Great Lakes Water Levels: Monitoring Change in Earth's Largest Surface Freshwater System

by Andrew D. Gronewold, Anne H. Clites and Laura Rear-McLaughlin

The Great Lakes, their connecting waterways and their watersheds, comprise the largest surface freshwater system on Earth. They are a dominant physical feature of North America and form part of the political boundary between the United States and Canada. The Great Lakes contain nearly 20 percent of the world's fresh surface water and have a coastline longer than the east or west coast of the US. One-third of the North American population lives within the Great Lakes watershed. The lakes provide drinking water to 40 million people as well as abundant aquatic recreation and natural beauty.

Coastal regions along the Great Lakes are impacted by lake level changes. The lakes rise and fall in regular seasonal patterns corresponding with rainfall, snow melt, and evaporation. Changes in the water levels of these inland seas impact environmental systems and basin residents across a broad spectrum of time and space scales. Storm events can result in short-term storm surge conditions threatening lives and property, sometimes with little warning. In addition to the annual pattern of rise and fall, periodic changes in regional precipitation and evaporation rates can lead to very high or low Great Lakes water levels that may last for many years. These periods of extreme water levels are very hard to predict. Long periods of low water levels cause difficulty for commercial shipping, recreational boating and hydropower concerns. High water levels lead to coastal erosion, flooding, and increased damage due to storm events.

NOAA/Great Lakes Environmental Research Laboratory

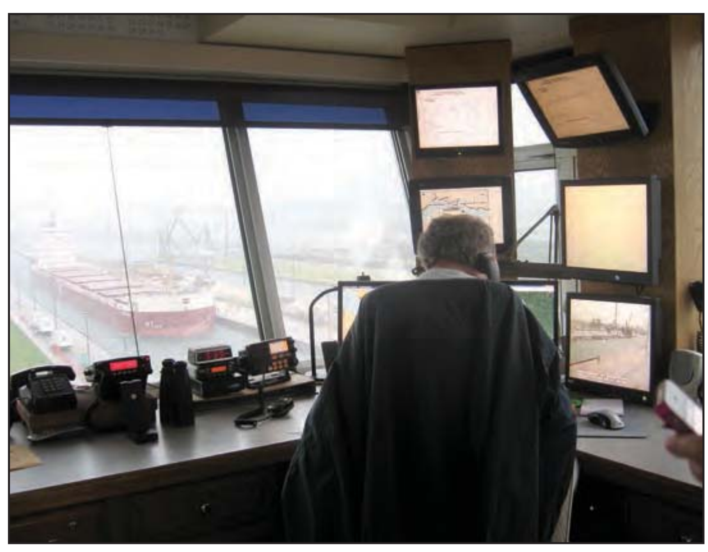
NOAA water level station at Mackinaw City, MI

Water Level Monitoring Network

The water levels of the Great Lakes and the flows in the connecting channels between them are monitored, analyzed and forecast by an international network of federal agencies including the National Oceanic and Atmospheric Administration (NOAA), the Army Corps of Engineers, the US Geological Survey, Environment Canada, and Canada's Department of Fisheries and Oceans. Seasonal six-month forecasts for Great Lakes water levels are a collaborative effort between the Army Corps of Engineers and Environment Canada. The effort that goes into the collaboration underscores the fact that the Great Lakes system is significant far beyond the borders of its watershed.

Monitoring Great Lakes water levels is an important part of NOAA's mission to understand and predict changes in climate, weather, oceans and coasts. Great Lakes water level data constitutes one of the longest high quality hydrometeorological data sets in North America, with the United States' reference gauge records beginning in 1860. The US Great Lakes water level monitoring network of 53 water level recording stations is maintained by NOAA's Center for Operational Oceanographic Products and Services (CO-OPS), part of the National Ocean Service. The Canadian Hydrographic Service (Department of Fisheries and Oceans) maintains an additional 35 stations on Canadian shorelines. These data sets are critically important for international navigation, planning for coastal development, monitoring regional climate change, and improving seasonal water level forecasts.

NOAA CO-OPS Great Lakes stations record a three-minute water level average every six minutes. Data is available at the CO-OPS website (http://tidesandcurrents.NOAA.gov/map/) at six-minute, hourly, daily, and monthly intervals. Primary features of a NOAA water level station in the lakes include a valve-controlled intake pipe into a "stilling" well or sump, data collection platforms, and GOES (Geostationary Operational Environmental Satellite) antenna for data transmission. Many of these stations also include meteorological sensors such as wind speed, air and water temperature, barometric pressure, and relative humidity.



NOAA/GLERL

US Army Corps of Engineers lock master uses NOAA water level data to guide freighter traffic through the St. Marys River locks at Sault Ste. Marie, MI.

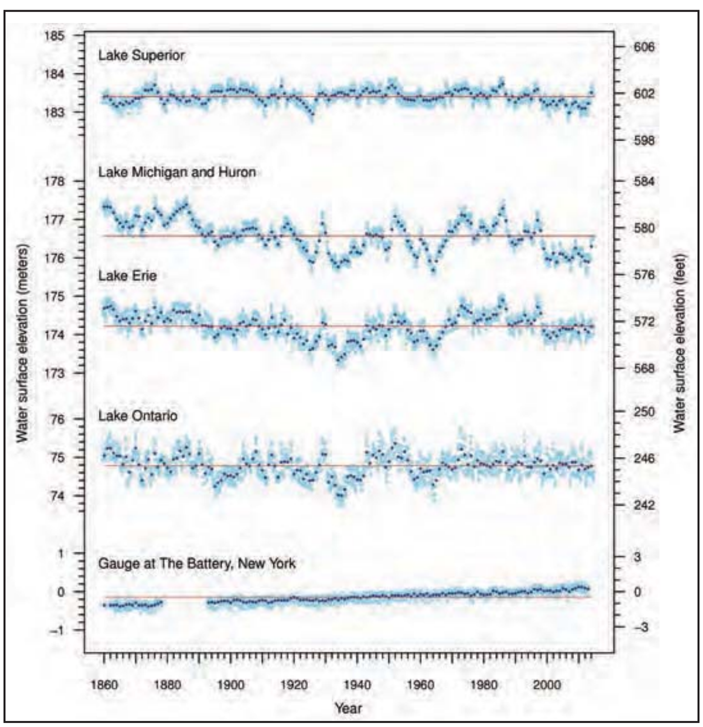
Historical Great Lakes Water Levels

It is important to recognize the magnitude of water level variability along the Great Lakes coastline in the context of that experienced on other US coasts. Great Lakes coastal residents have historically adapted to water level fluctuations through internationally coordinated water resources management, careful evaluation and occasional modification of expected ecosystem services, and technological innovation. Each of the four Great Lakes systems (Lakes Michigan and Huron, joined at the Straits of Mackinac, are considered one lake in terms of hydrology) fluctuate in response to different drivers and at different time and space scales. Monthly, interannual, and decadal Great Lakes water level variation, for example, is greater than water level variability along marine coasts, for similar time scales. Changes in hourly-scale Great Lakes water levels are driven by storms that produce storm surges and seiches that can threaten lives and property and are difficult to predict. NOAA's Great Lakes Environmental Research Laboratory (GLERL), part of NOAA's research branch, Oceanic and Atmospheric Research (OAR), uses historical water level data to analyze the relationships between water level dynamics and components of the regional water cycle (precipitation, over-lake evaporation, and basin runoff). GLERL's research is used to improve predictive models of both seasonal water level dynamics, and short-term hydrodynamics.

Recent Great Lakes Water Level Dynamics

The upper Great Lakes basin has experienced dramatic swings in water levels in recent years. A precipitous drop in the levels of Lakes Superior, Michigan and Huron began in 1997, leaving the upper lakes more than three feet lower in less than two years. These lakes stayed below their monthly averages, at times significantly below, for a period of 15 years, including an all-time record low set in January 2013 on Lakes Michigan and Huron. This long period of low water levels caused financial difficulties for the commercial shipping and hydropower industries, access issues for small harbor towns, and

continued on page 18



NOAA/Great Lakes Environmental Research Laboratory

Historical water levels for the Great Lakes and The Battery gauge, 1860–Present

continued from page 17

NOAA Great Lakes CoastWatch image of the Great Lakes basin and St. Lawrence Seaway

NOAA/Great Lakes CoastWatch Program – Space Science & Engineering Ctr., Univ. of Wisconsin-Madison

a renewed interest in structural methods to reducing flow from the upper basin. During 2013 and 2014, consistently above average precipitation contributed to remarkably swift water level rises on the upper lakes. By October 2014, all of the upper lakes were above their monthly averages for the first time since 1998. Interestingly enough, Lake Erie and Ontario water levels hovered around their long-term averages during this same period. Why the upper lakes stayed so low for such a long period, and how much of an impact two very cold winters had on the recent water level rise are questions GLERL hydrologists are still evaluating.

Vertical Reference for Great Lakes Water Levels

The vertical plane used to define water level heights within the Great Lakes – St. Lawrence River basin is the International Great Lakes Datum, or IGLD. This internationally-coordinated vertical datum plane must be redefined approximately every 25-30 years because the Earth's crust is still moving in response to the retreat of the glaciers 10,000 years ago. This "bounce back" of Earth's crust is known as isostatic rebound, or crustal movement. Although this movement is very small, it is significant enough to require this readjustment regularly. The current datum, IGLD 1985, went into effect in 1992. NOAA has begun working with its Canadian counterparts toward establishing the next vertical datum, IGLD 2020, which will go into effect in 2025. Changing the vertical datum will impact all nautical charts, and any reference to water levels in the Great Lakes will need to be adjusted once the new datum is in place.

Although the future of Great Lakes water levels is highly uncertain, the Great Lakes region has a long history of adapting to fluctuating levels. Changes in regional climate and meteorology could impact the water cycle and heat budgets of the lakes to either keep water levels above average, as all but Lake Ontario are today, or return them to another period of extended low levels. Continued monitoring of water levels, improvements in seasonal and long range forecasting, and anticipation of needed adaptation measures will ensure system resilience as future challenges are met.

Andrew D. Gronewold (drew.gronewold@noaa.gov), a hydrologist, and Anne H. Clites, a physical scientist, are both with NOAA/GLERL (glerl.noaa.gov) in Ann Arbor, MI. Laura Rear-McLaughlin, is Mapping and Charting Program Manager with NOAA/NOS/CO-OPS in Silver Spring, MD.