The Great Lakes are filled to their brims, with no signs of receding

David Kramer

Citation: Physics Today **73**, 10, 26 (2020); doi: 10.1063/PT.3.4589
View online: https://doi.org/10.1063/PT.3.4589
View Table of Contents: https://physicstoday.scitation.org/toc/pto/73/10
Published by the American Institute of Physics

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Experts see the fingerprints of climate change on the lakes' record high water levels.

US ARMY CORPS OF ENGINEERS

EROSION CAUSED BY HIGH WATER LEVELS has eaten away bluffs and beaches along the eastern shore of Lake Michigan.

Seven years ago, Ron Wilson's son was married on the beach in front of his cottage on the eastern shore of Lake Michigan. Were the couple to renew their vows today in the same spot, they'd be standing in nearly two meters of water. The 18-meter-wide beach has vanished, and the lake is now lapping at a steel seawall Wilson erected last winter to keep storms away from his foundation.

A few miles down the shore, Senator Debbie Stabenow (D-MI) is also losing ground to the water. Her property is on a bluff, so seawalls or other shoreline defenses to prevent further cave-ins must be installed either from a barge or after a path is cut for heavy equipment to gain access. Either will make the cost enormously higher than the $3000 per meter that Wilson says he had to pay for the work he had done. "It's pretty scary and pretty horrifying, and I wish there were an easy solution," Stabenow told an August virtual meeting of the Great Lakes Coalition, a nonprofit association of shoreline property owners. Wilson is the coalition's president.

Water levels have always fluctuated on the Great Lakes, but the recent extreme seesawing, particularly on the upper lakes—Superior, Michigan, and Huron—is unprecedented in the century that records have been kept (see charts). Michigan and Huron, which are linked and share the same level, stood at record highs in August, 84 cm above their historic average. The two lakes bottomed out at record lows in 2013. Although a relatively modest 25 cm above average, Superior in 2020 was just 5 cm below its record peak for August set a year ago.

Along all the Great Lakes, storm-driven waters are eroding public beaches, washing away sand dunes and bluffs, and damaging roads and other infrastructure. Michigan agencies estimate that shoreline repairs in cities and public parks will cost up to $250 million. In Detroit, pumps first have to push out water entering Detroit River outfalls before they can move stormwater from drains.

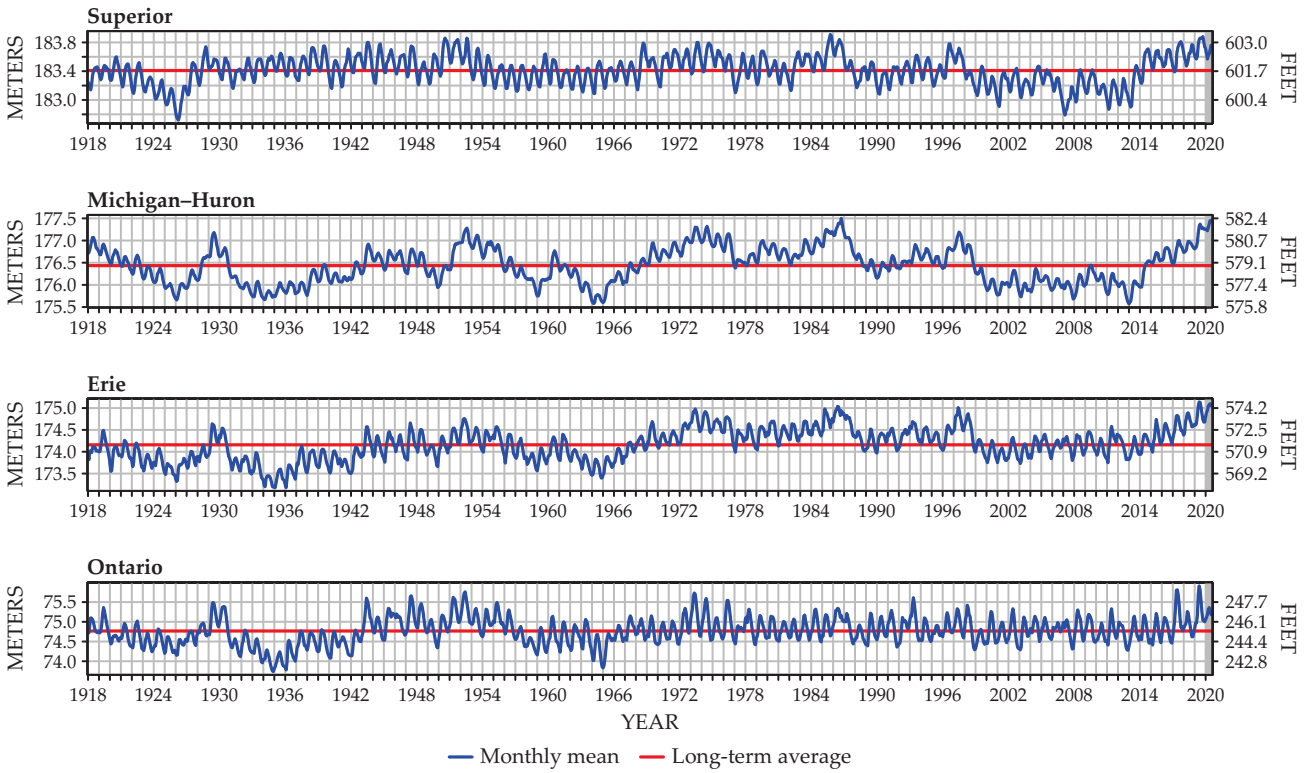
The Great Lakes system holds 21% of the world's surface fresh water, enough to cover the continental US to a depth of 3 m. Lake levels fluctuate according to changes in the balance between rainfall, snowmelt, and runoff in the watershed on the one hand, and evaporation and outflows on the other. Outflows from the five lakes are more or less constant. Evaporation, though, varies widely in response to air and surface water temperatures, and a good deal of the water vapor returns to the lakes as rainfall and lake-effect snows. Due to their vast volumes, the lakes cool slowly through the fall, when evaporation increases into the cooler, drier air. Ice cover, which varies from year to year, curbs evaporation during the cold months.

Signs of climate change

The past 10 years have been the wettest on record for the Great Lakes watershed. Andrew Gronewold, associate professor for environment and sustainability at the University of Michigan, says the rainy years began well before the 2013 ebb in the upper lakes. An extended period of excess evaporation that started in 1998 more than offset the added precipitation until the polar vortex event in early 2014 caused most of the lakes to freeze over. Since then, water supply has exceeded evaporation, partly because of several especially cold winters, Gronewold says. He adds that the 2014–17 period saw the fastest three-year increase in water levels since record-keeping began.

Donald Wuebbles, professor of atmospheric science at the University of Illinois at Urbana-Champaign, says precipitation over the watershed has risen 10% over the past century and is expected to grow another 10% over the next. Precipitation in the Great Lakes region is increasingly occurring in larger events, researchers say. As a result, more rainfall runs off into streams and rivers feeding the lakes instead of being absorbed in soils. The lakes themselves make up a major portion of the watershed.

"The rate at which precipitation has changed over the past decade simply cannot be explained by historical variability alone," says Gronewold. "The best



WATER LEVELS ON THE GREAT LAKES have fluctuated irregularly over the past century. The peaks and troughs on Lakes Michigan and Huron have been especially pronounced. From a record low in 2013, they have surged to record highs this year. (US Army Corps of Engineers.)

explanation is a warming atmosphere and warming global temperature." Deborah Lee, director of NOAA's Great Lakes Environmental Research Laboratory, notes the impact of warming oceans and changing circulation patterns. She and her colleagues have identified correlations between lake levels and the Pacific Decadal Oscillation, the North Atlantic Oscillation, and the Arctic Oscillation.

The rapidly warming Arctic has caused the polar jet stream to meander more than usual, bringing down frigid air to the lakes. But Wuebbles says the jet stream is expected to lose its influence in the coming decades as the difference narrows between Arctic and midlatitude temperatures.

Other regional factors could also be contributing to the fluctuations. Gronewold and others have theorized that during the 15 years of high evaporation, a feedback mechanism developed in which clouds dissipated over the lakes to an unusual extent and allowed more solar heating of the lakes. That mechanism may have led to the 2013 lows. He's unsure if an opposite feedback loop has been involved in the current highs.

The lakes' surface temperatures have been higher than normal this summer, which should intensify evaporation. But Gronewold cautions not to read too much into news reports of record high temperatures in some places. "There is a lot of variability in response to wind and circulation with the subsurface, but the question is, What's the heat content of the lake? How does the temperature stratify as you go down? That's the kind of heat that would carry over into the fall."

Managing lake levels

Over the decades, human-made diversions have affected lake levels to varying degrees. Wilson advocates changing those interventions to mitigate the high water. One measure would be to increase the outflow of an existing Chicago diversion. The Chicago River used to empty into Lake Michigan, but in 1848 it was redirected to flow into the Illinois River, which drains to the Mississippi River. The waterway was expanded around 1900 into what is now the Chicago Sanitary and Ship Canal. Its rate of flow was established by the Supreme Court in 1967 after several states and cities brought litigation to limit the diversion. But Lee likens the existing diversion's effect on lake levels to a pinprick on a gallon jug.

Wilson also urges shutting off the extra inflow to Lake Superior from two Ontario rivers that were diverted away from Hudson Bay in the 1940s. He says the Ontario utility responsible for those diversions already produces more hydroelectric power than the province needs.

Experts say such measures would accomplish little. Lee has participated in studies over 35 years that have examined possible interventions; she says lowering Lakes Michigan and Huron would require excavating a new channel that could carry the same flow as the St Clair and Detroit Rivers, which drain Huron into Lake Erie. Even if that were feasible, the scheme could fail because the lakes' water supply accumulates on annual, interannual, and decadal time scales. "You'd still have to have the ability to make forecasts far enough into the future to know when to open and close [the canal]," she says. Moreover, the channel would relocate flooding to the lower lake into which it dumps.

The International Joint Commission

THE GREAT LAKES SYSTEM holds about one-fifth of all surface fresh water on the globe.

(IJC), a Canadian–US body, regulates the flow of water from Lake Superior to Michigan and Huron through dams on the St Marys River. Following the previous high-water record in the 1980s, the IJC studied the hypothetical effects of increasing the Chicago diversion to its theoretical maximum flow and shutting off the two Canadian rivers. The commission's 1992 report found that those measures would lower Lakes Michigan and Huron by just 9 cm after two years and by 21 cm after five years.

Some of the same groups now calling for intervention were demanding action to restrict the flow out of Michigan–Huron during extreme low-water periods, says IJC spokesperson Frank Bevacqua. In a 2012 study, the IJC explored the possibility of installing contrivances such as inflatable weirs and flap gates on the St Clair River to slow its flow. The report noted that any of the structures would take up to a decade to achieve the desired effect. It estimated the cost of building new controls for Lakes Michigan, Huron, Erie, and Ontario at $27 billion. The report did not recommend they be built, but instead called for further studies by the Canadian and US governments. Those studies were never carried out, Bevacqua says.

The IJC also controls the flow into the St Lawrence River from Lake Ontario, the smallest of the five lakes by area. The river, which drains the Great Lakes to the ocean, was widened in the 1960s, when the Moses-Saunders Power Dam was built to help limit water-level fluctuations on the lake. The dam can only do so much, however, and it was unable to prevent the lake from reaching a record high in 2019. An IJC spokesperson says the flow released by the dam is restricted by international agreement to prevent flooding in Montreal.

There are environmental considerations to altering water levels, says Lee, including harmful effects to coastal wetlands and biodiversity. The natural, cyclical rise and fall of the lakes keeps wetlands healthy, limits invasive species, and prevents upland vegetation from moving downslope. "You need a mix of vegetation types—from submergent, to emergent, to upland. Fluctuating water levels cause that to happen on the decadal time scale," she says. Keeping the invasive Asian carp out of the lakes argues against increasing the flow rate of the Chicago diversion, says Lee.

Quo vadis?

Water levels are likely to decline somewhat in the next several months, as part of the usual seasonal cycle. But Gronewold cautions that soil moisture remains high in the upper lake basins, and he notes that even under dry conditions, it will be a couple years before the lakes would return to more typical levels.

Longer term, it's anyone's guess where lake levels are headed. The range of possibilities in the six-month forecasts by the

RON WILSON

EIGHTEEN METERS OF BEACH lay in front of Ron Wilson's cottage on Lake Michigan as recently as 2013. Last fall, the lake was lapping at the cottage's structure.

US Army Corps of Engineers is so broad in the latter months as to be of little use, researchers say. Two- to five-year forecasts would require an ability to predict such mesoscale phenomena as polar vortices and El Niño–Southern Oscillation cycles. For his part, Wilson is hoping for a La Niña event, which he says would likely bring colder than normal temperatures to the lakes this winter and boost evaporation.

"The lakes are very complicated, and it's not easy to forecast how they behave," says Lee. "They are at the crossroads of global circulation patterns, and there are local effects because the lakes have thermal memory and water levels take quite a while to drain from lake to lake."

Wuebbles is working with Argonne National Laboratory to refine a regional North American climate model to run at 4 km resolution. That should enable the simulation of clouds and convection needed to visualize precipitation trends. The model will be paired with the National Hydrologic Model. "If you were to ask me four or five years from now," Wuebbles says, "I'd be in much better shape to tell you what's happening to the lakes."

For now, adaptation is the only solution to high water. Stabenow says she is working to free up assistance from the Federal Emergency Management Agency and the Corps of Engineers, which are geared to respond to sudden disasters such as hurricanes but not to more gradual events such as erosion. Federal assistance should be provided to shore up states' shoreline protection efforts, she says, since their own budgets for that purpose had to be tapped to fight the coronavirus pandemic.

Gronewold thinks the solution is "to be careful where you build things near the shoreline, and be cautious about setback distances." That's not an option for people like Wilson, whose cottage has been in the family for generations.

"We want to get the politicians to understand that [high water] may be permanent with climate change," says Wilson. "Then where do we go? The cities will flood."

David Kramer PT