CLIMATE CHANGE AND GREAT LAKES WATER RESOURCES: AVOIDING FUTURE CONFLICTS WITH CONSERVATION[1]

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I. INTRODUCTION

The Earth's climate is warming. This is the unequivocal conclusion of climate scientists. Despite the complexities of climatology, certain consistent themes emerge with implications for water availability: as the world gets warmer, it will experience increased regional variability in precipitation, more frequent heavy precipitation events, becoming more susceptible to drought. These simple facts could have a profound impact on the Great Lakes, as the warmer climate may reduce water supply and increase water demand within the region. Further, as other regions suffer from shortages in water supply and increased demand for water resources, they will look to divert Great Lakes water to slake their thirst.

The science is compelling. Now the question for citizens and policymakers is whether existing laws and policies are adequate to protect the Great Lakes from the new pressures of climate change. Until this year, the unfortunate answer was, "No." However, the recently enacted Great Lakes-St. Lawrence River Basin Water Resources Compact ("Great Lakes Compact")[4] is an important step in improving Great Lakes water resource policy to meet the challenge of climate change.

Part II of this article focuses on how climate change will impact water resources. It begins with a brief summary of climate change science. It then explores what a changing climate will mean for the Great Lakes, including possible lowering of lake levels, impacts on fisheries and wildlife, changes in Great Lakes shorelines, and reduction of groundwater supplies. Climate change will also reduce water supplies in other parts of the country,

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1 This article is based on a report prepared by the authors for the National Wildlife Federation, NAT'L WILDLIFE FED'N, CLIMATE CHANGE AND GREAT LAKES WATER RESOURCES (2007), http://online.nwf.org/site/DocServer/Climate_Change_and_Great_Lakes_Water_Resources_Report_FI.pdf?docID=2442, and portions of this article rely on an article previously published in the *University of Colorado Law Review*, Noah D. Hall, *Toward a New Horizontal Federalism: Interstate Water Management in the Great Lakes Region*, 77 U. COLO. L. REV. 405 (2006). The authors are especially grateful to Molly Flanagan, formerly the Great Lakes Water Resources Program Manager for the National Wildlife Federation, for her support and contributions.

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4 The Great Lakes-St. Lawrence River Basin Water Resources Compact, Pub. L. No. 110–342, 122 Stat. 3739 (2008).

creating increased pressure to divert Great Lakes water to other regions. As the Great Lakes and other regions struggle with loss of water supplies, demand for water is expected to increase unless water conservation laws and policies are adopted. Taken together, the key findings of Part II present a major challenge to the Great Lakes region.

Part III evaluates the adequacy of Great Lakes water resource policies that predate the Great Lakes Compact for responding to the pressures of climate change. Unfortunately, these prior laws and policies intended to protect Great Lakes water resources from diversions (transfers of Great Lakes water outside of the basin) and overuse within the basin are not up to the new challenges posed by climate change. The region can better protect and manage Great Lakes water resources in a future of climate change by adopting new water resource policies that (1) emphasize water conservation as water becomes more scarce and valuable; (2) protect aquatic habitat for fisheries and wildlife in changing conditions; (3) provide strong legal protections against diversions of Great Lakes water to other regions; and (4) create regional governance institutions that can help adaptively manage water resources as new scientific information becomes available.

The article concludes by examining how the enactment and implementation of the Great Lakes Compact gives the region an opportunity to make these improvements in water resource policy and better protect the Great Lakes from the pressures of climate change.

II. HOW CLIMATE CHANGE IMPACTS GREAT LAKES WATER RESOURCES

Climate change will severely impact water resources. A brief summary of climate change science provides the basic data on rising temperatures and changes in precipitation. Under these conditions, the Great Lakes may experience a range of impacts, including lower lake levels, loss of ice cover, and shrinking surface area. Recent scientific studies are already predicting harms to fisheries and wildlife, wetlands, and Great Lakes shorelines, as well as economic costs to industries such as tourism and shipping. There may also be increased pressure to divert Great Lakes water[5] to other parts of the country, where climate change will result in loss of snowpack, declining aquifer levels, and rising sea levels causing salt water intrusion. The stress of reduced water supplies will be compounded by expected increased demand for water.

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[5] For purposes of this article, the terms "Great Lakes" and "Great Lakes water" refer to all waters of the Great Lakes, including all tributary surface and ground waters. *See* Great Lakes Compact, *supra* note 4, § 1.2 (defining "Waters of the Basin" or "Basin Water").

A. A Global Overview of Higher Temperatures and Precipitation Changes

The Earth is getting warmer.[6] This trend is evident in average global air and ocean temperatures.[7] Polar snow and ice are melting, and the average sea level around the globe is rising.[8] Not only is the Earth becoming warmer, but it is warming faster than at any time during the twentieth century. Global mean surface temperatures rose 1.33º F (0.74º C) over the period between 1906 and 2005.[9] But during the past fifty years, the rate of global warming has nearly doubled.[10] Eleven of the last twelve years rank among the twelve warmest years on record since 1850.[11]

It is very likely that the increase in global average temperatures since the mid-twentieth century was due to anthropogenic (man-made) releases of greenhouse gases.[12] Scientists also anticipate that the changes to the global climate system during the twenty-first century will be larger than those observed during the twentieth century.[13] Over the next two decades, global warming is expected to increase about 0.4º F (0.2º C) per decade.[14] During the twenty-first century, the best estimates are that average global temperatures will increase 3.2º to 7.2º F (1.8º to 4.0º C),[15] and it is expected that warming will be even more intense in North America.[16] Some of the consequences that climate scientists expect as a result of global warming are more heat waves, more extreme weather events (both heavy precipitation events and droughts), and increased tropical storm intensity.[17] Some of the increased precipitation, however, will be offset by a drying effect created by the warmer atmosphere's increased ability to absorb moisture through evaporation.

Although global temperatures, on average, are expected to increase anywhere from 3.2º to 7.2º F (1.8º to 4.0º C) during the twenty-first century,[18] the amount of temperature change is expected to vary significantly

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6 Intergovernmental Panel on Climate Change, *Summary for Policymakers* [hereinafter *Summary for Policymakers*], *in* CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS 5 (Susan Solomon et al. eds., 2007) [hereinafter CLIMATE CHANGE], *available at* http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print _SPM.pdf.

7 *Id.*

8 *Id.*

9 Kevin E. Trenberth et al., *Observations: Surface and Atmospheric Climate Change*, *in* CLIMATE CHANGE, *supra* note 6, at 237.

10 *Id.*

11 *Id.*

12 *Summary for Policymakers*, *supra* note 6, at 10.

13 *Id.* at 13.

14 *Id.* at 12.

15 *Id.* at 13.

16 Jens Hesselbjerg Christiansen et al., *Regional Climate Projections*, *in* CLIMATE CHANGE, *supra* note 6, at 850.

17 Trenberth et al., *supra* note 9, at 237-39.

18 *Summary for Policymakers*, *supra* note 6, at 13.

from region to region. For example, in North America the east coast is projected to warm 3.6º F (2º C), while Alaska and northern Canada could warm as much as 18º F (10º C).[19] In addition, summer temperatures in the American Southwest are expected to rise more quickly than the North American average.[20]

Similarly, climatologists anticipate temporal and regional variability in precipitation. The incidence of both floods and droughts will increase. One effect of the rising temperatures that are expected over the next century is that the atmosphere's capacity to hold moisture will go up. For every 1.8º F (1º C) increase in temperature, the water-holding capacity of the atmosphere rises 7%.[21] Increased moisture in the atmosphere will lead to more intense precipitation events—even when the annual total amount of precipitation is slightly reduced.[22] To paraphrase, when it rains it will pour, but when it doesn't, you might be looking at a drought.[23]

Changes in precipitation patterns are already observable. Over the past century, eastern North America has gotten wetter, while southern Africa and the Mediterranean have become drier.[24] In the twenty-first century, the northeastern U.S. is expected to receive more precipitation, while the Southwest is expected to become even drier.[25]

B. Climate Change in the Great Lakes Region

Like the rest of the country, the Great Lakes region felt the effects of a changing climate during the twentieth century. Within the Great Lakes region, temperatures increased 1.26º F (0.7º C) from 1895 to 1999.[26] This increase is nearly double the average increase in the U.S. as a whole. The most pronounced increases occurred in the winter and the fall.[27] Meanwhile, the ratio of snow to total precipitation decreased, annual snow cover shrank, and the freezing of the lakes started occurring later in the year.[28] While total annual precipitation increased, the number of wet *and* dry periods also increased.[29] Since temperature increased, the rate of evapotranspiration—the loss of water to the atmosphere through evaporation from land and water

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19 Christiansen et al., *supra* note 16, at 889.
20 *Id.*
21 Hervé Le Treut et al., *Historical Overview of Climate Change Science*, *in* CLIMATE CHANGE, *supra* note 6, at 105.
22 *Id.*
23 *Id.*
24 *Id.*
25 Christensen et al., *supra* note 16, at 850.
26 LINDA MORTSCH ET AL., INT'L JOINT COMM'N, CLIMATE CHANGE AND WATER QUALITY IN THE GREAT LAKES REGION 5 (2003), *available at* http://www.ijc.org/rel/pdf/climate_change_2003_part3.pdf.
27 *Id.* at 4.
28 *Id.*
29 *Id.*

surfaces and from the transpiration of plants—also increased.[30] In some areas of the Great Lakes during the period from 1970 to 1990, air temperatures increased 2.9° F (1.6° C) and average annual evaporation increased 50%.[31] This resulted in lower streamflow (runoff declining by more than half) and longer renewal times for the lakes, despite increased precipitation.[32]

Many of the trends observed during the twentieth century within the Great Lakes region are expected to continue in the twenty-first century. As air temperatures rise, evapotranspiration can be expected to increase.[33] By 2050, spring temperatures in the Great Lakes watershed may increase by as much as 9° F (5° C), while summer temperatures may increase by as much as 7.2° F (4° C).[34] As a result, precipitation increases will be at least partially offset by more rapid evaporation.[35] Mean annual lake surface evaporation could increase by as much as 39% due to an increase in lake surface temperatures.[36] This will present particular concern during summer and autumn, which are already characterized by low stream flow.[37] Moreover, with increased evapotranspiration and decreased snowpack, less moisture will enter the soil and groundwater zones, and runoff will be even further decreased.[38] Consequently, under future warmer and drier conditions, Great Lakes residents could become more vulnerable to water supply and demand mismatches.[39]

Although total annual precipitation in the Great Lakes basin is expected to increase by 2050, the change is not projected to be uniform throughout all seasons.[40] Further, precipitation is not expected to increase steadily. Instead, the Great Lakes region will be more susceptible to extreme precipitation events from a warmer atmosphere which has a greater moisture-holding capacity.[41] This will mean fewer days of moderate precipitation, and more dry days or days with light precipitation.[42]

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30 *Id.* at 13.
31 *Id.*
32 MORTSCH ET AL., *supra* note 26, at 13.
33 *Id.* at 33.
34 *Id.* at 34.
35 *Id.* at 35.
36 *Id.* at 38.
37 *Id.* at 35.
38 Thomas E. Croley, Research Hydrologist, Great Lakes Envtl. Research Lab., Address at Fox-Wolf Watershed Alliance Storm Water Conference: Great Lakes Climate Change Hydrologic Impact Assessment (Mar. 13, 2007) (on file with author).
39 MORTSCH ET AL., *supra* note 26, at 35.
40 *Id.*
41 *Id.*
42 *Id.*

C. Effects of Climate Change on the Great Lakes and Connected Waters

During the twentieth century, Great Lakes water levels have been influenced by several factors including climate variability.[43] Annual water levels varied about six feet from measured minimum and maximum levels.[44] Particularly high lake levels occurred in 1973-1975 and 1986-1987, and particularly low lake levels occurred in 1934-1935 and 1964-1965.[45] Typically, lake levels dropped most dramatically after especially hot years.[46] For example, lake levels dropped dramatically after achieving record highs in 1986 due to the 1988 drought.[47] They also dropped precipitously from a relatively high peak in 1997, as 1998 was the hottest and fifth driest year in the region in over half a century.[48]

Most climate models predict that Great Lakes water levels will drop during the next century.[49] The frequency and duration of low water levels could increase, dropping water levels below historic lows.[50] Predictions regarding climate change impacts on lake levels are complicated by the system of locks, hydropower plants, and outflow control mechanisms regulated by the International Joint Commission and other management bodies. However, recent research predicts that lake levels in Lake Michigan and Lake Huron may drop by as much as 4.5 ft (1.38 m) due to a combination of decreased precipitation and increased air temperature (and evapotranspiration).[51] Drastic reductions in ice cover may also result from air and lake temperature increases—by 2090 most of Lake Erie is projected to be ice-free over the winter 96% of the time.[52] Despite the difficulties in making exact future predictions of water levels, it is essential to note that *any* reduction in water levels will be felt acutely by a region where more than thirty-three million people now depend on the lakes for industrial, agricultural and residential needs.

In addition, higher air temperatures will warm the lake waters and groundwater.[53] A recent study of Lake Superior summer surface water temperatures over the past twenty-seven years found that the water

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43 *Id.* at 14.

44 *Id.* at 15.

45 MORTSCH ET AL., *supra* note 26, at 15.

46 *Id.*

47 *Id.*

48 *Id.*

49 PETER H. GLEICK ET AL., U.S. GLOBAL CHANGE RESEARCH PROGRAM, WATER: THE POTENTIAL CONSEQUENCES OF CLIMATE VARIABILITY AND CHANGE FOR THE WATER RESOURCES OF THE UNITED STATES 58 (2000), *available at* http://www.pacinst.org/reports/national_assessment/natl_assessment_water. pdf.

50 MORTSCH ET AL., *supra* note 26, at 47.

51 *See* Brent M. Lofgren et al., *Evaluation of Potential Impacts on Great Lakes Water Resources Based on Climate Scenarios of Two GCMs*, 28 J. GREAT LAKES RES. 537, 546 (2002), *available at* http://www.glerl.noaa.gov/pubs/fulltext/2002/20020020.pdf

52 *Id.*

53 MORTSCH ET AL., *supra* note 26, at 52.

temperatures have increased about 4° F (2.2° C) and are increasing faster than regional air temperatures. Declining winter ice cover and early onset of water stratification (absence of mixing between surface and deep waters) are lengthening the period over which the lake warms during the summer months.[54] Further, since groundwater will be warmer due to increased air temperatures, its important role in cooling lake water will be reduced.[55] Effects of warmer water include decreased oxygen-carrying capacity, decreased volume of water (because of higher evaporation rates) for dilution of chemical inputs, increased concentration of nutrients and pollutants, and decreased ice cover and depth of lake freezing.[56]

The increased variability in timing, intensity, and duration of precipitation under global warming conditions is expected to increase the frequency of droughts and floods in the Great Lakes region.[57] Overall, stream runoff is expected to decrease,[58] and baseflow—the contribution of groundwater to streamflow—could drop by nearly 20% by 2030.[59] When intense precipitation does occur, projections indicate that soil erosion, land and water quality degradation, flooding, and infrastructure failure will be more likely to occur,[60] and overflowing combined sewers could contaminate lakes.[61]

As baseflow, groundwater contributes more than half of the flow of streams discharging to the Great Lakes.[62] It is also an important source of drinking and irrigation water in the region.[63] Simulations indicate that baseflow is sensitive to changes in temperature and precipitation.[64] Increased frequency of droughts and heavy precipitation can reduce recharge and water levels in aquifers, especially in shallow aquifers.[65] Higher evapotranspiration losses (the loss of groundwater to the air through evaporation and plant transpiration) will impact groundwater supplies when temperatures are higher, as during droughts.[66] Aquifers will also suffer during heavy precipitation events, because more of the water will go to runoff before it can percolate into the aquifer.[67] Thus, even in a future where overall precipitation

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[54] Jay A. Austin & Steven M. Colman, *Lake Superior Summer Water Temperatures are Increasing More Rapidly Than Regional Air Temperatures: A Positive Ice-albedo Feedback*, 34 GEOPHYSICAL RES. LETTERS L06604 (2007).

[55] MORTSCH ET AL., *supra* note 26, at 52.

[56] *Id.* at 50.

[57] *Id.* at 41.

[58] *Id.*

[59] *Id.* at 45.

[60] *Id.* at 38.

[61] MORTSCH ET AL., *supra* note 26, at 75.

[62] *Id.* at 44.

[63] *Id.*

[64] *See Summary for Policymakers*, *supra* note 6, at 16.

[65] MORTSCH ET AL., *supra* note 26, at 44.

[66] *Id.*

[67] *Id.* at 45.

increases, aquifer levels can decrease, due to the increased intensity of precipitation events.[68]

In summary, climate change will dramatically affect the Great Lakes and other water resources in the region. Climate change may contribute to lowering lake levels and reducing the surface area of the Great Lakes. Water temperatures in the lakes and other water bodies will increase, perhaps even more than air temperatures in the region. Both droughts and floods will come with increased frequency. Groundwater will also be impacted, as aquifer levels and recharge rates are expected to drop.

D. Environmental and Economic Impacts of Climate Change in the Great Lakes

Lower lake levels and rising temperatures (both in the air and water) will significantly impact fisheries, wildlife, wetlands, shoreline habitat, and water quality in the Great Lakes region. The impacts are not only an environmental concern, but also have a huge economic cost. Tourism and shipping are critically important to the region, and both industries are extremely vulnerable to climate change impacts.

Climate change can impact the entire natural food chain in the Great Lakes basin. Rising temperatures will change the way that buoyancy-driven turnovers[69] in the water column occur.[70] Biannual turnovers of the water column could be eliminated in some lakes, decreasing oxygen available in deeper waters and releasing nutrients and metals from lake sediments.[71] Oxygen-carrying capacity is critical to support aquatic ecosystems.[72] Rising temperatures would also probably have a negative impact on the health of zooplankton and phytoplankton at the base of the food chain. Other effects of increased temperature could include higher thermal stress for cold-water fish, increased summer anoxia, and an overall loss of productivity in the lakes.[73]

Changes in air temperature, cloud cover, humidity, and winds will affect mixing of surface and deep water layers, with possible implications for food production over the next century. The mixed layer is important as it provides nutrients to algae at the surface (for food production) and transfers oxygen from the surface water to the bottom water. Climate change will increase the duration of thermal stratification (lack of mixing between surface and bottom waters) in all five lakes. For all lakes except Lakes Erie and Ontario, the amount of food produced by algae and consumed by fish

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[68] *Id.*

[69] For a more detailed explanation of buoyancy-driven turnovers, see *supra* notes 104-106 and accompanying text.

[70] Croley, *supra* note 38, at 68.

[71] *Id.*

[72] MORTSCH ET AL., *supra* note 26, at 52.

[73] GLEICK ET AL., *supra* note 49, at 58.

and other aquatic species will decrease in part due to nutrient limitation caused by the longer stratification period.[74]

Warming water may result in temperature thresholds being reached for certain species.[75] Cold water habitat for brook trout could decrease significantly.[76] Small, shallow lakes could disappear, and in the process, reductions in water volume could cause the lakes to become more contaminated.[77] Already, fish habitats in Lake Ontario have been altered by climate change. "Lake Ontario year-class productivity [has been] strongly linked to temperature," and during the warm 1990s, productivity shifted toward warm-water species.[78] Since walleye yield in lakes depends on the amount of cool, turbid habitat, walleye in the Bay of Quinte in Lake Ontario contracted in part due to warming and lower water levels.[79]

Warmer waters could also lead to invasion by exotic species.[80] Furthermore, increased temperatures could exacerbate existing problems with invasive species in the Great Lakes.[81] For example, while the cold water of Lake Superior currently limits the expansion of the zebra mussel, waters warmed by higher temperatures and loss of volume may allow the zebra mussel to become more widespread in Lake Superior.[82]

Wetlands will also be affected by warmer water and lower lake levels. Changing climate conditions will alter the timing, and lessen the amount of, water flowing through wetlands, thereby affecting flushing, sedimentation, nutrient input, and duration of ice cover.[83] Lower lake levels may cause an increase in fires and oxidation of wetland bottoms.[84] Trees in swamps respond slowly to environmental changes, and, consequently, Great Lakes shoreline fens may become vulnerable since they are highly reliant on groundwater.[85]

In addition, lower lake levels and increased air temperatures may lead to more invasive plant species in shoreline wetlands. For example, a recent study documented the invasion of an invasive strain of the aquatic plant *Phragmites australis* in wetlands at Long Point, Lake Erie, which

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74 John T. Lehman, *Mixing Patterns and Plankton Biomass of the St. Lawrence Great Lakes Under Climate Change Scenarios*, 28 J. GREAT LAKES RES. 583, 592 (2002) ("In both [Erie and Ontario] lakes there were no substantial differences in maximum mixed layer algal biomass predicted by either model . . . .").

75 MORTSCH ET AL., *supra* note 26, at 52.

76 *Id.* at 64.

77 *Id.*

78 Christopher B. Field et al., *North America*, *in* CLIMATE CHANGE 2007: IMPACTS, ADAPTATION AND VULNERABILITY 624 (Martin L. Parry et al. eds., 2007) [hereinafter CLIMATE CHANGE IMPACTS], *available at* http://www.ipcc.ch/ipccreports/ar4-wg2.htm.

79 *Id.*

80 MORTSCH ET AL., *supra* note 26, at 135.

81 *Id.* at 63.

82 *Id.*

83 *Id.* at 64.

84 *Id.* at 65.

85 *Id.*

resulted in the degradation of an important waterfowl habitat. Researchers mapped Long Point's wetland communities from aerial photographs and found that 90% of the areas studied had been invaded by this species, particularly between 1995 and 1999 as lake levels lowered and air temperatures increased.[86]

Global warming will have several effects on water quality in the Great Lakes basin. Taste and odor problems with drinking water may occur during the summer since warmer waters are conducive to algae growth.[87] In addition, climate change and weather variability pose a threat for water-borne diseases.[88] Under warmer conditions, it will likely be more costly to meet water quality goals.[89] Lower flows and lower lake levels will mean that water bodies can accept smaller concentrations of pollutants before they become contaminated.[90] Thus, violations of low flow criteria would increase.[91] Reductions in runoff will also result in alterations in chemical fate and transport with environmental consequences. Decreases in moisture and weathering could cause changes in chemical export from watersheds and alter chemical concentrations in streams.[92] In addition, decreased soil flushing would result in delayed recovery from acid rain events and enhanced sulfur and nitrate export following droughts.[93]

1. Case Study - Anoxia

When oxygen levels drop in lakes, certain fish and other organisms can no longer survive.[94] As they die, pollution-tolerant species that require less oxygen—such as sludge worms and carp—can take over.[95] Lake Erie notoriously suffered from oxygen depletion throughout much of the twentieth century, primarily due to phosphorus pollution.[96] Oxygen depletion—or anoxia—in Lake Erie led to turbid, greenish-brown, murky water, and beaches covered in green, slimy, rotting algae.[97]

Pollution is not the only cause of anoxia, however. Many of the conditions predicted by climate models for the Great Lakes will contribute to expanded anoxic zones. For example, lower water levels can reduce

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[86] Kerrie L. Wilcox et al., *Historical Distribution and Abundance of Phragmites australis at Long Point, Lake Erie, Ontario*, 29 J. GREAT LAKES RES. 664, 664-66 (2003).

[87] MORTSCH ET AL., *supra* note 26, at 53.

[88] *Id.* at 57.

[89] *Id.* at 54.

[90] *Id.*

[91] *Id.* at 55.

[92] *Id.* at 51.

[93] MORTSCH ET AL., *supra* note 26, at 51.

[94] U.S. ENVTL. PROT. AGENCY ET AL., THE GREAT LAKES: AN ENVIRONMENTAL ATLAS AND RESOURCE BOOK 29 (3d ed. 1995) [hereinafter ENVIRONMENTAL ATLAS], *available at* http://www.epa.gov/glnpo/atlas/glat-ch4.html.

[95] *Id.*

[96] *Id.* at 30.

[97] *Id.*

dissolved oxygen concentrations,[98] and water levels in all the Great Lakes are expected to drop significantly due to global warming—possibly by as much as 4.5 feet in Lake Huron and Lake Michigan.[99] Low lake levels will appear earlier in the year, and the annual averages—while still fluctuating from year to year—will be lower more often than has been the case in the past.

In addition, water temperatures are expected to rise during the next century, and warmer water can lead to anoxia.[100] Summer surface water temperatures in Lake Superior have already risen 4° F (2.2° C) over the past twenty-seven years. The metabolic rates of sediment bacteria which consume oxygen increase as water warms.[101] Biological productivity and respiration in the water column also increase,[102] providing more decomposing bottom matter and robbing the water of oxygen.[103] At the same time, warmer temperatures decrease dissolved oxygen saturation values,[104] limiting the amount of oxygen in the water.

A warming environment may also affect the circulation in the Great Lakes, further depleting oxygen in the waters. The Great Lakes mix vertically—or turn over—each spring and fall, when the near-surface water (warming in the spring and cooling in the fall) reaches 39° F (4° C), the temperature of maximum density for water. The turnovers bring oxygen from the surface to the deeper waters and resuspend nutrients previously trapped at the bottom of the lakes. But climate models predict that the surface water temperatures of deep lakes will stay above 39° F (4° C) in some years.[105] As a result, vertical mixing may occur only once a year.[106] Not only would this deplete oxygen in the lakes, altering their deep water chemistry,[107] but it would deprive phytoplankton and detritus-eating organisms of nutrients necessary for growth and survival. The entire food chain could be impacted.

Thus, global warming can be expected to reduce the oxygen content in the Great Lakes in several ways. Oxygen depletion will expand anoxic zones and lower the overall productivity of lakes.[108] And as we have seen during the recent history with Lake Erie, the consequences may be grim.

2. Case Study - Invasive **Phragmites**

Phragmites australis—or common reed—is a tall, reedy grass which can infest wetlands and marshy areas in the Great Lakes region (and

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98 GLEICK ET AL., *supra* note 49, at 53.
99 Lofgren et al., *supra* note 51, at 552.
100 MORTSCH ET AL., *supra* note 26, at 91.
101 *Id.*
102 *Id.*
103 ENVIRONMENTAL ATLAS, *supra* note 94, at 13-14.
104 MORTSCH ET AL., *supra* note 26, at 91.
105 Croley, *supra* note 38, at 68.
106 *Id.*
107 *Id.*
108 GLEICK ET AL., *supra* note 49, at 54.

elsewhere), often to the demise of native species. Residents of the Great Lakes are familiar with *Phragmites* as the tall, unsightly cane grass rings that surround receding lakes. While *Phragmites* appears to be indigenous to North America, an invasive genotype of the species (perhaps several) has been introduced to North America from Europe.[109] This European exotic, while physically indistinguishable from native *Phragmites*, is more vigorous than the North American variety and appears to be responsible for flushing other species out of their native environments in the Great Lakes region.[110]

Invasive *Phragmites* brings several detrimental effects in addition to adverse aesthetic impacts. First, it chokes out native species of plants and threatens the wildlife that depends on those plants.[111] At Long Point, *Phragmites* replaced typha (cattails), marsh meadow, sedge/grass hummock, and other mixed emergents.[112] Second, invasive species like *Phragmites* destroy wetland vegetation, thus diminishing the natural filtering capacity of shoreline wetlands. Third, *Phragmites* increases the potential for marsh fires during the winter when the reeds die and dry out.[113]

Phragmites spreads all the more quickly when water levels drop and temperatures rise.[114] Unfortunately for the inhabitants of the Great Lakes region, this is precisely what is predicted over the next century. Lake levels in the Great Lakes are expected to recede,[115] and stream runoff amounts will drop.[116] Temperatures will rise,[117] and *Phragmites* can be expected to thrive and expand throughout lower Great Lakes coastal wetlands.[118] *Phragmites* will blight the landscape, and the mounting loss of habitat and native species will add yet another stress to the fragile Great Lakes ecosystem.

3. Economic Impacts

Climate change will bring more than just environmental impacts to the Great Lakes. Many industries in the region will face new and significant economic challenges. Lower water levels restrict the access of commercial navigation throughout the lakes. Shippers will have to reduce the amount of cargo they carry and make more frequent trips to transport the same amount

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[109] Global Invasive Species Database, *Phragmites australis* (grass), http://www.issg.org/database/species/ecology.asp?si=301&fr=1&sts (last visited Apr. 13, 2008).
[110] Wilcox et al., *supra* note 86, at 664.
[111] Global Invasive Species Database, *supra* note 109.
[112] Wilcox et al., *supra* note 86, at 674.
[113] Global Invasive Species Database, *supra* note 109.
[114] Wilcox et al., *supra* note 86, at 675.
[115] GLEICK ET AL., *supra* note 49, at 58.
[116] MORTSCH ET AL., *supra* note 26, at 41.
[117] *Id.* at 34.
[118] *See* Wilcox et al., *supra* note 86, at 677-78 ("[I]f global warming predictions are realized and temperatures continue to increase, this may contribute to further *Phragmites* expansion on the Great Lakes.").

of cargo.[119] According to the U.S. Great Lakes Shipping Association, for every inch (2.5 cm) of lower lake levels, a cargo ship must reduce its load by 99 to 127 tons (90 to 115 metric tonnes).[120] Dredging, which can dislodge contaminated sediment creating health concerns, is not feasible everywhere and is an expensive alternative.[121] On the other hand, it should also be noted that the Great Lakes may be navigable for a longer season because of reduced ice cover. This can help lessen some of the negative impacts on the economy.

Tourism and recreation will also be severely impacted. Lower water levels will expose more shoreline, diminishing aesthetics and enjoyment of recreational property.[122] Winters with less ice on the Great Lakes increase coastal exposure to damage from storms.[123] Lower water levels also create the need for infrastructure investment in extending docks and dredging access.[124] Access to and safety of marinas could be significantly limited.[125] Further, water contact activities, such as swimming, will be severely limited by decreasing water quality.[126] In addition, changes in the habitats and ranges of fish, waterfowl, other birds, and mammals could have a negative impact on angling, hunting, and birdwatching.[127]

E. Water Shortages in Other Regions and the Threat of Great Lakes Diversions

In addition to the challenge of climate change impacts at home, the Great Lakes region must consider the potential water crises that climate change may bring to other regions. Climate change is expected to lead to reductions in water supply in most regions in the United States, including the southwest and west, many coastal areas, and the heavily groundwater-dependent interior of the country. These regions will face loss of water supplies from reduced snowpack, rising sea levels, and declining aquifers, respectively. The resulting water crises may lead to new threats of Great Lakes diversions to other parts of the country.

1. The American West in the Next Century: Even Hotter and Drier

The southwestern and western United States will become even more arid during the twenty-first century as the subtropical dry zone expands

119 MORTSCH ET AL., *supra* note 26, at 47.
120 *Water Levels in Great Lakes Hit New Low*, CBC NEWS, Jan. 4, 2002, http://www.cbc.ca/health/story/2002/01/04/great_lakes020104.html.
121 MORTSCH ET AL., *supra* note 26, at 47.
122 *Id.*
123 Field et al., *supra* note 78, at 623.
124 MORTSCH ET AL., *supra* note 26, at 47.
125 *Id.* at 73.
126 *Id.* at 74.
127 *Id.*

poleward.[128] Over the next 100 years, temperatures in the West are expected to rise 3.6º to 9º F (2º to 5º C) while precipitation amounts are not expected to change significantly.[129] This will occur because the added heat from global warming will have at least two effects: it will increase temperature and dry the atmosphere. Since warmer air has higher saturation humidity than cooler air, it can hold more moisture than cooler air.[130] In very wet areas (like over oceans) where there is adequate moisture, added heat is used up primarily by evaporation, so it moistens the air instead of warming it.[131] But in already dry areas like the western and southwestern U.S., there is little moisture to soften the impact of added heat. As a result, in these areas the added heat from global warming will go primarily to increasing temperature. Relative humidity will decrease and, with the increased saturation humidity, result in even less precipitation.[132]

In addition to the generally hotter and drier climate, the western and southwestern U.S. will be particularly impacted by reduced snowpack in the mountains. The loss of snowpack will drastically reduce the availability of water for California and the other Colorado River basin states (Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming). Historically, most precipitation in western North American mountains such as the Rockies and the Sierra Nevadas has fallen as snow during winter months.[133] Snow accumulates until spring and early summer, when warming temperatures melt the snowpack, releasing water as runoff.[134] In most river basins of the West, snow is the largest source of water storage (even greater than man-made reservoirs).[135] As a result, snowpack has been the primary source of water for arid western states during the spring and summer, when their water needs were greatest.

Snowpack losses will increase each year.[136] Under warmer climate conditions such as those expected during the next century, precipitation will be more likely to fall as rain than snow, especially in autumn and spring at the beginning and end of the snow season.[137] This trend is already observable. Scientists have demonstrated that April snowpack in western mountains has been declining over the long term.[138] Snowpack volume is

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[128] Richard Seager et al., *Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America*, 316 SCI. 1181, 1183 (2007).

[129] Philip W. Mote et al., *Declining Mountain Snowpack in Western North America,* 86 BULL. AMER. METEOR. SOC. 39, 48 (2005), *available at* http://ams.allenpress.com/archive/1520-0477/86/1/pdf/i1520-0477-86-1-39.pdf.

[130] Le Treut et al., *supra* note 21, at 105.

[131] *Id.*

[132] Seager et al., *supra* note 128, at 1183.

[133] Mote et al., *supra* note 129, at 39.

[134] *Id.*

[135] *Id.*

[136] *Id.* at 48.

[137] Le Treut et al., *supra* note 21, at 106.

[138] Mote et al., *supra* note 129, at 39.

measured by a metric called snow-water equivalent—the water volume if the snow were melted down. Snow-water equivalent has been dropping over much of the American West since 1925, and especially since 1950.[139] Between the period from 1945-1955 until the 1990s, April snow-water equivalent fell 15.8% in the Rockies, 21.6% in the Interior West, and 29.2% in the Cascades.[140]

As temperatures increase in the future, the snow season will shorten, beginning later and ending earlier.[141] Snowmelt runoff will begin earlier, reducing the availability of water during the summer months.[142] Under projected climate conditions, Colorado River runoff could be reduced by as much as 45% by mid-century.[143] Consequently, streamflows in the river would drop from the historical mean of 15 million acre-feet (maf), on which the legal governance of the river was founded, to 10 maf over the next twenty-five years, and to 7 maf from 2035 to 2060.[144] Thus, current water shortages will become more severe as demand outpaces supply.

This changing environment is already evident in California, especially at lower elevations.[145] During the twentieth century, April through July runoff in the Sacramento River decreased on average by 10%, indicating earlier melting of seasonal snowpack.[146] Flows in many western states are now arriving a week to three weeks earlier than they did in the middle of the twentieth century.[147] Streamflow peaks in snowmelt-dominated mountains in the western U.S. occurred one to four weeks earlier in 2002 than in 1948.[148] This change in timing is significant because it means that less water is available to meet the demands of competing water users when it is most needed, during historically drier parts of the year.

Reductions in snowpack volume will accelerate during the twenty-first century. In general, stream inflows to reservoirs will decline because of diminished snowpack and increased evaporation before mid-century.[149]

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139 *Id.* at 47.

140 *Id.* at 44.

141 MICHAEL KIPARSKY & PETER H. GLEICK, PAC. INST., CLIMATE CHANGE AND CALIFORNIA WATER RESOURCES 9 (July 2003), http://www.pacinst.org/reports/climate_change_and_california_water_resources. pdf.

142 Katharine Hayhoe et al., *Emissions Pathways, Climate Change, and Impacts on California*, 101 PROC. NAT. ACAD. SCI. 12422, 12425 (2004), *available at* http://www.fypower.org/pdf/NatAcadSciClimateChange.pdf.

143 Brad Udall, *Recent Research on the Effects of Climate Change on the Colorado River*, INTERMOUNTAIN W. CLIMATE SUMMARY, May 2007, at 1, 6 *available at* http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/articles/may_2007_feature_2.pdf.

144 *Id.* at 5.

145 Hayhoe et al., *supra* note 142, at 12425.

146 KIPARSKY & GLEICK, *supra* note 141, at 25.

147 MICHAEL DETTINGER, U.S. NAT'L STREAMFLOW INFO. PROGRAM, CHANGES IN STREAMFLOW TIMING IN THE WESTERN UNITED STATES IN RECENT DECADES (2005), *available at* http://pubs.usgs.gov/fs/ 2005/3018/.

148 Field et al., *supra* note 78, at 622.

149 Hayhoe et al., *supra* note 142, at 12425.

Agricultural, municipal, industrial, and ecological needs already compete for limited water resources in California, and thus any future reductions in overall water supply will impact the economy as a whole as well as the environment.[150] By the 2020's, 41% of the water supply to Southern California is expected to be in jeopardy due to the effects of reduced snowpack.[151] The California state government predicts that inflows to the entire state could be reduced by as much as 27% by 2050.[152] By 2069 snow cover in California may be almost completely depleted by the end of winter.[153] By the end of the twenty-first century, snow-water equivalent is expected to decrease by as much as 89% for the Sierra-Nevada region draining into the Sacramento-San Joaquin river system.[154]

California is heavily dependent on water stored in snowpack. Of California's population, 85% receives half of its water supply from rivers in the Central Valley, whose flow volumes are expected to decline significantly due in part to reduced snowpack.[155] This shrinking snowpack could result in average April to June reservoir inflow from the Sierra Nevadas of 3.4 maf (4.2 km^3), as compared with the 1961-1990 average of 7.4 maf (9.1 km^3), a 54% decline.[156] Climate models predict that droughts in the Sacramento River system will be longer, more frequent, and more severe during 2070–2099 than what was experienced in the twentieth century.[157] The proportion of years expected to be dry or critical could double by the end of the century.[158] The decline in water supplies, especially during spring and summer, will force California to look for other water sources.[159] Groundwater could offset some of the reduced streamflow supply, but it is already overdrafted in many California agricultural areas.[160]

The situation is similar in the rest of the western U.S. The Colorado River is the only significant water source for much of the southwestern U.S.[161] While important to southern California, it also supplies water to Wyoming, Colorado, Utah, New Mexico, Arizona, and Nevada.[162] Like the California communities that depend on stream flow from the Sierra Nevada Mountains, the Colorado River basin is vulnerable to impacts from reduced

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150 Martin Parry et al., *Technical Summary*, *in* CLIMATE CHANGE IMPACTS, *supra* note 78, at 67.

151 Field et al., *supra* note 78, at 633.

152 JOSUE MEDELLIN ET AL., CAL. CLIMATE CHANGE CTR., CLIMATE WARMING AND WATER SUPPLY MANAGEMENT IN CALIFORNIA 9 (2006), *available at* http://www.energy.ca.gov/2005publications/CEC-500-2005-195/CEC-500-2005-195-SF.PDF.

153 KIPARSKY & GLEICK, *supra* note 141, at 10.

154 Hayhoe et al., *supra* note 142, at 12425.

155 *Id.* at 12426.

156 *Id.* at 12423.

157 *Id.* at 12426.

158 *Id.*

159 *Id.*

160 Hayhoe et al., *supra* note 142, at 12426.

161 KIPARSKY & GLEICK, *supra* note 141, at 14.

162 *Id.*

snowpack.[163] Even more than the Sacramento-San Joaquin and the Columbia River basins, the Colorado River basin is sensitive to overall reductions in annual volume of inflow.[164] Scientists predict that precipitation volume in the Colorado River basin will remain stable during the next century while temperatures rise.[165] But as a result of reduced snowpack, streamflow in the Colorado River—and thus the water supply to Arizona, southern California, Colorado, Nevada, New Mexico, Utah, and Wyoming—is expected to decrease significantly in the twenty-first century.[166] Inflow could be reduced by as much as 45% by 2050.[167]

Reduced streamflow has other implications for the Colorado River basin. Reduced runoff into the basin will increase the salinity of the Colorado River.[168] The 1944 Colorado River Treaty requires the U.S. to take measures to keep salts out of the river.[169] But a decrease in runoff to the basin of only 5% would increase the salinity of the water such that it would violate the treaty.[170] The Colorado River basin may have to look elsewhere for water if it is to avoid shortages and reductions in water quality.

2. Less Water from the Ground in the Great Plains and Central Regions

The Great Plains and central U.S. regions, which are heavily dependent on groundwater, will also face reductions in water supply due to climate change. Aquifers must be recharged if they are to be used sustainably. Aquifer recharge is dependent on the timing and amount of precipitation, surface water interactions with the aquifer, and air temperature.[171] Changes in the timing of precipitation events, evaporation of surface waters, and increased air temperatures will result in aquifer recharge being impacted by global warming.[172] Rising temperatures increase evapotranspiration, reducing the contribution of lateral flow and percolations that contributes to groundwater recharge.[173] The reduced recharge, in turn, reduces aquifer productivity.

For example, the Edwards Aquifer in Texas is expected to have lower or ceased flows from springs, reducing the supply of available

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163 *Id.* at 15.

164 Niklas S. Christensen et al., *The Effects of Climate Change on the Hydrology and Water Resources of the Colorado River Basin*, 62 CLIMATIC CHANGE 337, 360 (2004), *available at* http://www.onthecolorado.com/Resources/ClimateDocs/Christensen2004.pdf.

165 Udall, *supra* note 143, at 6.

166 Christensen et al., *supra* note 164, at 361.

167 Udall, *supra* note 143, at 6.

168 GLEICK ET AL., *supra* note 49, at 55.

169 *Id.* at 57.

170 *Id.*

171 Field et al., *supra* note 78, at 629.

172 *Id.*

173 GLEICK ET AL., *supra* note 49, at 44.

water.[174] In the Ogallala Aquifer region (which includes portions of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming), groundwater recharge is expected to decrease by more than 20% with a 4.5° F (2.5° C) increase in temperature.[175] In the Ellensburg basin of the Columbia Plateau in Washington, aquifer recharge rates could decrease by as much as 25%.[176]

Regional groundwater storage volumes may be very sensitive to even modest changes in available recharge.[177] A study of an African basin concluded that a 15% reduction in rainfall would lead to a 45% reduction in groundwater recharge.[178] Further, water users have often looked to groundwater pumping when surface water supplies are diminished, which would compound problems of reduced aquifer recharge and storage.

3. Rising Sea Levels and Salt Water Intrusion in Coastal Areas

Relatively humid coastal areas will face their own challenges. Increasing salinity in freshwater supplies will become a bigger concern in coastal areas as temperatures rise. Rising sea levels are caused by thermal expansion of the oceans and increased melting of glaciers and the Greenland and Antarctic ice sheets. Water expands as it warms,[179] and the oceans are getting warmer. Oceans are absorbing more than 80% of the heat that is added to the climate system.[180] Increases in ocean temperature are observable down to depths of almost 10,000 ft (3000 m).[181] Further, air temperatures are rising as well,[182] and rising temperatures mean that glaciers and icecaps will melt faster.

Sea level is already rising worldwide. Mean sea levels have risen approximately 5 to 9 inches (12 to 22 cm) since the 1890s.[183] The rate of sea level rise is expected to increase in the future,[184] and global mean sea levels are expected to go up approximately almost 7 to 23 inches (18 to 59 cm) by 2100.[185] More recently available observations indicate that these projections might be conservative and global sea level could rise as much as 20 to 55

174 Field et al., *supra* note 78, at 629.

175 *Id.*

176 GLEICK ET AL., *supra* note 49, at 59.

177 *Id.* at 6.

178 *Id.* at 59.

179 Nathaniel L. Bindoff et al., *Observations: Oceanic Climate Change and Sea Level*, *in* CLIMATE CHANGE, *supra* note 6, at 409.

180 *Summary for Policymakers*, *supra* note 6, at 5.

181 Intergovernmental Panel on Climate Change, *Summary for Policymakers*, *in* CLIMATE CHANGE IMPACTS, *supra* note 78, at 5.

182 *Id.* at 13.

183 *Id.* at 7.

184 *Id.* at 3.

185 *Id.* at 13.

inches (50 to 140 cm) by 2100.[186] Rising sea levels push saltwater further inland in rivers, deltas, and coastal aquifers, causing saltwater intrusion on coastal freshwater supplies in many coastal states.[187]

Salinity problems in coastal areas are most acute during late summer and early fall. Water demand is high, and additional pumping from aquifers facilitates saltwater intrusion.[188] Releasing water from reservoirs can sometimes help keep saltwater out of aquifers (by reducing demand), but water availability to reservoirs is typically low in late summer and early fall.[189] Rising sea levels thus restrict the availability of freshwater and force water managers to look for other water supplies. In addition, the earlier snowmelt expected from warming temperatures will extend the drier summer season and create more opportunity for saltwater intrusion.[190]

Hotter and drier climates, loss of snowpack for water storage, declining groundwater supplies, rising sea levels, and salt water intrusion will create water shortages in many parts of the country. Some regions, such as coastal California, may be hit with all of these impacts simultaneously. Facing these water crises, it is increasingly likely that other regions will look to divert Great Lakes water. Massive diversion projects have been proposed before, but the availability of other water supplies and relative cost of such projects undermined their necessity and feasibility at the time.[191] That may change however, as climate change creates major water shortages across the country.

F. Increased Demand for Water in the Great Lakes and Nationally

As discussed in the above sections, climate change will have serious impacts on the Great Lakes and water resources in other regions. Compounding this problem are predictions for more demand for water unless new water policies are put into place. In the Great Lakes region, the International Joint Commission expects water demand for agriculture, which already consumes more water than any other sector, to increase.[192] The growing season is expected to extend in the future, and double cropping, the planting of a second crop after the first has been harvested, will become more common.[193] Irrigation in the Great Lakes region is applied as a supplement to natural rainfall, especially during short periods of drought,[194]

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186 Stephan Rahmstorf, *A Semi-Empirical Approach to Projecting Future Sea-Level Rise*, 315 SCI. 368, 368 (2007).

187 GLEICK ET AL., *supra* note 49, at 4.

188 KIPARSKY & GLEICK, *supra* note 141, at 19.

189 *Id.*

190 *Id.*

191 For an excellent and thorough discussion of Great Lakes diversions (both proposed and constructed), see PETER ANNIN, THE GREAT LAKES WATER WARS 57-190 (2006).

192 MORTSCH ET AL., *supra* note 26, at 66.

193 *Id.*

194 *Id.*

which are expected to increase under global warming conditions.[195] Projected demand for water in other sectors in the Great Lakes region (domestic, industrial, and energy generation) is less certain, and again depends significantly on whether water conservation policies and laws are adopted.

Population and economic growth in other regions, including those expected to be hit hardest by climate change impacts, will put even more demand on already stressed water resources. In California, for example, the state's population is expected to double or triple over the next century, which is likely to increase water use.[196] Regional growth in the Portland area is expected to increase water demand by 5.5 billion gallons (20.8 million cubic meters) per year by the 2040s.[197] The Colorado River Basin already has high demand relative to supply.[198] Under predicted climate change conditions, total system demands are expected to exceed system supply, bringing out substantial degradation of system performance.[199]

The potential for increased demand due to higher temperatures comes from all types of water use.[200] Domestic use, especially for outdoor purposes (such as yards and garden irrigation) is expected to rise with warming temperatures.[201] Industrial use may increase as well. Water is used for cooling on many electrical generating systems, and an increase in water temperature would decrease the cooling efficiency of the water and require more water to be used.[202] Similarly, demand for water will increase to compensate for loss of precipitation in many areas.[203]

The most significant water demand problems relate to irrigation. Irrigation accounts for 39% of all U.S. water withdrawals and 81% of consumptive water uses (unlike some other water withdrawals which return most of the water to the watershed, water withdrawn for irrigation is mostly consumed).[204] While it is difficult to forecast future irrigation needs, it appears that irrigation needs will increase substantially in regions where future drying is expected.[205] Where climate becomes more variable, regions will be subject to more frequent droughts and floods.[206] The frequency and severity of droughts is expected to increase in areas like the Southwest.[207] Even in other areas, higher rates of evaporation will tend to offset the

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195 *Id.* at 41.

196 *See generally* Hayhoe et. al., *supra* note 142 (explaining the impact of increased emissions in California on climate change).

197 Field et al., *supra* note 78, at 628.

198 Christensen et. al., *supra* note 164, at 339.

199 *Id.* at 360.

200 Field et al., *supra* note 78, at 619.

201 GLEICK ET. AL., *supra* note 49, at 81.

202 *Id.*

203 Field et al., *supra* note 78, at 631.

204 GLEICK ET AL., *supra* note 49, at 81.

205 *Id.* at 93.

206 *Id.* at 99.

207 *Id.* at 4.

benefits from periods of greater precipitation, while intensifying the impacts of periods of lesser precipitation.[208]

Climate change will have impacts on agriculture in addition to raising irrigation demands. Irrigation needs will be as much as 39% higher in Nebraska and 14% higher in Kansas, assuming no change in irrigated area.[209] But even with increased irrigation, crop yields can still be adversely affected by higher temperatures. In the corn and wheat belt of the U.S., yields of corn and soybeans from 1982 to 1998 were negatively impacted by warm temperatures, decreasing 17% for each 1.8° F (1° C) of warm temperature anomaly.[210] The reduced yields may spark efforts to increase acreage, thereby further increasing demand for water.

The predictions for increased water demand present a major challenge, but also an opportunity. Water conservation policies and laws can reverse these trends. Just as reducing climate change requires a national effort to invest in energy conservation and efficiency and in new energy technology and policy, adapting to climate change will require every sector of the economy to invest in water conservation and efficiency and new water management approaches. As discussed in the next part of this article, existing water laws and policies in the Great Lakes region do little to foster a culture of water conservation. However, by enacting and implementing new laws and policies, such as the Great Lakes Compact, the region can make itself a technological and economic leader in water conservation and efficiency and become an example for the rest of the country.

III. GREAT LAKES WATER RESOURCE POLICY FOR CLIMATE CHANGE

Meeting the challenge of climate change requires both policies to reduce greenhouse gas emissions that cause climate change and policies to adapt to the unavoidable climate change impacts on water resources. To avoid the worst impacts of global warming, the United States must reduce its greenhouse gas emissions by 80% by 2050 or about 2% per year. This is an attainable goal, and we already have many of the technologies and tools needed to accomplish it. At the same time, we need water resource policies to adapt to climate changes already underway. Key elements of a Great Lakes water resource policy for climate change include:

- Emphasizing water conservation as water becomes more scarce and valuable;
- Protecting aquatic habitat for fisheries and wildlife in changing conditions;

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208 Field et al., *supra* note 78, at 627.
209 Parry et al., *supra* note 150, at 59.
210 Field et al., *supra* note 78, at 624.

- Providing strong legal protections against diversions of Great Lakes water to other regions; and
- Creating regional governance institutions that can help adaptively manage water resources as new scientific information becomes available.

Unfortunately, Great Lakes water resource policies that predate the Great Lakes Compact intended to protect Great Lakes water resources from diversions (transfers of Great Lakes water outside of the basin) and overuse within the basin were not up to the new challenges posed by climate change. However, the recently enacted Great Lakes Compact gives the region an opportunity to make these improvements in water resource policy and better protect the Great Lakes from the pressures of climate change.

A. Great Lakes Water Resources Law and Policy

As detailed in the previous sections, climate change will put new and increased pressures on Great Lakes water resources. As other regions suffer from reduced water supplies and increased demands, they will increasingly look to divert Great Lakes water to solve their water resource needs. At the same time, climate change will directly impact the Great Lakes themselves and reduce available supplies of water within the region. This section examines Great Lakes water resource laws and policies intended to protect Great Lakes water resources from diversions and overuse.

For over one hundred years, federal and state governments have struggled with management of the Great Lakes. A vast resource shared by two countries, ten states and provinces, and hundreds of Indian tribes, First Nations, and local governments, the Great Lakes are a quintessential commons that has seen its share of tragedies. While the existing laws and policies have had some value, their adequacy during times of relative water abundance should provide little comfort for a future of water crises. Further, as detailed below, the Great Lakes water resource policies that predate the Great Lakes Compact have inherent limitations and shortcomings.

The Great Lakes have certainly received plenty of attention from policymakers, and their efforts have produced numerous laws and policies intended to protect the Great Lakes from diversions and overuse. However, the numerous international treaties, federal statutes, interstate compacts, handshake agreements, Supreme Court cases, inconsistent state laws, and patchwork of common law rules and local decisions had left the waters of the Great Lakes with few meaningful protections from diversions and overuse before the enactment of the Great Lakes Compact. Water conservation and resource protection was still not required of many water users. Prohibitions on diversions were vulnerable to legal challenges and political repeal. And while there were numerous regional governance mechanisms, none had the authority to fully provide comprehensive adaptive management of the Great Lakes from changing climate conditions.

1. The Boundary Waters Treaty of 1909

The Boundary Waters Treaty of 1909 between the United States and Canada has been in force for nearly a century.[211] As an international treaty it operates as "the Supreme Law of the Land" through the Supremacy Clause of the U.S. Constitution.[212] However, a review of the Boundary Waters Treaty's provisions and its role in managing Great Lakes water withdrawals and diversions shows that its international and historic status exceeds its actual value in Great Lakes water management.

The Boundary Waters Treaty provides for joint management and cooperation between the United States and Canada for the two countries' shared boundary waters. However, the first limitation of the Boundary Waters Treaty is evident from the scope of its coverage. "Boundary waters" are defined as:

> the waters from main shore to main shore of the lakes and rivers and connecting waterways . . . along which the international boundary between the United States and . . . Canada passes. [sic] including all bays, arms, and inlets thereof, but not including tributary waters which in their natural channels would flow into such lakes, rivers, and waterways, or waters flowing from such lakes, rivers, and waterways, or the waters of rivers flowing across the boundary.[213]

While four of the five Great Lakes (Superior, Huron, Erie, and Ontario) meet the definition of "boundary waters," Lake Michigan sits entirely within the United States' borders and is thus not considered a "boundary water" under the terms of the Boundary Waters Treaty. Further, the hundreds of tributary rivers and streams, as well as tributary groundwater, upon which the boundary Great Lakes depend are also excluded from coverage under the Boundary Waters Treaty.

Beyond the limited scope of coverage, the standard for protection provided by the Boundary Waters Treaty has little practical value. The respective parties may not use or divert boundary waters "affecting the natural level or flow of boundary waters on the other side of the [border]line" without the authority of the International Joint Commission,[214] an adjudicative body with equal United States and Canadian representation. The most significant problem with this standard relates directly to the size and scale of the Great Lakes. With their enormous volumes, it would take a

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211 Boundary Waters Treaty, U.S.-Gr. Brit., 36 Stat. 2448 (1909).

212 U.S. CONST. art. VI, cl. 2. "This Constitution, and the Laws of the United States which shall be made in Pursuance thereof; and all Treaties made, or which shall be made, under the Authority of the United States, shall be the supreme Law of the Land . . . ." *Id.*

213 Boundary Waters Treaty, preliminary art., 36 Stat. at 2448.

214 *Id.* art. III.

massive diversion to have any measurable effect on the levels or flow of the Great Lakes. For example, the Chicago diversion at its maximum (and subsequently prohibited) level of 8,500 cubic feet per second (cfs) (approximately 5.5 billion gallons per day) was found to have lowered water levels in Lakes Michigan and Huron by only six inches.[215] The vast majority of the water uses and diversions from the boundary Great Lakes themselves have no individual measurable effect on Great Lakes levels and flows (although they may very well have cumulative effects). Ironically, individual withdrawals and diversions from tributary rivers and streams often have a measurable effect on these waters, but these waters are not protected under this provision of the Boundary Waters Treaty.

Finally, while the International Joint Commission created by the Boundary Waters Treaty should be commended for its objectivity and leadership on environmental issues,[216] it is severely limited in its ultimate adjudicative power. For a dispute to be submitted to the International Joint Commission for a binding arbitral decision, a reference is required by both countries and specifically with the consent of the U.S. Senate.[217] As may be expected, the Senate has never consented to refer a matter for a binding decision in the history of the Boundary Waters Treaty. Further, Congress has never passed legislation implementing the Boundary Waters Treaty, so citizens cannot enforce its provisions in domestic court.

2. The 1986 Water Resources Development Act

While the U.S. Congress has never passed legislation to implement the Boundary Waters Treaty, it has provided a simple yet controversial statute intended to protect the Great Lakes from diversions within the United States. Section 1109 of the 1986 Water Resources Development Act, typically referred to as 1986 WRDA,[218] provides:

> No water shall be diverted or exported from any portion of the Great Lakes within the United States, or from any tributary within the United States of any of the Great Lakes, for use outside the Great Lakes basin unless such diversion

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215 Wisconsin v. Illinois, 278 U.S. 367, 407 (1929).

216 The IJC has been a valuable regional governance mechanism for studying the potential impacts of climate change and recommending adaptive measures. For example, in 2000, the IJC released an important report that considered how climate change will put additional pressure on Great Lakes water resources. *See* INT'L JOINT COMM'N, PROTECTION OF THE WATERS OF THE GREAT LAKES: FINAL REPORT TO THE GOVERNMENTS OF CANADA AND THE UNITED STATES (2000), http://www.ijc.org/php/publications/html/finalreport.html. More recently, the IJC released a detailed report that comprehensively reviewed potential impacts of climate change in the Great Lakes. *See* MORTSCH ET AL., *supra* note 26.

217 Boundary Waters Treaty, U.S.-Gr. Brit., art. X, 36 Stat. 2448 (1909).

218 Water Resources Development Act of 1986, Pub. L. No. 99-662, § 1109, 100 Stat. 4082 (1986) (codified as amended at 42 U.S.C. § 1962d-20 (2000)).

> or export is approved by the Governor of each of the Great Lake [sic] States.[219]

Thus, any of the Great Lakes governors can veto a proposed diversion of Great Lakes water out of the basin. The statute not only requires the unanimous approval of the governors for a proposed diversion, but further requires unanimous approval of the governors before any federal agency can even study the feasibility of a Great Lakes diversion.[220] While 1986 WRDA is remarkable as a clear statement of Congress' intent to leave decisions regarding Great Lakes diversions to the states, it suffers from numerous limitations and flaws that have undermined its value in terms of both protection and process.

The Act contains no standards to guide the governors in deciding to approve or deny a proposed diversion or diversion study. Nor does it provide any judicial remedy to challenge a governor's decision, even if the challenge is by another Great Lakes state. From a citizen's perspective, 1986 WRDA is fatally limited by its lack of a private right of action to enforce compliance.[221] It is also limited by its narrow scope of coverage. First, it only applies to diversions, not in-basin consumptive uses, essentially ignoring the other half of Great Lakes water management. Second, it might not apply to groundwater, which comprises over 15% of the total water supply in the Great Lakes basin.[222]

Congress has made clear that 1986 WRDA is not intended to be sole source of law to protect and manage Great Lakes water resources, and instead has encouraged the states to be more proactive and comprehensive in how they use their authority. Congress amended 1986 WRDA in 2000 to include the following provision:

> [T]o encourage the Great Lakes States, in consultation with the Provinces of Ontario and Quebec, to develop and implement a mechanism that provides a common conservation standard embodying the principles of water conservation and resource improvement for making decisions concerning the withdrawal and use of water from the Great Lakes Basin.[223]

As discussed below, the Great Lakes Compact is the result of a lengthy process that began, in part, with this Congressional encouragement.

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219 42 U.S.C. § 1962d-20(d) (2000).

220 *Id.* § 1962d-20(e).

221 *See, e.g.*, Little Traverse Bay Bands of Odawa Indians v. Great Spring Waters of Am., Inc., 203 F. Supp. 2d 853, 863-865 (W.D. Mich. 2002) (holding no explicit or implicit private cause of action under the Act).

222 N.G. GRANNEMANN ET AL., THE IMPORTANCE OF GROUND WATER IN THE GREAT LAKES REGION 00-4008 1 (2000), *available at* http://water.usgs.gov/ogw/pubs/WRI004008/WRIR_00-4008.pdf.

223 Water Resources Development Act of 2000, Pub. L. No. 106-541, § 504, 114 Stat. 2572, 2644 (codified as amended at 42 U.S.C. § 1962d-20(b)(2) (2000)).

There are also significant political pressures that may undermine and ultimately undo 1986 WRDA. It will be increasingly difficult for the Great Lakes states to keep their veto power over diversions. A recent study predicts that the Great Lakes states will lose a combined total of twenty-one seats in the U.S. House of Representatives by 2030.[224] With the Great Lakes states losing their relative power in Congress to the same regions that may be seeking Great Lakes diversions, 1986 WRDA is a risky bet for long-term protection.

3. Original Great Lakes Basin Compact

The original Great Lakes Basin Compact[225] (not to be confused with the Great Lakes Compact that was recently enacted) includes each of the eight Great Lakes states as members and creates a Great Lakes Commission comprised of representatives from the member states.[226] However, the functions of the Great Lakes Basin Compact and its Great Lakes Commission are limited to gathering data and making non-binding recommendations regarding research and cooperative programs. Its functions are purely advisory, and it does not and cannot provide any legal protections against diversions or overuse of Great Lakes water. While it can help provide information about climate change impacts and adaptive strategies, it lacks the authority to turn recommendations into actions.

4. The Great Lakes Charter of 1985 and Annex 2001

In 1985, the Great Lakes states and provinces signed the Great Lakes Charter.[227] While only a good faith agreement, the Great Lakes Charter contains individual commitments and a cooperative process for Great Lakes water management that would be tremendously valuable if fully implemented. However, handshake agreements such as the Great Lakes Charter are not sanctioned by the Constitution, and thus these informal agreements have limited legal value.

The Great Lakes Charter has three key components integrated throughout the agreement: (1) the commitment of the states and provinces to manage and regulate new or increased consumptive uses or diversions of Great Lakes water greater than 2,000,000 gallons per day ("gpd"); (2) the prior notice and consultation procedure with all of the states and provinces for new or increased consumptive uses or diversions of Great Lakes water greater than 5,000,000 gpd; and (3) the commitment of the states and

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[224] Jonathan Tilove, *Sun Belt Needs More Notches*, ANN ARBOR NEWS, May 27, 2005, at A3.

[225] Great Lakes Basin Compact, Pub. L. No. 90-419, 82 Stat. 414, 414 (1968).

[226] *Id.* at 414-16.

[227] COUNCIL OF GREAT LAKES GOVERNORS, THE GREAT LAKES CHARTER 1 (1985), http://www.cglg.org/projects/water/docs/GreatLakesCharter.pdf.

provinces to gather and report comparable information on all new or increased withdrawals of Great Lakes water greater than 100,000 gpd.[228] If the Great Lakes Charter's terms were incorporated into a binding and enforceable compact, it would have been an important first step toward comprehensive water management of the Great Lakes. Without the legal authority of a binding compact, the Great Lakes Charter's terms will remain voluntary.

In 2001, the Great Lakes governors and premiers signed an Annex to the Great Lakes Charter, commonly referred to as Annex 2001.[229] Annex 2001 reaffirmed the commitments of the 1985 Great Lakes Charter and set forth a new commitment to develop an "enhanced water management system" that will incorporate several notable new principles.[230] Among these new principles is the concept of return flow—requiring diverted water to be returned to its source watershed. Also newly added is the establishment of water conservation as a goal and management approach. Further, Annex 2001 recognized that comprehensive water management requires protection of all water-dependent natural resources in the basin, not just the Great Lakes themselves. Most controversially, it introduced the concept of "resource improvement" to ensure that all new diversions and withdrawals incorporate measures to improve the Great Lakes ecosystem. As a voluntary agreement, just like the Charter of which it is a part, Annex 2001 itself has no binding legal effect. Rather, Annex 2001 is a promise by the states and provinces to develop binding agreements, such as the Great Lakes Compact.

5. *Protecting the Great Lakes from Diversions through Supreme Court Litigation*

Litigation always looms as an option for a state to use to challenge the diversion or allocation of interstate water resources by another state. The U.S. Supreme Court has original jurisdiction to hear these cases.[231] While most cases have arisen in the arid West, the largest existing diversion from the Great Lakes—the Chicago diversion—was limited but ultimately allowed by the U.S. Supreme Court.[232] Relying on Supreme Court litigation to protect

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228 *Id.* at 6, 8.

229 *Id.* at 230.

230 *Id.* at 3.

231 U.S. CONST. art. III, § 2, cl. 2.

232 *See* Wisconsin v. Illinois, 449 U.S. 48, 48-49 (1980) (allowing the diversion of water from Lake Michigan under certain restrictions by the State of Illinois); *see also* Wisconsin v. Illinois, 388 U.S. 426, 430 (1967) (enlarging and superseding previous decrees regulating Illinois water use from Lake Michigan); Wisconsin v. Illinois, 289 U.S. 395, 412 (1933) (enlarging decree); Wisconsin v. Illinois, 281 U.S. 696, 696-97 (1930) (entering decree for reduction in water use by Illinois from the Great Lakes); Wisconsin v. Illinois, 281 U.S. 179, 201 (1930) (requiring the court to enter a decree for a reduction in water use by Illinois from the Great Lakes from the current date through December 31, 1938); Wisconsin v.

regional water resources is a risky proposition. The Supreme Court has not developed a uniform approach to interstate water allocation, instead resolving individual disputes with heavy reliance on the specific facts and circumstances. This approach has been termed equitable apportionment, and it generally favors states looking to utilize, rather than conserve, water resources.[233]

6. State Common Law and Statutory Law

Neither the common law rules nor the varying statutory schemes adopted by the Great Lakes states are adequate to protect against the pressures of climate change. All of the Great Lakes states follow the common law of riparian rights for surface water use. Riparian law is premised on the principle that all riparians have correlative rights in shared water bodies.[234] Conflicts regarding these rights are adjudicated according to the concept of reasonable use,[235] as opposed to capture or prior appropriation (as has been traditional in the western states). However, the historical abundance of surface water in the Great Lakes region has produced relatively few conflicts and controversies over surface water allocation and use. As a result, riparian law does not provide much certainty for water resource protection. According to Professor Dan Tarlock, one of the leading authorities on water law, "the common law of water allocation [in the Great Lakes] consists of fragmented decisions and statements of general principles that yield little guidance to concrete controversies."[236]

Historically, groundwaters and surface waters in the Great Lakes states were subject to different rights and rules for allocation. However, over time the Great Lakes states have moved towards correlative rights in groundwater, essentially applying riparian reasonable use rules. For example, in *Michigan Citizens for Water Conservation v. Nestlé Waters North America Inc.*, the Michigan Court of Appeals applied a correlative rights balancing test for the competing surface water rights of riparians and ground water rights of a water bottling company.[237] Similarly, in *McNamara v. City of Rittman*, the Ohio Supreme Court recognized that property owners have shared correlative rights in the groundwater under their property, and when government unreasonably causes wells to go dry, it can give rise to a takings claim.[238]

Illinois, 278 U.S. 367, 420-21 (1929) (requiring Illinois to reduce diversion of water from Lake Michigan and remanding to determine the measures needed to effect the goal).

[233] Colorado v. New Mexico, 467 U.S. 310, 315-16 (1984).

[234] State v. Zawistowski, 290 N.W.2d 303, 309 (Wis. 1980).

[235] State v. Apfelbacher, 167 N.W. 244, 245 (Wis. 1918).

[236] A. Dan Tarlock, *Inter and Intrastate Usage of Great Lakes Waters: A Legal Overview*, 18 CASE W. RES. J. INT'L L. 67, 68 (1986).

[237] Mich. Citizens for Water Conservation v. Nestlé Waters N. Am. Inc.,709 N.W.2d 174, 201-02 (Mich. Ct. App. 2005).

[238] McNamara v. City of Rittman, 838 N.E.2d 640, 646 (Ohio 2005).

Theoretically, the common law of riparian reasonable use and correlative rights would provide a viable legal framework for managing scarce water supplies under stress of climate change. The common law balances competing rights in light of the available water supply, requiring judges to make fact-specific determinations on the evidence presented. However, in practice, common law water disputes are terribly inefficient and ineffective for managing water resources. The cases take many years to be resolved, provide little certainty as to how competing interests are to be weighed, and are necessarily limited to the named parties before the court (ignoring the many other water uses in a given watershed). As water becomes more scarce and disputes become more common, an administrative water management system becomes necessary. Most importantly, under an administrative system, water use decisions can be made proactively based on science, thus reducing the need for reactive decisions based on the facts affecting only the specific parties to the dispute.

For these reasons, every Great Lakes state has implemented some form of an administrative water use system by statute. While a few states had statutory authority regarding water use before the Great Lakes Charter in 1985, the commitments made in the Great Lakes Charter have prompted most states to take some steps toward regulating Great Lakes water withdrawals. Minnesota has the most comprehensive water management and regulatory system in the region, requiring permits for use of any public waters (ground or surface) within the state.[239] Michigan, the only state located entirely within the Great Lakes basin, has a statute prohibiting Great Lakes diversions and managing other large water withdrawals based on principles similar to those contained in the Great Lakes Compact (discussed below).[240] The scope and standards of the Great Lakes states' water management laws vary greatly, resulting in much inconsistency and little certainty in water resource protection. Thus, while these individual state statutes are important, collective state action is necessary to comprehensively manage a shared water resource such as the Great Lakes.

B. The Great Lakes-St. Lawrence River Basin Water Resource Compact

This section describes the Great Lakes Compact and how it offers some needed policy improvements for adapting to climate change impacts on the Great Lakes. Under the Great Lakes Compact, the world's largest freshwater resource is now protected and managed pursuant to a common baseline set of standards administered primarily under the authority of individual states and provinces. The Great Lakes Compact puts much needed water conservation and resource protection rules into a proactive public law regime. Further, the Great Lakes Compact puts these policy solutions into a

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239 *See* MINN. STAT. § 103G.271 (2006).

240 *See* MICH. COMP. LAWS ANN. §§ 324.32723 *et seq.* (2008).

durable, legally-enforceable regime that would have force under both state and federal law. Finally, the Great Lakes Compact provides a regional governance institution that can help adaptively manage water resources as new scientific information regarding climate change impacts becomes available.

1. The Decision Making Standard: Water Conservation and Resource Protection

To adapt to the stress of climate change, water resource policy must emphasize water conservation and protect fisheries and wildlife habitat in changing conditions. These elements are at the core of the Great Lakes Compact's "decision making standard" for new or increased water withdrawals of Great Lakes basin water.[241] The applicability of these standards is not limited to water taken directly from one of the Great Lakes. Rather, the compact broadly defines the waters of the Great Lakes to include all tributary surface and ground waters.[242] Just this initial recognition of connected groundwater and surface water as a single resource to be managed uniformly is a long overdue advance in water law. Addressing both ground and surface water is also critical to the eventual success of any Great Lakes water policy, since groundwater comprises over 15% of the total water supply in the Great Lakes basin.[243]

While the decision making standard applies broadly to all waters, it primarily applies to new or increased withdrawals of water.[244] Existing uses are not grandfathered or protected by the compact; individual jurisdictions are simply free to regulate (or not regulate) existing uses as they see fit. The compact does require registration and reporting for all withdrawals (existing and new or increased) over 100,000 gpd, averaged over any thirty-day period,[245] which may facilitate management of existing water withdrawals in the future. Further, while existing withdrawals are not regulated under the compact, states are required to implement "a voluntary or mandatory" water conservation program with state-specific goals and objectives for all water users, including existing users.[246]

The decision making standard contains the following criteria for new or increased water withdrawals:

1) All Water Withdrawn shall be returned, either naturally or after use, to the Source Watershed less an allowance for Consumptive Use;

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[241] Great Lakes Compact, *supra* note 4, § 4.11.
[242] *Id.* § 1.2 (defining "Waters of the Basin or Basin Water").
[243] GRANNEMANN ET AL., *supra* note 222.
[244] Great Lakes Compact, *supra* note 4, § 4.10(1).
[245] *Id.* § 4.1(3).
[246] *Id.* §§ 4.2(2), (5).

2) The Withdrawal . . . will be implemented so as to ensure that [it] will result in no significant individual or cumulative adverse impacts to the quantity or quality of the Waters and Water Dependent Natural Resources [of the Great Lakes Basin] and the applicable Source Watershed;
3) The Withdrawal . . . will be implemented so as to incorporate Environmentally Sound and Economically Feasible Water Conservation Measures;
4) The Withdrawal . . . will be implemented so as to ensure that it is in compliance with all applicable municipal, State and federal laws as well as regional interstate and international agreements, including the Boundary Waters Treaty of 1909;
5) The proposed use is reasonable, based upon a consideration of the following factors:
    a. Whether the proposed Withdrawal . . . is planned in a fashion that provides for efficient use of the water, and will avoid or minimize the waste of Water;
    b. If the Proposal is for an increased Withdrawal . . . whether efficient use is made of existing supplies;
    c. The balance between economic development, social development and environmental protection of the proposed Withdrawal and use and other existing or planned withdrawals and water uses sharing the water source;
    d. The supply potential of the water source, considering quantity, quality, and reliability and safe yield of hydrologically interconnected water sources;
    e. The probable degree and duration of any adverse impacts caused or expected to be caused by the proposed Withdrawal and use under foreseeable conditions, to other lawful consumptive or non-consumptive uses of water or to the quantity or quality of the Waters and Water Dependent Natural Resources of the Basin, and the proposed plans and arrangements for avoiding or mitigation of such impacts; and
    f. If a Proposal includes restoration of hydrologic conditions and functions of the Source Watershed, the Party [i.e. state] may consider that.[247]

Water conservation and resource protection underlie almost every one of the Great Lakes Compact's decision-making criteria, from requiring efficient use of water and return flow to source watersheds, to preventing resource impacts and restoring hydrologic conditions. While the criteria are a significant advance in water resource policy, they have discernable roots in

[247] Great Lakes Compact, *supra* note 4, § 4.11.

the "background principles" of common law riparian rules and the doctrine of reasonable use. This gives the Great Lakes states a solid defense against potential takings claims relating to the enforcement of the compact standards.[248]

Despite the Great Lakes Compact's generally limited focus on managing and regulating only new or increased water uses, even existing uses may need to consider new water conservation techniques under criterion (5)(b).[249] If applied strictly, a community could not obtain approval for an increase in its water withdrawal to meet the needs of a growing population without first implementing conservation measures for its existing uses. Similarly, a manufacturer or irrigator that wishes to expand and increase its water use must first take measures to reasonably reduce its current water use through conservation practices. Through this criterion, the compact could force efficiency improvements and water conservation on many existing users as they expand, encouraging a "hard look" at existing water use practices and methods.

The compact makes clear that the decision-making standard is only a minimum for the states, and they may impose more restrictive standards for water withdrawals under their individual authority.[250] Some jurisdictions (such as Michigan) already have permitting standards in place. Other states may wish to later strengthen their compact-compliant programs above the minimum standards. The compact does not affect states' ability to provide such protections or take innovative approaches to adapting to the stress of climate change.

The Great Lakes Compact's decision-making standard is a major evolution in eastern water law. Water conservation and resource protection—key elements of a water resource policy for a changing climate—are required of all major new water withdrawals. Even some existing water uses will be required to consider using water conservation and more efficient use of water to meet their needs before simply pumping more water.

2. Prohibiting Great Lakes Diversions

The Great Lakes Compact has a general prohibition on new or increased diversions of Great Lakes water.[251] Diversions are defined to include both the transfer of Great Lakes basin water into another watershed (interbasin diversion) as well as diversions from one Great Lake watershed into another Great Lake watershed (intrabasin diversion).[252] However, although the compact includes intrabasin transfers in its introductory definition of diversions, it also contains a provision which expressly *excludes*

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[248] *See* Lucas v. S.C. Coastal Council, 505 U.S. 1003, 1029 (1992).
[249] Great Lakes Compact, *supra* note 4, § 4.11(5)(b).
[250] *Id.* § 4.12(1).
[251] Great Lakes Compact, *supra* note 4, § 4.8.
[252] *Id.* § 1.2 (defining "Diversion").

intrabasin transfers (as well as two other categories of transfers) from the general prohibition on diversions of Great Lakes water. While not subject to the prohibition on diversions, intrabasin transfers are subject to the "exception standard" (which is similar to the decision-making standard described above) and varying state approvals and additional requirements based on the amount of the withdrawal and consumptive use.[253]

The standard for the limited exceptions to the prohibition on diversions is substantively similar to the decision-making standard. However, instead of requiring a multi-factor reasonable use determination, the exception standard requires that both "[t]he need for all or part of the proposed Exception cannot be reasonably avoided through the efficient use and conservation of existing water supplies" and that "[t]he Exception will be limited to quantities that are considered reasonable for the purposes for which it is proposed."[254]

The other two exceptions to the prohibition on diversions involve communities and counties that straddle the surface water basin divide. The compact addresses this contentious issue by bringing straddling communities and counties that use Great Lakes surface water for public water supply purposes into the management regime. A straddling community (defined as an incorporated city or town whose boundary lies partly within the basin)[255] that proposes to use Great Lakes water for public water supply purposes outside of the surface water basin is treated similarly to an in-basin withdrawal—subject to state regulation—but pursuant to the exception standard rather than the in-basin decision-making standard.[256] In addition, such proposed uses that result in a new or increased consumptive use of five million gpd or greater are subject to non-binding regional review.[257] To prevent exploitation of this exception by growing incorporated cities and towns through mergers and annexations, the compact limits the defined straddling community to the boundaries existing as of the effective date of the compact.[258]

A proposal for a diversion in a straddling county, which encompasses a far greater area than a "community," is subject to additional standards and regional approval. First, the water can only be used for the public water supply purposes of a community that is without "adequate supplies of potable water."[259] Second, the proposal is subject to an additional "cautionary" standard, requiring a showing that the proposal "will not endanger the integrity of the Basin Ecosystem."[260] Finally, the proposal is

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[253] *Id.* § 4.9(2).
[254] *Id.* § 4.9(4).
[255] *Id.* § 1.2 (defining "Straddling Community").
[256] *Id.* § 4.9(1).
[257] Great Lakes Compact, *supra* note 4, § 4.9(1)(c).
[258] *Id.* § 1.2 (defining "Straddling Community").
[259] *Id.* § 4.9(3)(a).
[260] *Id.* § 4.9(3)(e).

subject to both non-binding regional review and the unanimous approval of the Compact Council.[261]

Like almost any environmental public policy, the compact makes some compromises and avoids some difficult political decisions. For example, the compact leaves the politically contentious issue of bottled water to the individual states, not subjecting bottled water to the limitations on new or increased diversions.[262] Similarly, the uncertainty regarding groundwater basin boundaries in the region is left unresolved in the compact, which circularly defines the "Waters of the Basin or Basin Water" to include "tributary groundwater[] within the Basin" and defines the "Basin or Great Lakes [] Basin" as "the watershed of the Great Lakes."[263]

Even with the exceptions and other compromises, the Great Lakes Compact provides a clear prohibition on most diversions in a legally-enforceable policy. Any aggrieved person can commence a civil enforcement action in the relevant state court against a water user that has failed to obtain a required permit or is violating the prohibition on diversions.[264] Similarly, any person can challenge a state action under the compact (such as issuance of a permit) pursuant to state administrative law, with an express right of judicial review in state court.[265] These provisions are fairly standard under state environmental and administrative law, and provide an important check against arbitrary decisions that ignore available scientific evidence.

3. Regional Governance to Adaptively Manage Great Lakes Water Resources

The stress and uncertainty of climate change requires regional governance institutions to adaptively manage Great Lakes water resources as conditions change and new information becomes available. The Great Lakes Compact creates a Compact Council comprised of the governors of each party state (or their designated alternates).[266] The Compact Council can promulgate and enforce rules to implement its duties under the compact,[267] a critically important authority that may need to be exercised to adapt to climate change. The Compact Council also has authority to plan, conduct research, prepare reports on water use, and forecast water levels[268]—again, critically important functions to ensure the best science is used in managing the Great Lakes.

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[261] *Id.* § 4.9(3)(f)-(g).

[262] *Id.* § 4.12(10).

[263] Great Lakes Compact, *supra* note 4, § 1.2 (defining "Basin or Great Lakes—St. Lawrence River Basin" and "Waters of the Basin or Basin Water").

[264] *Id.* § 7.3(3).

[265] *Id.* § 7.3(1).

[266] *Id.* §§ 2.1-2.3

[267] *Id.* § 3.3(1).

[268] *Id.* § 3.2.

While the individual states have the primary authority to implement the compact's decision-making standard for water users in their jurisdiction, the states must make periodic reports to the Compact Council regarding their implementation.[269] The Compact Council must then review the state programs and make findings regarding their adequacy and compliance with the compact.[270] Similarly, the individual states must work in cooperation with the Compact Council to develop and promote water conservation programs within two years of the effective date of the compact.[271] These programs are designed to promote water conservation measures such as "[d]emand-side and supply-side [m]easures or incentives."[272]

Finally, the Compact Council will have the benefit of comprehensive water use data collected by the individual states.[273] The states are required to develop and maintain a water resources inventory with information regarding both available water resources and water withdrawals within the state.[274] As part of this requirement, all water users (both existing and new) making water withdrawals greater than 100,000 gpd (averaged over any ninety-day period) must register with their state and report the details of their water use.[275] The information gathered by the individual states will create a regional common base of data for interstate information exchange.[276] This information is critical to protect the Great Lakes from cumulative impacts of water withdrawals as climate change puts new stresses on the region.[277]

The Great Lakes are an international resource shared with Canada, and state-provincial cooperation has been a regional goal for decades, implicitly promised by the Great Lakes Charter and the 2001 Annex to the Great Lakes Charter and expressly encouraged by Congress in its 2000 amendments to 1986 WRDA.[278] However, the inclusion of the Canadian provinces in the compact could bring political and legal challenges. In an attempt to meet the goal of state-provincial cooperation without running afoul of constitutional treaty limitations, the Council of Great Lakes Governors enacted a companion non-binding good faith agreement that includes the provinces of Ontario and Quebec, the Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement.[279] This dual structure creates a legally and politically acceptable mechanism for cooperation with Canadian provinces. A "Regional Body" comprised of representatives from

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269 Great Lakes Compact, *supra* note 4, § 3.4(1).
270 *Id.* § 3.4(2).
271 *Id.* §§ 4.2(2),(4).
272 *Id.* § 4.2(4)(d).
273 *Id.* § 4.1(2)
274 *Id.* § 4.1(1).
275 Great Lakes Compact, *supra* note 4, § 4.1(3).
276 *Id.* § 4.1(2).
277 *Id.* § 4.1(6).
278 Water Resources Development Act of 1986, Pub. L. No. 106-541, § 504, 114 Stat. 2572, 2644–45 (codified as amended at 42 U.S.C. § 1962d-20(b)(2) (2000)).
279 Great Lakes Compact, *supra* note 4, §1.2 (defining "Agreement").

both states and provinces[280] provides a non-binding regional review of "regionally significant or potentially precedent setting" proposals and the exceptions to the prohibition on diversions discussed above.[281] Thus, the Regional Review process avoids infringing on federal treaty powers, but still gives the provinces an evaluative and procedural role that may prove useful for affecting major decisions. Through this process, the best available scientific information can be used in Great Lakes water management, regardless of whether the information comes from Canadian provinces or American states.

The Great Lakes Compact provides the region with an opportunity to significantly improve water policy for adapting to climate change. It brings much needed requirements for water conservation and resource protection, as climate change makes water more valuable and threatens the health of fisheries and wildlife habitat. Climate change will almost certainly create water shortages in other regions, and the compact provides a legally durable and enforceable ban on diversions to other parts of the country. Finally, the compact creates a regional governance mechanism empowered to adaptively manage Great Lakes water resources as new scientific information becomes available and assist the Great Lakes states in their efforts to manage individual water withdrawals with the best available information.

IV. CONCLUSION

Climate change is certain to put additional stress on freshwater resources in the United States. In the Great Lakes region, climate change may lead to lower lake levels, impacts on fisheries and wildlife, changes in Great Lakes shorelines, and reduction of groundwater supplies. Climate change will also create severe water shortages in other parts of the country, potentially raising new pressures to divert Great Lakes water to other regions. As the Great Lakes and other regions struggle with loss of water supplies, demand for water is expected to increase unless water conservation laws and policies are adopted.

Responding to climate change requires both mitigating greenhouse gas emissions and adapting to changing conditions. For water resource policy in the Great Lakes region, this means investing in water conservation as water becomes increasingly scarce and valuable; protecting aquatic habitat for fisheries and wildlife in changing conditions; providing strong legal protections against diversions of Great Lakes water to other regions; and creating regional governance institutions that can help adaptively manage water resources as new scientific information becomes available. While prior laws and policies were not adequate to protect the Great Lakes from diversions and overuse, the Great Lakes Compact offers a significant

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[280] *Id.* § 1.2 (defining "Regional Body").
[281] *Id.* §§ 4.5(1)(f), 4.5(1)(c).

improvement by providing new water conservation and resource protection standards, a legally durable and enforceable ban on diversions, and a regional governance mechanism with the authority to adaptively manage the Great Lakes based on the best available science.