

The reconstructed water-level history of Lake Michigan-Huron over the past 4,700 years shows three major high phases from 2,300 to 3,300, 1,100 to 2,000, and 0 to 800 years ago. Within that record is a quasi-periodic rise and fall of about 160 ± 40 years in duration and a shorter fluctuation of 32 ± 6 years that is superimposed on the 160-year fluctuation. Recorded lake-level history from 1860 to the present falls within the longer-term pattern and appears to be a single 160-year quasi-periodic fluctuation. Independent investigations of past climate change in the basin over the long-term period of record confirm that most of these changes in lake level were responses to climatically driven changes in water balance, including lake-level highstands commonly associated with cooler climatic conditions and lows with warm climate periods. The mechanisms underlying these large hydroclimatic anomalies are not clear, but they may be related to internal dynamics of the ocean-atmosphere system or dynamical responses of the ocean-atmosphere system to variability in solar radiation or volcanic activity.

The large capacities of the Great Lakes allow them to store great volumes of water. As calculated at chart datum, Lake Superior stores more water ($2,900 \text{ mi}^3$) than all the other lakes combined ($2,539 \text{ mi}^3$). Lake Michigan's storage is $1,180 \text{ mi}^3$; Lake Huron's, 850 mi^3 ; Lake Ontario's, 393 mi^3 ; and Lake Erie's, 116 mi^3 . Seasonal lake-level changes alter storage by as much as 6 mi^3 in Lake Superior and as little as 2.1 mi^3 in Lake Erie. The extreme high and low lake levels measured in recorded lake-level history have altered storage by as much as 31 mi^3 in Lake Michigan-Huron and as little as 9 mi^3 in Lake Ontario. Diversions of water into and out of the lakes are very small compared to the total volume of water stored in the lakes.

The water level of Lake Superior has been regulated since about 1914 and levels of Lake Ontario since about 1960. The range of Lake Superior water-level fluctuations and storage has not been altered greatly by regulation. However, fluctuations on Lake Ontario have been reduced from 6.6 ft preregulation to 4.3 ft over the past three decades postregulation, and storage changes have been reduced from 9 mi^3 to 6 mi^3 . Regulation affects shoreline property owners and industries that have structures in the flood-hazard zone; they generally desire lower lake levels. Higher lake levels are preferred by recreational boaters and marinas concerned about lake access in shallow areas, as well as by municipal and industrial water-supply facilities concerned about water-intake structures. The shipping industry and hydropower industry prefer increased flow through the connecting channels and lower St. Lawrence River.

Regulation of lake levels has created problems for wetlands of Lakes Superior and Ontario. Periodic high lake levels are needed to kill trees, shrubs, and canopy-dominating emergent plants in Great Lakes wetlands, and low water levels following the highs are needed to promote seed germination and growth of a multitude of species. Occasional low water levels are also needed to restrict growth of plants that require very wet conditions, such as cattails, at higher elevations in

wetlands that are typically colonized by sedges and grasses. The diversity of wetland plant communities and the habitats they provide for fish and wildlife in Great Lakes wetlands are dependent on water-level fluctuations. The effects of regulation have been most severe in Lake Ontario, where the natural pattern of high and low lake levels has largely been eliminated. As a result, extensive stands of cattails have become established in nearly all wetlands in Lake Ontario, mostly at the expense of the sedge/grass community, and diversity of habitats has been reduced substantially.

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Glossary

For purposes of this circular, the following terms and definitions apply. The definitions are not the only valid ones for these terms.

barrier beach Dune and beach deposits that occur as a shore-parallel topographic high with a landward standing body of water or wetland.

chart datum A reference point for water-level elevation where 95 percent of recorded/historical elevations are above the datum.

consumptive use That portion of water withdrawn or withheld from the Great Lakes Basin and assumed to be lost or otherwise not returned to the Great Lakes Basin because of evaporation, incorporation into products, or other processes.

crustal movement Vertical and horizontal displacement of the Earth's lithosphere.

detrital material Nonliving organic matter (for example, dead organisms or leaves) in water.

diversion A transfer of water from the Great Lakes Basin into another watershed, or from the watershed of one of the Great Lakes into that of another.

emergent Refers to those species that occur on saturated soils or on soils covered with water for most of the growing season. The foliage of emergent aquatics is partly or entirely borne above the water surface.

eolian Pertaining to the action or effects of wind.

glacial isostatic adjustment (GIA) Vertical crustal movement related to the removal of the weight of glaciers. (See box 1 in main text.)

ground water In the broadest sense, all subsurface water; more commonly, that part of the subsurface water in the saturated zone (the subsurface zone in which all openings are full of water).

hemi-marsh An area that is half vegetated and half open water.

highstand The uppermost topographic position or elevation reached by lake level during a specific period in time.

hydrograph A graph showing water level, flow rate, or some other property of water with respect to time.

hydrologic system A zone in three-dimensional space, with a boundary, that receives water and other inputs; stores, processes, and (or) transmits them; and releases them as outputs.

littoral Pertaining to the area of the coast affected by nearshore waves and currents.

macrophytes Plant species that can be observed without the use of optical magnification.

mainland-attached beaches Dune and beach deposits that occur as a shore-parallel topographic high with a landward upland.

meadow marsh Marsh that occurs in areas that are occasionally covered with water, dominated by grasslike plants and wildflowers.

Medieval Warm Period A warm interval lasting several centuries, beginning around 1,000 years ago and particularly well documented in Europe. Climate anomalies during this time period also have been documented in various other regions of the world.

net basin supply The net amount of water entering a Great Lake. Although scientists use various methods to calculate net basin supply, all methods subtract the amount of water leaving a Great Lake from the amount of water entering that Great Lake.

Nipissing Phase One or more high levels of the Great Lakes between 6,000 and 4,000 years ago. Nipissing lake levels were slightly more than 4 meters (13 feet) higher than historical levels.

paleoclimate The climate of a given period of time in the past.

palustrine Refers to inland wetland area.

peatland A wetland where the rate of biomass production exceeds the rate of decomposition, resulting in the accumulation of organic-rich sediment that contains the partially decomposed remains of plants and other organisms.

perched dunes Dunes that sit on a plateau high above the shore; they consist of sand as well as other loose material, and dramatically changing lake levels help to create them.

proxy record A reconstructed history of environmental changes based on the contents of a natural archive (for example, sediments, ice cores), typically using an indicator,

measurement, or suite of measurements that are highly correlated with a particular environmental variable (for example, temperature).

quasi-periodic A repetitive behavior that is not uniform in period or amplitude.

revetment A facing of stone, concrete, or other durable material to protect an embankment or shore structure against erosion by wave action or currents.

seiche A stationary wave usually caused by strong winds and (or) changes in barometric pressure. It is found in lakes, semi-enclosed bodies of water, and areas of the open ocean.

spit Dune and beach deposits that occur as a shore-parallel topographic high that extend from a headland. These deposits commonly occur with a landward standing body of water or wetland and contain several or more beach ridges that recurve landward.

strandplain Shore-parallel ridges of sand commonly occurring in embayments along the lakes, forming a washboard pattern inland from the shore.

surficial geology The geology of material at or near the Earth's surface; can include near-surface bedrock in addition to unconsolidated (loose) material deposited by the activity of streams, glaciers, and weathering.

swash zone The zone of wave action on the beach, which moves as water levels vary.

testate amoebae Amoeboid protozoa that produce decay-resistant and morphologically distinct outer shells and have been used as environmental and paleoenvironmental indicators of water-table depth in peatlands.

water balance An accounting of inflow to, outflow from, and storage in a hydrologic unit, such as the Great Lakes.

wave-cut terraces Erosional scarp and platform cut into bedrock or unconsolidated deposits.