

## Meeting the Challenges of Climate Change

**T**his report has highlighted a variety of challenges the Great Lakes region will face as climate change magnifies the pressures imposed by a growing human population on the region's environment and natural resources. Many of the impacts explored here are not inevitable. The negative consequences of change can in some cases be minimized or avoided. This chapter examines actions that people and policymakers can take now to reduce the vulnerability of ecosystems and vital ecological services and to safeguard the economy and well-being of the human population of the region.

Three overlapping approaches are needed to meet the challenges posed by a changing climate. The first is to reduce the region's contribution to the global problem of heat-trapping greenhouse gas emissions. Some warming is already inevitable because historical emissions of CO<sub>2</sub> will continue to have a warming effect for decades; nevertheless, many of the most extreme outcomes for the region can be avoided if the pace and eventual severity of climate change are damped. Many scientists agree that ultimately worldwide emissions of heat-trapping gases need to be reduced significantly in order to avoid dangerous changes in the climate system. The sooner these reductions are begun, the lower the cost of making necessary

changes and dealing with potentially disruptive economic and social impacts.

Second, minimizing human pressures on the global and local environment now will lessen the severity of future impacts and reduce the vulnerability of ecosystems to further stresses from climate. Finally, anticipating and planning for the impacts of change through both short-term adjustments and long-term adaptations will help to reduce future damage. The cost of these adjustments and adaptations serve as an additional incentive to slow climate change by reducing the emissions of heat-trapping gases as soon as possible.

Although there is uncertainty in predictions of specific climate change impacts on the region, we have much greater confidence in the general predictions for change (see box, p.68). Even where uncertainty remains, taking actions now to reduce emissions and minimize threats to ecosystems is the prudent and responsible course. Waiting to begin reducing emissions or to plan for managing the effects of climate change only increases the eventual expense and urgency and the possibility of irreversible losses. Furthermore, many actions that can be taken now provide immediate collateral benefits such as cost savings, cleaner air and water, or improved quality of life in our communities.

## Reducing Emissions by Sector

Reducing emissions of greenhouse gases, and thus the rate and eventual severity of climate change, could forestall many of the worst outcomes. Some emission reduction measures can be implemented with no net cost. Others involve net costs but will also stimulate new technological devel-

opment, economic growth, jobs, and opportunities.

None of the Great Lakes states currently has mandatory greenhouse gas registries (although Wisconsin is developing one), but Ontario and all the states except Michigan have inventories of their greenhouse gas emissions for 1990 (Table 8, p.70). Overall

### How Confident Can We Be About Climate Change Impacts on Great Lakes Ecosystems?

The climate change assumptions that underlie the assignment of confidence levels\* include:

- an increase in air temperature of 5 to 12°F (3 to 7°C) in winter and 5 to 20°F (3 to 11°C) in summer (high confidence).
- a concurrent increase in surface water temperatures and reductions in ice cover on all lakes (high confidence).
- precipitation increases in winter and spring, but declines in summer and autumn, producing most notably a general drying in the southwest part of the region. In response, levels of surface water, ground water, and soil moisture are expected to drop in summer (medium confidence).
- a continued increase in extreme rain events lasting from 24 hours to 7 days that could cause increased flooding (medium confidence).

The projected impacts are viewed against the backdrop of continued increases in population, urbanization, and landscape fragmentation across the region. For example, urbanization will increase the area of pavement and other impervious surfaces in watersheds, which in combination with increased likelihood of extreme downpours will result in more flooding.

#### Confidence Levels\*

Potential Impacts on Great Lakes Ecosystems	High Confidence	Medium Confidence	Lower Confidence
Across All Systems	<p>Significant alterations in the climate that we feel as temperature and precipitation changes</p> <p>Longer growing seasons</p> <p>Altered productivity and distribution of a variety of organisms</p>	<p>Decrease in ecosystem services due to greater variability in all climate and ecological drivers</p> <p>Earlier flowering, breeding, and emergence of biota that use temperature rather than day length as a cue</p>	

Potential Impacts	High Confidence	Medium Confidence	Lower Confidence
<b>Aquatic Ecosystems</b>	<p>Increased water temperatures in the Great Lakes, inland lakes, streams, and wetlands</p> <p>Decreases in ice-cover duration and extent</p> <p>Shifts to earlier ice-out dates and spring melt</p> <p>Altered timing of hydrologic flows; increased variability in timing, frequency, and duration of disturbances</p> <p>Altered distributions of current fish species and other aquatic organisms; increased invasions by nonnative species</p>	<p>Decreased water levels in all aquatic habitats, especially in summer</p> <p>Increased flooding from climate interactions with urbanization and land management practices</p> <p>Decreased safe breeding sites for amphibians, migratory shorebirds, and waterfowl</p> <p>Altered timing and extent of migration for waterfowl</p>	<p>Increased ultraviolet radiation damage to organisms in shallow-water habitats</p>
<b>Terrestrial Ecosystems</b>	<p>Altered plant distribution, including northern movement of forest species</p> <p>Range shifts in insects, including expansions of forest and agricultural pest species (e.g., gypsy moths and bean leaf beetles)</p> <p>Impacts on crop and livestock sectors (+ or –) will be moderated by technological advances and trends in market sectors</p>	<p>Short-term increases in forest growth from CO<sub>2</sub> fertilization and nitrogen deposition; long-term growth responses are unclear</p> <p>Lowered food availability to migrant birds, especially those that time their migration by daylength rather than weather</p> <p>Crop yields in the region vary from positive in northern to negative in southern areas because of temperature and precipitation changes</p>	<p>Increased vulnerability of crop yields to weather extremes as production shifts northward, away from prime production areas</p>
<b>Human Impacts</b>	<p>Shorter, warmer winters will result in losses in winter recreation such as skiing, ice fishing, and snowmobiling; possibly longer season for warm-weather recreation</p>	<p>Increased health risks from respiratory disease, heat-related morbidity or mortality, extreme weather events, and infectious disease</p> <p>Decreased health risks from cold-related morbidity or mortality</p>	

\* “Confidence” refers to the level of scientific certainty and is based on expert understanding and judgment of current information supporting the likely ecological impacts of the climate-related changes described above. Confidence is not related to the degree of ecosystem vulnerability or the relative economic or social importance of a potential impact. A “lower” confidence level does not imply that the change is unlikely or that the impact will be small.

TABLE 8 Total Greenhouse Gas Emissions by State/Province and Sector (1990)

Total GHG (in Million Metric Tons of Carbon Equivalent—MMTCE) for 1990 State/Province<sup>(a)</sup>

SECTOR	IL	IN	MN	NY	OH	PA	WI	ONT
Energy - Residential	6.9	2.6	2.1	8.5	5.6	6.2	2.6	4.9 <sup>(b)</sup>
Energy - Commercial	3.4	1.4	1.4	6.5	2.8	3.0	1.3	2.5
Energy - Industrial	14.7	15.2	2.3	4.5	15.7	16.8	3.3	11.4
Energy - Transport	15.8	11.2	7.2	22.5	15.2	15.4	6.6	13.1
Energy - Utility	15.7	25.6	7.9	19.1	31.4	24.2	8.9	7.1
Energy - Exported Electricity	*	*	*	*	*	*	*	*
Energy - Other	-2.31	1.0	0.5	1.2	6.3	*	0.8	*
Total Energy	56.6	57.0	21.3	62.3	76.9	68.3	23.4	39
Waste	6.9	1.7	1.2	11.6	11.3	3.6	0.9	2
Agriculture	2.3	1.8	2.5	0.9	1.7	3.3	2.5	3.3
Industry	0.3	1.0	*	0.9	0.6	0.7	0.1	4.1
Land Use	0.02	-0.4	-2.4	*	-1.6	0.1	0.2	0.3
<b>TOTAL</b>	<b>66.1</b>	<b>61.3</b>	<b>22.5</b>	<b>75.7</b>	<b>88.9</b>	<b>76.0</b>	<b>27.1</b>	<b>48.7</b>
<b>PER CAPITA <sup>(c)</sup></b>	<b>5.8</b>	<b>11.0</b>	<b>5.1</b>	<b>4.2</b>	<b>8.2</b>	<b>6.4</b>	<b>5.5</b>	<b>4.8</b>

Sources: See note 182.

Notes: An asterisk (\*) indicates that GHG emissions from this sector were zero, insignificant, or not reported.

(a) US and Canadian GHG inventory methodologies not necessarily comparable; no emissions information available for MI

(b) Residential and agricultural energy use combined in Canadian GHG inventory

(c) GHG emissions in MMTCE per million population. Average per capita emissions in 1995 in the US was 6.6 and in Canada was 6.0. Canadian population data from 1991.

emissions have increased in every state and province since 1990, but these inventories—while not always perfectly accurate—offer a starting point to identify opportunities for reducing the output of heat-trapping gases. In fact, Canada in 2002 ratified the Kyoto Protocol and made a commitment to reduce country-wide emissions by about 6 percent below 1990 levels

by 2008–2012.

Far and away the major sources of emissions throughout the region are the utilities and transportation sectors, followed by energy use in the industrial sector, emissions from landfills and waste incinerators, and other locally important sources such as commercial, agricultural, or residential sec-

tors. There are opportunities for emission reductions in all these sectors. Moreover, changes in forestry practices and agricultural soil management offer the potential for reducing emissions and sequestering carbon, a process that can be thought of as “negative emissions.”

### Energy

Opportunities for emission reductions in the energy sector include:

- Increasing energy efficiency and conservation in industry and by consumers, using both technological and behavioral changes
- Increasing the amount of energy produced from renewable power sources such as wind, solar, and organic wastes
- Switching from carbon-intensive energy sources such as coal to natural gas and biofuels
- Achieving more efficient fossil fuel generation of electricity

FIGURE 35  
Minnesota Wind Farm



See page 51  
for full-size color image of this figure

Several Great Lakes states and Ontario currently employ some of these strategies and can serve as models for others. In Indiana, for example, the Industrial Energy Efficiency Fund provides zero-interest loans to increase the energy efficiency of manufacturing processes.<sup>183</sup> Minnesota and Wisconsin have established targets and timetables for increasing electricity production from renewable energy and, together with Illinois and New York, are also financing investments in renewable energy and efficiency for homes and businesses.<sup>184</sup>

Most Great Lakes states have commercially viable wind energy resources. Minnesota is already the third largest wind power producer in the nation (Figure 35), and new wind projects are being built in Illinois, Michigan, New York,<sup>185</sup> and in Ontario.<sup>186</sup> Illinois has the technical potential to produce 83 percent of its electricity needs (based on 2000 usage) from its wind resources and 35 percent from its bioenergy resources.<sup>187</sup>

A recent study shows Ontario can practically and economically reduce energy waste and generate enough green energy for the province to phase out all five of its coal-fired power plants.<sup>188</sup> The approach would involve demand-side management programs that increase energy efficiency, shift subsidies away from fossil fuel-derived energy toward support of renewable energy, and reform electricity prices to reflect their real cost to human health and the environment.

Developing these alternative energy resources promises a number of benefits. A study by the Environmental Law and Policy Center examined the impacts of 22 percent use of renewable energy in the US states of the region by 2020. It found that CO<sub>2</sub> emissions could be cut in half, while increasing electricity costs by only 1.5 percent in 2010 and 3.4 percent in 2020. Additional benefits would include reducing air emissions of sulfur dioxide and nitrogen oxides, creating 200,000 new jobs, and generating \$5.5 billion (US) in additional income.<sup>189</sup>

**Minnesota and Wisconsin finance investments in renewable energy and efficiency for homes and businesses.**

## Transportation

Opportunities for emission reductions in the transportation sector include

- Increasing the efficiency of conventional vehicles
- Introducing hybrid and fuel cell cars
- Developing low-carbon fuels such as ethanol
- Reducing the number of miles driven, in part through anti-sprawl planning and better public transportation

Fuel economy (CAFE) standards are set at the national level. While the United States has had mandatory standards in place since the oil crises of 1975, Canada currently has only a voluntary fuel efficiency initiative and levels mimic those in the United States. Raising

the CAFE standard over the next 20 years to 55 miles per gallon for new cars and light-trucks would take advantage of the tremendous potential for technological innovation and could save US drivers billions of dollars at the fuel pump, while reducing millions of tons of heat-trapping gases, smog-forming pollutants, and other toxic emissions.

Although the federal Energy Policy Act of 1992 required state government fleets to purchase alternative fuel vehicles, few state governments actually fulfill this requirement. An exception is Minnesota, which has developed state vehicle fleet efficiency standards. Indiana encourages the building of alternative fueling sites through its Alternative Fuel Vehicle Infrastructure Program (Figure 36).

Even at local scales, travel-reduction strategies including ride-share, telecommuting, bicycle and pedestrian programs, transit promotion, and parking management can produce multiple benefits such as emission reductions, healthier air, and higher quality of life.<sup>190</sup> Large cities with heavy commuter traffic such as Chicago, Detroit, and Toronto are particularly amenable to such improvements.

FIGURE 36  
**Illinois Fuel Cell Bus**



*See page 51*  
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## Toronto: A Leader Among Cities in Reducing Greenhouse Gas Emissions

While nations, states, and provinces continue to debate the economic wisdom of reducing greenhouse gas emissions, key cities across North America have taken the lead in showing that cutting carbon emissions can not only save energy but also generate revenue. One of the first local governments in the world to commit to voluntary cuts in greenhouse gas emissions, and one of the most successful, is Toronto. In 1990, Canada's largest city committed to a goal of reducing its emissions 20 percent below 1988–1990 levels by 2005. By 1998, Toronto had already exceeded its 2005 goal more than three times over, achieving emission reductions of 67 percent below 1990 levels. That represents a drop from 2.3 million tons of carbon dioxide released into the atmosphere to 765,000 tons released, one of the largest reductions achieved anywhere in Canada.

Toronto used a wide range of measures to achieve its emission goals: improving the energy efficiency of city buildings and streetlights (Figure 37a), improving energy efficiency and switching to alternative fuels for its vehicle fleet, procuring and developing "green" power sources, and capturing landfill

FIGURE 37A  
City Hall, Toronto



See page 51  
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FIGURE 37B  
Toronto Shows Climate Solutions Leadership



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gases for use in power production (Figure 37b). The latter strategy, in fact, produced the greatest reduction in emissions and also generates \$2.5 million (Cdn) in yearly income for the city. Although energy efficiency measures resulted in much smaller emission reductions, they save the city \$10 million (Cdn) in energy costs each year.

To help pay for the program and educate the public about its goals, the city in 1991 contributed \$23 million (Cdn) in revenues from the sale of city property to set up the Toronto Atmospheric Fund (TAF). While many cities around the world have committed to greenhouse gas reductions, Toronto remains the only one that has created an independent agency to fund such projects. TAF-sponsored projects to date have financed emission reductions of more than 225,000 tons, saved the city \$2.7 million (Cdn) a year in energy and maintenance costs, and jump-started organizations such as Green\$aver, Greenest City, the Toronto Renewable Energy Cooperative, and the Black Creek Regional Transportation Management Association. Among its other initiatives, TAF also holds an annual Smog Summit and funds studies on transportation and smart growth issues. TAF

believes that Toronto has the potential to achieve another 31 percent emission reductions between 1998 and 2010.<sup>191</sup>

More than 500 communities worldwide, including 100 in the United States, have joined Toronto as participants in the Cities for Climate Protection Campaign of the International Council for Local Environmental Initiatives. Together these local communities, which collectively account for 8 percent of global greenhouse gas emissions, are not only cutting their emissions and pioneering cost-effective strategies for reducing their impact on the global climate, but also setting examples for nations to follow.

## Waste Management

Opportunities for emission reduction in the waste management sector include

- Waste avoidance
- Waste recovery and recycling, including use of waste for biomass energy
- Capture of methane emissions

Again, several Great Lakes states and Ontario have programs that could be emulated throughout the region. Indiana, for example, has a Recycling Market Development Program that aims to boost recycling rates and the purchase of recycled products. In methane recapture, Ontario's City of Welland Landfill Gas Recovery Program currently collects and destroys more than 100,000 tons of methane per year—the equivalent of taking 560,000 cars off the road.<sup>192</sup>

## Forestry and Agriculture

Opportunities for emission avoidance and carbon capture in forestry and agricultural land use include

- Forest protection
- Reforestation or afforestation
- Sustainable soil management to increase carbon sequestration

Forestry opportunities may be particularly relevant in the northern parts of the region, although other areas could also benefit. For example, Minnesota's ReLeaf Program promotes and funds the planting and maintenance of trees as a means to store carbon and save energy.<sup>193</sup> Several other forest carbon sequestration projects are under way in Indiana, Ohio, and Ontario. In Wisconsin, several projects on land owned or managed by The Nature Conservancy are funded by utilities needing to offset CO<sub>2</sub> emissions. Maintaining and increasing urban tree cover is becoming

more important both for storing carbon and for reducing the urban "heat island" effect that intensifies summer heat.

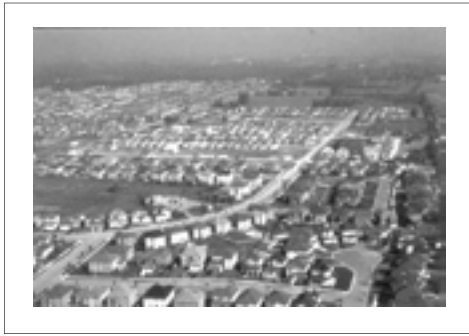
In the agricultural sector, numerous studies have shown that certain best practices in soil management such as no till, low input, and use of cover crops can enhance short-term soil carbon sequestration. In addition, the Environmental Protection Agency supports several programs that can reduce methane emissions from livestock and livestock wastes, such as the AgSTAR Program and the Ruminant Livestock Efficiency Program.<sup>194</sup>

## Integrated Emission Strategies

Several states in the region have comprehensive climate change action plans. All will require strong support for implementation, however, and none specifies reduction targets by certain dates. Similarly, at least 14 American municipalities in the region have committed themselves to local emission reductions through the International Cities for Climate Protection Campaign.<sup>195</sup> In Ontario, more than 20 municipalities participate in the Partners for Climate Protection program of the Federation of Canadian Municipalities<sup>196</sup> (see box, opposite).

Another possible strategy for reducing emissions cost-effectively is through carbon credits and trading. The US leader in developing voluntary carbon-trading strategies is the Chicago Climate Exchange.<sup>197</sup> In Canada, the federal government's Tradable Permits Working Group has set up a prototype trading system in Ontario, which could be adapted in the future to include heat-trapping gases.<sup>198</sup> In anticipation of this, utilities have begun to purchase emission-reduction credits from elsewhere to offset their own CO<sub>2</sub>

FIGURE 38  
Minimizing Sprawl



See page 52  
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emissions. Thus, timely research and development activities could position the Great Lakes region as a leader in the emerging carbon-trading market. Principles guiding effective emissions trading have yet to be developed in both the United States and Canada. In general, effective emissions

trading systems share several traits: At minimum they are fair by rewarding leaders rather than laggards; they are cost-effective; and they lead to actual emis-

sion reductions through absolute, progressively lowered caps on emissions.

Scientific evidence demonstrates that the most desirable approaches to reducing emissions not only achieve real climate benefits, but also avoid exacerbating other environmental problems. Policymakers have to agree on principles that define best practices such as the following: First, the results of emissions reduction efforts are easily verified and ensure that carbon is stored permanently. Second, emission reduction approaches go beyond standard practices and existing regulations.<sup>199</sup> Third, projects must minimize and account for leakage, or the potential that the project may simply displace emissions elsewhere. Finally, forest-based projects for climate should enhance, and not detract from, biodiversity protection.<sup>200</sup>

## Minimizing Human Pressures on the Environment

Reducing or minimizing human pressures on the environment often results in long-term economic benefits that outweigh the initial cost. These benefits include flood protection, human health benefits from water and air purification, improved agricultural and forestry productivity, water supply security, safeguarding of habitat for native plants and animals, aesthetic benefits, and recreational opportunities. The following are key strategies for reducing human stresses.

### Air Quality Improvements

Air pollutants, such as ozone, damage the natural environment as well as human health and crops. Strategies to reduce heat-trapping gas emissions, whether from coal-fired power plants or commuter traffic, have the ancillary benefit of reducing air pollution.<sup>201</sup> In Ontario alone, air pollution claims the lives of an estimated 1,900 people a year and costs the medical system about \$1.1 billion (Cdn) annually, according to an analysis by the Ontario Medical Association.<sup>202</sup> Recognizing this problem, the city of Mississauga in southern Ontario's industrial and commuter belt established in 1998 the Mississauga Air Quality Advisory Committee, which implemented a comprehensive air quality improvement plan. The results have included

significant utility savings, reductions in energy use and pollution, an expanded transit service and bike path network, greater tree cover, and reduced air pollution.<sup>203</sup>

### Water Quality Protection and Demand/Supply Management

Protecting ground and surface water supplies, as well as the ecological quality of aquatic habitats and the species that live in them, offers benefits for human health and well-being in the water-rich Great Lakes region. Water management and conservation efforts also increase the reliability of supplies for economic sectors and industries dependent on steady availability of high-quality water. Key water quality improvements that need to be more widely implemented include efforts to upgrade sewer and septic systems and to contain nonpoint pollution from roads, farmland, and other dispersed sources.<sup>204</sup> Many smaller Great Lakes communities still have sewer outflow systems that release untreated sewage and industrial waste directly into surface water bodies during storm events that overwhelm the capacity of local water treatment facilities. If the frequency of heavy rain events increases in the future, that will increase the urgency of technological upgrades to these systems to prevent water-

and foodborne diseases and also to protect people from illnesses contracted during recreational activities such as swimming, boating, and fishing.

Water supply concerns in the region can be addressed by developing more effective water-conservation strategies for use during summer months and in water-intensive agricultural and industrial operations. A more controversial issue concerning future water supplies involves schemes to divert water to users outside the basin. Such diversions would have significant ecological and social implications for the entire Great Lakes basin and potentially create legal, policy, and procedural conflicts within the region.<sup>205</sup>

### Urban and Land Use Planning

Urban and rural land use planning can reduce sprawl, which in turn reduces greenhouse gas emissions from commuter traffic. Reducing sprawl has added benefits

of preventing habitat destruction and fragmentation, reducing or at least containing the area of impervious surfaces that contribute to flooding, reducing municipal spending on services, and decreasing the loss of valuable farmland (Figure 38). In Grand Rapids, Michigan, which is quickly becoming the poster-child of the nation's growing antisprawl movement, a civic campaign led to comprehensive land-use policy reforms, including preservation of connected open lands and natural areas, establishment of compact business centers served by mass transit, and establishment of boundaries on extending water and sewer services.<sup>206</sup>

### Habitat Protection and Restoration

Rehabilitation of wooded riparian buffer strips, restoration of floodplain forests, wetland preservation and restoration, and reduction of the extent of impervious surfaces are strategies that help to main-

TABLE 9 **Examples of Adaptive Measures for Mitigating Impacts of Climate Change on Fisheries**

Adaptation Strategy	Specific Option	Limitations
<b>Choose/Change:</b>		
Location	Encourage fishers to move fishing grounds as locations of preferred fish habitat change	Most stocks of desirable fish species are heavily exploited already
Use	Exploit previously unused or underused resources	Local aquatic ecosystems will become generally overexploited as the focus of fishers extends to all levels of the food web
<b>Reduce Losses:</b>		
Prevent effect	Not possible	
Modify effect	Artificially accelerate natural rates of range extension for warm-water species	Careless actions will exacerbate problems
	Reduce impacts from other agents of stress; particularly relevant for fisheries located in areas of high human population density	Resistance to limit destructive environmental impacts of industry and other human activities
	Remove potential barriers to migration and range extension	
<b>Accept Losses:</b>		
Share loss	Compensation/insurance programs for fishers	Such actions provide only short-term mitigation, if the precipitating environmental changes are permanent
Bear loss	Do nothing to save species or stocks	

tain and restore valuable habitat, improve recreational experiences, and provide vital human services such as water purification and flood control. Given the already large threat to Great Lakes biodiversity from invasive species, it is also vital to continue to implement strong protection against invasive aquatic and terrestrial organisms. One example is the Great Lakes-

wide effort to contain the spread and expansion of nonnative Eurasian water milfoil, an imported waterweed that forms thick, smothering mats in lakes and streams, depleting oxygen and crowding out native plants.<sup>207</sup> Invasive species such as water milfoil are likely to exacerbate problems created by a warmer climate, especially in shallow lakes and wetlands.

## Managing the Impacts of Climate Change

Even if our societies, regional and global, are successful in relieving human pressures on ecosystems and minimizing climate change by reducing emissions, climate changes already in progress will continue for decades or more. Because of this, society must begin planning and preparing to manage future impacts that cannot be avoided. A robust strategy in the face of uncertainty, or even unpredictability, is one that will be flexible enough to fare well

under a wide range of possible outcomes. The sections below describe some “no regrets” actions that may be taken to manage the impacts of climate change on the Great Lakes economy, peoples, and environment.

### Fisheries

The histories of aboriginal, commercial, and sport fisheries provide

many examples of the adaptability of fishers. When traditionally exploited stocks fail, effort is quickly redirected and fishing methods are adjusted to other stocks and species. Likewise, as regional waters warm, fisheries may be able to adapt to a new mix of fish species. This does not mean, however, that individual fishers or specific fishing communities will necessarily avoid serious negative effects, in part because habits and cultural preferences are typically slow to change (Table 9, p.75).

Effective adaptation will likely involve reallocation of harvest from adversely affected populations, such

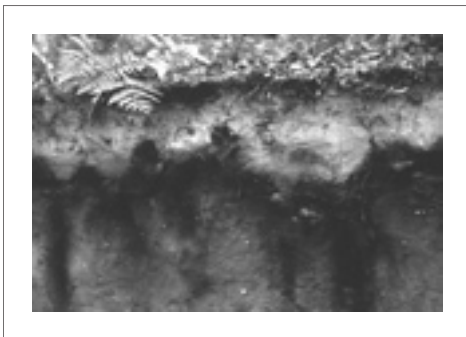
as lake trout in southern inland lakes, to populations that are positively affected, such as walleye in northern waters and smallmouth bass throughout the basin. However, the fish community may face a prolonged period of restructuring while productivity and water temperatures are in transition. This transitional stage may create great uncertainty in determining sustainable harvests of any fish species. Also, both fishermen and consumers have preferences for particular species that may be difficult to change and may prolong exploitation of populations that should be protected. Overall, robust fisheries management should be guided by some basic principles, including:

- Maintaining exploitation rates at levels that include a safety margin based on historical uncertainties in fish stocks
- Reducing the negative impacts of other human stressors such as acidification and habitat destruction
- Initiating concerted efforts to reduce overinvestment in a fishery that can exploit certain species at unsustainable rates
- Ensuring that no practice applied for a short time could produce extreme outcomes

### Aquatic Ecosystems, Resources, and Wildlife

To help sustain aquatic resources and ecosystems, efforts should focus on protecting riparian zones of rivers, existing wetlands and headwater streams, groundwater systems, and lakes. Protecting and revegetating riparian zones, for example, can yield a large return on investment in terms of reducing damages and economic losses from flooding and improving water quality. Native species chosen for such projects should be evaluated in terms of their suitability for a warmer climate and their ability to withstand frequent floods and droughts. To boost the chances

FIGURE 39  
Ecological Limits to Adaptation  
in Agriculture



See page 52  
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for wetland survival, efforts can be initiated to increase water retention in wetlands and to restore or maintain connections between wetlands and lakes or rivers.

Increasing water conservation and reducing human demands for water are vital goals that can be achieved through changes in human behavior in households, farms, and industries. Water management policies can also be reviewed to insure that they are adequate and flexible enough to meet the long-term challenges of a changing and potentially drier climate.<sup>208</sup>

Finally, an effective strategy for sustaining habitats and wildlife populations will benefit from active planning and implementation of development regulations designed to minimize landscape fragmentation. Preserving or restoring migration corridors across the landscape will allow species to move to more suitable climates and will also help to sustain populations of native plants and animals that are large and genetically diverse enough to cope with future disturbances.

## Agriculture

Many factors other than climate will heavily influence the ease with which agriculture in the region adapts to future changes, and also the direction that adaptation takes (Figure 39). Typically, assessments of agriculture's capacity to adapt to climate change produce relatively favorable predictions because they assume that farmers, accustomed to having to make adjustments every season, have the ability to shift planting times, crop varieties, fertilizer inputs, irrigation methods, and other factors to optimize production.<sup>209</sup> Such assessments also point out that changes in technology, availability of resources, subsidies, and management policies as well as climate will affect both trends in crop yields and shifts in national and global markets. Usually missing from these assessments, however, are the costs of adaptation and change that individual farmers must bear, and the differing impacts on small versus large farms. On the farm, management choices in a changing climate will be governed not only by farmers' technological options and resources, but also by their ability and desire to

Climate change will affect individual farms as well as local farming communities, potentially changing the character of rural landscapes across the region.

change. Finally, an indirect impact of climate change often ignored involves the influence that changes on the farm will have on local farming communities.

These impacts have the potential to change the character of rural landscapes across the Great Lakes region.

## Forestry

The following approaches may help forestry operations in the northern portion of the Great Lakes region adjust to a warmer and potentially drier climate:

- Shifting species and genetic varieties of trees as well as forestry practices to increase water use efficiency of trees
- Improving soil management, spacing, and tree rotation length to enhance the success of forests under new or variable climate patterns
- Moving toward greater production of saw timber and less pulp production, which will help sequester carbon in long-lived products
- Creating biologically diverse rather than single-species tree plantations to enhance and hasten species' dispersal to more suitable new ranges
- Investing more in prevention, management, and containment of large forest fires, especially during dry periods, while developing improved fire management strategies for relatively small fires

Many of the best practices common in sustainable forestry today could help ensure the resilience of biologically diverse forests and habitat protection for birds and other wildlife under future climate stresses. Particularly important are adaptive strategies that retain management flexibility in the face of uncertainty, together with improved land use planning and pest management.<sup>210</sup> As in the agricultural sector, how-

FIGURE 40  
**Managing the Lake and Stream  
Impacts of Climate Change**



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ever, many market-related and industry-wide changes occurring nationally and globally will affect the economic viability, technological changes, and productivity of forestry in the Great Lakes region.<sup>211</sup>

### Infrastructure Protection and Built Environments

People have traditionally responded to climate variability and weather extremes by shielding themselves through both structural measures such as bulkheads along shorelines, levees in floodplains, or dredging of lakes (Figure 40, p.77), and nonstructural measures including insurance coverage, warning systems, emergency management plans, and land use planning. These same tools can help society adapt to climate change, although many current applications fail to include the necessary long-term perspective or even an awareness of climate change. For example, when levees and other structures are being upgraded or replaced, it may be inadequate to engineer replacements based solely on historical frequencies of extreme events or water-level fluctuations. Complementary strategies may be needed because of current trends in the insurance industry, including ever more expensive coverage and withdrawal from high-risk areas. For example, progressive relocation of homes and businesses out of the most hazardous areas and other improvements in zoning, planning, and building codes

can avoid creating greater vulnerability and liability in the future.

### Human Health

Coordinated health management plans that specifically take into account changing patterns of disease threats in a warmer climate will be vital in managing future health risks, as suggested in a recent report on adaptation options for the Toronto-Niagara region.<sup>168</sup> As the frequency or intensity of extreme heat events increases, earlier forecasting, better public education efforts, and assistance directed at elderly, low-income, and other high-risk populations will be needed. Earlier warnings during periods of increased ground-level air pollution could also help the elderly and people with preexisting respiratory conditions reduce their exposure. Public education can help people reduce their risk of exposure to many vectorborne diseases in the region, including Lyme disease, Eastern equine encephalitis, and West Nile encephalitis, by modifying outdoor activity, clothing, or housing.

Obviously, limiting construction of houses in flood plains and improving housing construction standards could reduce risk of flood damage, injuries, and deaths. In general, infrastructure improvements that maintain or improve sanitation, sewage treatment, waste disposal, stormwater drainage, and water supply will all help reduce health risks.

## Meeting the Challenges

**G**lobal warming is under way and already causing changes to our environment. Much uncertainty remains about specific ecological and economic changes that a warmer climate with drier summers will bring to the Great Lakes region, but it is certain that the impacts will magnify in importance in the future. This knowledge provides no excuse for inaction or fatalism, however, because innovative, affordable, and prudent solutions are available

to help reduce the severity of climate change globally, increase the health and resilience of ecological and economic systems vital to the region, and begin planning and preparing now to adapt to those future changes that cannot be avoided. By acting now, we can protect the rich natural heritage, vibrant economy, and well-being of people and communities in North America's heartland.