Sub-Indicator: Water Levels

Overall Assessment

Trends:

10-Year Trend (2014 – 2023): No Trend on all lakes

30-Year Trend (1994-2023): No Trend on all lakes

Long-term Trend (1918-2023): No Trend or Increasing, depending on lake

Rationale: Notable basin-scale water level dynamics for the 1918-2023 period of record include a period of low water levels from the late 1990s to 2013, followed by a surge in water levels on all lakes with record high water levels at certain times from 2017 to 2020, and in recent years a shift back towards near average water levels. For this report, an anomaly or deviations-based approach has been used to compare 10-year, 30-year and long-term (1918 to 2023) trends for each individual Great Lake. The base period chosen for comparison was 1961 to 1990 in order to be consistent with other State of the Great Lakes Physical Condition sub-indicators. No trends were found on all the lakes for the 10- and 30-year trends. For the 106-year period from 1918 to 2023, only Lake Erie and Lake Ontario showed a statistically significant ($P<0.05$) upward trend in water level.

Lake-by-Lake Assessment

Lake Superior

10-Year Trend (2014 – 2023): No Trend

30-Year Trend (1994-2023): No Trend

Long-term Trend (1918 – 2023): No Trend

Rationale: Regulation of Lake Superior outflows has had some influence on water levels on the lake since 1916, however, natural hydrological factors such as precipitation, runoff and evaporation continue to be the main determinants in water levels. Additionally, water diversion from the Hudson Bay watershed into Lake Superior has been occurring since 1939.

Lake Superior annual mean and monthly mean water levels were predominantly below long-term average values (period of record beginning in 1918) between 1999 and 2013. However, levels started to rise in 2013 and continued to rise for about the next six years. In fact, very high water supply to Lake Superior in 2017 and again in 2019 culminated in record high water levels from May to September in 2019. The water levels in the last three years have receded from these record highs but were still slightly above the (1961-1990) average.

Lake Michigan-Huron

10-Year Trend (2014 – 2023): No Trend

30-Year Trend (1994-2023): No Trend

Long-term Trend (1918 – 2023): No Trend

Rationale: Lake Michigan and Lake Huron are commonly considered one lake system from a hydrological perspective due to direct connection of the lakes through the Straits of Mackinac, and therefore are referenced collectively as Lake Michigan-Huron.

Lake Michigan-Huron's annual mean and monthly mean water levels were predominantly below long-term average values between the late 1990s and late 2014. In late 2014, however, as part of a very rapid 6-year rise that began in early 2013, water levels rose above long-term average values and have remained well above average to the end of 2020. These high water levels included an eight month period from January of 2020 to August of 2020, when the monthly average water level was the highest for each month in the period of record (1918-2020). From 2021-2023, the lake levels have quickly declined, with 2023 falling enough to now being a bit below the (1961-1990) average.

Lake Erie

10-Year Trend (2014 – 2023): No Trend

30-Year Trend (1994-2023): No Trend

Long-term Trend (1918 – 2023): Increasing

Rationale: As with the previous lakes, Lake Erie's annual mean and monthly mean water levels experienced a period of lower than average values from the late 1990s and 2014. From the year 2014 the lake saw a rapid 6-year rise up to 2020, which resulted in individual monthly records at various times during 2019 and 2020. Since then, the water levels have stayed above the long term average, but have declined from their highs from a few years ago.

Located between Lake Huron and Erie, Lake St. Clair also experienced a similar pattern in the last 3 years.

Lake Ontario

10-Year Trend (2014 – 2023): No Trend

30-Year Trend (1994-2023): No Trend

Long-term Trend (1918 – 2023): Increasing

Rationale: Regulation of outflow from Lake Ontario has influenced water levels on the lake and the St. Lawrence River since 1960; however, natural hydrological factors such as precipitation, runoff and evaporation continue to be the main determinants in water levels. Generally, the overall range and interannual variability of water levels on Lake Ontario has been reduced due to regulation when compared to pre-regulation water levels. A new outflow regulation plan (Plan 2014) was implemented in early 2017, that was designed to result in a similar overall range in Lake Ontario water levels relative to the previous regulation plan but increase the variability of water levels on Lake Ontario closer to that of natural conditions based on historical water supplies.

In the years immediately following the implementation of Plan 2014, the basin has experienced some of the wettest conditions on record, resulting in monthly record high lake levels in 2019. During the past 3 years, levels have varied from slightly below to slightly above the (1961-1990) average.

Trend Assessment Definitions

Trend reporting was based on comparison of annual mean water level to the average annual water level for each lake using the baseline period 1961 to 1990. Anomalies were calculated between the average water levels and a trend line was established by fitting a linear model to the anomaly data. The significance of the trend was determined using p-values from a bootstrap based Mann-Kendall model to account for significant autocorrelation identified in the data. A trend was considered significant for probability of occurrence less than 0.05 ($P<0.05$)

(Table 1). It was noted that the analysis was relatively sensitive to the period of analysis (1918-2023), which is not surprising due to interannual and multi-year variability of Great Lake water levels.

Increasing: an increasing anomaly trend line with a P<0.05 indicating that water levels are increasing relative to baseline water level.

Unchanging: an anomaly trend line with P>0.05 indicating that there was no statistically significant trend, and there is low variability in the data.

No Trend: Data are available for a 10-year or longer period, but the trend is not statistically increasing or decreasing, and there is high variability in the data.

Decreasing: a decreasing anomaly trend line with a P<0.05 indicating that water levels are decreasing relative to baseline water level.

Undetermined: data are not available to report on a trend.

Sub-Indicator Purpose

- The purpose of this sub-indicator is to track seasonal, interannual, and long-term (i.e. decadal) trends in lake-wide average water levels across each of the Great Lakes.
- The water levels sub-indicator is used in support of the Watershed Impacts and Changes in Physical Conditions indicator suite as well as general objective #9 of the Great Lakes Water Quality Agreement (GLWQA) and annexes 2, 7, and 9 of the GLWQA.

Ecosystem Objective

This sub-indicator best supports work towards General Objective #9 of the 2012 Great Lakes Water Quality Agreement which states that the Waters of the Great Lakes should be “free from other substances, materials, or conditions that may negatively impact the chemical, physical or biological integrity of the Waters of the Great Lakes.”

Water level fluctuations have strong influences on Great Lakes habitats and the biological communities associated with them. Impacts of alterations in water level fluctuations on shoreline ecosystems (particularly coastal wetlands are widely documented (e.g. Wilcox and Nichols, 2008, Langer et al., 2018, Anderson et al., 2023), and underscore important relationships between ecosystem response and water level management.

Methods

This water level sub-indicator measures:

- Long-term water level variability: an assessment of trends in the anomalies of annual mean water levels relative to the base period of 1961-1990 over the period of record for each of the Great Lakes (data from 1918-2023).

The set of measures associated with this sub-indicator are calculated from existing estimates of lake-wide average water levels based on gage measurements since 1918. This formal network of gages for each lake was established and has served as the basis for an internationally coordinated set of monthly mean lake-wide average water level

measurements. The 1918 to 2023 period was chosen as the analysis period, because data for this period have been internationally coordinated by the Coordinating Committee for Great Lakes Basic Hydraulic and Hydrologic Data. Although the basin has experienced elevation changes as a result of post-glacial isostatic rebound, these changes are accounted for in the long term coordinated water level record.

Similar to the previous reports, an anomaly-based approach to reporting on the Physical Conditions sub-indicators, which include Water Levels, Precipitation Amounts, Ice Cover and Surface Water Temperatures, has been implemented for 2025 State of the Great Lakes reports.

The approach includes identifying a defined base period and comparing all data (the full period of record) to this base period to identify "anomalies" or "deviations" from the base period mean. The base periods selected in the reports include up to 1990 but not beyond as it is expected that accelerated changes in Physical conditions would be occurring after 1990. The base period for the water level sub-indicator was chosen to be from 1961 to 1990 as this is consistent with other State of the Great Lakes Physical Conditions sub-indicators. Note that the trends (if not the magnitude of the annual anomalies) resulting from the analysis of anomaly data are the same regardless of base period.

Discussion

Changes in Great Lakes water levels take place over a variety of time scales ranging from hourly fluctuations to those taking place over hundreds and even thousands of years. Most of the monthly and interannual changes documented over the past 150 years are the result of changes in the Great Lakes hydrologic cycle. For example, the recent lake level fluctuations in the mid- to late-2010s, were found to be the result of weather extremes (Gronewold and Rood, 2019). These are influenced by natural and anthropogenic factors, and long-term trends in physical conditions in the Great Lakes (Baedke and Thompson 2000; Booth and Jackson 2003). Anthropogenic factors include items such as the regulation of the outflow and inter-basin diversions, although it is generally considered that these have much less of an influence than the natural factors. Changes in Great Lakes water levels not only impact the shoreline, which will have impacts on the area of accessible and suitable habitat, but also the complex and dynamic coastal processes of the lakes. The potential for impacts of water level changes to physical habitats around the Great Lakes are dependent on a complex interrelationship of many factors which include erodibility of shoreline substrates, sediment supply and shoreline management practices (Theuerkauf and Braun 2021). Many of the shorelines of the Great Lakes are dynamic, with the sorting action of erosion and accretion playing an important role in habitat creation, while other areas consist of natural bedrock or engineered structures which will have less potential for erosion with associated lower sediment supply to replace features that are susceptible to erosion (USACE and Univ. of Wisconsin 2003). Higher water levels can cause more erosion along shorelines consisting of unconsolidated substrates as wave energy works further up the shore on less stable banks (Mickelson et al., 2004). However, the sediment supplied by erosion is important in maintaining dynamic shoreline features such as beaches and underwater gravel areas. During times of low water levels, wave action will tend to move unconsolidated substrates, redistributing beach material over time. When considering ecological impacts due to changes of water levels, changes in shoreline dynamics and the associated change in shoreline structure for short and long-term periods should be considered. Additionally, the impact that changing water levels may have on shoreline development practices such as shoreline protection structures, water pollution sources, dredging and in water work with their potential changes in habitat may also be considered.

Water level conditions have historically varied and continue to vary considerably between each of the Great Lakes and temporally over the period that Great Lakes levels have been recorded (1860 to present). Various modifications to the Great Lakes watersheds and their connecting channels have had some impact on water levels to varying degrees in the last 100 years. It should be noted that the impacts due to anthropogenic changes along with the flow characteristics of the Great Lakes basin were not separated for the purposes of this analysis, but are discussed in the report. Water level fluctuations at finer spatial scales (such as the St. Marys River) were not considered in this report. In general, it can be assumed that higher levels on Lake Superior will provide generally higher flow to the St. Marys River. However, specific impacts to the connecting channel in regard to water depths, velocities and wetted perimeter would need more detailed study.

The summary below is an account of the overall factors affecting the Great Lakes water balance (Neff and Killian 2003), and ultimately the water levels, and a limited discussion on water level history and variability.

The natural factors associated with long-term water level changes in the Great Lakes include environmental processes that contribute to inflow, outflow, and storage in the system. Within broad scales, water inflow and outflow are dictated by the long-term meteorological conditions that that affect the components of the hydrologic cycle. These components include over-lake precipitation, runoff, over-lake evaporation, and connecting channel flows (i.e. the flow of water into and out of each lake through the upstream and downstream connecting channel). Groundwater flows are assumed to have an insignificant contribution to long-term water level variability relative to over-lake precipitation, runoff, and evaporation.

An additional natural factor that affects the accurate measurement of water levels, as well as the wetted perimeter of the lakes with its associated impacts on habitat, is glacial isostatic adjustment (GIA), which is the response of the earth's crust to removal of the weight of the last glacial ice sheets that crossed the area (Wilcox et al. 2007; IUGLS 2009). Unlike hydrologic factors, GIA impacts on water levels vary from one location to another around a lake. At some locations, water levels appear to be rising as a result of GIA, while levels appear to be falling at other locations on the same lake. This has an implication for the analysis of historic water level data. Measurement error due to GIA is minimized by using a representative set of gauges around each lake to calculate a lake wide average level and by periodically adjusting the datum for level measurement. As well as introducing some water level measurement error, GIA will also change the wetted perimeter of each lake over time, generally with the more northern portions of the lake drying and southern portions of the lakes seeing more wetted area. The changes in wetted perimeter of the lakes due to GIA was not specifically considered in this analysis; however, for comparison the northern part of Lake Superior is rising at a vertical velocity of about 50 cm/century and part of the southwest shoreline of Lake Michigan is falling at a vertical velocity of about 14 cm/century.

Lake Superior water levels have been regulated since 1916. In its 1914 Order of Approval, the International Joint Commission (IJC) established the International Lake Superior Board of Control and delegated to it responsibility for setting Lake Superior outflows. The Board of Control established a regulation plan that has undergone several revisions. The regulation plan currently in place incorporates the concept of balancing Lake Superior and Lake Michigan-Huron levels.

With the approval by the IJC of the hydropower project at Cornwall, Ontario and Massena, New York under the Order of Approval of 1952, Lake Ontario's outflow became subject to regulation. The first regulation plan became operational in 1960. The subsequent reduction of the variability in Lake Ontario water levels has been shown to diminish wetland plant diversity and the habitats they support (LOSLR Study Board, 2006). A new water regulation plan (Plan 2014) was implemented in early 2017, that was designed to result in a similar overall range in Lake Ontario water levels relative to the previous regulation plan, but an increase in variability of water levels on Lake Ontario closer to that of natural conditions based on historical water supplies. An expected outcome of this

more natural variability in Lake Ontario water levels is to increase the suitability of habitat in wetlands for a number of plant and wildlife species. The plan has not been in place for a long enough duration to make any conclusions about its long-term effect on the variability of lake levels.

Water levels are measured at several locations along the shore of the Great Lakes and their connecting channels by the National Oceanic and Atmospheric Administration (NOAA) in the United States and by the Canadian Hydrographic Service (CHS) in Canada. Several gauges in the current network of multiple gauges have been in operation only since 1918, while others have gauge records (some less reliable) extending back to the 1860s.

Status and Trends in Lake Levels

Graphs of water level anomalies relative to the base period (Figure 1) show some similarities of interest. Generally, periods of higher levels occurred in the late 1920s, the mid-1950s, from the early 1970s to mid-1990s, and in the late 2010s and early 2020s. Pronounced low lake level periods occurred in the mid-1920s, the mid-1930s, the mid-1960s, and the 2000s. Though less-well documented, low levels also occurred in the late 1890s, following a long period of high lake levels. In addition to computing trends, Figure 1 also includes a line showing the 9-year rolling average anomaly.

Based on the historical record as shown in Figure 2, there appears to be a range within which the lake levels remain, but paleo records indicate a range that may have been greater *(*Brown et al. 2012). There is considerable uncertainty in how changes in physical conditions in the Great Lakes basin, particularly changes in precipitation, runoff, and evaporation, may impact net basin water supplies and water levels and flows in the Great Lakes-St. Lawrence River region. The current state-of-the-art in models indicates that water levels are likely to continue to fluctuate both above and below their long-term averages in the future, but that there is not strong evidence for a pronounced shift in the long-term mean (e.g. Hayhoe et al., 2010, Notaro et al., 2015, Lofgren et al., 2016, Lofgren et al., 2011, MacKay and Seglenieks, 2013, Seglenieks and Temgoua, 2022). Generally, the models also indicate that the lakes may experience more extreme levels (both high and low) in the future.

Other Spatial Scales

Water level fluctuations at finer spatial scales (including the fluctuations on Lake St. Clair) are not considered in this report.

Linkages

- Coastal Wetland sub-indicators (Coastal Wetland Invertebrates, Coastal Wetland Fish, Coastal Wetland Birds, Coastal Wetland Amphibians, Coastal Wetland Plants, and Coastal Wetlands: Extent and Composition) – water levels have a major influence on undiked coastal wetlands and are basic to any analysis of wetland change trends.
- Phytoplankton, Zooplankton, Benthos, *Diporeia*, Native Preyfish Diversity, Lake Trout, Walleye, Lake Sturgeon, and Fish Eating and Colonial Nesting Waterbirds – water levels are related to habitat available for food, cover and travel corridors for these animals.
- Ice Cover- evaporation rates from the lakes are in part related to ice cover in the winter.
- Surface Water Temperature – ice cover and lake evaporation are linked to surface water temperature.
- Precipitation Amounts – are linked to lake levels as this is the source of water for the Great Lakes watershed.

Assessing Data Quality

Data Characteristics	Agree	Neutral or Unknown	Disagree	Not Applicable
Data are documented, validated, or quality-assured by a recognized agency or organization	X			
Data are from a known, reliable and respected generator of data and are traceable to original sources	X			
Geographic coverage and scale of data are appropriate to the Great Lakes Basin	X			
Data obtained from sources within the U.S. are comparable to those from Canada	X			
Uncertainty and variability in the data are documented and within acceptable limits for this sub-indicator report	X			
Data used in assessment are openly available and accessible	Yes	https://www.greatlakescc.org/en/coordinating-committee-products-and-datasets/		

Notes on Accessing Data

Monthly Great Lakes water level data are available from the website of the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data at https://www.greatlakescc.org/ under the Products page.

Data Limitations

Great Lakes long-term water level data are based on an internationally coordinated set of measurements from shoreline gaging stations and are explicitly intended to be comparable for both the United States and Canada. Issues regarding the integrity of the monitoring network are typically addressed by the federal agencies that participate in the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, and thus we consider the dataset to be robust for this analysis.

Additional Information

Maintenance and operation of the Great Lakes water level monitoring network are critical to understanding the Great Lakes regional water budget and are currently a central regional mission of both the National Oceanic and Atmospheric Administration - National Ocean Service (NOAA-NOS), and the Fisheries and Oceans Canada - Canadian Hydrographic Survey (CHS). Synthesizing and communicating lake-wide average water level data is coordinated through the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, a regional

partnership led by the United States Army Corps of Engineers (USACE) Detroit District, and Environment and Climate Change Canada (ECCC). Continuation of an accurate Great Lakes water level monitoring network is important in determining future changes in the Great Lakes.

This analysis provides an indication of water level trends over different time scales, and there are dozens (if not hundreds) of important connections to regional meteorological trends; commerce, such as commercial shipping and hydropower capacity; and ecosystem and human health. These connections are likely more clearly identified within other ecosystem indicators (including, for example, shoreline integrity, coastal wetlands, and ice cover).An anomaly-based approach was chosen for this sub-indicator to be consistent through the report and is a more representative way of describing the state of an ecosystem variable where the typical value is not necessarily common knowledge. It also allows for easy comparison of the state of variables that are not necessarily similar, such as precipitation in different seasons or different geographic locations. Since the base period mean is a constant, trends determined using the anomalies are identical to trends determined from the original data. The anomaly-based approach helps put the longer periods of record into context and compares the historical data to more recent changes that are occurring in the ecosystem.

Water level variability across different time scales can serve as an index of significant changes in regional meteorology and a reflection of anthropogenic influence (including regulation of outflows from Lakes Superior and Ontario), and an important indicator of potential impacts on coastal ecosystems, hydropower capacity, and other socioeconomic factors.

Water levels on each of the Great Lakes follow a strong seasonal pattern in which water levels tend to rise in the spring (as a result of increasing precipitation, melting of snow from the previous winter, and decreasing over-lake evaporation) until a peak is reached in mid-summer. Water levels then typically decline through the summer into the fall months (primarily through increased evaporation rates and reduced runoff), reaching a typical seasonal low in early winter. Persistent shifts in the timing of either the seasonal maximum or minimum may reflect shifts in the regional water budget (including changes in the timing and magnitude of precipitation, tributary flows, and evaporation) and provide insight into potential impacts on aquatic plants and fish spawning habitats, and other sensitive aspects of the coastal ecosystem.

A persistent increase in the magnitude of spring rise might reflect increasing “flashiness” in tributary inflows, while periods of decreased declines in the fall may reflect cooler water temperatures and diminished evaporation rates. Changes in the physical conditions that drive the water budget have important implications for the magnitude of seasonal rises and declines and impacts on the coastal ecosystem. Long-term changes in Great Lakes water levels often occur through persistent above or below average water level changes in the spring and fall. For example, systematic increases in long-term water levels are often a consequence of consistent above average runoff rates in the spring and below average evaporation rates in the fall. In addition, the magnitude of seasonal rise and decline (within a given year) has important implications for coastal recreational activities and the design of coastal infra-structure. It also has implications for biological phenology and sediment-water nutrient exchange.

Differences between the water levels of each of the lakes may follow a relatively consistent and predictable pat-tern; anomalies in these differences may suggest an imbalance in the regional water budget, physical changes in the channels that connect the lakes, or the apparent and physical impacts of glacial isostatic adjustment on rec-orded water levels.

Other anthropogenic changes in the last 100 years have had some impacts on Great Lakes water levels . Some of these include water diversions between watersheds (e.g. Long Lac and Ogoki water diversions have diverted water from the James Bay watershed into Lake Superior watershed, and the Chicago diversion diverting water from Lake Michigan to the Mississippi River), channelization and dredging (e.g. dredging of the Detroit - St. Clair River System

for ship navigation, construction of the Welland Canal) and changing regulation plans (e.g. Lake Superior regulation since 1916 and Lake Ontario regulation since 1960). Specific analysis has not been undertaken to separate these effects for this report.

Changes in Great Lakes water levels, regardless of their cause, provide an important key to assessing future potential ecological vulnerabilities. The interaction between ecosystem components and physical water levels, along with other climatic variables, is extremely complex, and is an evolving science. As the science of ecosystem assessment evolves, methods such as critical threshold criteria should continue to be considered in assessment of potential impacts of varying lake water levels. This could include consideration of critical thresholds for lake levels as well as development of finer scale understanding of depths and velocities of the connecting rivers (e.g. St. Marys River, Detroit-St. Clair River, Niagara River and St. Lawrence River).

The authors concur with previous State of the Great Lakes reports that additional future reporting cycles may want to focus on explicit connections between water level variability, coastal processes and ecosystem response. Given the water level patterns that have been experienced there might be a significant opportunity to improving that understanding if and when hydrological, coastal process and ecological data becomes available.

The existing long-term water level monitoring network on the Great Lakes is robust, and is a core component of the operational mission of federal agencies in both the United States and Canada. In the near-term, both countries' agencies are cooperating on a major update to the International Great Lakes Datum (IGLD); the benchmark against which surface water elevations across the Great Lakes are measured. It will be important for future water level inference to take the IGLD adjustments into consideration. Alternative technologies for monitoring surface water elevations in the Great Lakes, including satellite telemetry, are and will continue to be available in the future, however it is unlikely that (at least in the near-term) they will replace the data provided by the long-term shoreline-based gaging network.

In the last report, we provided additional insight by showing changes in the magnitude of the seasonal rises and declines across the Great Lakes throughout the period of record (1918-2020). In this report, the Figures were recreated showing the recent changes in water levels with an extended period of record to 2023 for seasonal rises and 2022 for the seasonal declines. An analysis of the seasonal rise (Figure 3) and seasonal decline (Figure 4) are shown using a similar anomaly-based approach to what was used for annual average water levels in Figure 1. The seasonal rise was calculated by computing the change in level from the seasonal low to the seasonal peak water level. The seasonal decline was calculated by computing the change in level from the seasonal peak to the seasonal low in the following fall/winter/spring. The base period used for these graphics was 1961-1990. The seasonal declines are referenced to the year that the peak occurred. For example, if the seasonal peak level occurred in July 1918 and the seasonal low occurred in the following year in February, the decline would be referenced to the year the maximum occurred (July 1918). The seasonal rises are also referenced to the year the seasonal peak occurred.

Overall, significant ($p<0.05$) trends found in this rise/decline analysis using a linear model fit were long-term trends in the seasonal rise (increasing) and seasonal decline (increasing) for Lake Ontario. Also, for Lake Michigan-Huron the 10-year trend for the seasonal decline was significant (increasing). By plotting the magnitude of the seasonal rise and declines across all of the lakes it becomes apparent that the high-water level period in 2019 and 2020 was not only a result of strong water level rises in the years leading up to it, but also smaller than normal seasonal declines, except on Lake Ontario, which had larger than average seasonal decline in those years. The large rises are noticeable on Lakes Superior and Lake Michigan-Huron in 2013 and 2014, as well as 2017 and 2019 on Lake Michigan-Huron. Lake Erie had above normal seasonal rises in all years from 2016 to 2019, with 2017 and 2019 being anomalously high. Lake Ontario experienced very large rises in 2017 and 2019, which also corresponded to

the record high levels seen during those two years. However, since 2020 seasonal rises have been below normal for Lake Michigan-Huron in all years from 2020 to 2023. During that 4-year period, Lake Superior and Lake Ontario had below normal rises in 3 of the 4 years, while Lake Ontario had two anomalously low seasonal rises in 2021 and 2022. The recent change away from high water can also be noticed in the seasonal declines. On Lakes Superior and Michigan-Huron, the seasonal declines were above normal in 2020 and 2021, as well as 2022 for Lake Michigan-Huron. Due to the anomalous change from seasonal declines that were predominantly below normal from 2013 to 2019, and then above normal in 2020 to 2022 the 10-year trend for Lake Michigan-Huron is significant (increasing). Lake Erie and Lake Ontario also had seasonal declines that were above normal in 2019, 2020, and 2022.

Another item that was investigated in this report cycle, was the timing of the water level minimum and maximum and analyzing changes over time in the month in which that maximum or minimum occur. Overall, looking at the full period of record of water levels back to 1918, there was not a clear change over time in the month when the seasonal maximum or minimums occurred. Although the maximums and minimums have a seasonal component to them, there is variability from year to year depending on the weather and hydrologic conditions that are experienced in the region.

Other measures to consider in the future could include:

1. Lake-to-lake water level difference: an assessment of long-term trends in the difference between the monthly mean water level for each lake and the monthly mean water level for the downstream lake (data from 1918-2020).
2. Changes in coastal processes on the Great Lakes with changes in water levels and associated impacts on habitat structures.
3. The conclusions of this report are based on the best available data set at the time of writing this report (i.e. 1918 to 2023). Trends should be reevaluated as data becomes available.
4. Explore the implications of changes in extreme precipitation events for the runoff into the lakes, and ultimately, water levels.

- Explore how trends in individual components of net basin supply (overlake precipitation, lateral tributary runoff to the lakes, and evaporation from the lake surface) explain variations and trends in lake levels.

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List of Tables

Table 1. Trend line p-values for lake level anomalies for 1918-2023 computed using 1961-1990 baseline period. A value of $p<0.05$was considered significant. Data from USACE.

List of Figures

Figure 1. Water level anomalies (m) relative to average of the baseline period 1961-1990 for each Great Lake over the period 1918-2023. Note that the mean of each 9-year interval is centered on the middle year so the first year of the running mean is 1922. Data from USACE.

Figure 2. Monthly and yearly mean annual water levels (m) for the Great Lakes.

Source: U.S. Army Corps of Engineers, Detroit District.

Figure 3. Water level rise anomalies (m) relative to the average rise of the baseline period 1961-1990 for each Great Lake over the period 1919-2023. Note that the mean of each 9-year interval is centered on the middle year so the first year of the running mean is 1923. Data from USACE.

Figure 4. Water level decline anomalies (m) relative to the average decline of the baseline period 1961-1990 for each Great Lake over the period 1918-2022. Note that the mean of each 9-year interval is centered on the middle year so the first year of the running mean is 1922. Data from USACE.

Last Updated

State of the Great Lakes 2025 Report

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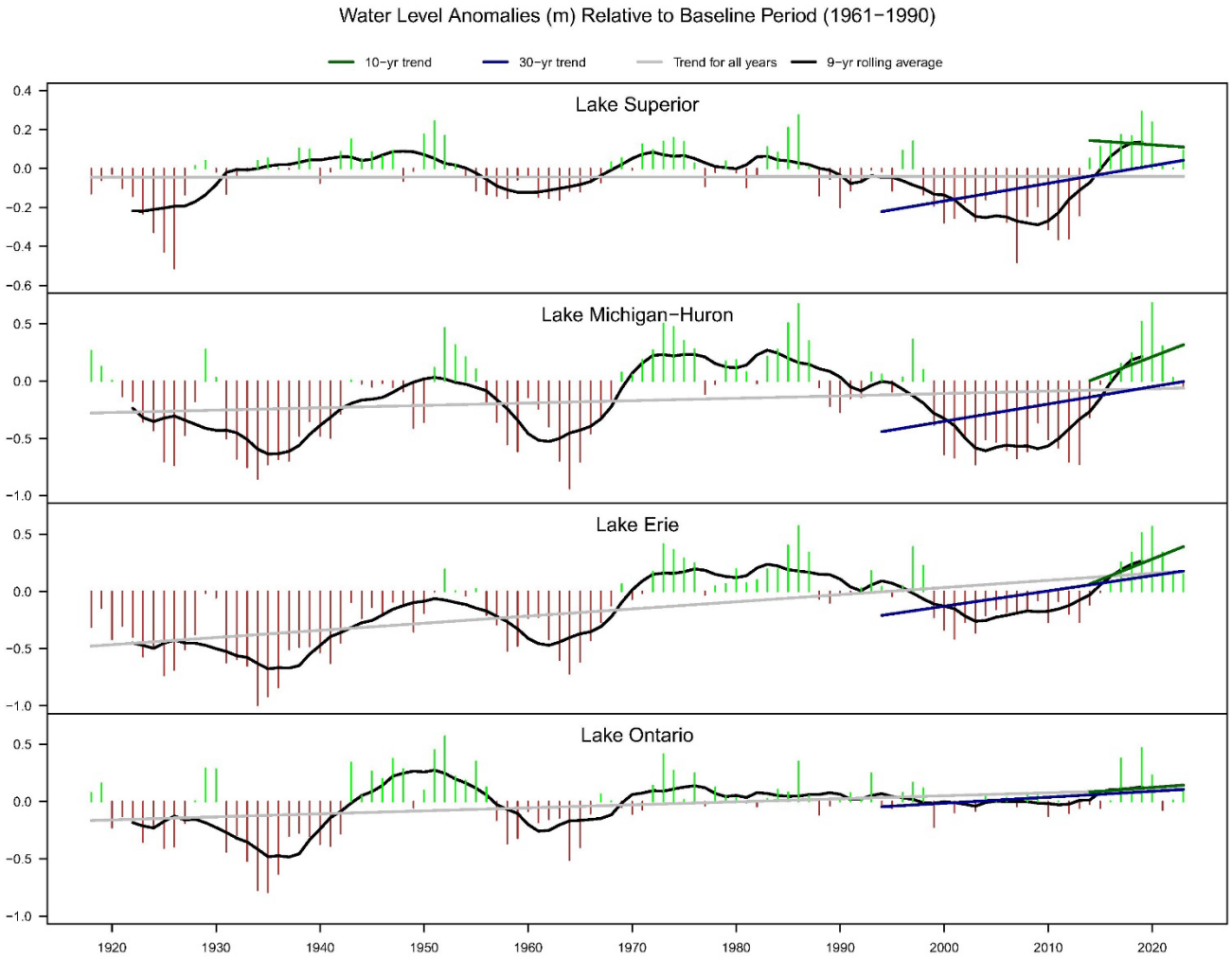
Trend	Lake			
	Superior	Michigan-Huron	Erie	Ontario
10-year (2014-2023)	0.87 (-)	0.25 (+)	0.19 (+)	0.58 (+)
30-year (1994-2023)	0.21 (+)	0.34 (+)	0.09 (+)	0.07 (+)
Long-term (1918-2023)	0.96 (+)	0.25 (+)	0.00 (+)	0.00 (+)

(+) increasing trend, (-) decreasing trend



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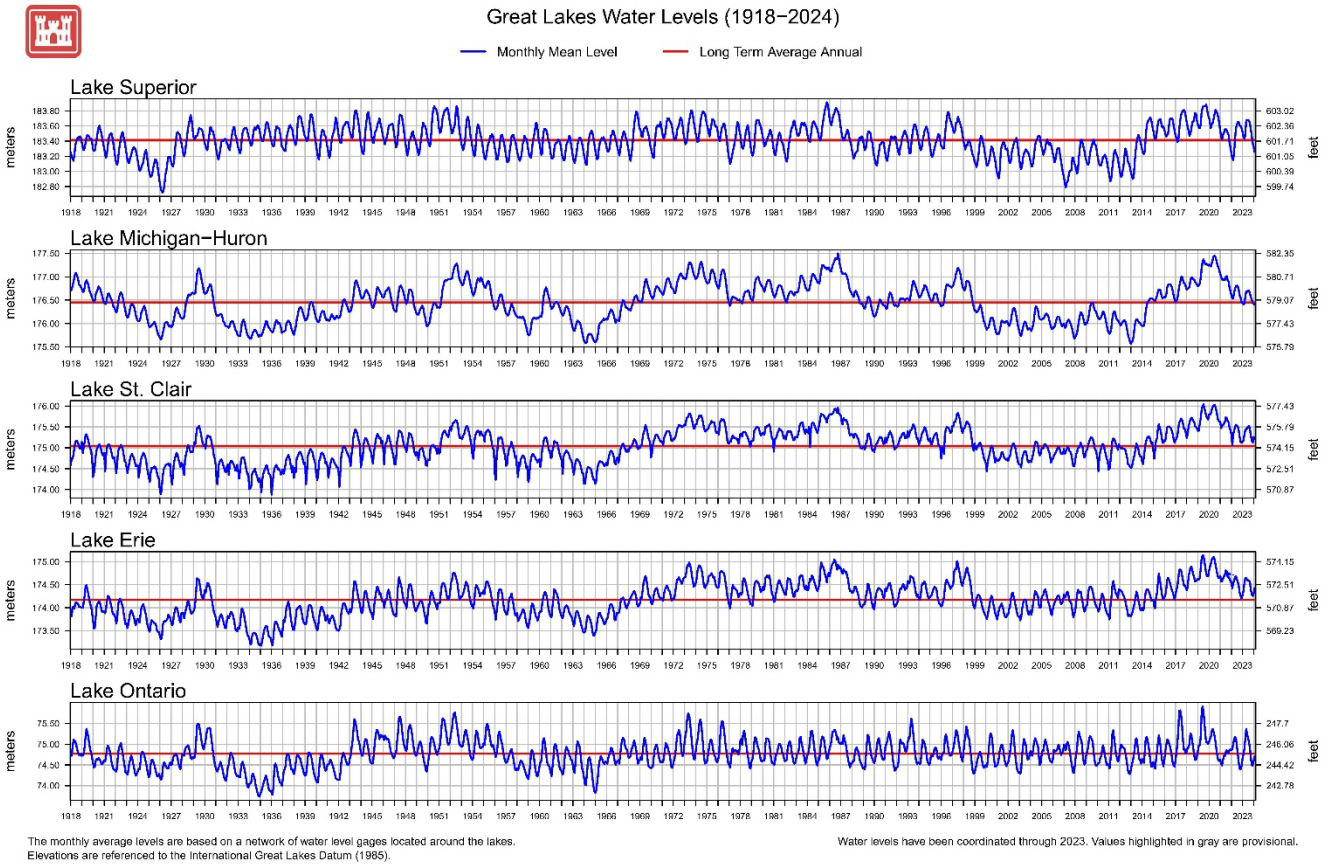

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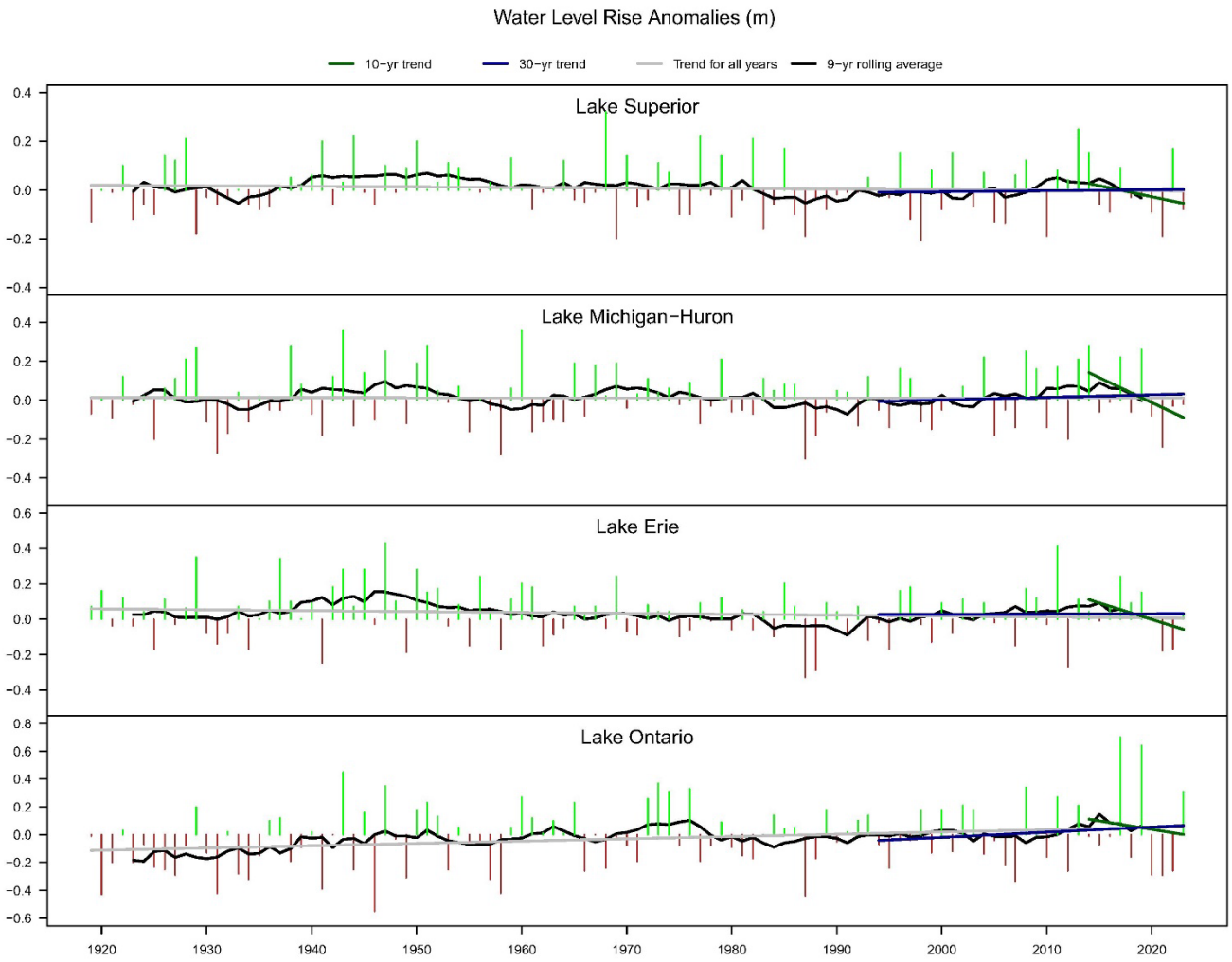

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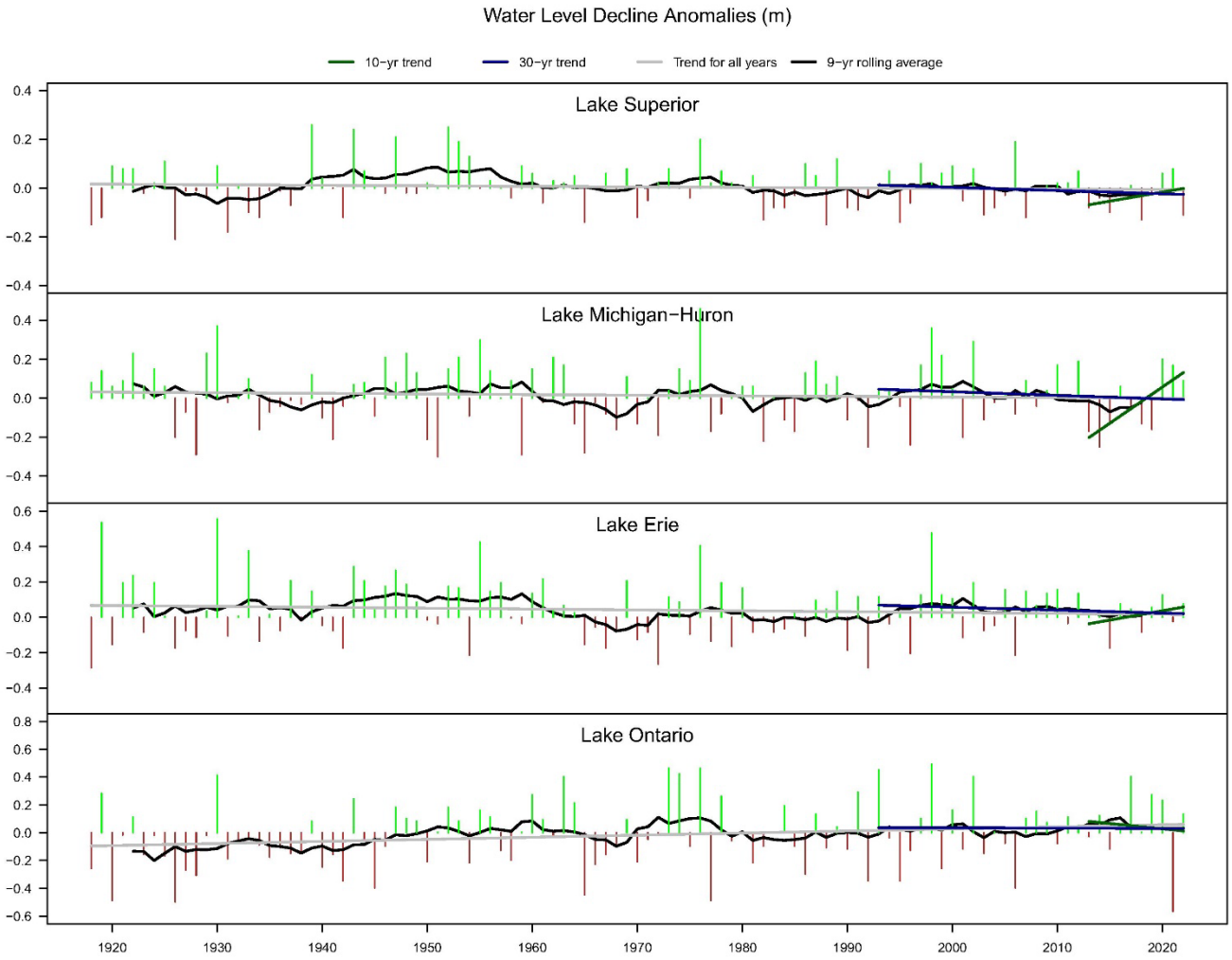

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