## Land Cover Adjacent to Coastal Wetlands
Indicator # 4863

**Overall Assessment**

| | |
|---|---|
| Status: | Not Fully Assessed |
| Trend: | Undetermined |
| Primary Factors Determining Status and Trend | The status and trends are currently under investigation and proposed for additional investigation for the full basin (see Data Sources). Although other results exist for Canada (see Data Sources), "Land Cover Adjacent to Coastal Wetlands" results are currently unavailable for Canada. |

**Lake-by-Lake Assessment**

**Lake Superior**

| | |
|---|---|
| Status: | Not Fully Assessed |
| Trend: | Undetermined |
| Primary Factors Determining Status and Trend | The status and trends are currently under investigation and proposed for additional investigation in the Lake Superior Basin (see Data Sources) |

**Lake Michigan**

| | |
|---|---|
| Status: | Not Fully Assessed |
| Trend: | Undetermined |
| Primary Factors Determining Status and Trend | The status and trends are currently under investigation and proposed for additional investigation in the Lake Michigan Basin (see Data Sources) |

**Lake Huron**

| | |
|---|---|
| Status: | Not Fully Assessed |
| Trend: | Undetermined |
| Primary Factors Determining Status and Trend | The status and trends are currently under investigation and proposed for additional investigation in the Lake Huron Basin (see Data Sources) |

**Lake Erie**

| | |
|---|---|
| Status: | Not Fully Assessed |
| Trend: | Undetermined |
| Primary Factors Determining Status and Trend | The status and trends are currently under investigation and proposed for additional investigation in the Lake Erie Basin (see Data Sources) |

**Lake Ontario**

| | |
|---|---|
| Status: | Not Fully Assessed |
| Trend: | Undetermined |
| Primary Factors Determining Status and Trend | The status and trends are currently under investigation and proposed for additional investigation in the Lake Ontario Basin (see Data Sources) |

**Purpose**
Assess the basin-wide presence, location, and/or spatial extent of land cover in close proximity to coastal wetlands. Infer the condition of coastal wetlands as a function of adjacent land cover. Relevant coastal areas in the Great Lakes Basin have been mapped to assess the presence and proximity of general land cover in the vicinity of wetlands using satellite remote-sensing data and geographic information systems (GIS), providing a broad scale measure of land cover in the context of habitat suitability and habitat vulnerability for a variety of plant and animal species. For example, upland grassland and/or upland forest areas adjacent to wetlands may be important areas for forage, cover, or reproduction for organisms. Depending upon the particular physiological and sociobiological requirements of the different organisms, the wetland-adjacent land cover extent (e.g., the width or total area of the upland area around the wetland) may be used to describe the potential for suitable habitat, or the vulnerability of these areas of habitat to loss or degradation. Although other SOLEC Indicators are described for Canada (see Data Sources) at a broad scale, basin-wide "Land Cover Adjacent to Coastal Wetlands" results are currently unavailable for Canada.

**Ecosystem Objective**
Restore and maintain the ecological (i.e., hydrologic and biogeochemical) functions of Great Lakes coastal wetlands. Presence, wetland-proximity, and/or spatial extent of land cover should be such that the hydrologic and biogeochemical functions of wetlands continue.

**State of the Ecosystem**
The state of the Great Lakes Ecosystem (i.e., the sum of ecological functions for the full Great Lakes Basin) is currently under investigation and proposed for additional investigation (see Data Sources). Differences in the regional status of "Habitat Adjacent to Coastal Wetlands" can be determined using the existing data (see Pressures), but the results are preliminary and observations are not conclusive. Nor can the regional trends be extrapolated to determine the state of the ecosystem as a whole.

Percent forest adjacent to wetlands
The amount of forest land cover on the periphery of wetlands may indicate the amount of upland wooded habitat for organisms that may travel relatively short distances to and from nearby forested areas and wetland areas for breeding, water, forage, or shelter. Also, the affects of runoff on wetlands from nearby areas (e.g., nearby agricultural land) may be ameliorated by biogeochemical processes that occur in the forests on the periphery of the wetland. For example, forest vegetation may contribute to the uptake, accumulation, and transformation of chemical constituents in runoff. Broad-scale approaches to assessing percentage of forest directly adjacent to wetlands may be calculated by summing the total area of forest land cover directly adjacent to wetland regions in a reporting unit (e.g., an Ecoregion, a watershed, or a state) and dividing by wetland total area in the reporting unit. This calculation ignores those upland areas of forest outside of the adjacent "buffer zone" for wetlands within each reporting unit. Other buffer distances may be appropriate for other habitat analyses, depending on the type of organism; for runoff analyses the chemical constituent(s), flow dynamics, soil conditions, position of wetland in the landscape, and other landscape characteristics should be carefully considered. Coastal wetland areas may be generally assessed by calculating forest wetland-adjacency in specifically targeted

coastal wetlands of interest, by targeting narrow coastal areas such as areas within 1 km of the lake shoreline (Figure 1), or by targeting all wetlands in a specific inland and coastal region of the historical lake plain (Figure 2).

Percent grassland adjacent to wetlands
The amount of grassland on the periphery of wetlands may indicate the amount of upland herbaceous plant habitat for organisms that might travel relatively short distances to and from nearby upland grassland and wetland areas for breeding, water, forage, or shelter. As with forested areas, the affect of runoff on wetlands from areas nearby (e.g., agricultural) land may be ameliorated by biogeochemical processes that occur in herbaceous areas that are on the periphery of the wetland. For example, herbaceous vegetation stabilizes soils and may reduce erosional soil loss to nearby wetlands and other surface water bodies. As with forest calculations, broad-scale approaches to assessing percentage of grassland directly adjacent to wetlands may be calculated by summing the total area of grassland directly adjacent to wetland regions in a reporting unit. Other buffer distances may be more appropriate for habitat analyses, depending on the type of organism; for runoff analyses the chemical constituent(s), flow dynamics, soil conditions, position of wetland in the landscape, and other landscape characteristics should be carefully considered. Coastal wetland areas may be generally assessed by calculating grassland wetland-adjacency in specifically targeted coastal wetlands of interest; by targeting narrow coastal areas such as areas within 1 km of the lake shoreline (Figure 3), or by targeting all wetlands in a specific inland and coastal region of the historical lake plain (Figure 4).

Standard Deviation
Classes describe the distribution of percentage of forest or percentage of grassland adjacent to wetlands (among reporting units) relative to the mean value for the metric distribution. Class breaks are generated by successively described by standard deviations from the mean value for the metric. A two-color ramp (red to blue) emphasizes values (above to below) the mean value for a metric, and is a useful method for visualizing spatial variability of a metric.

**Pressures**
Although several causal relationships have been postulated for changes in “Land Cover Adjacent to Coastal Wetlands” for the Great Lakes Basin (see Data Sources), it is undetermined as to the relative contribution of the various factors. However, some preliminary regional trends exist. For example, in the 1 km coastal region of southern Lake Superior there is a relatively high percent of forest adjacent to coastal wetlands, and in the 1 km coastal region of western Lake Michigan there is a relatively low percent of forest adjacent to coastal wetlands. Differences in percent forest between these two coastal zones generally track with respect to percent of agricultural land cover or urban land cover, as measured with similar techniques (see Data Sources). These results are preliminary and observations are not conclusive. Similar phenomena are currently under investigation and proposed for additional regional and full-basin investigation.

**Management Implications**
Because critical forest and grassland habitat areas on the periphery of coastal wetlands may influence the presence and fitness of localized and migratory organisms in the Great Lakes, natural resource managers may use these data to determine the ranking of their areas of interest, such as areas where they are responsible for coastal wetland resources, among other areas in the Great Lakes. It is important for managers to understand that results for their areas of interest are

reported among a distribution for the entire Great Lakes Basin (USA) and that caution should be used when interpreting the results at finer scales.

**Comments from the author(s)**
To conduct such measures at a broad scale, the relationships between wetland-adjacent land cover and the functions of coastal wetlands need to be verified. This measure will need to be validated fully with thorough field sampling data and sufficient a priori knowledge of such endpoints and the mechanisms of impact. The development of indicators (e.g., a regression model using adjacent vegetation characteristics and wetland hydroperiod) is an important goal, and requires uniform measurement of field parameters across a vast geographic region to determine accurate information to calibrate such models.

**Acknowledgments**
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**Data Sources**
Lopez, R.D., D.T. Heggem, J.P. Schneider, R. Van Remortel, E. Evanson, L.A. Bice, D.W. Ebert, J.G. Lyon, and R.W. Maichle. 2005. The Great Lakes Basin Landscape Ecology Metric Browser (v2.0). EPA/600/C-05/011. The United States Environmental Protection Agency, Washington, D.C. Compact Disk and Online at http://www.epa.gov/nerlesd1/land-sci/glb_browser/GLB_Landscape_Ecology_Metric_Browser.htm.

**Citation/Source**
Lopez, R.D., D.T. Heggem, J.P. Schneider, R. Van Remortel, E. Evanson, L.A. Bice, D.W. Ebert, J.G. Lyon, and R.W. Maichle. 2005. The Great Lakes Basin Landscape Ecology Metric Browser (v2.0). EPA/600/C-05/011. The United States Environmental Protection Agency, Washington, D.C. Compact Disk and Online at http://www.epa.gov/nerlesd1/land-sci/glb_browser/GLB_Landscape_Ecology_Metric_Browser.htm

**List of Figures**
Figure 1. Percent forest adjacent to wetlands, among 8-digit USGS Hydrologic Unit Codes (HUCs), measured within 1 km of shoreline; data are reported as standard deviations from the mean.
Source: Lopez *et al.*, 2006

Figure 2. Percent forest adjacent to wetlands, among 8-digit USGS Hydrologic Unit Codes (HUCs), measured within 5 km of shoreline; data are reported as standard deviations from the mean.
Source: Lopez *et al.*, 2006

Figure 3. Percent grassland adjacent to wetlands, among 8-digit USGS Hydrologic Unit Codes (HUCs), measured within 1 km of shoreline; data are reported as standard deviations from the mean.

Source: Lopez *et al.*, 2006

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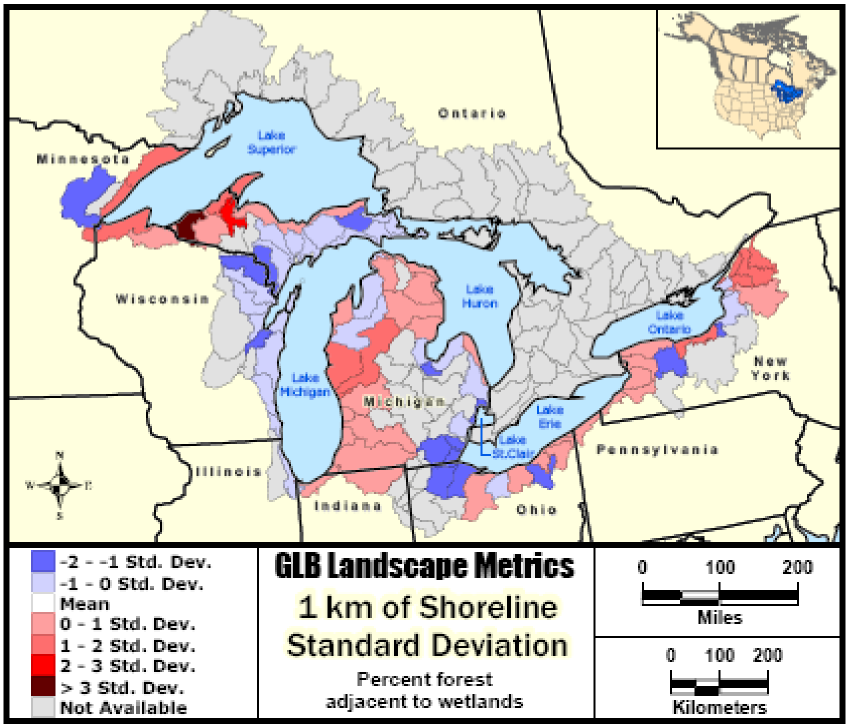


**Figure 1**. Percent forest adjacent to wetlands, among 8-digit USGS Hydrologic Unit Codes (HUCs), measured within 1 km of shoreline; data are reported as standard deviations from the mean.
Source: Lopez *et al.*, 2006

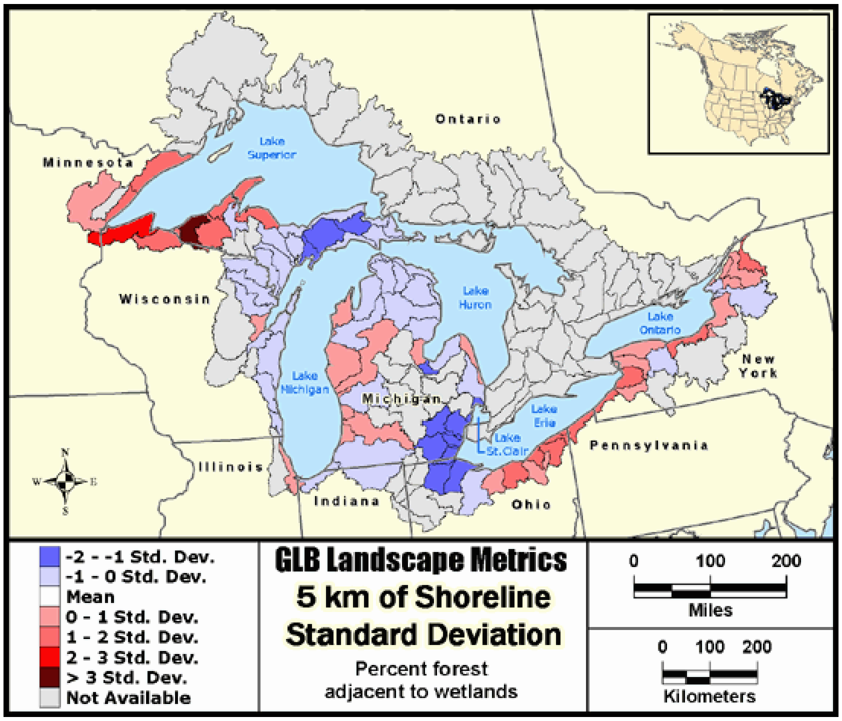


**Figure 2**. Percent forest adjacent to wetlands, among 8-digit USGS Hydrologic Unit Codes (HUCs), measured within 5 km of shoreline; data are reported as standard deviations from the mean.
Source: Lopez *et al.*, 2006

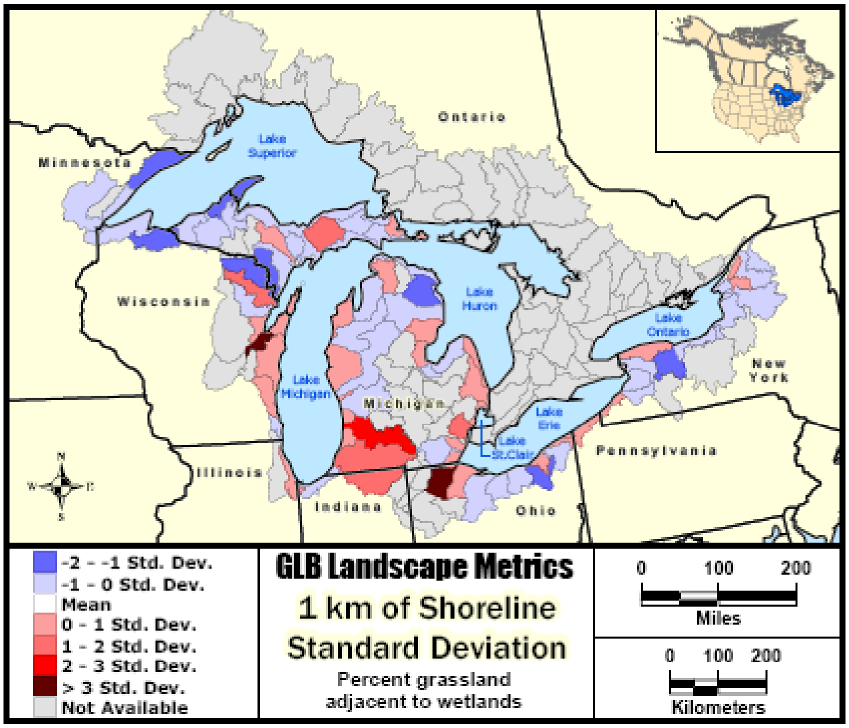


**Figure 3**. Percent grassland adjacent to wetlands, among 8-digit USGS Hydrologic Unit Codes (HUCs), measured within 1 km of shoreline; data are reported as standard deviations from the mean
Source: Lopez *et al.*, 2006

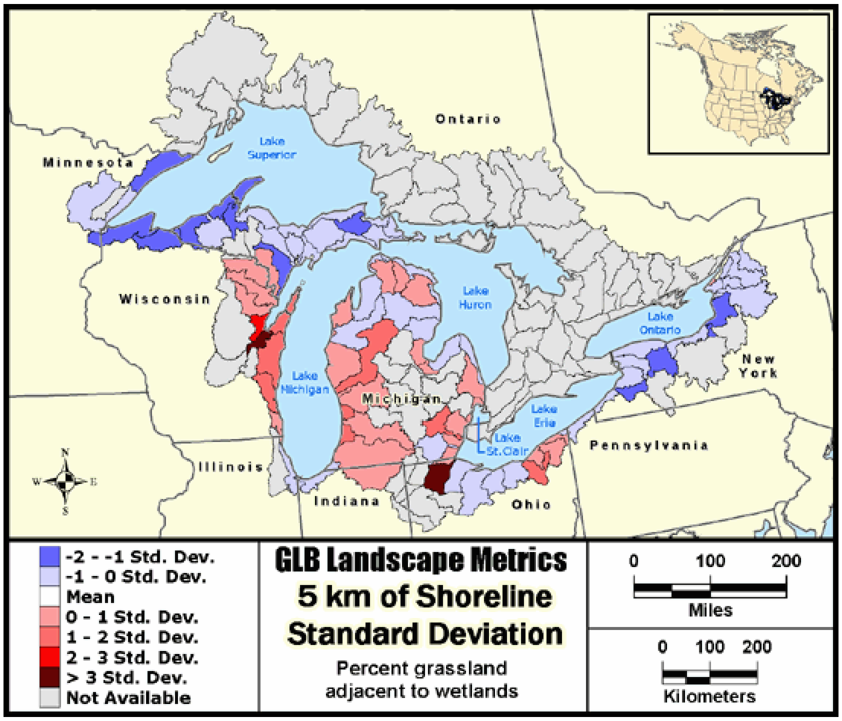


Figure 4. Percent grassland adjacent to wetlands, among 8-digit USGS Hydrologic Unit Codes (HUCs), measured within 5 km of shoreline; data are reported as standard deviations from the mean (Lopez *et al.*, 2006).

# Urban Density

Indicator #7000

**Overall Assessment**

Status: **Mixed/ Trend Not Assessed**
Trend: **Improving, Unchanging, Deteriorating or Undetermined**
Primary Factors Determining Status and Trend

**Lake by Lake Assessment**

Trends on a lake-to-lake basis are unavailable due to insufficient data.

**Purpose**

To assess the urban human population density in the Great Lakes basin, and to infer the degree of land use efficiency for urban communities in the Great Lakes ecosystem.

**Ecosystem Objective**

Socio-economic viability and sustainable development are the generally acceptable goals for urban growth in the Great Lakes basin. Socio-economic viability indicates that development should be sufficiently profitable and social benefits are maintained over the long term. Sustainable development requires that we plan our cities to grow in a way so that they will be environmentally sensitive, and not compromise the environment for future generations. Thus, by increasing the densities in urban areas while maintaining low densities in rural and fringe areas, the amount of land consumed by urban sprawl will be reduced.

**State of the Ecosystem**

Background

Urban density is defined as the number of people per square kilometer of land for urban use in a municipal or township boundary. Low urban density indicates urban sprawl that is low-density development beyond the edge of service and employment, which separates residential areas from commercial, educational, and recreational areas - thus requiring automobiles for transportation (TCRP, 1998; TCRP, 2003; Neill et al. 2003). Urban sprawl has many detrimental effects on the environment. This process consumes large quantities of land, multiplies the required infrastructure, and increases the use of personal vehicles as the feasibility of alternate transportation declines. When there is an increased dependency on personal vehicles, consequentially, there is an increased demand for roads and highways, which in turn, produce segregated land uses, large parking lots, and urban sprawl. These implications result in the increased consumption of many non-renewable resources, the creation of impervious surfaces and damaged natural habitats, and the production of many harmful emissions. Segregated land use also lowers the quality of life as the average time spent traveling increases and the sense of community diminishes. For this assessment, the population data used was derived from 1990-2000 U.S. census and 1996 - 2001 Canadian census.

This indicator offers information on the presence, location, and predominance of human-built land cover and implies the intensity of human activity in the urban area. It may provide information about how such land cover types affect the ecological characteristics and functions of ecosystems, as demonstrated by the use of remote-sensing data and field observations.

Status of Urban Density

Within the Great Lakes basin there are 10 Census Metropolitan Areas (CMAs) in Ontario and 24 Metropolitan Statistical Areas (MSAs) in the United States. In Canada, a CMA is defined as an area consisting of one or more adjacent municipalities situated around a major urban core with a population of at least 100,000. In the United States, an MSA must have at least one urbanized area of 50,000 or more inhabitants and at least one urban cluster of at least a population of 10,000 but less than 50,000. The urban population growth in the Great Lakes basin show consistent patterns in both the United States and Canada. The population in both countries has been increasing over the past five to ten years. According to the 2001 Statistics Canada report, between 1996 and 2001, the population of the Great Lakes basin CMAs grew from 7,041,985 to 7,597,260, an increase of 555,275 or 7.9% in five years. The 2000 U.S. census reports that from 1990 to 2000 the population contained in the MSAs of the Great Lakes basin grew from 26,069,654 to 28,048,813, an increase of 1,979,159 or 7.6% in 10 years.

In the Great Lakes basin, as there has been an increase in population, there has also been an increase in the average population densities of the CMAs and MSAs. However, using the CMA or MSA as urban delineation has two major limitations. First, CMA and MSA contain substantial land areas that is rural and by themselves result in over-estimation of the land area occupied by a city or town. Second, these area delineations are based on a population density threshold and hence provide information on residential distribution and not necessarily on other urban land categories such as commercial land, recreational land. If within the CMAs and MSAs the amount of land being developed is escalating at a greater rate than the population growth rate, the average amount of developed land per person is increasing. For example, “In the GTA (Greater Toronto Area) during the 1960s, the average amount of developed land per person was a modest 0.019 hectares. By 2001 that amount tripled to 0.058 hectares per person” (Gilbert et al. 2001).

Population densities illustrate the development patterns of an area. If an urban area has a low population density this indicates that the city has taken on a pattern of urban sprawl and segregated land uses. This conclusion can be made as there is a greater amount of land per person; however, it is important to not only look at the overall urban density of an area, but also the urban dispersion. For example, a CMA or MSA with a relatively low density could have different dispersion characteristics than another CMA or MSA with the same density. One CMA or MSA could have the distribution of people centred around an urban core, while another could have a generally consistent sparse dispersion across the entire area and both would have the same average density. Therefore, to properly evaluate the growth pattern of an area, it is necessary to examine not only at the urban density but also at the urban dispersion.

While density is a readily understandable measure, it is challenging to quantify because of the difficulty in estimating true urban extent in a consistent and unbiased way. The geographic extents of MSAs and CMAs give approximate indications of relative city size, however, they tend to contain substantial areas of rural land use. Recently satellite remote sensing data has been used to map landuse of Canadian cities as part of a program to develop an integrated urban database, the Canadian Urban Land Use Survey (CUrLUS). In southern Ontario a total of 11 cities have been mapped using Landsat data acquired in the 1999-2002 timeframe and densities estimated using population statistics from the 2001 Canadian census (Figure 1). Population density is related with the city size. Bigger cities with higher population pressure have higher population density and more efficient land use. Comparing the population densities of 11 cities (or CMAs) in southern Ontario, derived from remote sensing mapping and 2001 census (Zhang and Guindon, 2005), the Great Toronto Area (GTA) has a higher population density (2848 $km^{-2}$) than other smaller cities.

The growth characteristics of 5 large Canadian cities have also been studied for the period 1986-2000. Preliminary analyses (Figure 2) indicate that the areal extents of these communities have grown at a faster rate than their populations and thus that sprawl continues to be a major problem.

A comparison of the ten CMAs and MSAs with the highest densities to the ten CMAs and MSAs with the lowest densities in the Great Lakes basin shows there is a large range between the higher densities and lower densities. Three of the ten lowest density areas have experienced a population decline while the others have experienced very little population growth over the time period examined. The areas with population declines and areas of little growth are generally occurring in northern parts of Ontario and eastern New York State. Both of these areas have had relatively high unemployment rates (between 8% and 12%) which could be linked to the slow growth and decreasing populations.

Overall, the growing urban areas in the Great Lakes basin seem to be increasing their geographical area at a faster rate than their population.  This trend has many detrimental effects as outlined previously, namely urban sprawl and its implications.  Such trends may continue to threaten the Great Lakes basin ecosystem unless this pattern is reversed. However, there is a need for a solid definitive information about relying on relatively fine-scale urban delineation data as it pertains to broad-scale trends for the Great Lakes region.

**Pressures**

Under the pressure of rapid population growth in the Great Lakes region, mostly in the metropolitan cities, the urban development has been undergoing unprecedented growth. For instance, the urban built-up area of the Greater Toronto Area (GTA) has been doubled since 1960s.   Sprawl is increasingly becoming a problem in rural and urban fringe areas of the Great Lakes basin, placing a strain on infrastructure and consuming habitat in areas that tend to have healthier environments than those that remain in urban areas. This trend is expected to continue, which will exacerbate other problems, such as increased consumption of fossil fuels, longer commute times from residential to work areas, and fragmentation of habitat. For example, at current rates in Ontario, residential building projects will consume some 1,000 square kilometres of the province's countryside, an area double the size of Metro Toronto, by 2031. Also, gridlock could add 45% to commuting times, and air quality could suffer due to a 40% increase in vehicle emissions (Loten 2004). The pressure urban sprawl exerts on the ecosystem has not yet been fully understood. It may be years before all of the implications have been realized.

**Management Implications**

Urban density impacts can be more thoroughly explored and explained if they are linked to the functions of ecosystems (e.g., as it relates to surface water quality). For this reason, interpretation of this indicator is correlated with many other Great Lakes indicators and their patterns across the Great Lakes. Urban density impacts on ecosystem functions should be linked to the ecological endpoint of interest, and this interpretation may vary as a result of the specificity of land cover type and the contemporaneous nature of the data. Thus, more detailed land cover specificity is required.

To conduct such measures at a broad scale, the relationships between land cover and ecosystem functions need to be verified. This measure will need to be validated fully with thorough field-sampling data and sufficient *a priori* knowledge of such endpoints and the mechanisms of impact (if applicable). The development of indicators (e.g., a regression model) is an important goal, and requires uniform measurement of field parameters across a vast geographic region to determine accurate information to calibrate such models.

The governments of the United States and Canada have both been making efforts to ease the strain caused by pressures of urban sprawl by proposing policies and creating strategies. Although this is the starting point in implementing a feasible plan to deal with the environmental and social pressures of urban sprawl, it does not suffice. Policies are not effective until they are put into practice and in the meantime our cities continue to grow at unsustainable rates. In order to mitigate the pressures of urban sprawl, a complete set of policies, zoning bylaws and redevelopment incentives must be developed, reviewed and implemented. As noted in the Urban Density indicator report from 2000, policies that encourage infill and brownfields redevelopment within urbanized areas will reduce sprawl. Compact development could save 20% in infrastructure costs (Loten 2004). Comprehensive land use planning that incorporates “green” features, such as cluster development and greenway areas, will help to alleviate the pressure from development.

For urban sustainable development, we should understand fully the potential negative impacts of urban high density development. High urban density indicates intensified human activity in the urban area, which would be potential threads to the urban environment quality.  Therefore, the urbanization strategies should be based on the concept of sustainable development on the balance the costs and benefits.

**Comments from the author(s)**
A thorough field-sampling protocol, properly validated geographic information, and other remote-sensing-based data could lead to successful development of urban density as an indicator of ecosystem function and ecological vulnerability in the Great Lakes basin. This indicator could be applied to select sites, but would be most effective if used at a regional or basin-wide scale. Displaying U.S. and Canadian census population density on a GIS map will allow increasing sprawl to be documented over time in the Great Lakes basin on a variety of scales. For example, the maps included with the 2003 Urban Density report show the entire Lake Superior basin and a closer view of the southwestern part of the basin.

To best quantify the indicator for the whole Great Lakes watershed, a watershed-wide consistent urban built-up database is needed.

**Acknowledgments**
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Bert Guindon, Natural Resources Canada, Ottawa, ON;
Ric Lopez, U.S. Environmental Protection Agency, Las Vegas, NV
Lindsay Silk, Environment Canada Intern, Downsview, ON; and
Ying Zhang, Natural Resources Canada, Ottawa, ON.

**Data Sources**

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GEM Center for Science and Environmental Outreach. 2000. Baseline Sustainability Data for the Lake Superior Basin: Final Report to the Developing Sustainability Committee, Lake Superior Binational Program, November 2000. Michigan Technological University, Houghton, MI. http://emmap.mtu.edu/gem/community/planning/lsb.html.

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http://factfinder.census.gov/servlet/DTGeoSearchByRelationshipServlet?_ts=109848346281.

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**List of Figures**

Figure 2. Growth characterization of 5 urban areas in the period of 1986-2001.

**Last updated**
SOLEC 2006

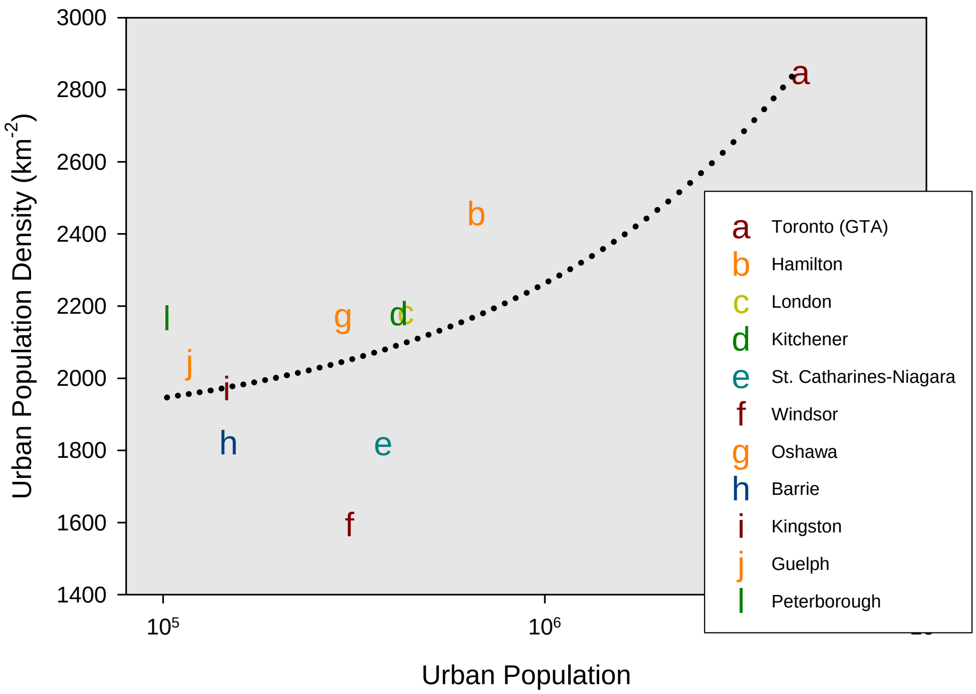


Figure 1. Population densities of cities with population more than 100,000 in southern Ontario of the Great Lakes watershed for 2001. Source: 'Y. Zhang and B. Guindon, private communication'

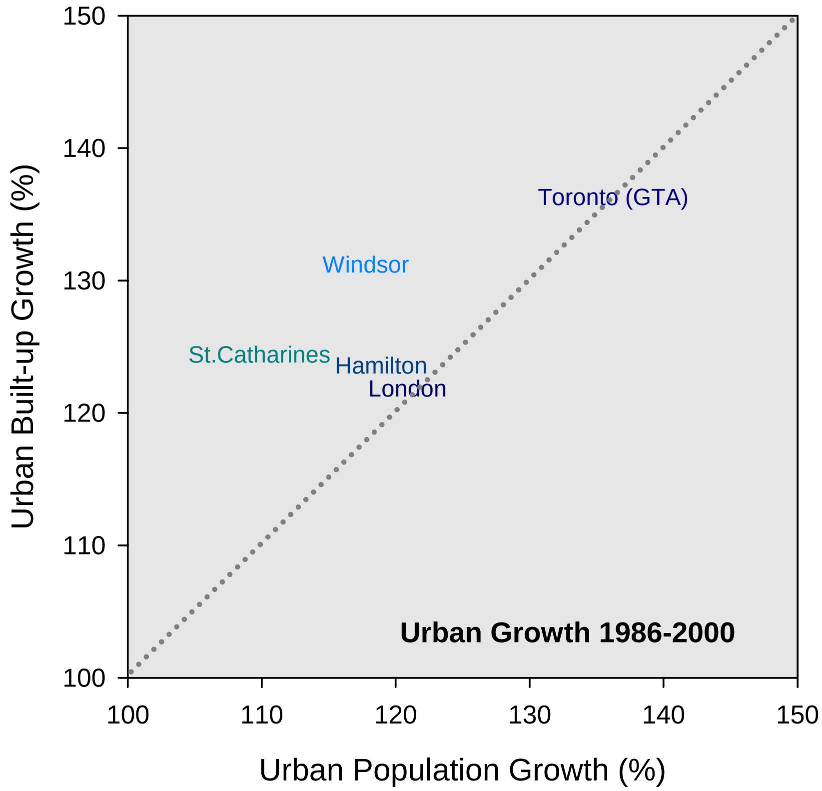


Figure 2. Growth characterization of 5 urban areas in the period of 1986-2001. Source: 'Y. Zhang and B. Guindon, private communication'

## Land Cover/Land Conversion

Indicator #7002

### Overall Assessment

| | |
|---|---|
| Status: | **Mixed** |
| Trend: | **Undetermined** |
| Primary Factors Determining Status and Trend | Low-intensity development increased 33.5%, road area increased 7.5%, and forest decreased 2.3% from 1992 and 2001. Agriculture lost 210,000 ha of land to development. Approximately 50% of forest losses were due to management and 50% to development. |

### Lake-by-Lake Assessment

**Lake Superior**

| | |
|---|---|
| Status: | Good |
| Trend: | Undetermined |
| Primary Factors Determining Status and Trend | Lowest conversion rate of non-developed land to development and highest conversion rate of non-forest to forest. Of the 4.2 million ha watershed area on the U.S. side, 1,676 ha of wetland, 2,641 ha of agricultural land, and 14,300 ha of forest land were developed between 1992 and 2001. |

**Lake Michigan**

| | |
|---|---|
| Status: | Mixed |
| Trend: | Undetermined |
| Primary Factors Determining Status and Trend | Intermediate to high rate of land conversions to development. Of the 1.2 million ha watershed, 9,724 ha of wetland, 78,537 ha of agricultural land, and 57,529 ha of forest land were developed between 1992 and 2001. |

**Lake Huron**

| | |
|---|---|
| Status: | Fair |
| Trend: | Undetermined |
| Primary Factors Determining Status and Trend | Second lowest rate of conversion of land to development. Of the 4.1 million ha watershed area on the U.S. side, 4,314 ha of wetland, 17,881 ha of agricultural land, and 17,730 ha of forest land were developed between 1992 and 2001. |

**Lake Erie**

| | |
|---|---|
| Status: | Poor |
| Trend: | Undetermined |
| Primary Factors Determining Status and Trend | Highest conversion rate of non-developed to development LULC. Of the 5.0 million ha watershed area on the U.S. side, 3,352 ha of wetland, 52,502 ha of agricultural land, and 27,869 ha of forest land were developed between 1992 and 2001. |

**Lake Ontario**

| | |
|---|---|
| Status: | Mixed |
| Trend: | Undetermined |

| | |
|---|---|
| Primary Factors Determining Status and Trend | Intermediate to high conversion rate of non-developed to development LULC coupled with the lowest rates of wetland development. Of the 3.4 million ha watershed area on the U.S. side, 458 ha of wetland, 24,883 ha of agricultural land, and 20,670 ha of forest land were developed between 1992 and 2001. |

**Purpose**

•To document the proportion of land in the Great Lakes basin under major land use classes, and assess the changes in land use over time; and

•To infer the potential impact of existing land cover and land conversion patterns on basin ecosystem health.

**Ecosystem Objective**

Sustainable development is a generally accepted land use goal. This indicator supports Annex 13 of the Great Lakes Water Quality Agreement.

**State of the Ecosystem**

Binational land use data from the early 1990s was developed by Guindon (Natural Resources Canada). Imagery data from the North American Landscape Characterization and the Canada Centre for Remote Sensing archive were combined and processed into land cover using Composite Land Processing System software. This data set divides the basin into four major land use classes – water, forest, urban, and agriculture and grasses.

Later, finer-resolution satellite imagery allowed analysis to be conducted in greater detail, with a larger number of land use categories. For instance, the Ontario Ministry of Natural Resources has compiled Landsat TM (Thematic Mapper) data, classifying the Canadian Great Lakes basin into 28 land use classes.

On the U.S. side of the basin, the Natural Resources Research Institute (NRRI) of the University of Minnesota – Duluth has developed a 25-category classification scheme (Table 1) based on 1992 National Land Cover Data (NLCD) from the U.S. Geological Survey supplemented by 1992 WISCLAND, 1992 GAP, 1996 C-CAP and raw Landsat TM data to increase resolution in wetland classes (Wolter et al. 2006). The 1992 Topologically Integrated Geographic Encoding and Reference (TIGER) data were also used to add roads on to the map. Within the U.S. basin, the NRRI found the following:

Between two nominal time periods (1992 and 2001), the U.S. portion of the Great Lakes watershed has undergone substantial change in many key LULC categories (Fig. 1). Of the total change that occurred (798,755 ha, 2.5 % of watershed area), salient transition categories included a 33.5 % increase in area of low-intensity development, a 7.5% increase in road area, and a decrease of forest area by over 2.3 % – the largest LULC category and area of change within the watershed. More than half of the forest losses involved transitions into **early successional vegetation** (ESV), and hence, will likely remain in forest production of some sort. However, nearly as much forest area was, for all practical purposes, permanently converted to developed land. Likewise, agriculture lost over 50,000 more hectares of land to development than forestland, much of which involved transitions into urban/suburban sprawl (See: Fig. 2).

Approximately 210,068 ha (81 %) of agricultural lands were converted to development, and 16.3 % of that occurred within 10 km of the Great Lakes shoreline.

Land use/land cover transitions between 1992 and 2001 within near-shore zones of the Great Lakes (0-1, 1-5, 5-10 km) largely parallel those of the overall watershed. While the same transition categories dominated, their proportions varied by buffered distance from the lakes. Within the 0-1 km zone from the Great Lakes shoreline, conversions of forest to both ESV (9,087 ha, 5.0 % of **total category change** (TCC)) and developed land (8,657 ha, 5.6 % of TCC) were the largest transitions, followed by conversion of 3,935 ha (1.9 % of TCC) of agricultural land to developed. For the 1-5 km zone inland from the shore, forest to developed conversion was the largest of the three transitions (17,049 ha, 11.0 % of TCC), followed by agricultural to developed (14,279 ha, 6.8 % of TCC) and forest to ESV (13,116 ha, 7.3 % of TCC). Within the 5-10 km zone from shoreline, transition category dominance was most similar to the trend for the whole watershed, with 16,113 ha (7.7 % of TCC) of agriculture converted to developed, 14,516 ha (8.0 % of TCC) of forest converted to ESV, and 14,390 ha (9.3 % of TCC) of forestland being developed by 2001. When all buffers form shoreline out to 10 km are combined, the forest to developed transition category was the largest (40,099 ha, 25.9 % of TCC), followed by forest to ESV (36,726 ha, 20.3 % of TCC), and agricultural to developed (34,328 ha, 16.3 % of TCC).

Contrary to previous decadal estimates showing an increasing forest area trend from the early 1980s to the early 1990s, due to agricultural abandonment and transitions of forest land away from active management, we observed an overall decrease (~2.3 %) in forest area between 1992 and 2001. Explanation of this trend is largely unclear; however, both increased forest harvesting practices in parts of the region coupled with forest clearing for new developments may be overshadowing gains from the agricultural sources observed in previous decades.

When analyzed on a lake-by-lake basis (Fig. 3, Table 2), Michigan's watershed naturally has experienced the greatest area of change from 1992 to 2001 (286587 ha, ~2.5 %), as its watershed is entirely within the U.S., and hence, the largest analyzed. Michigan's watershed leads in all LULC transition categories but two: 1) misc. veg. to flooded and 2) ESV to forest (Fig. 3). When normalized by area, however, Michigan's proportion of LULC change is intermediate when compared to the other Great Lakes watersheds on the U.S. side of the boarder. Although not a Great Lake, and largely metropolitan (See: Fig 2), Lake St. Clair's watershed shows the highest rates of change into development from wetland, ESV, agriculture, and forest sources (Fig. 4).

Of the Great Lakes, Erie's watershed shows the greatest proportion of land conversion to development (87,077 ha, 1.74 %), while Superior's watershed had the lowest proportion (20,351, 0.48 %) (Table 2). For example, Erie had the highest proportion of agricultural land conversion to development. However, Ontario's watershed showed the greatest proportion of forest conversion to development (Fig. 4). Superior's watershed reflects a high proportion of lands under forest management in that it has both the highest proportion of forest conversion to ESV and visa-versa. Lastly, Huron's watershed had the highest proportion of wetlands being converted to development, followed closely by Michigan and Erie (Fig. 4).

**Management Implications**
As the volume of data on land use and land conversion grows, stakeholder discussions will assist in identifying the associated pressures and management implications.

**Comments from the author(s)**
Land classification data must be standardized. The resolution should be fine enough to be useful at lake watershed and sub-watershed levels. LULC classification updates need to be completed in a timely manner to facilitate effective remedial action if necessary.

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**Data Sources**
Data courtesy of: Bert Guindon (Natural Resources Canada), Lawrence Watkins (Ontario Ministry of Natural Resources) and Peter Wolter (Natural Resources Research Institute at the University of Minnesota – Duluth). Forest Inventory and Analysis statewide data sets downloaded from USDA Forest Service website and processed by the author to extract data relevant to Great Lakes basin.

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Table 1. Classification scheme used to analyze LULC change in the U.S. portion of the Great Lakes basin. Original 25 classes are listed in the left column, while aggregated LULC categories are listed in the right column. Numbers in parentheses indicate aggregated class membership. Miscellaneous vegetation class was generated (code 6) to represent land that was vegetated, but not mature forest or annual row crop.
Source: Wolter, P.T., Johnston, C.A., and Neimi, G.J. 2006. Land use land cover change in the U.S. Great Lakes basin 1992 to 2001. J. Great Lakes Res. 32: 607-628.

Table 2. Total area (ha) and proportion of watershed converted from non-developed to developed LULC from 1992 to 2001 for each of the Great Lakes and Lake St. Clair.
Source: Wolter, P.T., Johnston, C.A., and Neimi, G.J. 2006. Land use land cover change in the U.S. Great Lakes basin 1992 to 2001. J. Great Lakes Res. 32: 607-628.

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Source: Wolter, P.T., Johnston, C.A., and Neimi, G.J. 2006. Land use land cover change in the U.S. Great Lakes basin 1992 to 2001. J. Great Lakes Res. 32: 607-628.

Figure 2. LULC change in the lower Green Bay basin of Lake Michigan (A) and the area surrounding Detroit, MI (B).
Source: Wolter, P.T., Johnston, C.A., and Neimi, G.J. 2006. Land use land cover change in the U.S. Great Lakes basin 1992 to 2001. J. Great Lakes Res. 32: 607-628.

Figure 3. Lake-by-lake LULC transitions for the U.S. portion of the Great Lakes basin.

Source: Wolter, P.T., Johnston, C.A., and Neimi, G.J. 2006. Land use land cover change in the U.S. Great Lakes basin 1992 to 2001. J. Great Lakes Res. 32: 607-628.

Figure 4. Lake-by-lake LULC transitions for the U.S. portion of the Great Lakes basin as a percent of respective watershed area.
Source: Wolter, P.T., Johnston, C.A., and Neimi, G.J. 2006. Land use land cover change in the U.S. Great Lakes basin 1992 to 2001. J. Great Lakes Res. 32: 607-628.

**Last updated**
SOLEC 2006

| | | |
|---|---|---|
| (1) | Low Intensity Residential | 1 Developed |
| (1) | High Intensity Residential | 2 Agriculture |
| (1) | Commercial/Industrial | 3 Early Successional Vegetation |
| (1) | Roads (Tiger 1992) | 4 Forest |
| (3) | Bare Rock/Sand/Clay | 5 Wetland |
| (1) | Quarries/Strip Mines/Gravel Pits | 6 Miscellaneous Vegetation |
| (6) | Urban/Recreational Grasses | |
| (2) | Pasture/Hay | |
| (2) | Row Crops | |
| (2) | Small Grains | |
| (3,6) | Grasslands/Herbaceous | |
| (2,6) | Orchards/Vineyards/Other | |
| (4) | Deciduous Forest | |
| (4) | Evergreen Forest | |
| (4) | Mixed Forest | |
| (3,6) | Transitional | |
| (3,6) | Shrubland | |
| (5) | Open Water | |
| (5) | Unconsolidated Shore | |
| (5) | Emergent Herbaceous Wetlands | |
| (5) | Lowland Grasses | |
| (5) | Lowland Scrub/Shrub | |
| (5) | Lowland Conifers | |
| (5) | Lowland Mixed Forest | |
| (5) | Lowland Hardwoods | |

**Table 1**. Classification scheme used to analyze LULC change in the U.S. portion of the Great Lakes basin. Original 25 classes are listed in the left column, while aggregated LULC categories are listed in the right column. Numbers in parentheses indicate aggregated class membership. Miscellaneous vegetation class was generated (code 6) to represent land that was vegetated, but not mature forest or annual row crop. Source: Wolter, P.T., Johnston, C.A., and Neimi, G.J. 2006

| | Erie | Huron | Michigan | Ontario | Superior | St. Clair | Erie/St. Clair |
|---|---|---|---|---|---|---|---|
| Total watershed area | 4994413 | 4114697 | 11702442 | 3428229 | 4226924 | 564825 | 5559238 |
| Non-dev. to developed | 87077 | 42857 | 155936 | 46507 | 20351 | 16112 | 103189 |
| % of watershed | 1.74 | 1.04 | 1.33 | 1.36 | 0.48 | 2.85 | 1.86 |

**Table 2**. Total area (ha) and proportion of watershed converted from non-developed to developed LULC from 1992 to 2001 for each of the Great Lakes and Lake St. Clair.
Source: Wolter, P.T., Johnston, C.A., and Neimi, G.J. 2006

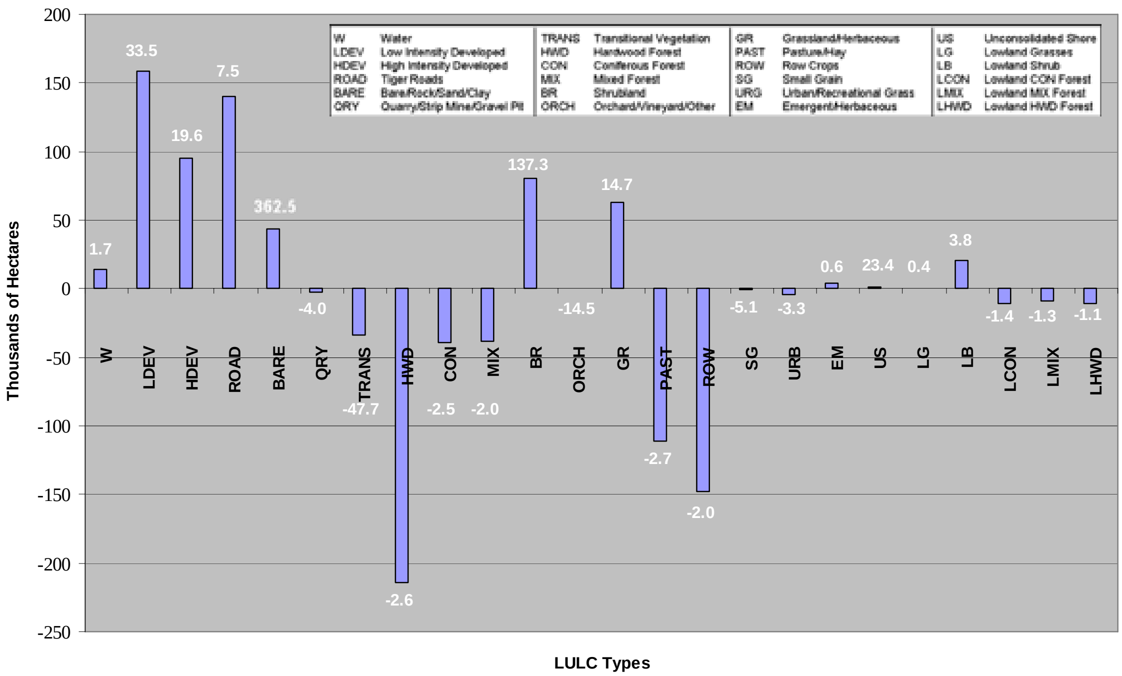


**Figure 1**. LULC type changes for the U.S. Great Lake basin by area and percent change since 1992 (numbers above and below bars).
Source: Wolter, P.T., Johnston, C.A., and Neimi, G.J. 2006

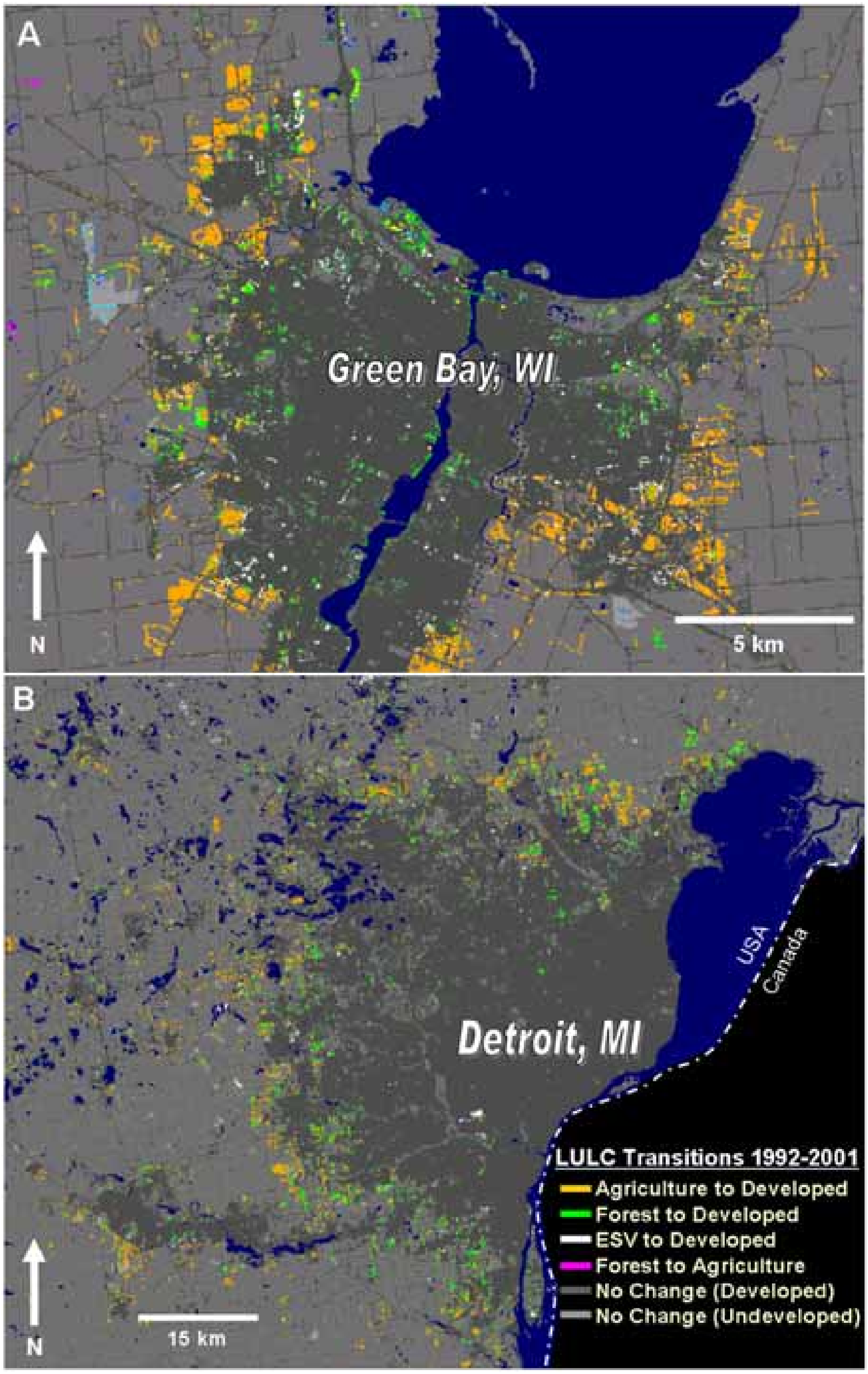


**Figure 2**. LULC change in the lower Green Bay basin of Lake Michigan (A) and the area surrounding Detroit, MI (B).
Source: Wolter, P.T., Johnston, C.A., and Neimi, G.J. 2006

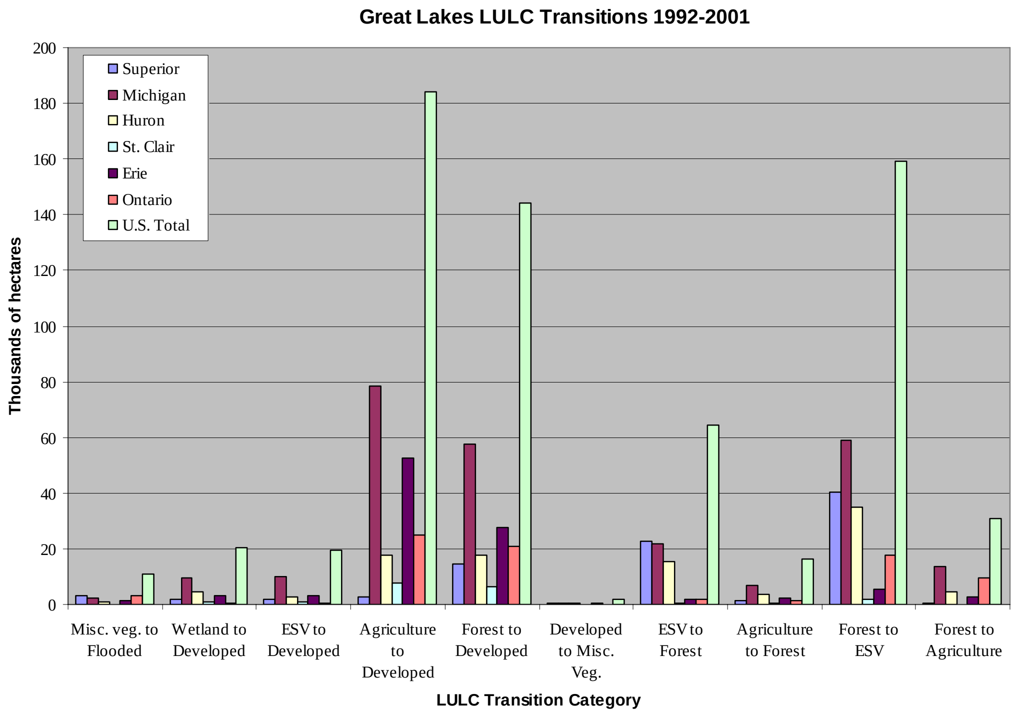


**Figure 3.** Lake-by-lake LULC transitions for the U.S. portion of the Great Lakes basin. Source: Wolter, P.T., Johnston, C.A., and Neimi, G.J. 2006

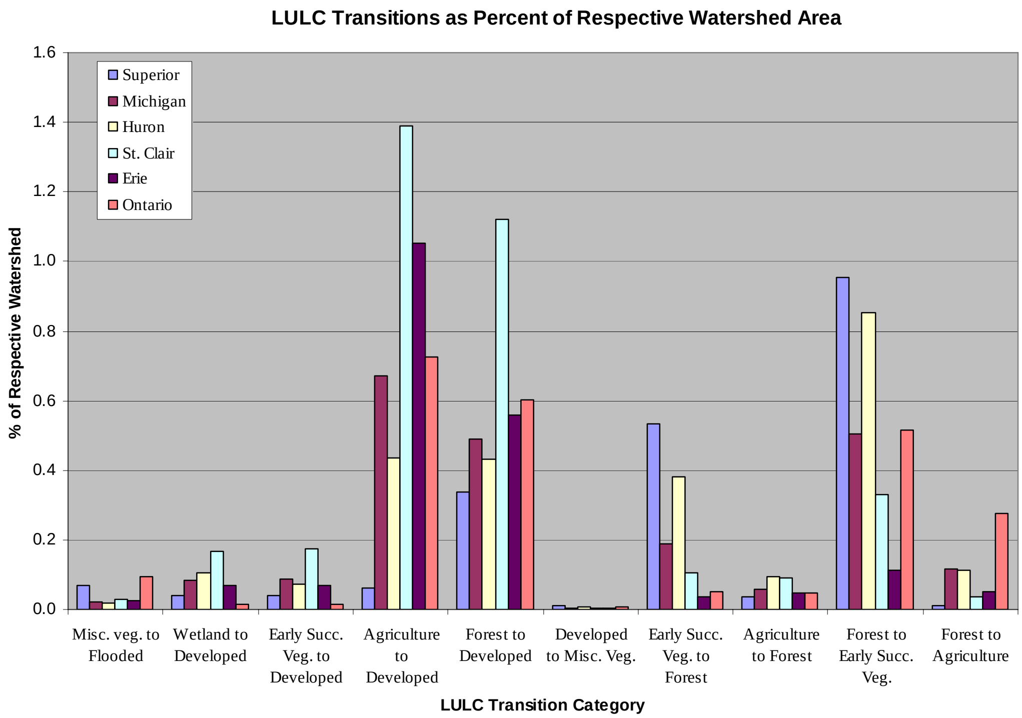


**Figure 4**. Lake-by-lake LULC transitions for the U.S. portion of the Great Lakes basin as a percent of respective watershed area.
Source: Wolter, P.T., Johnston, C.A., and Neimi, G.J. 2006

**Brownfields Redevelopment**
Indicator #7006

**Overall Assessment**

| | |
|---|---|
| Status: | **Mixed** |
| Trend: | **Improving** |
| Primary Factors Determining Status and Trend | Data from multiple sources are not consistent. Inventories of existing brownfields are not available in Ontario so it is difficult to determine a trend for the redevelopment of brownfields. Since more sites are being redeveloped and/or are being planned, there is some trend of an improvement in the Great Lakes basin, but it is not based on a quantitative assessment. Funding and liability issues are obstacles for brownfields redevelopment and can hinder progress. |

**Purpose**
- To assess the area of redeveloped brownfields; and
- To evaluate over time the rate at which society remediates and reuses former developed sites that have been degraded or abandoned.

**Ecosystem Objective**
The goal of brownfields redevelopment is to remove threats of contamination associated with these properties and to bring them back into productive use. Remediation and redevelopment of brownfields results in two types of ecosystem improvements:

1. reduction or elimination of environmental risks from contamination associated with these properties; and

2. reduction in pressure for open space conversion as previously developed properties are reused.

**State of the Ecosystem**
Brownfields are abandoned, idled, or under-used industrial and commercial facilities where expansion, redevelopment or reuse is complicated by real or perceived environmental contamination. In 1999, 21,178 brownfields sites were identified in the United States which was equivalent to approximately 33,010 hectares (81,568 acres) of land (The United States Conference of Mayors). Although similar research does not exist for Canada and no inventory exists for either contaminated or brownfields sites in Ontario, it is estimated that approximately 50,000 to 100,000 brownfields sites may exist in Canada (Globe 2006).

All eight Great Lakes states, Ontario and Quebec have programs to promote remediation or clean-up and redevelopment of brownfields sites. Several of the brownfields clean-up programs have been in place since the mid-to-late 1980s, but establishment of more comprehensive brownfields programs that focus on remediation and redevelopment has occurred during the 1990s. Today, each of the Great Lakes states has a voluntary clean-up or environmental response program and there are over 5,000 municipalities with some type of brownfields program in the U.S. (Globe 2006). These clean-up programs offer a range of risk-based, site-specific background and health clean-up standards that are applied based on the specifics of the contaminated property and its intended reuse.

In Quebec, the *Revi-Sols* program was established in 1998 and is aimed at assessing and cleaning urban contaminated sites for the purpose of reuse. Through this program, it was possible to collect some data on the number of contaminated sites in Quebec as it was compulsory for the land owner to report this information to complete the application for financing. Based on this program, more than 7,000 sites are included in this inventory.

To encourage redevelopment, Ontario's environmental legislation provides general protection from environmental orders for historic contamination to municipalities, creditors and others. Ontario Regulation 153/04, which came into effect on October 1, 2004, details the requirements that property owners must meet in order to file a record of site condition. Two technical documents are referenced by this regulation, one providing applicable site condition standards, the other providing laboratory analytical protocols for the analysis of soil, sediment and ground water. A Brownfields Environmental Site Registry offers property owners the opportunity to complete an online record of site condition with this information then being publicly accessible. This registry is currently voluntary. As of October 2005, property owners are required to file a record of site condition before a property or commercial use to a more sensitive area, such as residential. A record of site condition ensures that a property meets regulated site-assessment and clean-up standards that are appropriate for the new use (Ontario Legislation Promotes Stronger Healthier Community).

The 2003 enactment of the New York State Brownfield Law has resulted in increased interest by private developers and municipalities in the redevelopment of contaminated properties.

Efforts to track brownfields redevelopment are uneven among Great Lakes states and provinces. Not all jurisdictions track brownfields activities and methods vary where tracking does take place. States, provinces and municipalities track the amount of funding assistance provided as well as the number of sites that have been redeveloped. They also track the number of applications that have been received for brownfields redevelopment funding. These are indicators of the level of brownfields redevelopment activity in general, but they do not necessarily reflect land renewal efforts (i.e., area of land redeveloped), the desired measure for this indicator. Compiling state and provincial data to report a brownfields figure that represents the collective eight states and two provinces is challenging. Several issues are prominent. First, state and provincial clean-up data reflect different types of clean-ups, not all of which are "brownfields" (e.g. some include leaking underground storage tanks and others do not). Second, some jurisdictions have more than one program, and not necessarily all relevant programs engage in such tracking. Third, program figures do not include clean-ups that have not been part of a state or provincial clean-up program (e.g. local or private clean-ups). That said, several states and provinces do track acres of brownfields remediated, although no Great Lakes state or province tracks acres of brownfields redeveloped.

Information on area of brownfields remediated from Illinois, Minnesota, New York, Ohio, Pennsylvania, Quebec and Ontario indicate that, as of August, 2002, a total of 13,413 hectares (33,143 acres) have been remediated. Available data from eight Great Lakes states, Quebec and Ontario indicate that almost 27,000 brownfields sites have participated in brownfields clean-up programs since the mid-1990s, although the degree of remediation varies considerably. In

Ontario, brownfields redevelopment is planned for 108 hectares (267 acres) of land between 2006 and 2008 for the municipalities that participated in this assessment.

Remediation is a necessary precursor to redevelopment. Remediation is often used interchangeably with "clean-up," though brownfields remediation does not always involve removing or treating contaminants. Many remediation strategies utilize either engineering or institutional controls (also known as exposure controls) or adaptive reuse techniques that are designed to limit the spread of, or human exposure to, contaminants left in place. In many cases, the cost of treatment or removal of contaminants would prohibit reuse of land. All Great Lakes states and provinces allow some contaminants to remain on site as long as the risks of being exposed to those contaminants are eliminated or reduced to acceptable levels. Capping a site with clean soil or restricting the use of groundwater are examples of these "exposure controls" and their use has been a major factor in advancing brownfields redevelopment. Several jurisdictions keep track of the number and location of sites with exposure controls, but monitoring the effectiveness of such controls occurs in only three out of the ten jurisdictions.

Redevelopment is a criterion for eligibility under many state brownfields clean-up programs. Though there is inconsistent and inadequate data on area of brownfields remediated and/or redeveloped, available data indicate that both brownfields clean-up and redevelopment efforts have risen dramatically in the mid-1990s and steadily since 2000. The increase is due to risk-based clean-up standards and the widespread use of state liability relief mechanisms that allow private parties to redevelop, buy or sell properties without being liable for contamination they did not cause. Canadian law does not provide liability exemptions for new owners such as those in the U.S. Small Business Liability Relief and Brownfields Revitalization Act (Globe 2006). Environmental liability is a major barrier to successful brownfields redevelopment in Canada. Current owners do not want to sell brownfields sites for fear of liability issues in the future, purchasers of land do not want to buy sites without some level of protection and municipalities assume liability when they become site owners (Brownfields Redevelopment versus Greenfield Development). The Ontario Ministry of Finance has proposed changes under Bill 130 (Municipal Statute Law Amendment Act, 2006) which would allow brownfields to be advertised as "free" of any provincial crown liens if a municipality assumes ownership of a property with a failed tax sale. Also, under certain circumstances, this new policy will allow for the removal of crown liens on brownfields properties at tax sale. If passed, this change in legislation would reduce some of the issues related to civil and regulatory liabilities. One recommendation is that once a property owner has met regulatory standards in the cleanup phase that they are not forced to meet stricter standards in the future.

In 2005, the Government of Canada allocated $150 million for brownfields remediation. Other initiatives include the Sustainable Technologies Canada Funding, and the Federal Contaminated Sites Action Plan. Also, more financial tools for brownfields redevelopment are available though a Community Improvement Plan (CIP), which allows municipalities to encourage brownfields redevelopment by offering financial incentives. Other grants and loans can be provided to supplement the CIP including an exemption or a reduction in the cost of fees associated with permits, parkland dedications and zoning amendments. Tax incentives can also be provided by municipalities to encourage the cleanup of contaminated sites (Financial Tools for Brownfields Redevelopment).

Data also indicate that the majority of clean-ups in the Great Lakes states and provinces are occurring in older urbanized areas, many of which are located on the shoreline of the Great Lakes and in the basin. Based on the available information, the state of brownfields redevelopment is **mixed** and **improving**.

**Pressures**

Laws and policies that encourage new development to occur on undeveloped land instead of on urban brownfields, are significant and on-going pressures that can be expected to continue. Programs to monitor, verify and enforce effectiveness of exposure controls are in their infancy, and the potential for human exposure to contaminants may inhibit the redevelopment of brownfields. Several Great Lakes states allow brownfields redevelopment to proceed without cleaning up contaminated groundwater as long as no one is going to use or come into contact with that water. However, where migrating groundwater plumes ultimately interface with surface waters, some surface water quality may continue to be at risk from brownfields contamination even where brownfields have been remediated.

**Management Implications**

Programs to monitor and enforce exposure controls need to be fully developed and implemented. More research is needed to determine the relationship between groundwater supplies and Great Lakes surface waters and their tributaries. Because brownfields redevelopment results in both reduction or elimination of environmental risks from past contamination and reduction in pressure for open space land conversion, data should be collected that will enable an evaluation of each of these activities. For every hectare (2.5 acres) developed in a brownfields project, it can save an estimated minimum of 4.5 hectares (11 acres) of land from being developed in an outlying area (Cleaning Up the Past, Building the Future).

Ontario is expected to add 3.7 million more people to its population in the next 25 years with most of the growth occurring in the Greater Golden Horseshoe (western end of Lake Ontario) (Places to Grow: Better Choices, Brighter Future). Brownfields redevelopment needs to be a part of the planning and development reform in order to address the issue of urban sprawl.

**Comments from the author(s)**

Great Lakes states and provinces have begun to track brownfields remediation and or redevelopment, but the data is generally inconsistent or not available in ways that are helpful to assess progress toward meeting the terms of the Great Lakes Water Quality Agreement. Though some jurisdictions have begun to implement web-based searchable applications for users to query the status of brownfields sites, the data gathered are not necessary consistent, which presents challenges for assessing progress in the entire basin. States and provinces should develop common tracking methods and work with local jurisdictions incorporating local data to online databases that can be searched by: 1) area remediated; 2) mass of contamination removed or treated (i.e., not requiring an exposure control); 3) type of treatment; 4) geographic location; 5) level of urbanization; and 6) type of reuse (i.e., commercial, residential, open, none, etc). A recent development in the province of Ontario is the designation of a Provincial Brownfields Coordinator who will coordinate provincial brownfields activities and provide a single point of access on brownfields in Ontario.

**Acknowledgments**
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City of London, Terry Grawey, Planning Division
City of Thunder Bay, Katherine Dugmore, Manager of Planning Division
City of Toronto, Glenn Walker, Economic Development Officer
City of Toronto Economic Development Corporation (TEDCO)
Province of Quebec, Michel Beaulieu

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**List of Tables**

Source: Various state, municipal and provincial brownfields coordinators and city planners

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**Last updated**

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| State/Province | Acres remediated | Hectares remediated | Time frame | Sites remediated | Time frame |
|---|---|---|---|---|---|
| WI | 1,220 | 494 | 2004-2006 | 18,000 | 1994-2005 |
| PA | 13,229 | 5354 | 2000- 2006 | 1,097 | 1996-2002 |
| OH | 4,204 | 1701 | 1994-2006 | 156 | 1996-2002 |
| MI | not tracked | not tracked | | 5,539† | 1995-2002 |
| IN | not tracked | not tracked | | 382 | 1997-2002 |
| MN | 7,047 | 2852 | 1998-2002 | 462 | 1998-2002 |
| IL | 6,412 | 2595 | 1990-2001 | 899 | 1990-2001 |
| NY | 55 | 22 | 2000-2002 | 16 | 2000-2002 |
| ON | 92 | 37 | 2002-2005 | 13 | 2002-2005 |
| QC | 741 | 300 | 1998-2002 | 309 | 1998-2005 |
| Total | **33,143** | **13,413** | | **26,873** | |

**Table 1**. Summary of acres remediated and number of sites remediated in the Great Lakes basin, 1990 – 2006.
Source: Various state, municipal and provincial brownfields coordinators and city planners


**Figure 1**. Redeveloped brownfields site, Spencer Creek, Hamilton, Ontario.
Source: City of Hamilton

## Sustainable Agriculture Practices

Indicator #7028

**Assessment: Not Assessed**

### Purpose

- To assess the number of environmental and conservation farm plans and environmentally friendly practices in place such as: integrated pest management to reduce the potential adverse impacts of pesticides; conservation tillage and other soil preservation practices to reduce energy consumption and sustain natural resources and to prevent ground and surface water contamination.

### Ecosystem Objective

The goal is to create a healthy and productive land base that sustains food and fiber, maintains functioning watersheds and natural systems, enhances the environment and improves the rural landscape. The sound use and management of soil, water, air, plant, and animal resources is needed to prevent degradation of agricultural resources. The process integrates natural resource, economic, and social considerations to meet private and public needs. This indicator supports Annex 2, 3, 12 and 13 of the Great Lakes Water Quality Agreement.

### State of the Ecosystem

Background

Agriculture accounts for approximately 35% of the land area of the Great Lakes basin and dominates the southern portion of the basin. In years past, excessive tillage and intensive crop rotations led to soil erosion and the resulting sedimentation of major tributaries. Inadequate land management practices contributed to approximately 57 metric tons of soil eroded annually by the 1980s. Ontario estimated its costs of soil erosion and nutrient/pesticide losses at $68 million (CA) annually. In the United States, agriculture is a major user of pesticides, with an annual use of 24,000 metric tons. These practices lead to a decline of soil organic matter. Since the late 1980s, there has been increasing participation by Great Lakes basin farmers in various soil and water quality management programs. Today's conservation systems have reduced the rates of U.S. soil erosion by 38% in the last few decades. The adoption of more environmentally responsible practices has helped to replenish carbon in the soils back to 60% of turn-of-the-century levels.

Both the Ontario Ministry of Agriculture and Food (OMAF) and the U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) provide conservation planning advice, technical assistance and incentives to farm clients and rural landowners. Clients develop and implement conservation plans to protect, conserve, and enhance natural resources that harmonize productivity, business objectives and the environment. Successful implementation of conservation planning depends largely upon the voluntary participation of clients. Figure 1 shows the number of acres of cropland in the U.S. portion of the Great Lakes basin that are covered under a conservation plan.

The Ontario Environmental Farm Plan (EFP) encourages farmers to develop action plans and adopt environmentally responsible management practices and technologies. Since 1993, the Ontario Farm Environmental Coalition (OFEC), OMAF, and the Ontario Soil and Crop Improvement Association (OSCIA) have cooperated to deliver EFP workshops. The Canadian federal government, through various programs over the years, has pro-

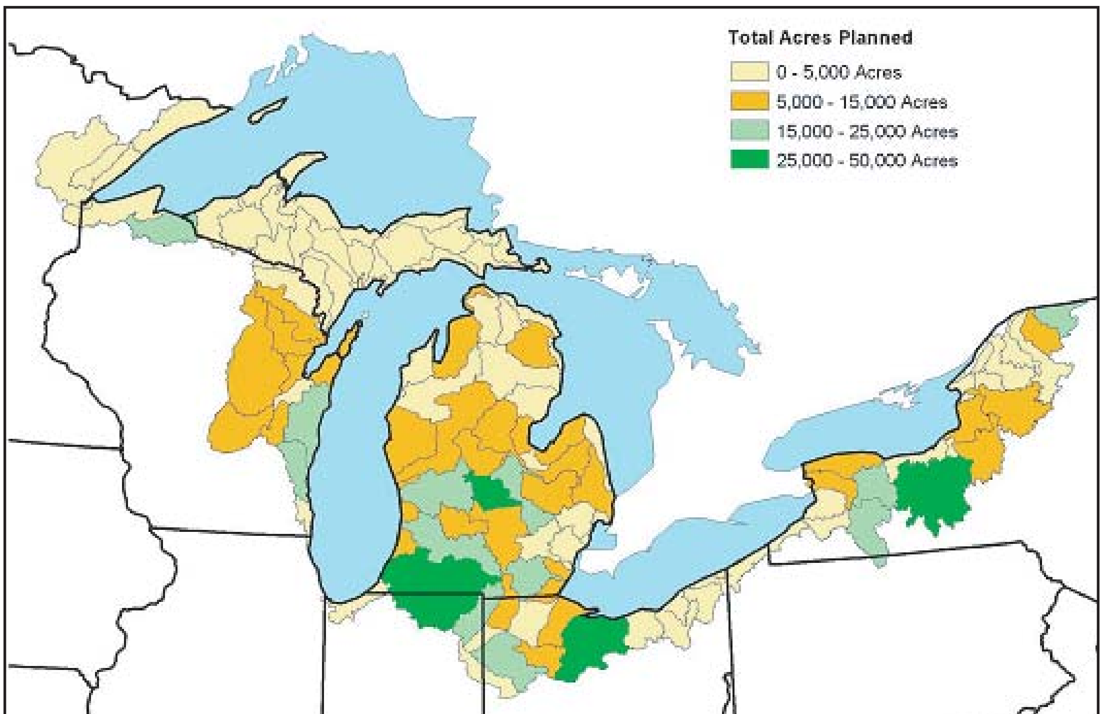


Figure 1. Acres of cropland in U.S portion of the basin covered under a conservation plan, 2003.
Source: Natural Resource Conservation Service, U.S. Department of Agriculture

vided funding for EFP. As can be seen from Figure 2 the number of EFP incentive claims rose dramatically from 1997 through 2004, particularly for the categories of soil management, water wells, and storage of agricultural wastes. As part of Ontario's Clean Water Strategy, the Nutrient Management Act (June 2002) is setting province-wide standards to address the effects of agricultural practices on the environment, particularly as they relate to land-applied materials containing nutrients.

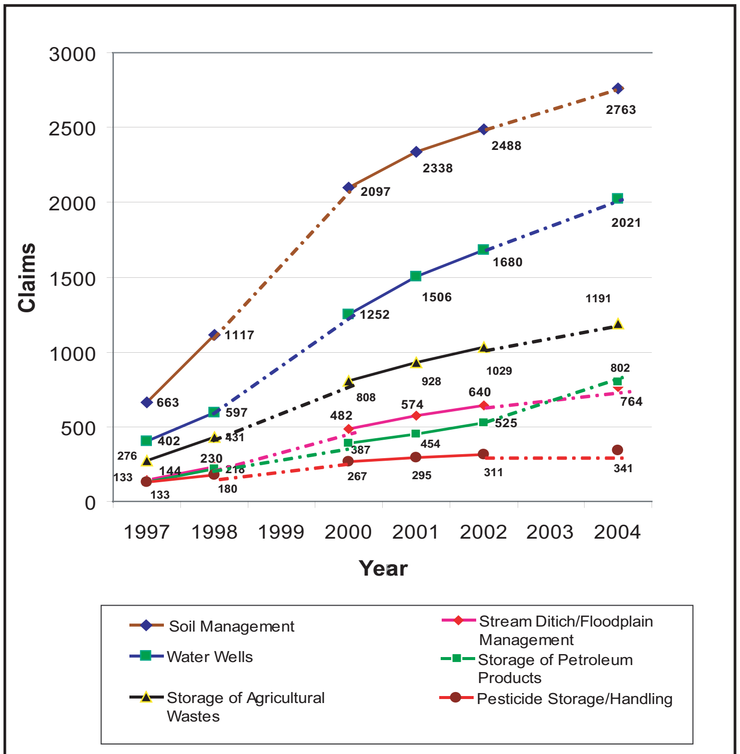


Figure 2. EFP: Cumulative Number of Incentive Claims by Worksheet (Issues). Six of 23 worksheets/issues are represented here - these six worksheets represent 70% of all EFP incentive claims. Three worksheets (Soil, Water and Storage of Agricultural Wastes) represent significant environmental actions taken by farmers.
Source: Ontario Soil and Crop Improvement Association

USDA's voluntary Environmental Quality Incentives Program provides technical, educational, and financial assistance to landowners that install conservation systems. The Conservation Reserve Program allows landowners to convert environmentally sensitive acreage to vegetative cover. States may add funds to target critical areas under the Conservation Reserve Enhancement Program. The Wetlands Reserve Program is a voluntary program to restore wetlands.

**Pressures**

The trend towards increasing farm size and concentration of livestock will change the face of agriculture in the basin. Development pressure from the urban areas may increase the conflict between rural and urban landowners. This can include pressures of higher taxes, traffic congestion, flooding, nuisance complaints (odours) and pollution. By urbanizing farmland, we may limit future options to deal with social, economic, food security and environmental problems.

**Management Implications**

In June of 2002, the Canadian government announced a multi-billion dollar Agricultural Policy Framework (APF). It is a national plan to strengthen Canada's agricultural sector, with a goal for Canada to be a world leader in food safety and quality, and in environmentally responsible production and innovation, while improving business risk management and fostering renewal. As part of the APF, the Canadian government is making a \$100 million commitment over a 5-year period to help Canadian farmers increase implementation of EFPs. The estimated commitment to Ontario for the environment is \$67.66 million while the province is committing \$42.72 million. These funds are available to Ontario's farmers since the federal government has signed a contribution agreement with the OFEC in the spring of 2005. This is expected in the fall of 2004. Currently Ontario's Environmental Farm Plan workbook has been revised for new APF farm planning initiatives launched in the spring of 2005. Ontario Farm Plan workshops are being delivered starting in the spring of 2005 under the new APF initiative.

In the spring of 2004, OMAF released the Best Management Practices (BMP) book *Buffer Strips*. This book assists farmers to establish healthy riparian zones and address livestock grazing systems near water – two important areas for improvements in water quality and fish habitat. Pesticide use surveys, conducted every 5 years since 1983, were conducted in 2003. Results were released in June 2004.

The U.S. Clean Water Action Plan of 1998 calls for USDA and the U.S. Environmental Protection Agency (USEPA) to cooperate further on soil erosion control, wetland restoration, and reduction of pollution from farm animal operations. National goals are to install 2 million miles of buffers along riparian corridors by 2002 and increase wetlands by 100,000 acres annually by 2005. Under the 1999 USEPA/USDA Unified National Strategy for Animal Feeding Operation (AFO), all AFOs will have comprehensive nutrient management plans implemented by 2009. The Conservation Security Program was launched in 2004, and it provides financial incentives and rewards for producers who meet the highest standards of conservation and environmental management on their operations.

**Acknowledgments**

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**Last Updated**

*State of the Great Lakes 2005*

## Economic Prosperity

Indicator #7043

**Assessment: Mixed (for Lake Superior Basin), Trend Not Assessed**
Data are not system-wide.

**Purpose**

- To assess the unemployment rates within the Great Lakes basin; and
- To infer the capacity for society in the Great Lakes region to make decisions that will benefit the Great Lakes ecosystem (when used in association with other Great Lakes indicators).

**Ecosystem Objective**
Human economic prosperity is a goal of all governments. Full employment (i.e. unemployment below 5% in western societies) is a goal for all economies.

**State of the Ecosystem**
This information is presented to supplement the report on Economic Prosperity in SOLEC 2000 Implementing Indicators (Draft for Review, November 2000). In 1975, 1980, 1985, 1990, 1995 and 2000 the civilian unemployment rate in the 16 U.S. Lake Superior basin counties averaged about 2.0 points above the U.S. average, and above the averages for their respective states, except occasionally Michigan (Figure 1). For example, the unemployment rate in the four Lake Superior basin counties in Minnesota was consistently higher than for Minnesota overall, 2.7 points on average but nearly double the Minnesota rate of 6.0% in 1985. Unemployment rates in individual counties ranged considerably, from 8.6% to 26.8% in 1985, for example.

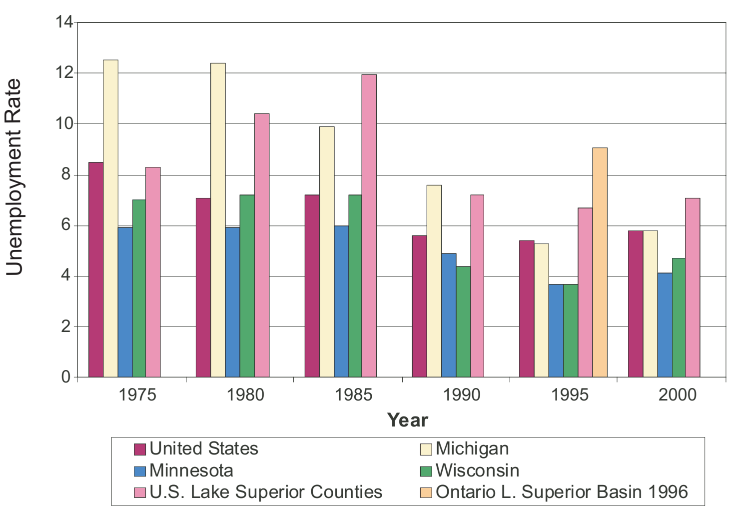


Figure 1. Unemployment rate in the U.S. (national), Michigan, Wisconsin, and the U.S. portion and Ontario portion of the Lake Superior basin, 1975-2000.
Source: U.S. Census Bureau and Statistics Canada

In the 29 Ontario census subdivisions mostly within the Lake Superior watershed, the 1996 unemployment rate for the population 15 years and over was 11.5%. For the population 25 years and older, the unemployment rate was 9.1%. By location the rates ranged from 0% to 100%; the extremes, which occur in adjacent First Nations communities, appear to be the result of small populations and the 20% census sample. The most populated areas, Sault Ste. Marie and Thunder Bay, had unemployment rates for persons 25 years and older of 9.4% and 8.6%, respectively. Of areas with population greater than 200 in the labour force, the range was from 2.3% in Terrace Bay Township to 31.0% in Beardmore Township. Clearly, the goal of full employment (less than 5% unemployment) was not met in either the Canadian or the U.S. portions of the Lake Superior basin during the years examined.

**Acknowledgments**
Authors: Kristine Bradof, GEM Center for Science and Environmental Outreach, Michigan Technological University, MI; and
James G. Cantrill, Communication and Performance Studies, Northern Michigan University, MI.

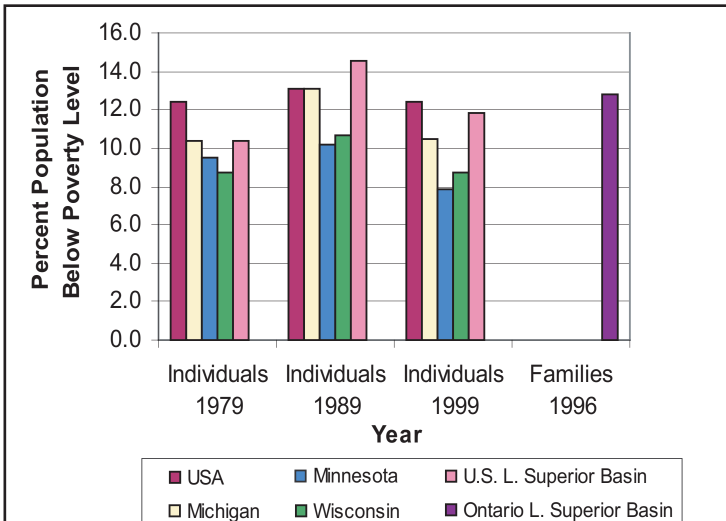


Figure 2. Individuals below poverty level in the U.S. (national), Michigan, Wisconsin, and the U.S. Great Lakes basin counties, 1979-1999, and families below poverty level in Ontario Great Lakes basin subdivisions, 1996.
Source: U.S. Census Bureau and Statistics Canada

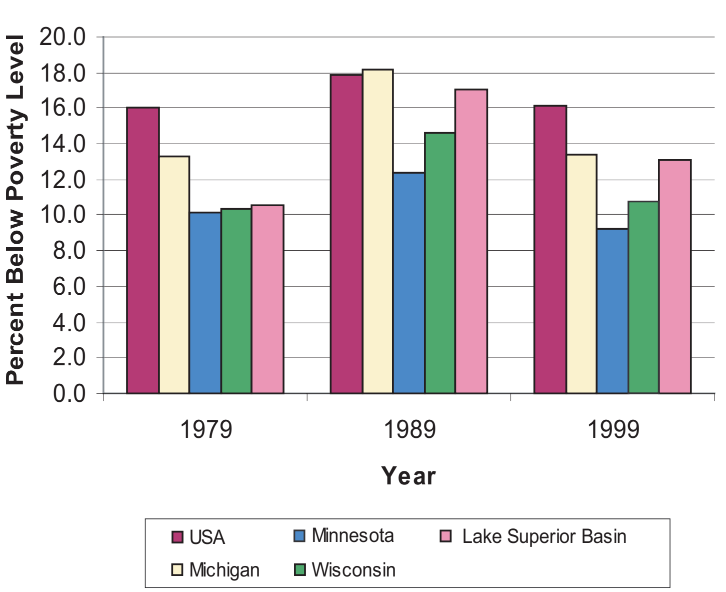


Figure 3. Children under age 18 below the poverty level, 1979-1999, U.S. (national), Michigan, Minnesota, Wisconsin and U.S. portion of the Lake Superior basin.
Source: U.S. Census Bureau

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U.S. Census Bureau. *USA Counties 1998 CD-ROM* (includes unemployment data from Bureau of Labor Statistics).


**Authors' Commentary**

As noted in the State of the Great Lakes 2001 report for this indicator, unemployment may not be sufficient as a sole measure. Other information that is readily available from the U.S. Census Bureau and Statistics Canada includes poverty statistics for the overall population, children under age 18, families, and persons age 65 and older. Two examples of trends in those measures are shown in Figures 2 and 3. For persons of all ages within the U.S. Lake Superior basin for whom poverty status was established, 10.4% were below the poverty level in 1979. That figure had risen to 14.5% in 1989, a rate of increase higher than the states of Michigan, Minnesota, and Wisconsin and the U.S. overall over the same period. Poverty rates for individuals and children in the U.S. Lake Superior basin in 1979, 1989, and 1999 ranged from 10.4% to 17.1%, while 12.8% of families in the Ontario Lake Superior basin had incomes below the poverty level in 1996. Poverty rates in all areas were lower in 1999, but the U.S. Lake Superior basin (and Ontario portion of the basin in 1996) was higher than any of the three states. The 1979 poverty rate for counties within the Lake Superior basin ranged from a low of 4.4% in Lake County, Minnesota, to a high of 17.0% in Houghton County, Michigan. In 1989 and 1999, those same counties again were the extremes. Similarly, among children under age 18, poverty rates in the Great Lakes basin portions of the three states in 1979, 1989, and 1999 exceeded the rates of Minnesota and Wisconsin as a whole, though they remained below the U.S. rate. In a region where one-tenth to one-sixth of the population lives in poverty, environmental sustainability is likely to be perceived by many as less important than economic development.

**Last Updated**

*State of the Great Lakes 2003*

## Water Withdrawals

Indicator #7056

**Assessment: Mixed, Unchanging**

**Purpose**

- To use the rate of water withdrawal to help evaluate the sustainability of human activity in the Great Lakes basin.

**Ecosystem Objective**

The first objective is to protect the basin's water resources from long-term depletion. Although the volume of the Great Lakes is vast, less than one percent of their waters are renewed annually through precipitation, run-off and infiltration. Most water withdrawn is returned to the watershed, but water can be lost due to evapotranspiration, incorporation into manufactured goods, or diversion to other drainage basins. In this sense, the waters of the Great Lakes can be considered a non-renewable resource.

The second objective is to minimize the ecological impacts stemming from water withdrawals. The act of withdrawing water can shift the flow regime, which in turn can affect the health of aquatic ecosystems. Water that is returned to the basin after human use can also introduce contaminants, thermal pollution or invasive species into the watershed. The process of withdrawing, treating and transporting water also requires energy.

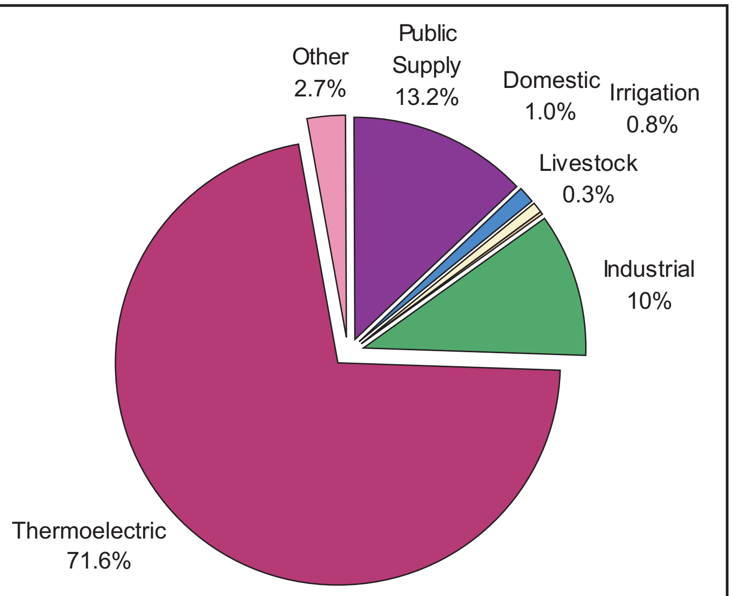


Figure 1. Water Withdrawals in the Great Lakes basin, by category as percentage of total, 2000.
Source: Great Lakes Commission, 2004

**State of the Ecosystem**

Water was withdrawn from the Great Lakes basin at a rate of 46,046 million gallons per day (MGD) in 2000 (or 174 billion litres per day), with almost two-thirds withdrawn in the U.S. side (30,977 MGD) and the remaining one-third in Canada (15,070 MGD). Self-supplying thermoelectric and industrial users withdrew over 80% of the total. Public water systems, which are the municipal systems that supply households, commercial users and other facilities, comprised 13% of withdrawals. The rural sector, which includes both domestic and agricultural users, withdrew 2%, with the remaining 3% used for environmental, recreation, navigation and quality control purposes. Hydroelectric use, which is considered "in-stream use" because water is not actually removed from its source, accounted for additional withdrawals at a rate of 799,987 MGD (Figure 1) (GLC 2004).

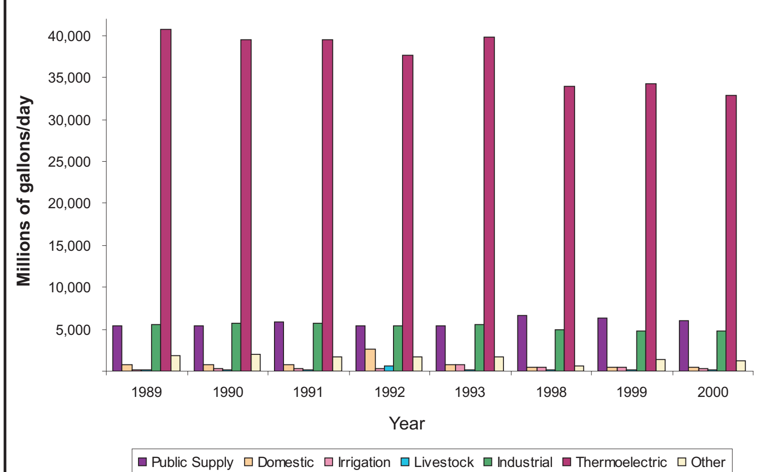


Figure 2. Great Lakes basin water withdrawals by category, 1989-1993 and 1998-2000.
Source: Great Lakes Commission, 1991-2004

Withdrawal rates in the late 1990s were below their historical peaks and do not appear to be increasing at present. On the U.S. side, withdrawals have dropped by more than 20% since 1980, following rapid increases from the 1950s onwards (USGS 1950-2000)[1]. Canadian withdrawals continued rising until the mid-1990s, but have decreased by roughly 30% since then (Harris and Tate 1999)[2]. In both countries, the recent declines have been caused by the shutdown of nuclear power facilities, advances in water efficiency in the industrial sector, and growing public awareness on resource conservation. Part of the decrease, however, may be attributed to improvements in data collection methods over time (USGS 1985). Refer to Figures 2,3 and 4.

The majority of waters withdrawn are returned to the basin through run-off and discharge. Approximately 5% is made unavailable, however, through evapotranspiration or

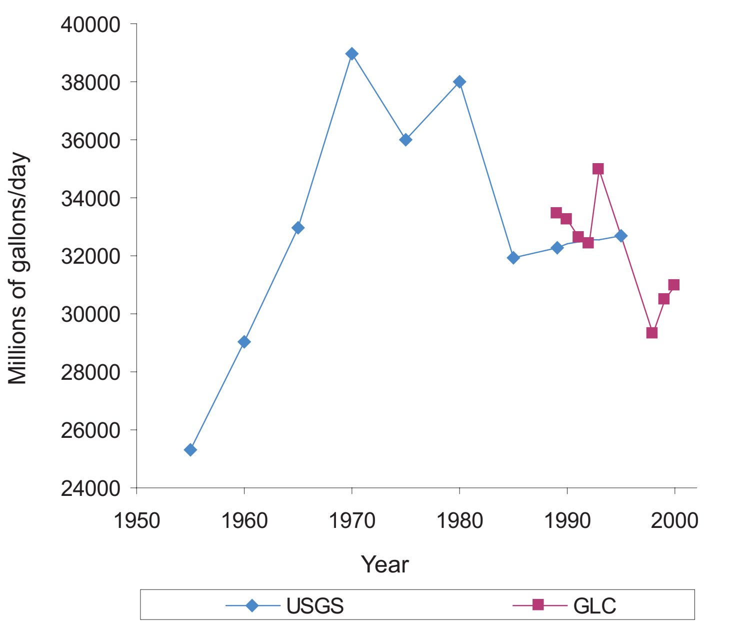


Figure 3. U.S. basin water withdrawals, 1950-2000. Source: U.S. Geological Survey, 1950-2000. Great Lakes Commission (GLC).

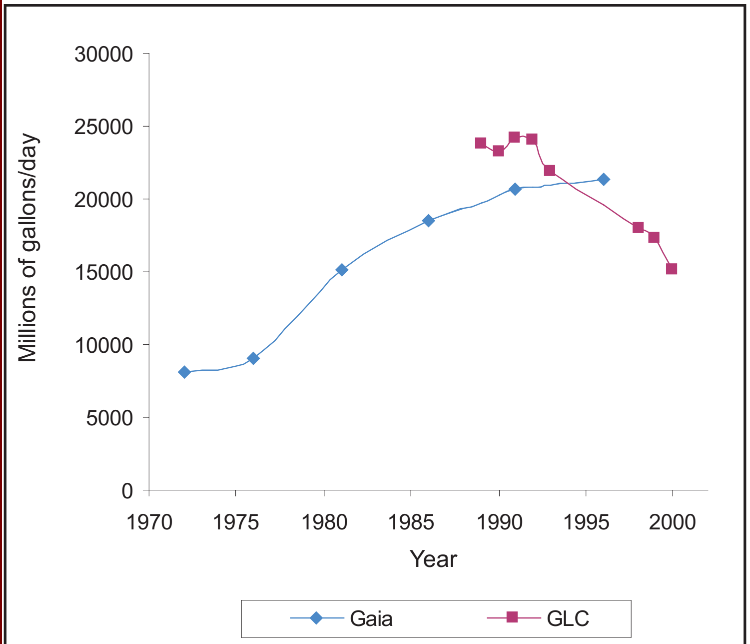


Figure 4. Canadian basin water withdrawals, 1972-2000. Source: Gaia Economic Research Associates, 1999 (based on data from Environment Canada and Statistics Canada). Great Lakes Commission (GLC).

incorporation into manufactured products. This quantity, referred to as "consumptive use," represents the volume of water that is depleted due to human activity. It is argued that consumptive use, rather than total water withdrawals, provides a more suitable indicator on the sustainability of human water use in the region. Basin-wide consumptive use was estimated at 3,166 MGD in 2000. Although there is no consensus on an optimal rate of consumptive use, a loss of this magnitude does not appear to be placing significant pressure on water resources. The long-term Net Basin Supply of water (sum of precipitation and run-off, minus natural evapotranspiration), which represents the maximum volume that can be consumed without permanently reducing the availability of water, and equals the volume of water discharged from Lake Ontario into the St. Lawrence River, is estimated to be 132,277 MGD (estimate is for 1990-1999 period, Environment Canada 2004). It should be noted, however, that focusing on these basin-wide figures can obscure pressures at the local watershed level.

Moreover, calculating consumptive use is a major challenge because of the difficulty in tracking the movement of water through the hydrologic cycle. Consumptive use is currently inferred by multiplying withdrawals against various coefficients, depending on use type. For instance, it is assumed that thermoelectric users consume as little as 1% of withdrawals, compared to a loss rate of 70-90% for irrigation (GLC 2003). There are inconsistencies in the coefficients used by the various states and provinces. Estimating techniques were even more rudimentary in the past, making it problematic to discuss historical consumptive use trends. Due to these data quality concerns, it may not yet be appropriate to consider consumptive use as a water use indicator.

Water removals from diversions, by contrast, are monitored more closely, a result of the political attention that prompted the region's governors and premiers to sign the Great Lakes Charter in 1985. The Charter and its Annexes require basin-wide notification and consultation for water exports, while advocating that new diversions be offset by a commensurate return of water to the basin. The two outbound diversions approved since 1985 have accommodated this goal by diverting water in from external basins. The outbound diversions already in operation by 1985, most notably the Chicago diversion, were not directly affected by the Charter, but these losses are more than offset by inbound diversions located in northwestern Ontario. Thus, there is currently no net loss of water due to diversions.

There is growing concern over the depletion of groundwater resources, which cannot be replenished following withdrawal with the same ease as surface water bodies. Groundwater was withdrawn at a rate of 1,541 MGD in 2000, making up 3% of total water withdrawals (GLC 2004). This rate may not have a major effect on the basin as a whole, but high-volume withdrawals have outstripped natural recharge rates in some locations. Rapid groundwater withdrawals in the Chicago-

Milwaukee region during the late 1970s produced cones of depression in that local aquifer (Visocky 1997). However, the difficulty in mapping the boundaries of groundwater supplies makes unclear whether the current groundwater withdrawal rate is sustainable.

**Pressures**

The Great Lakes Charter, and its domestic legal corollaries in the U.S. and Canada, was instituted in response to concerns over large-scale water exports to markets such as the arid southwestern U.S. There does not appear to be significant momentum for such long distance shipments due to legal and regulatory barriers, as well as technical difficulties and prohibitive costs. In the immediate future, the greatest pressure will come from communities bordering the basin, where existing water supplies are scarce or of poor quality. These localities might look to the Great Lakes as a source of water. Two border-basin diversions have been approved under the Charter and have not resulted in net losses of water to the basin. This outcome, however, was achieved through negotiation and was not proscribed by treaty or law.

As for withdrawals within the basin, there is no clear trend in forecasting regional water use. Reducing withdrawals, or at least mitigating further increases, will be the key to lessening consumptive use. Public water systems currently account for the bulk of consumptive use, comprising one-third of the total, and withdrawals in this category have been increasing in recent years despite the decline in total withdrawals. Higher water prices have been widely advocated in order to reduce water demand. Observers have noted that European per-capita water use is only half the North American level, while prices in the former are twice as high. However, economists have found that both residential and industrial water demand in the U.S. and Canada are relatively insensitive to price changes (Renzetti 1999, Burke *et al.* 2001)[3]. The over-consumption of water in North America may be more a product of lifestyle and lax attitudes. Higher prices may still be crucial for providing public water systems with capital for repairs; this can prevent water losses by fixing system leaks, for example. But reducing the underlying demand may require other strategies in addition to price increases, such as public education on resource conservation and promotion of water-saving technologies.

Assessing the availability of water in the basin will be complicated by factors outside local or human control. Variations in climate and precipitation have produced long-term fluctuations in surface water levels in the past. Global climate change could cause similar impacts; research suggests that water levels may be permanently lower in the future as a result. Differential movement of the Earth's crust, a phenomenon known as isostatic rebound, may exacerbate these effects at a local level. The crust is rising at a faster rate in the northern and eastern portions of the basin, shifting water to the south and west. These crustal movements will not change the total volume of water in the basin, but may affect the availability of water in certain areas.

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Site-specific water withdrawal data courtesy of James Casey (Illinois Department of Natural Resources), Sean Hunt (Minnesota Department of Natural Resources), Paul Spahr (Ohio Department of Natural Resources) and Ralph Spaeth (Indiana Department of Natural Resources). Ontario water permit map courtesy of Danielle Dumoulin (Ontario Ministry of Natural Resources).

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**Endnotes**

[1] USGS estimates show water withdrawals in the U.S. Great Lakes watershed increasing from 25,279 MGD in 1955 to a peak in the 36-39,000 MGD range during the 1970-80 period, but dropping to the 31-32,000 MGD range for 1985-1995. GLC reported U.S. water withdrawals in the 32-34,000 range for 1989-1993, and around 30,000 MGD since 1998, with 30,977 MGD in 2000.

[2] Historical Canadian data from Gaia Economic Research Associates (GERA) report, and are based on data from Statistics Canada and Environment Canada. GERA reported that Canadian water withdrawals increased from 8,136 MGD in 1972 to 21,316 MGD in 1996. GLC reported Canadian withdrawals of 21-24,000 MGD in 1989-1993, around 17,000 MGD for 1998 and 1999, and 15,070 MGD in 2000.

[3] Econometric studies of both residential and industrial water demand consistently display relatively small price elasticities. Literature review on water pricing economics can be found in Renzetti (1999). However, the relationship between water demand and price structure is complex. The introduction of volumetric pricing (metering), as opposed to flat block pricing (unlimited use), is indeed associated with lower water use, perhaps because households become more aware of their water withdrawal rate (Burke *et al.* 2001).

**Authors' Commentary**

Water withdrawal data is already being compiled on a systemic basis. However, improvements can be made in collecting more accurate numbers. Reporting agencies in many jurisdictions do not have, or do not exercise, the statutory authority to collect data directly from water users, relying instead on voluntary reporting, estimates, and models. Progress is also necessary in establishing uniform and defensible measures of consumptive use, which is the component of water withdrawals that most clearly signals the sustainability of current water demand.

Mapping the point sources of water withdrawals could help identify local watersheds that may be facing significant pressures. In many jurisdictions, water permit or registration programs can provide suitable geographic data. However, only in a few states (Minnesota, Illinois, Indiana and Ohio) are withdrawal data available per registered facility. Permit or registration data, moreover, has limited utility in locating users that are not required to register or obtain permits, such as the rural sector, or facilities with a withdrawal capacity below the statutory threshold (100,000 gallons per day in most jurisdictions.) Refer to Figures 5 and 6.

Further research into the ecological impact of water withdrawals should also be a priority. There is evidence that discharge from industrial and thermoelectric plants, while returning water to the basin, alters the thermal and chemical integrity of the lakes. The release of water at a higher than normal temperature has been cited as facilitating the establishment of non-native species (Mills *et al*. 1993). The changes to the flow regime of water, through hydroelectric dams, internal diversions and canals, and

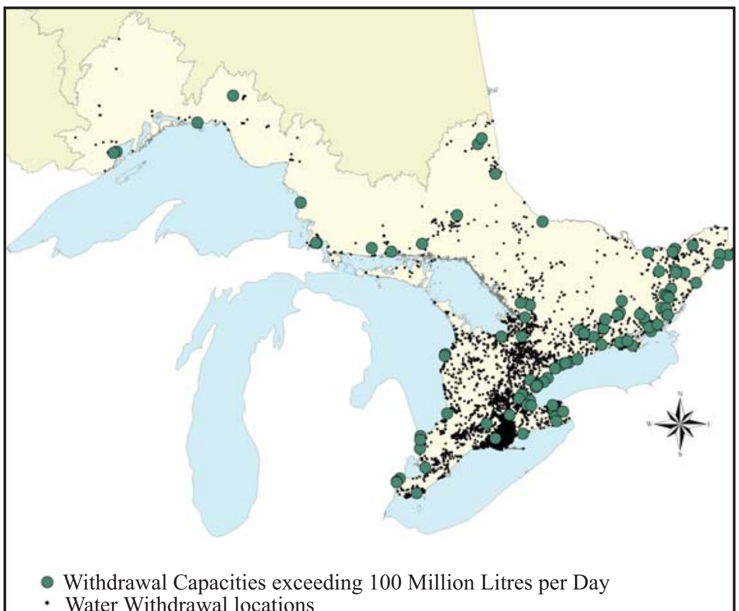


Figure 5. Permitted water withdrawal capacities in the Ontario portion of the Great Lakes basin.
Source: Ontario Ministry of Natural Resources

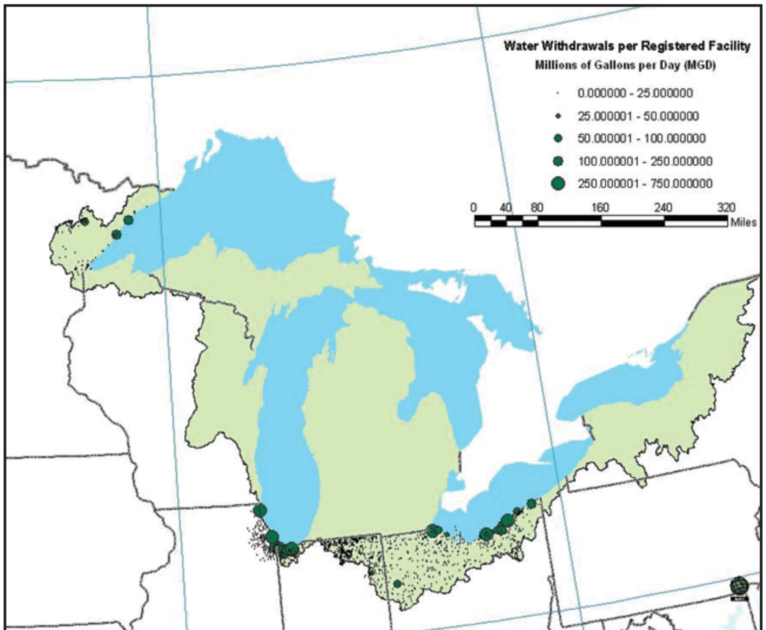


Figure 6. Permitted water withdrawal capacities in the Ontario portion of the Great Lakes basin.
Source: Ontario Ministry of Natural Resources

other withdrawal mechanisms, may be impairing the health of aquatic ecosystems. Reductions in groundwater discharge, meanwhile, may have negative impacts on Great Lakes surface water quality. Energy is also required for the process of withdrawing, treating and transporting water. These preliminary findings oblige a better understanding of how the very act of withdrawing water, regardless of whether the water is ultimately returned to the basin, can affect the larger ecosystem.

**Last Updated**
*State of the Great Lakes 2005*

## Energy Consumption
Indicator #7057

**Assessment: Mixed, Trend Not Assessed**

**Purpose**
- To assesses the energy consumed in the Great Lakes basin per capita; and
- To infer the demand for resource use, the creation of waste and pollution, and stress on the ecosystem.

**Ecosystem Objective**
Sustainable development is a generally accepted goal in the Great Lakes basin. Resource conservation minimizing the unnecessary use of resources is an endpoint for ecosystem integrity and sustainable development. This indicator supports Annex 15 of the Great Lakes Water Quality Agreement.

**State of the Ecosystem**
Energy use per capita and total consumption by the commercial, residential, transportaion, industrial, and electricity sectors in the Great Lakes basin can be calculated using data extracted from the Comprehensive Energy Use Database (Natural Resources Canada), and the State Energy Data 2000 Consumption tables (U.S. EIA 2000). Table 1 lists populations and total consumption in the Ontario and U.S. basins, with the U.S. basin broken down by states. For this report, the U.S. side of the basin is defined as the portions of the eight Great Lakes states within the basin boundary (which totals 214 counties either completely or partially within the basin boundary). The Ontario basin is defined by eight sub-basin watersheds. The most recent data available are from 2002 for Ontario and 2000 for the U.S. The largest change between 2000 and 2002 energy consumption by sector in Ontario was a 4.4% increase in the commercial sector (all other sectors changed by less than 2% in either direction).

In Ontario, the per capita energy consumption increased by 2% between 1999 and 2000. In the U.S. basin, per capita consumption decreased by an average of 0.875% from 1999 to 2000. Five states showed decreases in per capita energy consumption, while three states had increases (Figure 1). Electrical energy consumption per capita was fairly similar on both sides of the basin in 2000 (Figure 2). Over the last four decades, consumption trends in the U.S. basin have been fairly steady, although per capita consumption increased in each state from 1990 to 2000 (Figure 3). Interestingly, New York and Ohio consumed less per capita in 2000 than in 1970. Looking at the trends in Ontario from 1970 to 2000, the per capita energy consumption has stayed relatively consistent, with the exception of an increase seen in 1980. The per capita energy consumption figures for Ontario do not include the electricity generation sector due to an absence of data for this sector up until 1978. It is important to note that the quality of data processing and validation has improved over the last four decades and therefore the data quality may be questionable for the 1970s.

Total secondary energy consumption by the five sectors on the

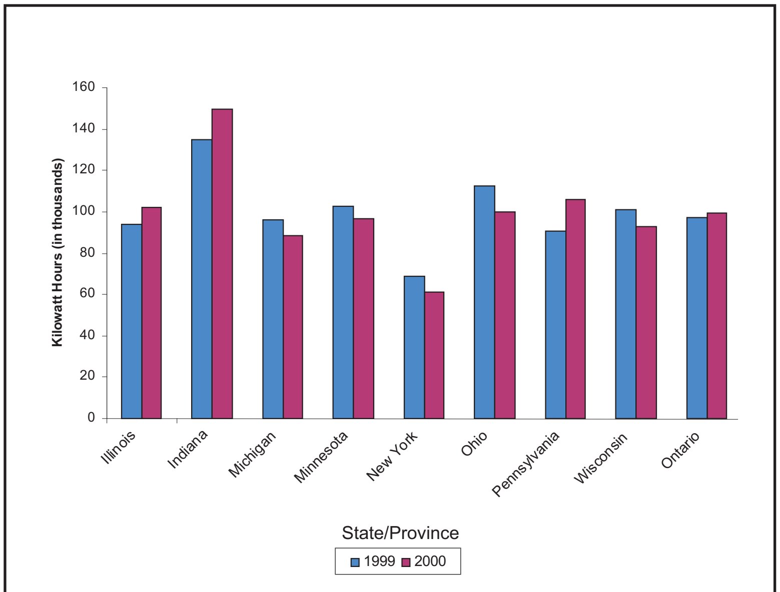


Figure 1. Total energy consumption per capita 1999-2000. 1 MWh = 1000 kWh.
Source: Energy Information Administration (2000) and Natural Resources Canada (2000)

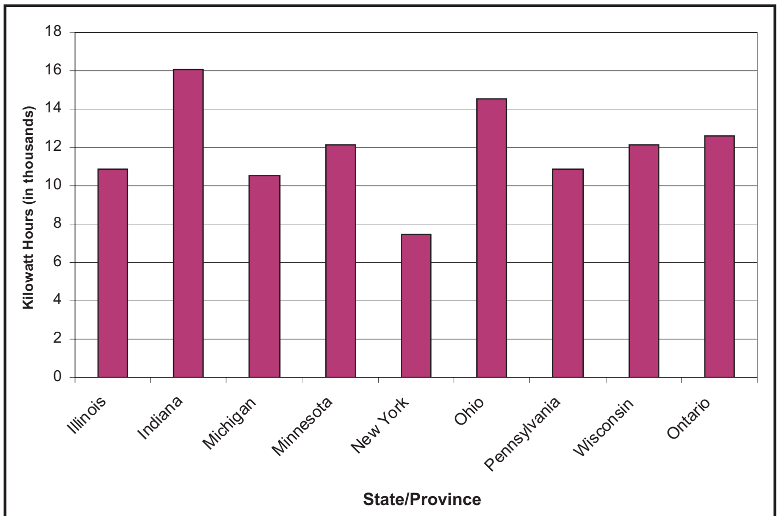


Figure 2. Electric energy consumption per capita 2000. 1 MWh = 1000 kWh.
Source: Energy Information Administration (2000) and Natural Resources Canada (2000)

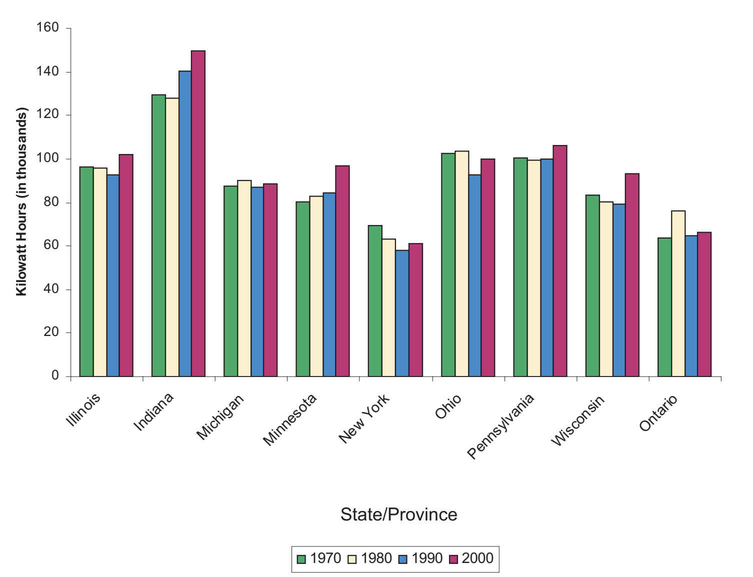


Figure 3. Total per capita energy consumption 1970-2000.1 MWh = 1000 kWh. Other energy sources include geothermal, wind, photovoltaic and solar energy. The Ontario data do not include the electricity generation sector due to an absence of data for this sector until 1978.
Source: Energy Information Administration (2000) and Natural Resources Canada (2000)

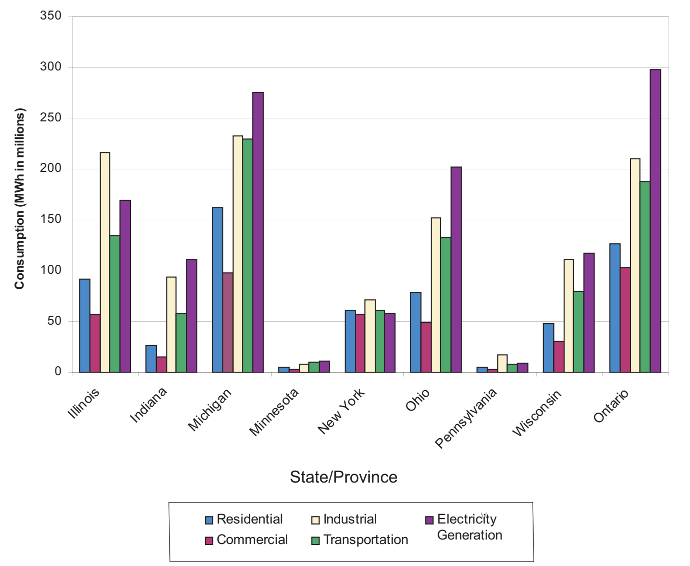


Figure 4. Secondary energy consumption within the Great Lakes basin by sector. Note: all data are from 2000, although 2002 data from Ontario are discussed in the report.
Source: Energy Information Administration (2000) and Natural Resources Canada (2000)

Canadian side of the basin in 2002 was 930,400,000 Megawatts-hours (MWh) (Table 1). Secondary energy is the energy used by the final consumer. It includes energy used to heat and cool homes and workplaces, and to operate appliances, vehicles and factories. It does not include intermediate uses of energy for transporting energy to market or transforming one energy form to another, this is primary energy. Accounting for 33% of the total secondary energy consumed in the Canadian basin, electricity generation was the largest end user of all the sectors. The other four sectors account for the remaining energy consumption as follows: industrial, 22%; transportation 20%; residential, 15%; and commercial, 12% (Table 2). Note that due to rounding, these figures do not add up to 100. There was a 0.5% increase in total energy consumption by all sectors in Ontario between 2000 and 2002.

| State/Province | Total energy consumption by State/Province within the Great Lakes basin (MWh) | Population within the Great Lakes basin* |
|---|---|---|
| Ontario (2002 data) | 930,400,000 | 9,912,707 |
| U.S. Basin Total (2000 data) | 3,364,000,000 | 31,912,867 |
| Illinois (IL) | 669,400,000 | 6,025,752 |
| Indiana (IN) | 304,900,000 | 1,845,344 |
| Michigan (MI) | 998,500,000 | 9,955,795 |
| Minnesota (MN) | 36,600,000 | 334,444 |
| New York (NY) | 309,600,000 | 4,506,223 |
| Ohio (OH) | 614,000,000 | 5,325,696 |
| Pennsylvania (PA) | 43,700,000 | 389,210 |
| Wisconsin (WI) | 387,300,000 | 3,530,403 |

* The U.S. side of the basin is defined as the portions of the 8 Great Lakes states within the basin boundary (which totals 214 counties either completely or partially within the basin boundary).

Table 1: Energy consumption and population within the Great Lakes basin, by state for the year 2000 (U.S.) and 2002 (Ontario). The U.S. basin population was calculated from population estimates by counties (either completely or partially within the basin) from the 2000 U.S. Census (U.S. Census Bureau 2000). Ontario basin populations were determined using sub-basin populations provided by Statistics Canada.
Source: U.S. Energy Information Administration and Natural Resources Canada

Total secondary energy consumption by the five sectors on the U.S. side of the basin in 2000 was 3,364,000,000 MWh (Table 1). As in the Canadian basin, electricity generation was the largest consuming sector in the U.S. basin, using 28% of the total secondary energy in the U.S. side of basin. The U.S. industrial sector consumed only slightly less energy, 27% of the total. The remaining three U.S. sectors account for 44% of the total, as follows: transportation, 21%; residential, 14%; and commercial, 9% (Table 2). Note that due to rounding, these percentages do not add up to 100. Figure 4 shows the total energy consumption by sector for both the Ontario and U.S. sides of the Great Lakes basin in 2000.

| Sector | U.S. Basin Total Energy Consumption - 2000* | Canadian Basin Total Energy Consumption - 2002 |
|---|---|---|
| Residential | 478,200,000 | 127,410,000 |
| Commercial | 314,300,000 | 107,800,000 |
| Industrial | 903,900,000 | 206,410,000 |
| Transportation | 714,000,000 | 184,950,000 |
| Electricity Generation | 953,600,000 | 303,830,000 |

* Note: 2000 is the most recent data available on a consistent basis for the U.S. More recent data is available for some energy sources from the EIA, but survey and data compilation methods may vary.

Table 2: Total Secondary Energy Consumption in the Great Lakes basin, in Megawatts-hours (MWh).
Source: U.S. Energy Information Administration and Natural Resources Canada

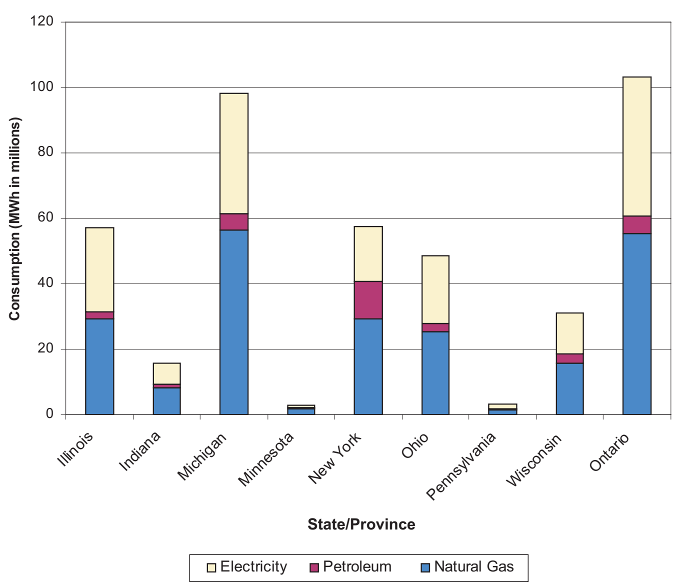


Figure 5. Commercial sector energy consumption by source, 2000. Wood and coal were minor sources in this sector.
Source: Energy Information Administration (2000) and Natural Resources Canada (2000)

The commercial sector includes all activities related to trade, finance, real estate services, public administration, education, commercial services (including tourism), government and institutional living and is the smallest energy consumer of all the sectors in both Canada and the U.S. (Table 2). Of the total secondary energy use by this sector in the Ontario basin, 57% of the energy consumed was supplied by fossil fuel (natural gas, 50%; and petroleum, 7%) and 43% was supplied by electricity. In Ontario, this sector had the largest increase in total energy consumption, 4.4%, between 2000 and 2002. By source, on the U.S. side of the basin, 61% was supplied by fossil fuel (natural gas, 53%; and petroleum, 8%) and 39% was supplied by electricity. On both sides of the basin, the commercial sector had the highest proportion of electricity use of any sector. Figure 5 shows energy consumption by source for the commercial sector for the Canadian and the U.S. basins in 2000.

The residential sector includes four major types of dwellings: single detached homes, single attached homes, apartments and mobile homes, and excludes all institutional living facilities. Fossil fuels (natural gas, petroleum, and coal) are the dominant energy source for residential energy requirements in the Great Lakes basin. Of the total secondary energy use by the residential sector in the Ontario basin in 2002 (Table 2), the source for 67% of the energy consumed was supplied by fossil fuel (natural gas, 61%; and petroleum, 6%), 30% by electricity and 3% by wood (Figure 6).

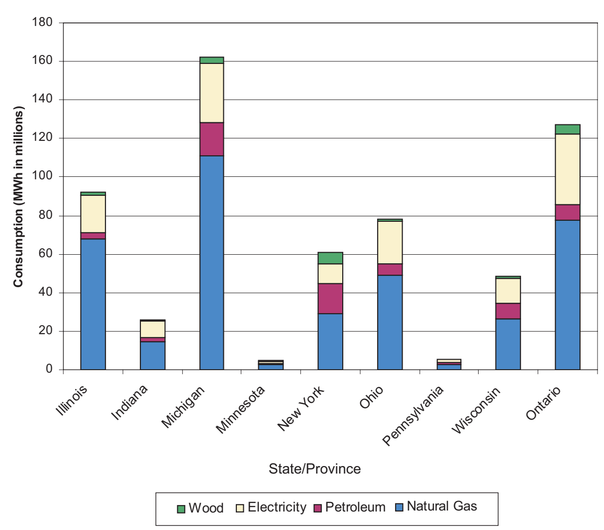


Figure 6. Residential sector energy consumption by source, 2000. Coal, geothermal, and solar energy were minor sources in this sector.
Source: Energy Information Administration (2000) and Natural Resources Canada (2000)

There was a 0.3% increase in total energy consumption by the Ontario residential sector between 2000 and 2002. On the U.S. side of the basin, fossil fuels are the leading source of energy accounting for 75% of the total residential sector consumption. Natural gas and petroleum are both consumed by this sector, but it is important to note that this sector has the highest natural gas consumption of all five sectors. The remaining energy sources were electricity, 22% and wood, 3% (Figure 6).

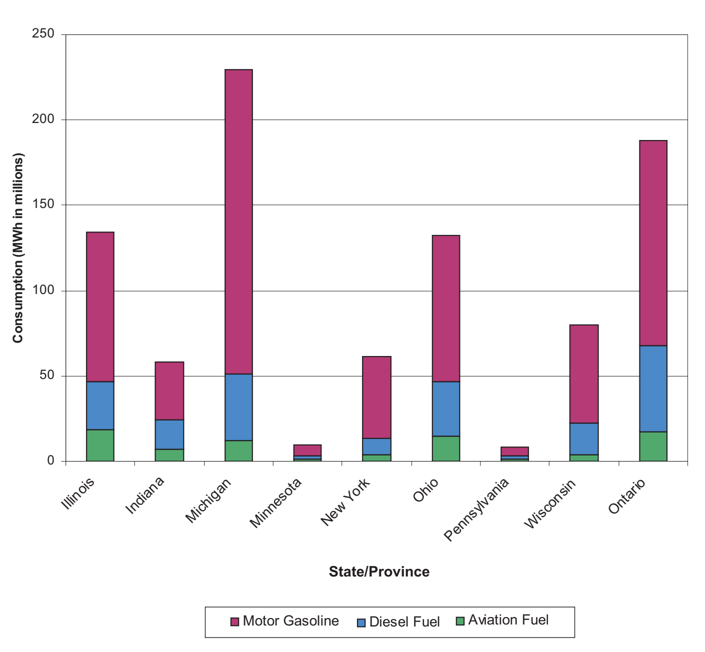


Figure 7. Transportation sector energy consumption by source, 2000. Natural gas and electricity were very minor energy sources in this sector.
Source: Energy Information Administration (2000) and Natural Resources Canada (2000)

The transportation sector includes activities related to the transport of passengers and freight by road, rail, marine and air. Off-road vehicles, such as snowmobiles and lawn mowers, and non-commercial aviation are included in the total transportation numbers. On both sides of the basin, 100% of the total secondary energy consumed by the transportation sector (Table 2) was supplied by fossil fuel, specifically petroleum. Motor gasoline was the dominant form of petroleum consumed, making up 67% of the Ontario basin total and 70% of the U.S. basin total. This was followed by diesel fuel, 27% in Ontario and 21% in the U.S., and aviation fuel, 6% in Ontario and 9% in the U.S. Figure 7 shows energy consumption by source for the Canadian and U.S. transportation sector in 2000, which had a decrease of 1.7% in total energy consumption on the Canadian side between 2000 and 2002.

The industrial sector includes all manufacturing industries, metal and non-metal mining, upstream oil and gas, forestry and construction, and on the U.S. side of the basin also accounts for agriculture, fisheries and non-utility power producers. On the Canadian side, in 2000, 71% of the energy consumed by this sector was supplied by fossil fuel (natural gas, 35%; petroleum, 20%; and coal, 16%), 19% was supplied by electricity, and the remaining 10% was supplied by wood. Between 2000 and 2002, consumption by industry in Ontario decreased by 1.8%. In addition to these energy sources, steam was a minor contributor to the total energy consumption.

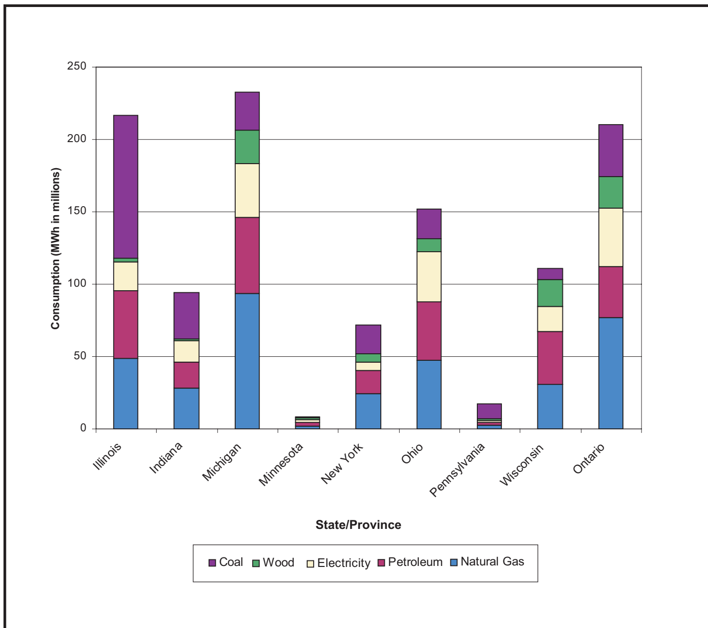


Figure 8. Industrial sector energy consumption by source, 2000. Hydroelectric power was a minor source in this sector. U.S. data for wood include wood waste.
Source: Energy Information Administration (2000) and Natural Resources Canada (2000)

For the same sector, on the U.S. side of the basin, fossil fuels were the dominant energy source contributing 79% of the total energy (natural gas, 31%; coal, 24 %; and petroleum, 24%). The remaining sources were electricity, at 15%, and wood/wood waste, at 7%. Figure 8 shows energy consumption by source for the industrial sector on both the Canadian and U.S. sides of the basin in 2000. It is important to note that the numbers given for the Ontario industrial sector are likely underestimations of the total energy consumption on the Canadian side of the basin. Numbers were estimated using the population of the Canadian side of the basin as a proportion of the total population of Ontario, this results in an estimation of 87% of total industrial energy use in Ontario being contained within the basin. However, Statistics Canada estimates that as much as 95% of industry in Ontario is contained within the basin. Estimating by population was done to remain consistent with the data provided for the U.S. side of the basin.

The last, and the largest consuming sector in both the Canadian and the U.S. basins, is the electricity generation sector. Of the total secondary energy use in the Ontario basin (Table 2), 67% of the energy consumed by this sector was supplied by nuclear energy, 26% was supplied by fossil fuel (coal, natural gas and

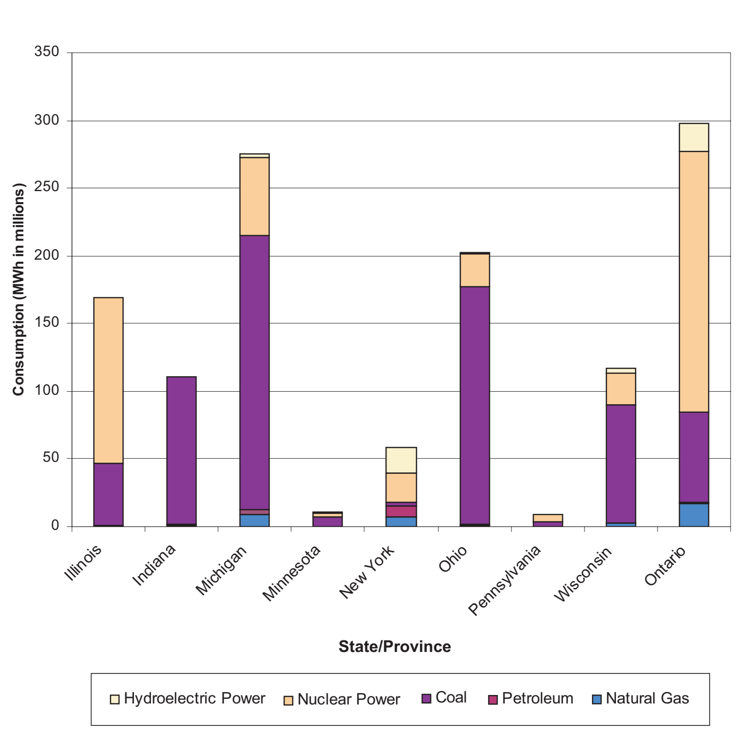


Figure 9. Electricity generation sector energy consumption by source, 2000. Wood and wood waste were very minor energy sources in this sector.
Source: Energy Information Administration (2000) and Natural Resources Canada (2000)

petroleum), and 7% was supplied by hydroelectric energy. There was an increase in total energy use of 1.9% between 2000 and 2002 in Ontario. It is important to note that the Great Lakes basin contains the majority of Canada's nuclear capacity. Of the total secondary energy use by this sector in the U.S. basin (Table 2), 70% was supplied by the following types of fossil fuel: coal (66%), natural gas (2%), and petroleum (2%). The other two major sources, nuclear and hydroelectric energy, provided 27% and 3% respectively. This sector consumed 75% of the coal used in the entire U.S. basin. Figure 9 shows energy consumption by source for the electricity generation sector for the Canadian and U.S. sides of the basin in 2000.

The overall trends in energy consumption by sector were quite similar on both sides of the basin. Ranked from highest to lowest energy consumption, the pattern for the sectors was the same for the U.S. and Canadian basins (Table 2). Analyses of the sources of energy within each sector and trends in resources consumption also indicate very similar trends.

**Pressures**

In 2001, Canada was ranked as the fifth largest energy producer and the eighth largest energy consuming nation in the world. Comparatively, the United States is ranked as "the world's largest energy producer, consumer, and net importer" (U.S. EIA 2004). The factors responsible for the high energy consumption rates in Canada and the U.S. can also be attributed to the Great Lakes basin. These include a high standard of living, a cold climate, long travel distances, and a large industrial sector. The combustion of fossil fuels, the dominant source of energy for most sectors in the basin, releases greenhouse gases such as carbon dioxide and nitrous oxide into the air contributing to smog, climate change, and acid rain.

*Canada's Energy Outlook 1996-2020* (http://nrn1.nrcan.gc.ca:80/es/ceo/toc-96E.html) notes that "a significant amount of excess generating capacity exists in all regions of Canada" because demand has not reached the level predicted when new power plants were built in the 1970s and 1980s. Demand is projected to grow at an average annual rate of 1.3 percent in Ontario and 1.0 percent in Canada overall between 1995 and 2020. From 2010-2020, Ontario will add 3,650 megawatts of new gas-fired and 3,300 megawatts of clean coal-fired capacity. Several hydroelectric plants will be redeveloped. Renewable resources are projected to quadruple between 1995 and 2020, but will contribute only 3 percent of total power generation.

The pressures the U.S. currently faces will continue into the future, as the U.S. works to renew its aging energy infrastructure and develop renewable energy sources. Over the next two decades, U.S. oil consumption is estimated to grow by 33%, and natural gas consumption will increase by more than 50%. Electricity demand is forecast to increase by 45% nationwide (National Energy Policy 2001). Natural gas demand currently outstrips domestic production in the U.S. with imports (largely from Canada) filling the gap. 40% of the total U.S. nuclear output is generated within five states, including three within the Great Lakes basin (Illinois, Pennsylvania, and New York) (U.S. EIA 2004). Innovation and creative problem solving will be needed to work towards balancing economic growth and energy consumption in the Great Lakes basin in the future.

**Management Implications**

Natural Resources Canada, Office of Energy Efficiency has implemented several programs that focus on energy efficiency and conservation within the residential, commercial, industrial, and transportation sectors. Many of these programs work to provide consumers and businesses with useful and practical information regarding energy saving methods for buildings, automobiles, and homes. The U.S. Department of Energy Office of Energy Efficiency and Renewable Energy recently launched an educational website (http://www.eere.energy.gov/consumerinfo/), which provides homes and businesses with ways to improve efficiency, tap into renewable and green energy supplies, and reduce energy costs. In July 2004, Illinois, Minnesota, Pennsylvania, and Wisconsin were awarded $46.99 million to weatherize low-income homes, which is expected to save energy and cost (EERE 2004). The U.S. Environmental Protection Agency Energy Star program, a government/industry partnership initiated in 1992, also promotes energy efficiency through product certification. In 2002, Americans saved more than $7 billion in energy costs through Energy Star, while consuming less power and preventing greenhouse gas emissions (USEPA 2003).

In addition to these programs, the Climate Change Plan for Canada challenges all Canadians to reduce their greenhouse gas emissions by one tonne, approximately 20% of the per capita production on average each year. The One-Tonne Challenge offers a number of ways to reduce the greenhouse gas emissions that contribute to climate change and in doing so will also reduce total energy consumption.

Renewable energy sources such as solar and wind power are available in Canada, but constitute only a fraction of the total energy consumed. Research continues to develop these as alternate sources of energy, as well as developing more efficient ways of burning energy. In the United States, according to the U.S. Energy Information Administration, 6% of the total 2002 energy consumption came from renewable energy sources (biomass, 47%; hydroelectric, 45%; geothermal, 5%; wind, 2%; and solar, 1%). The U.S. has invested almost a billion dollars, over three years, for renewable energy technologies (Garman 2004). Wind energy, cited as one of the fastest growing renewable sources worldwide, is a promising source for the Great Lakes region. The U.S. Department of Energy, its laboratories, and state programs are working to advance research and development of renewable energy technologies.

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**Authors' Commentary**
Ontario data are available through Natural Resources Canada, Office of Energy Efficiency. Databases include the total energy consumption for the residential, commercial, industrial, transportation, agriculture and electricity generation sectors by energy source and end use. Population numbers for the Great Lakes basin, provided by Statistics Canada, were used to calculate the

energy consumption numbers within the Ontario side of the basin. This approach for the residential sector should provide a reasonable measure of household consumption. For the commercial, transportation and especially industrial sectors, it may be a variable estimation of the total consumption in the basin. The data are provided on nation-wide, or province-wide basis. Therefore it provides a great challenge to disaggregate it by any other methods to provide a more precise representation of the Great Lakes basin total energy consumption.

Energy consumption, price, and expenditure data are available for the United States (1960-2000) through the Energy Information Administration (EIA). The EIA is updating the State Energy Data 2000 series to 2001 by August 2004. There may be minor discrepancies in how the sectors were defined in the U.S. and Canada, which may need further investigation (such as tourism in the U.S. commercial sector, and upstream oil and gas in the U.S. industrial sector). Actual differences in consumption rates may be difficult to distinguish from minor differences between the U.S. and Canada in how data were collected and aggregated. Hydroelectric energy was not included in the industrial sector analysis, but might be considered in future analyses. In New York State, almost as much energy came from hydroelectric energy as from wood. Wisconsin and Pennsylvania also had small amounts of hydropower consumption.

In the U.S. the current analysis of the total basin consumption is based on statewide per capita energy consumption, multiplied by the basin population. The ideal estimate of this indicator would be to calculate the per capita consumption within the basin, and would require energy consumption data at the county level or by local utility reporting areas. Such data may be quite difficult to obtain, especially when electricity consumption per person is reported by utility service area. The statewide per capita consumption may be different than the actual per capita consumption within the basin, especially for the states with only small areas within the basin (Minnesota and Pennsylvania). The proportion of urban to rural/agricultural land in the basin is likely to influence per capita consumption within the basin. Census data are available at the county and even the block level, and may in the future be combined with the U.S. basin boundary using GIS to refine the basin population estimate.

Additionally, the per capita consumption data for the U.S. in Figures 1, 2, and 3 are based on slightly different energy consumption totals than the data in Tables 1 and 2. The next update of this indicator should examine whether it is worthwhile to include the minor sources in the sector analysis on both sides of the basin or to exclude them from the per capita figures.

**Last Updated**

*State of the Great Lakes 2005*