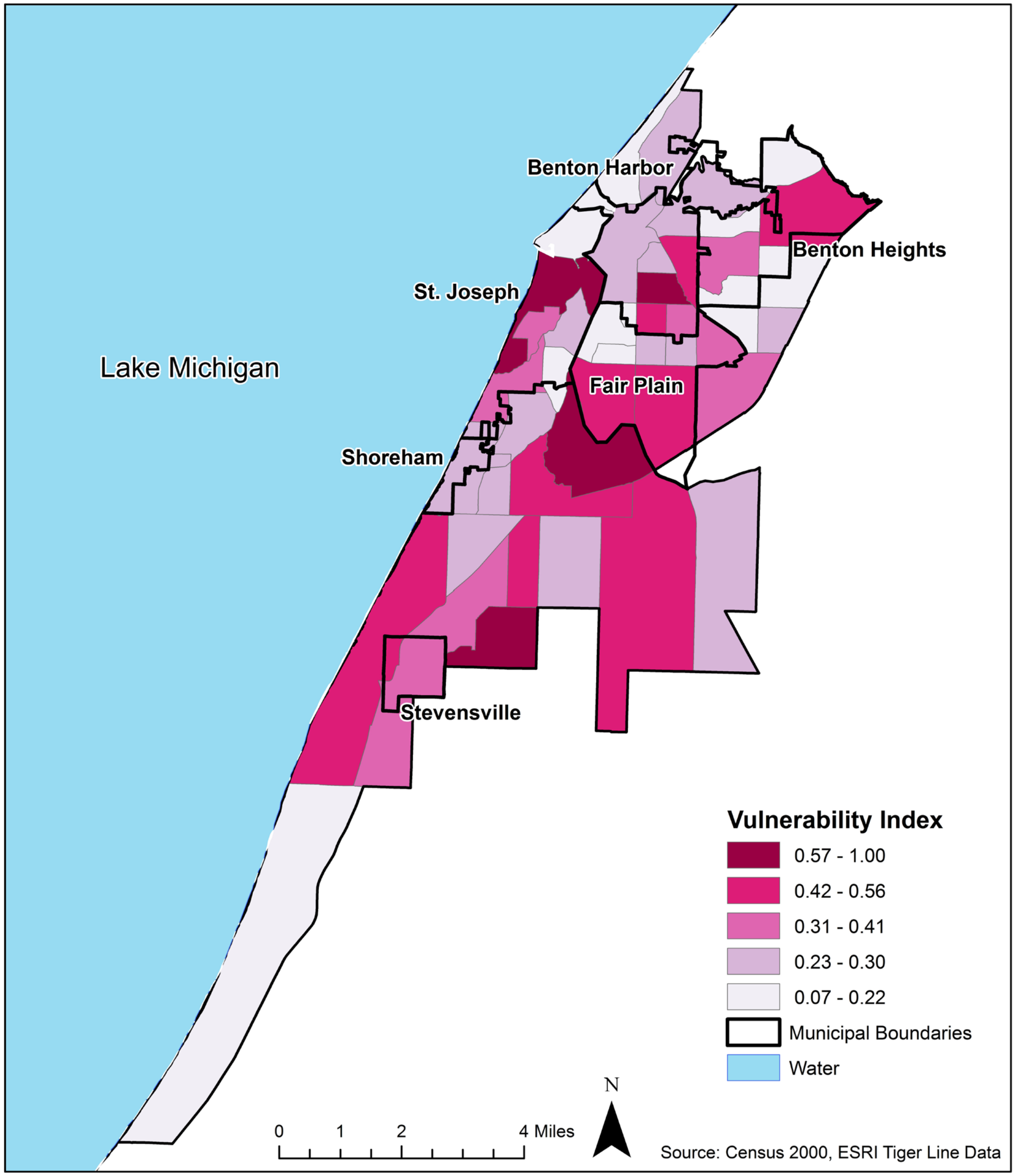
Map 2 Distribution of Female Vulnerability, St. Joseph/Benton Harbor, MI Area by Census Block Group (2000)

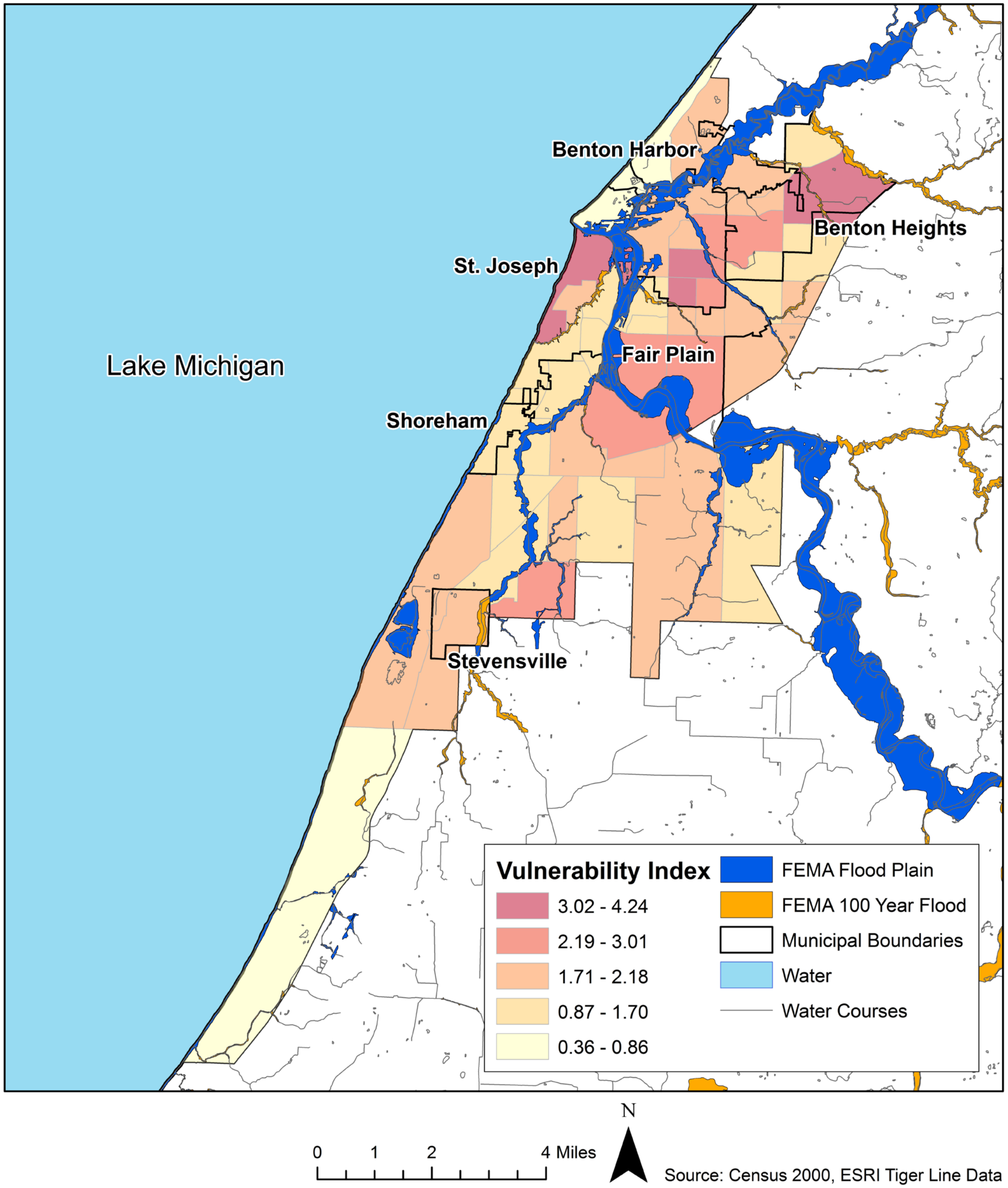


Map 3 Distribution of Non-white Vulnerability, St. Joseph/Benton Harbor, MI Area by Census Block Group (2000)



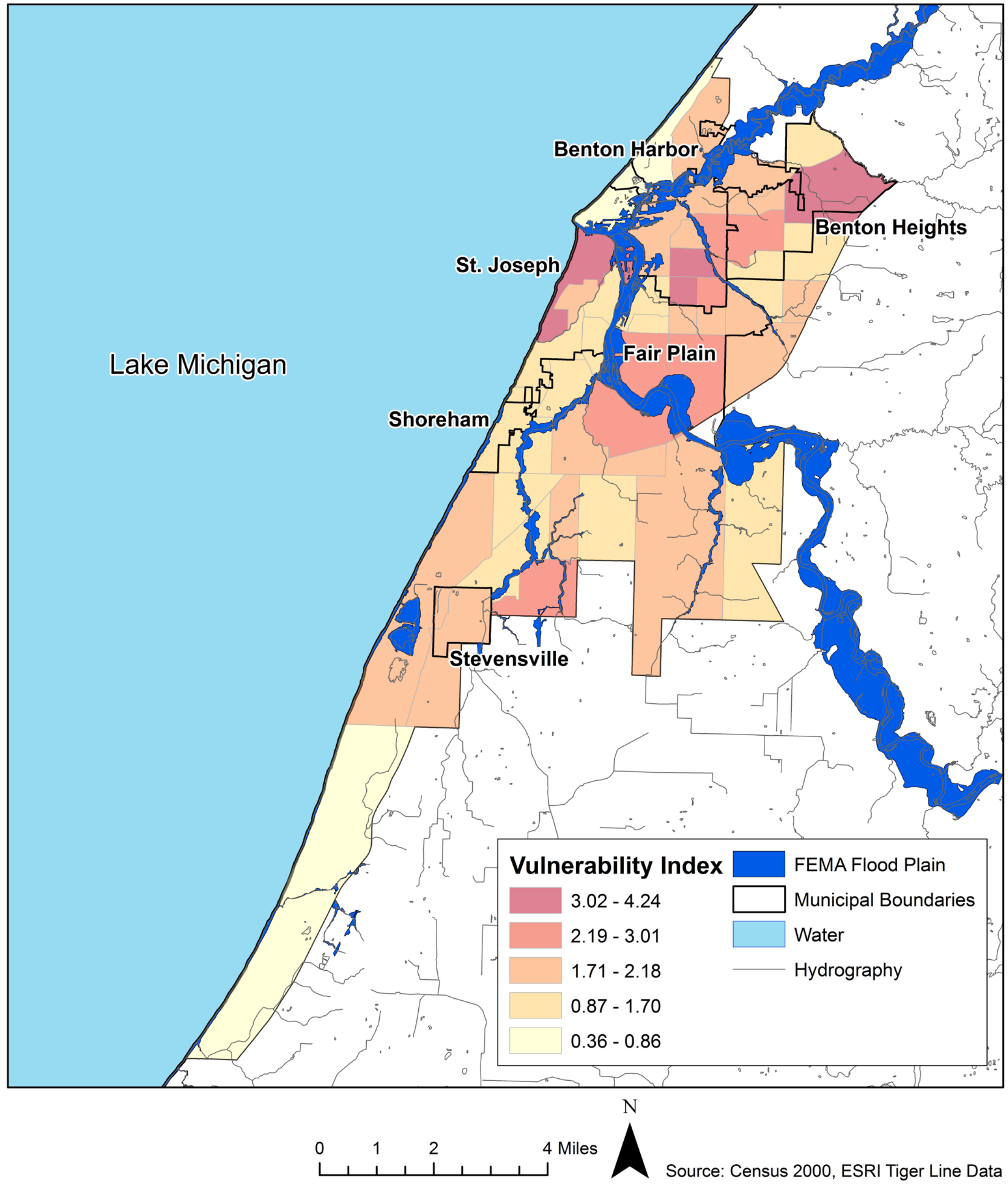
Map 4 Distribution of Population Density Vulnerability, St. Joseph/Benton Harbor, MI Area by Census Block Group (2000)

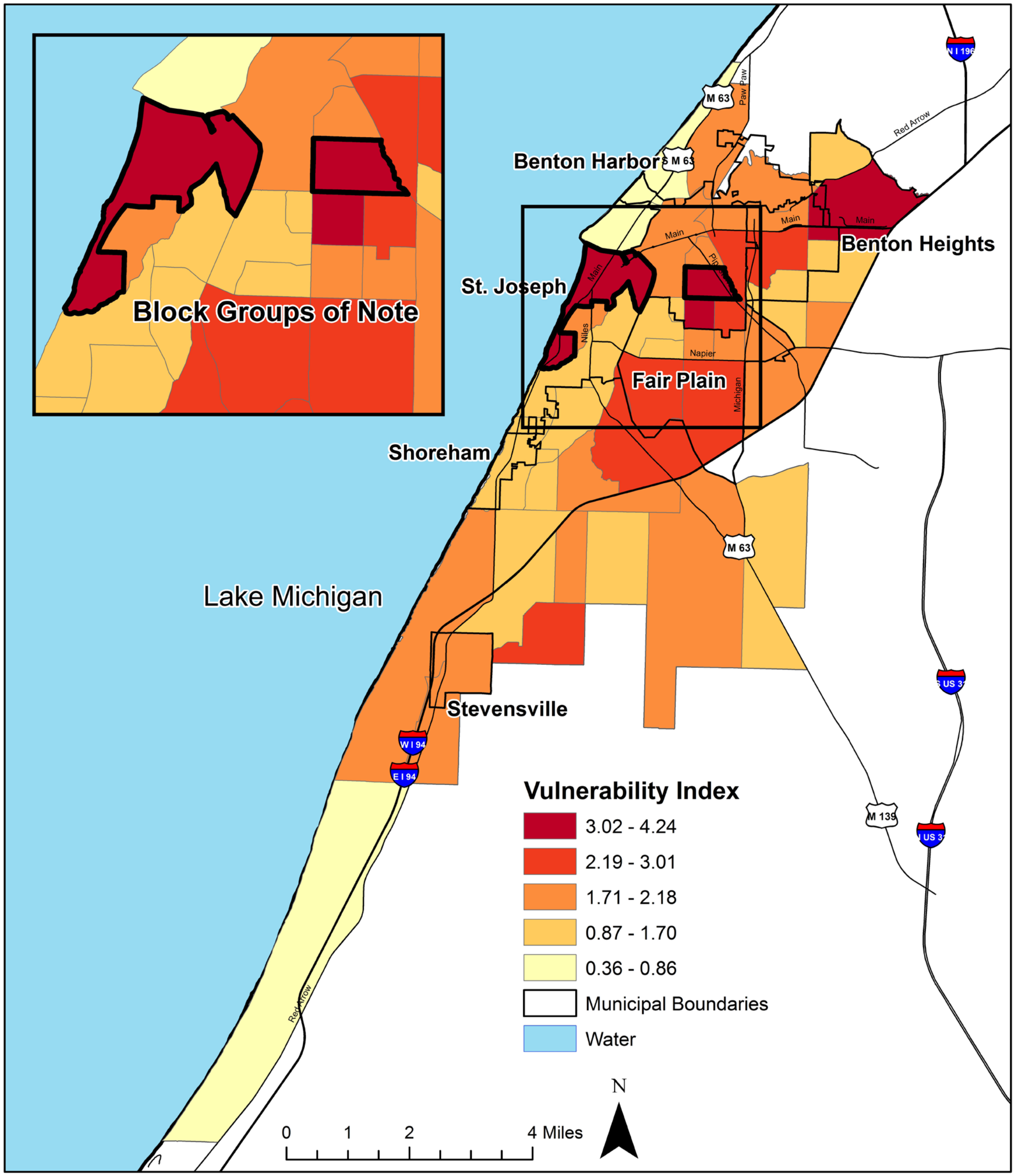




Map 5 100 Year Flood Impacts on Vulnerable Populations, St. Joseph/Benton Harbor, MI Area by Census Block Group (2000)

Map 6 Flood Plain Impacts on Vulnerable Population, St. Joseph/Benton Harbor, MI Area by Census Block Group (2000)

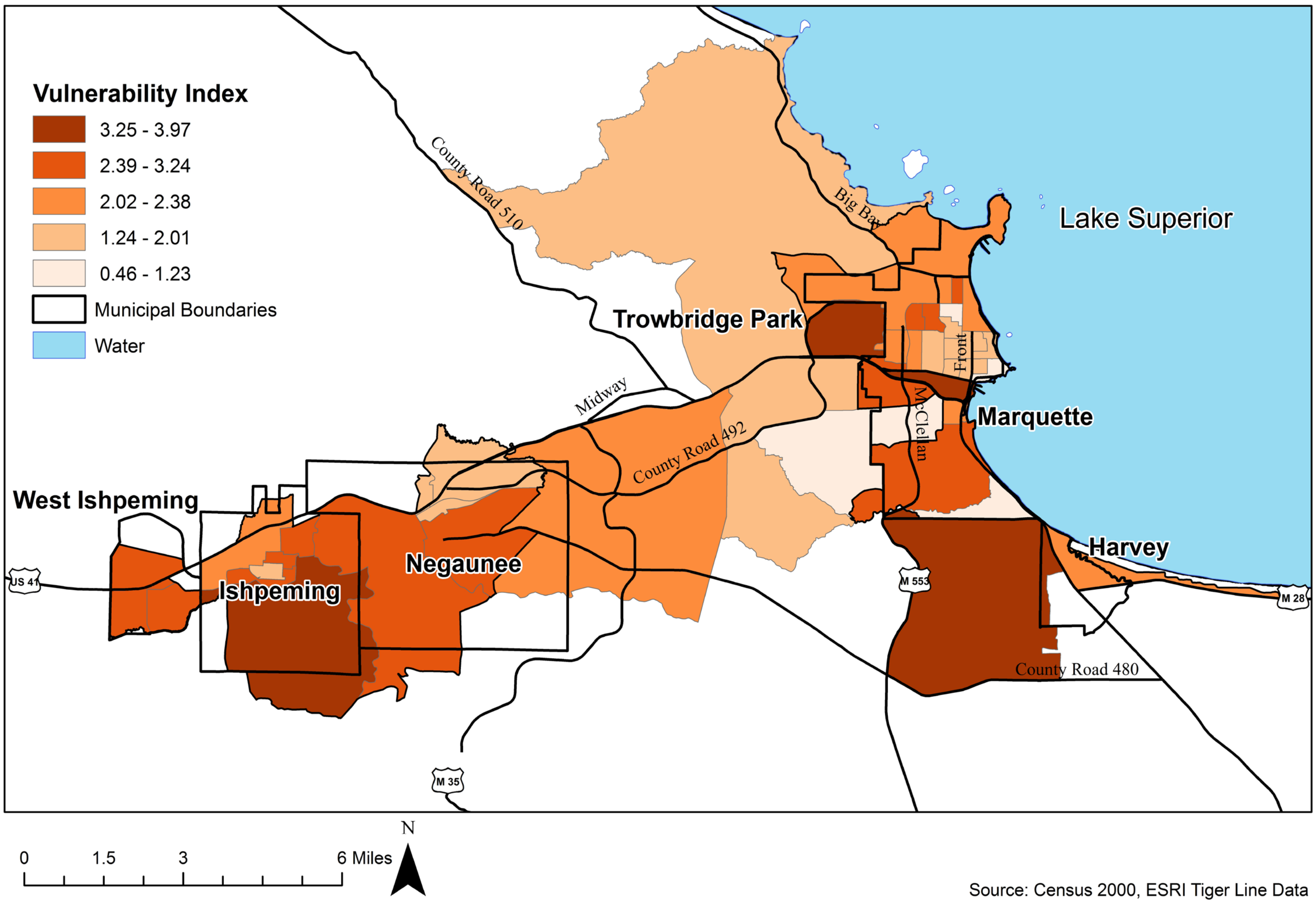




Source: Census 2000, ESRI Tiger Line Data

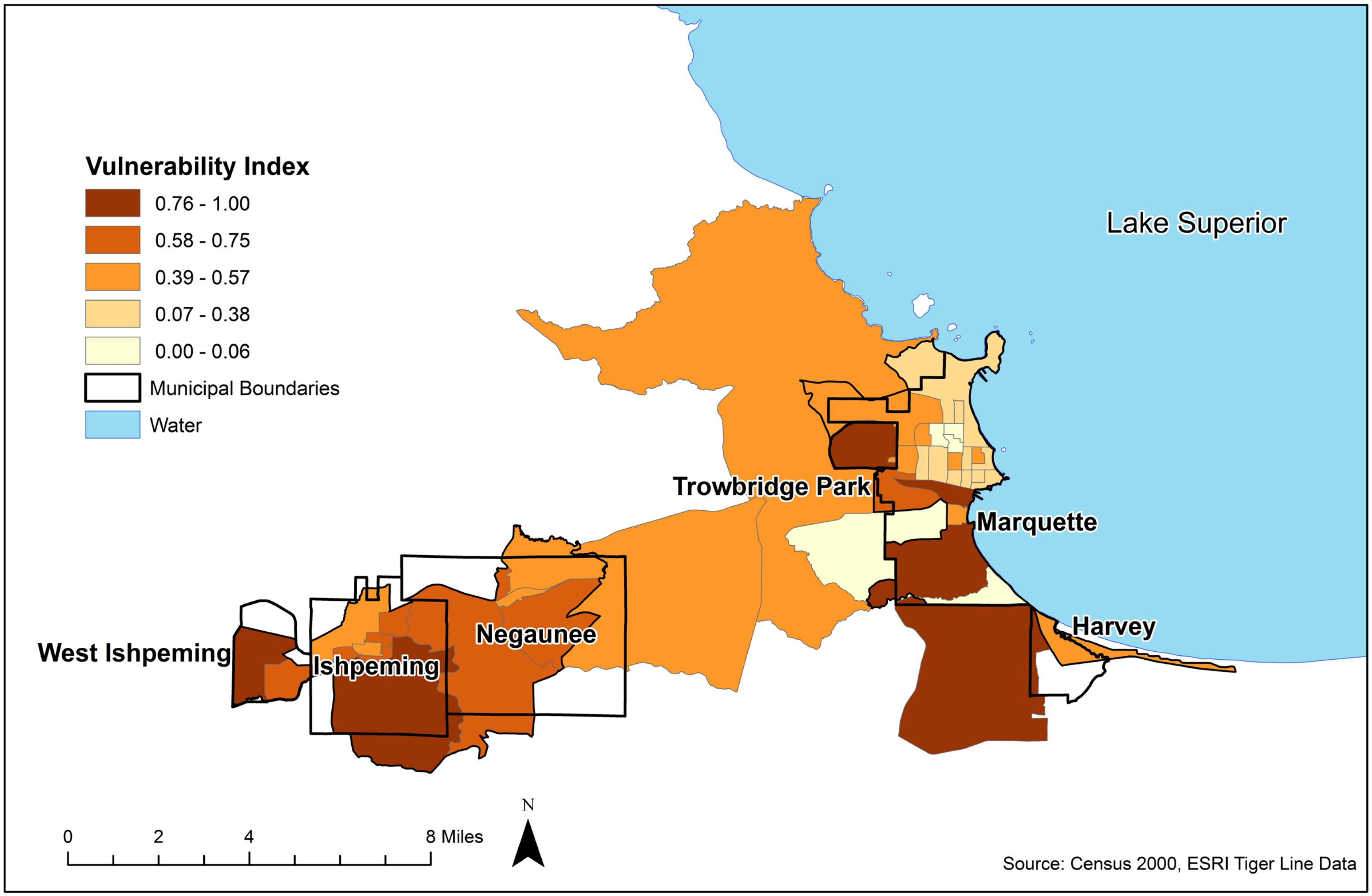
Map 7 Distribution of Vulnerable Population, (Bolck Groups of Note), St. Joseph/Benton Harbor, MI Area by Census Block Group (2000)

Map 8 Distribution of Vulnerable Population, Marquette/Ishpeming, MI UrbanizedArea by Census Block Group (2000)

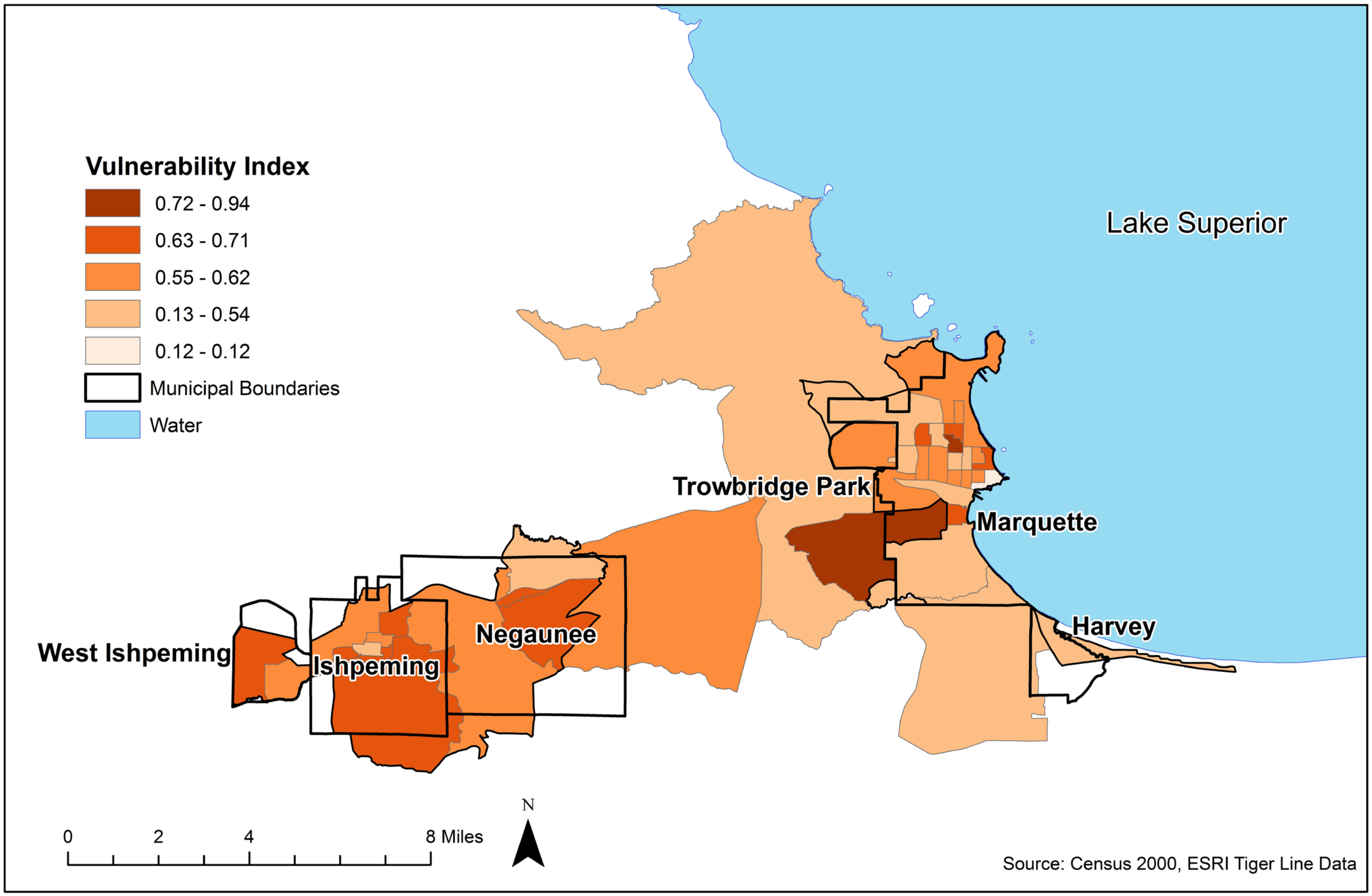


Source: Census 2000, ESRI Tiger Line Data

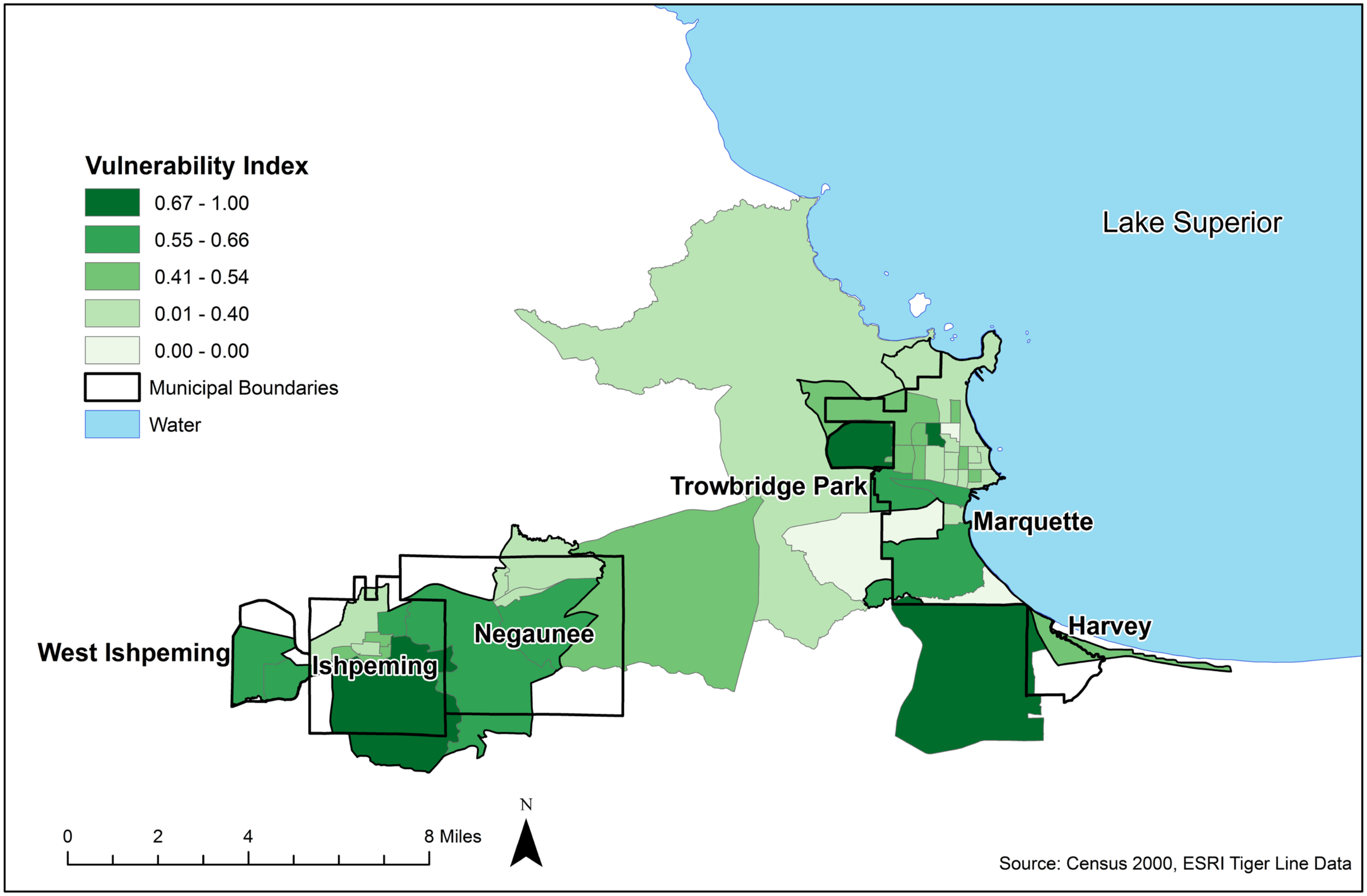
Map 9 Distribution of Age Vulnerability, Marquette/Ishpeming, MI UrbanizedArea by Census Block Group (2000)



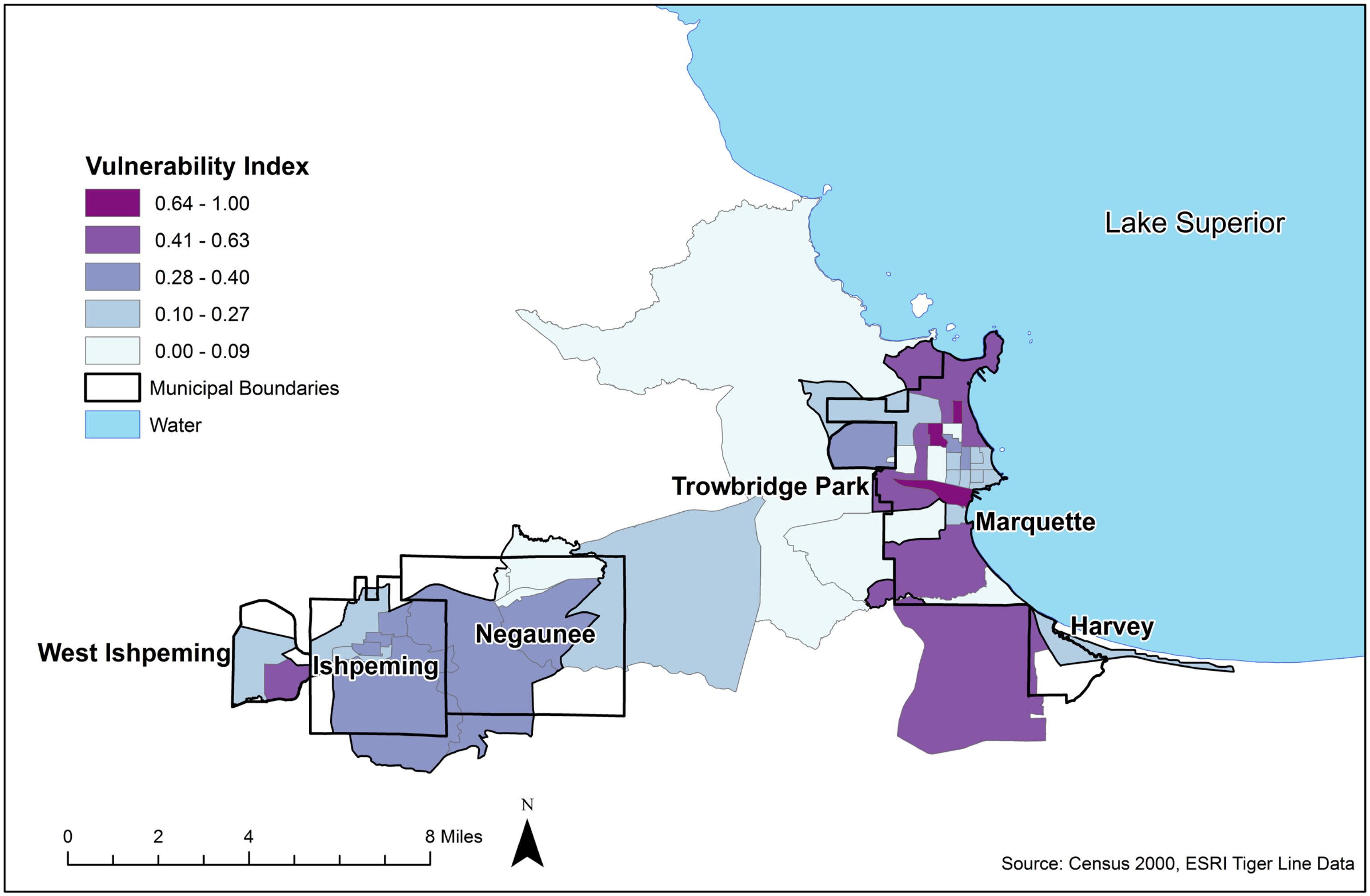
Map 10 Distribution of Dwelling Value Vulnerability, Marquette/Ishpeming, MI UrbanizedArea by Census Block Group (2000)



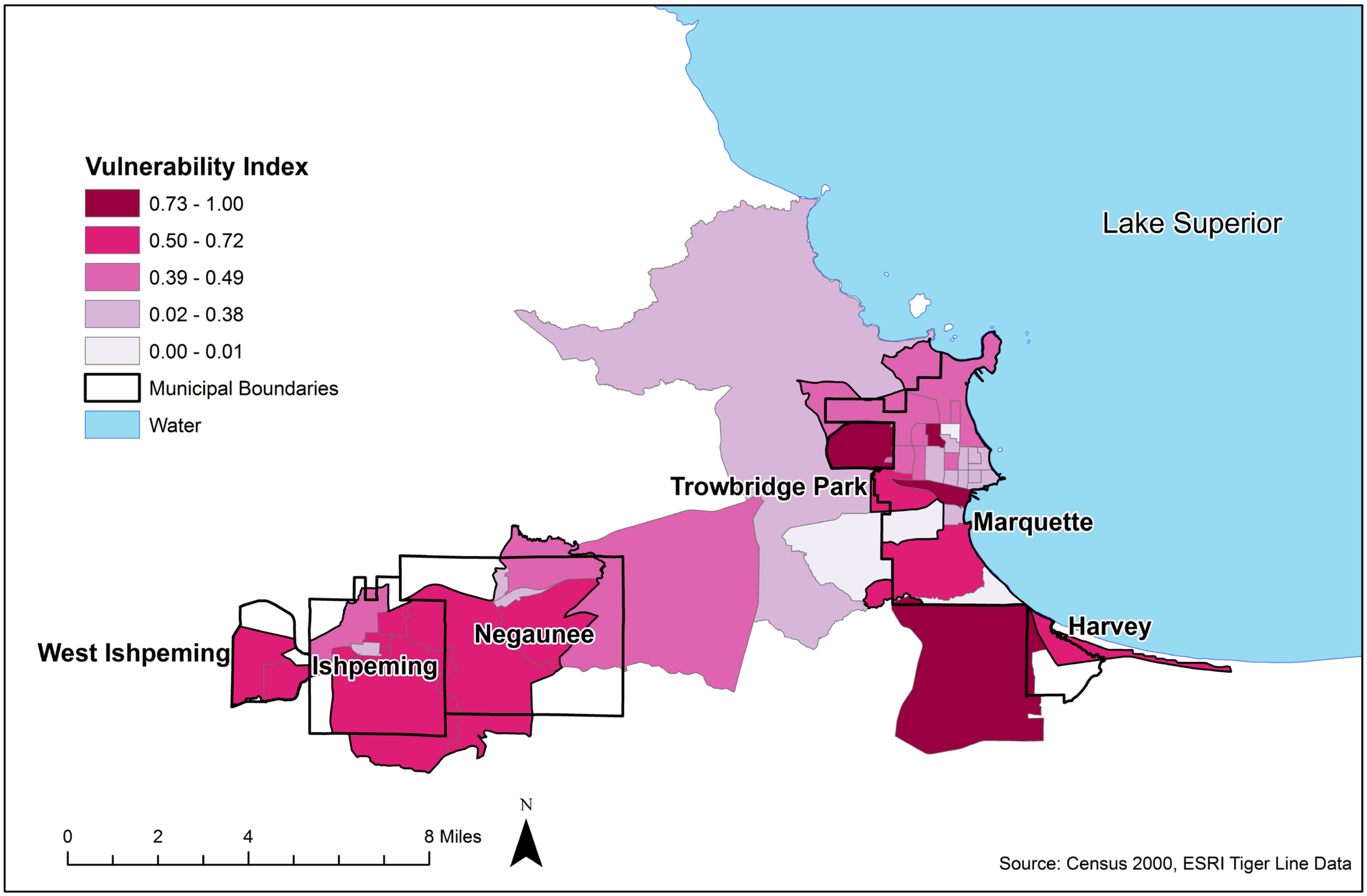
Map 11 Distribution of Female Vulnerability, Marquette/Ishpeming, MI UrbanizedArea by Census Block Group (2000)



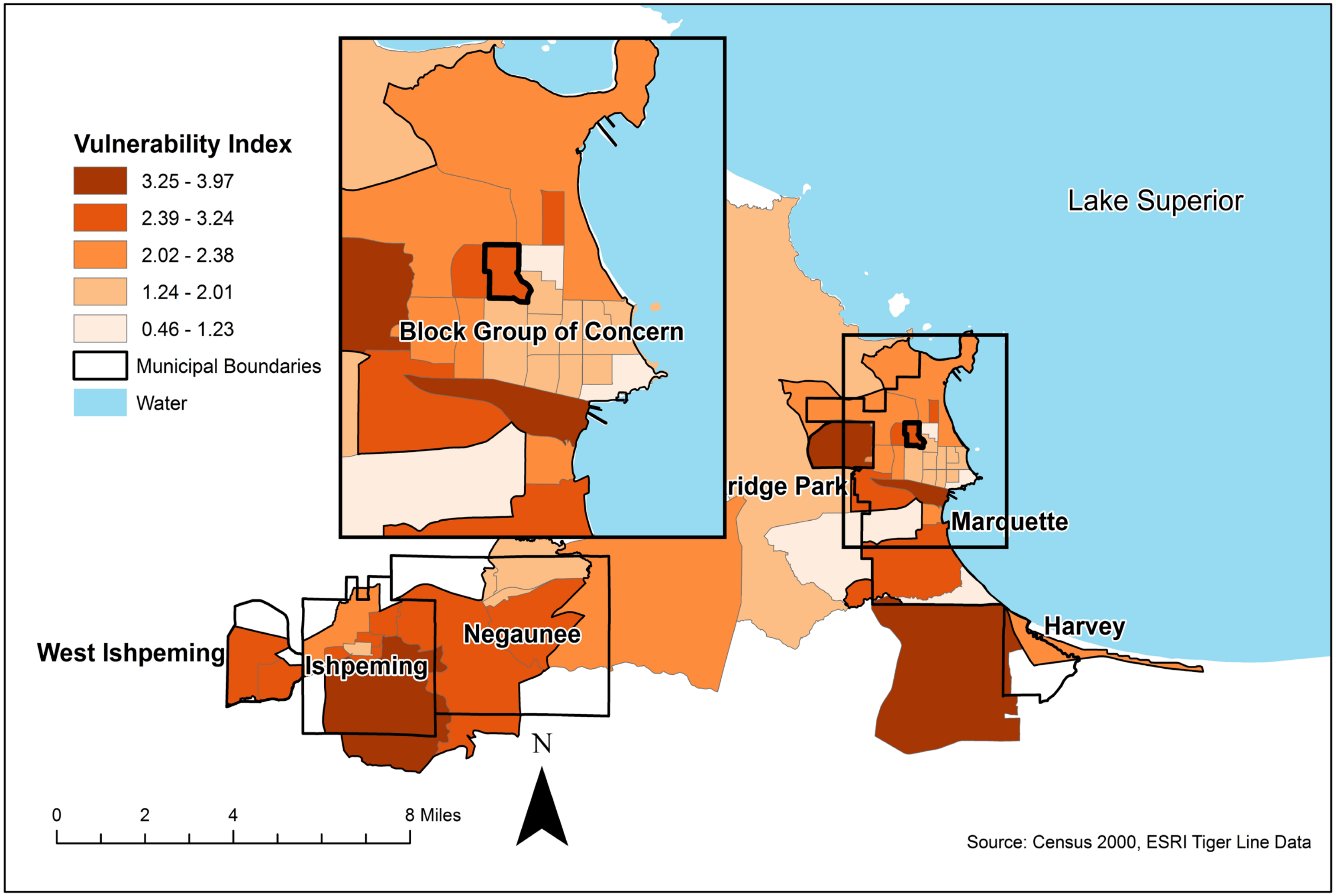
Map 12 Distribution of Non-white Vulnerability, Marquette/Ishpeming, MI UrbanizedArea by Census Block Group (2000)



Map 13 Distribution of Population Density Vulnerability, Marquette/Ishpeming, MI UrbanizedArea by Census Block Group (2000)



Map 14 Distribution of Vulnerable Population, (Block Group of Concern), Marquette/Ishpeming, MI UrbanizedArea by Census Block Group (2000)



APPENDIX-E Additional Text

Vulnerability Mapping Method

All of the demographic data used for this study was downloaded from the census website. The following census data tables from the SF3 dataset were used:

P3 Population

P6 Race

P8 Sex by age

H1 Housing units

H 70 Median gross rent as a percentage of household income

H 85 Median value for all owner occupied housing units

The vulnerability index for female, non-white, under 18 and over 65 population, and population density was calculated using the following method. First the percentage (X) of each variable that falls within each census block group was calculated where (a) is the number of individuals in a census block group and (b) is the total number of individuals in the study area.

$$X=a/b$$

For example, if a census block group has a female population of 500 (a) of a total female population of 10,000 (b) within the study area the X value is calculated as 500/10000. The social vulnerability (SV) for each variable is then determined by dividing each the X value by the X value of the census block group with the largest X value or Xmax.

$$SV=X/Xmax$$

This provides a 0-1 value for each characteristic where 0 is the lowest vulnerability where none of that population characteristic occurs in the census block group and 1 is the census block group that has the maximum number of that population characteristic in the study area. The census block group with 500 females has an X value of 0.05. The highest female population of any census block group is 600 with an X value of 0.06. Thus the 0-1 vulnerability index for female population in that census block group is 0.05/0.06 or 0.83. This value not only orders each census block from containing the smallest amount of each variable to the most of each variable, but also shows the magnitude of difference between each census block (188).

The housing value/rent vulnerability consists of an aggregation of both housing value and owner occupied units in each census block group. The rent vulnerability index is calculated using the same formula as the other variables, however the housing value is calculated differently. First the difference between the study area median housing value (c) is calculated and is subtracted from the census block group median housing value (d)

A = c-d

The absolute value of A is taken to find the difference between the block group's median value and the study area's median value. The block group whose value has the largest difference from the median is then added to every block group's median value to create the B value

B=A+|Amax|

The B value for each census block group is then divided by the largest B value in the study area to give the 0-1 vulnerability index value.

SV=B/Bmax

In order to correctly weight the housing value and the median rent proportion correctly, the percentage of both renter and owner occupied units.

R=(Renter Occupied Units)/(Total Units)

H=(Owner Occupied Units)/(Total Units)

The both the housing value and rent vulnerability indices are multiplied by their respective R and H values to reflect the proportion of the housing stock in each census block group.

The SV for each of the variables is then added to create the overall social vulnerability index for the entire study area. (Dunn, Kenneth & Sotherland, Peter. (2011) Vulnerability Analysis: Socioeconomic vulnerability and flood risk in Milwaukee, Wisconsin, St. Joseph/Benton Harbor, Michigan, and Marquette Michigan. University of Michigan, Taubman College of Architecture and Urban Planning.)

Works Sited

Blaikie P, Cannon T, Davis I, Wisner B. At Risk: Natural Hazards, People's Vulnerability and Disasters. London: Routledge. 1st ed. (1994)

Carpenter SR, Walker BH, Anderies JM, Abel N. From metaphor to measurement: Resilience of what to what? Ecosystems 4:765–81 (2001)

Cutter, Susan L; Boruff, Bryan J; Shirley, W Lynn. Social Vulnerability to Environmental Hazards: Social Science Quarterly (2003)

Cutter SL. Vulnerability to environmental hazards. Prog. Hum. Geogr. 20:529–39 (1996)

Eakin, Hallie and Luers, Amy Lund. Assessing the Vulnerability of Social-Environmental Systems. Anu. Rev. Environ. 2006 31:365-94. (2006)

Climate Change

Fossil Fuels & Greenhouse Gases: A Deadly Combination?

The discovery and widespread consumption of fossil fuels as the primary source of energy has enabled an unprecedented standard of living in the developed world. Human development has relied so heavily on the burning of fossil fuels that atmospheric levels of greenhouse gases such as carbon dioxide—a primary byproduct of development—are beginning to raise global temperatures to unnaturally high levels. Neglecting the environmental consequences associated with fossil fuel consumption for decades, "business as usual" practices have placed us beyond the critical point of no return. The key question that is heavily debated at the moment is the impact greenhouse gas levels in the atmosphere will have on the earth's climate. More specifically, will this ultimately affect the health, longevity, and water levels of the Great Lakes?

What's to be expected?

The National Academy of Sciences estimates that by 2100, global temperatures will increase 2 to 11 ^{o}F. In the United States and Southern Canada, temperature will increase an estimated 3 to 17 ^{o}F if emissions or not curtailed (Kling et al., 2003, p. 12). By comparison, the enormous glaciers from the last great Ice Age (approximately 20,000 years ago) receded with a 9 to

11 ^{o}F rise in temperature (Kling et al., 2003, p. 13). If scientific estimates are accurate, then a rise of 3 to 17 ^{o}F could threaten this valuable freshwater resource.

Billy Ho (Researcher, Team Photographer, and Assistant Editor)

Billy is a Masters of Urban Planning candidate at the University of Michigan specializing in Transportation Planning. He holds a B.A. in Geography/Environmental Studies from UCLA. During his course of study, Billy worked as a fellow with Amigos de los Rios, a non-profit agency in Southern California that focuses on park space dedication and preservation in urbanized areas. He is the lead author and researcher on climate change science, and a field researcher for the Marquette case study team.

Clayton Ross Martin (Researcher, GIS Specialist, and Lead Editor)

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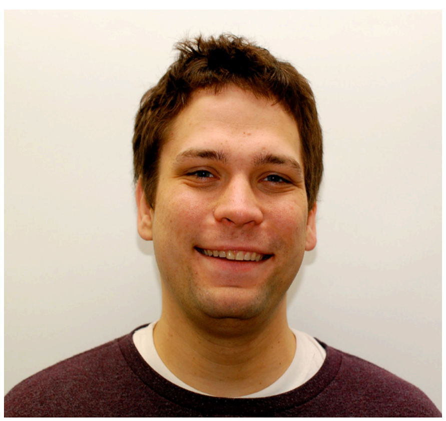

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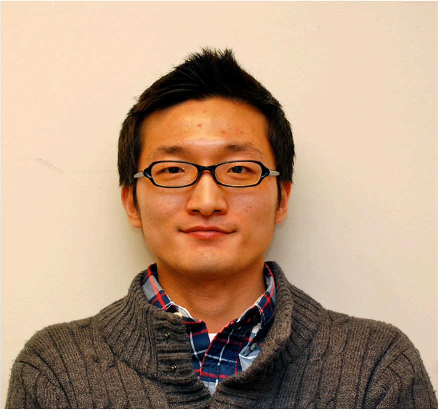

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Yanhang is a Masters of Urban Planning candidate at the University of Michigan. She holds a B.E. in Urban and Regional Planning and a B.A. in Economics from Peking University in China. Yanhang has experience in conducting market analysis, surveying, and publication layout and design. She is the lead document designer and researcher for the history of port cities within the Great Lakes region.

University of Michigan
April 2011