US Army Corps of Engineers
Detroit District

Great Lakes Update

Volume 205: 2019 Annual Summary

Background

The U.S. Army Corps of Engineers (USACE) monitors and forecasts the water levels of each of the Great Lakes. This report is primarily focused on summarizing the hydrologic conditions of the Great Lakes basin in 2019.

Official water levels are based on monthly lake-wide means, and the period of record used for each of the lakes includes the years 1918 to 2019. These data have been coordinated between the United States and Canada.

The elevations used are referenced to the International Great Lakes Datum of 1985. The water level of each lake is averaged from a network of individual gages around each lake. Also of note is that Lake Michigan and Lake Huron are hydraulically treated as one lake due to their connection at the Straits of Mackinac.

The Great Lakes are very large and behave differently from smaller, inland lakes. In general, Great Lakes water levels do not rise and fall with individual storms. Significant water level fluctuations require multiple months, seasons, or years of wet or dry conditions.

Seasonal changes in weather patterns typically cause an annual pattern of rising and falling of Great Lakes water levels. Each of the Great Lakes exhibits a seasonal rise in the spring primarily caused by an increase in liquid precipitation, increased runoff due to melting of accumulated snow, and low evaporation rates. The typical seasonal decline of the water levels in the fall and winter is primarily caused by an increase in evaporation, a decrease in precipitation, and the accumulation of snowpack on the land area.

The Net Basin Supply (NBS) is an important quantity for understanding the amount of water which arrives to the lake. USACE uses the residual method to compute NBS, shown below in the summarizing equations:

Residual Method Net Basin Supply:

$$NBS = WL - I - D + O$$

WL:	Water Level Change
I:	Connecting Channel Inflow
O:	Connecting Channel Outflow
D:	Diversion into(+) or out(-) of lake

Altogether, NBS represents the combined effects of precipitation over the lake, runoff to the lake, and evaporation off of the lake. NBS is the main driver of water levels, and is also discussed in more detail in the following sections for each lake.

Record-High Waters Levels in 2019

All of the Great Lakes remained significantly above average in 2019. Lakes Superior, Michigan-Huron, St. Clair and Erie have been above their monthly average levels since at least November 2015. Lake Ontario's level has been above average since January 2017 except for a three-month period of near average levels in 2018. Lakes Superior, St. Clair, Erie, and Ontario all matched or set record high monthly mean levels in 2019. In June and July, all four aforementioned lakes set record high monthly mean levels.

Lake Michigan-Huron was the only lake that did not break any record-high monthly level in 2019. Figure 1 below summarizes the months in which record high levels were met or surpassed in 2019. Figure 2 shows the peak monthly level reached by each lake in 2019 and how they compare to the highest monthly mean level achieved by each lake since 1918, the beginning of their period of record.

LAKE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SUP	1986	1986	1986	1986	2019	2019	2019	2019	2019	1985	1985	1985
M-H	1987	1986	1986	1986	1986	1986	1986	1986	1986	1986	1986	1986
STC	1986	1986	1986	1986	2019	2019	2019	2019	2019	1986	1986	1986
ERI	1987	1987	1986	1985	2019	2019	2019	2019	2019	1986	1986	1986
ONT	1946	1952	1952	1973	2017	2019	2019	1947	1947	1945	1945	1945

Figure 1: Table indicating when record high levels were set on all the Great Lakes dating back to 1918.

LAKE	Peak Level (ft)	Ranking
Superior	603.28	3rd highest
Mich-Huron	581.92	6th highest
St. Clair	577.56	Highest
Erie	574.61	Highest
Ontario	249.05	Highest

Figure 2: Peak 2019 Monthly Level of each Lake and how they compare to each Lake's overall monthly record high since 1918

Lake Superior

Figure 3 shows the 2019 water levels of Lake Superior compared with the 2018 levels and the monthly long-term average (LTA) levels. A similar figure is shown for each lake in the following sections. Each lake's data has been plotted relative to chart datum (a.k.a. low water datum). Chart datum for Lake Superior is 601.1 feet. The dark line in Figure 3 represents the daily 2019 water levels and the solid gray line shows the 2018 levels. The LTA levels for each month are shown by the circles. Figure 4 shows monthly residual NBS, and the NBS shown is relative to the monthly LTA NBS. The lake's annual NBS, which is the sum of the monthly NBS for all twelve months, was above average for the 7th year in a row. The lake's 2019 annual NBS compared to recent annual NBS and its average annual NBS is provided in Figure 5.

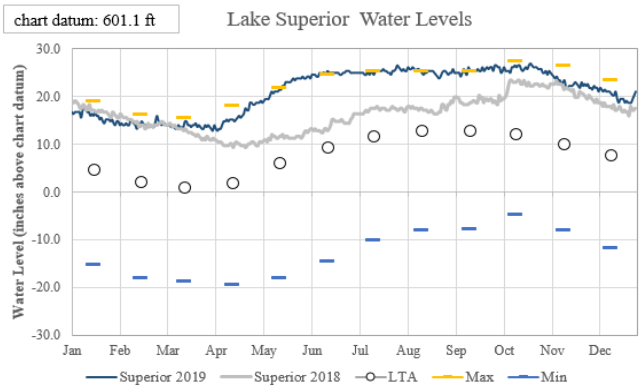

Figure 3: Lake Superior Water Levels

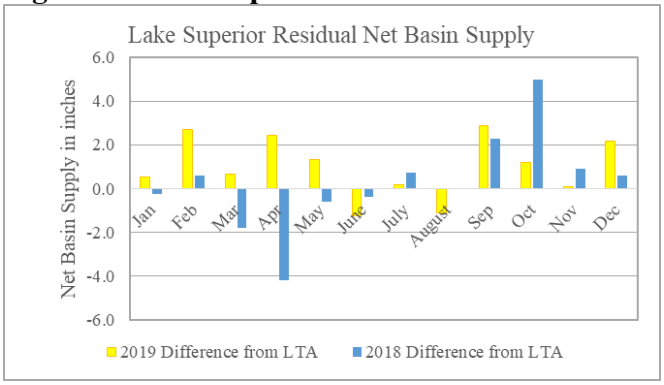

Figure 4: Lake Superior Residual Net Basin Supply, deviation from Long-Term Average

Year	Percent of Average Annual NBS (based on Coordinated Period of Record, 1900-2008)
2019	140%
2018	110%
2017	147%
2016	107%
2015	113%
2014	157%
2013	137%

Figure 5: Lake Superior's Annual NBS from 2013-2019 compared its Average Annual NBS

Lake Superior hovered within an inch of its 2018 monthly levels during the first 3 months of 2019.

However, by June 2019, Lake Superior was 11 inches above its level of a year ago, and 15 inches above its June LTA. The net basin supply to the lake was above average the first five months of 2019. February's NBS was buoyed by precipitation that was much above average. The lake's April 2019 NBS, aided by above average precipitation and melting of significant snowpack, was also well above average.

Lake Superior's 2019 seasonal rise of 12 inches mirrored its 2018 seasonal rise and its average annual rise, but the lake's seasonal decline prior to its 2019 rise was just 8 inches. Lake Superior's seasonal rise took place from April to October, when it reached its peak monthly average level of 603.28 feet, its highest level since November 1985, and its 3rd highest monthly level since 1918. Due to below average NBS during the summer months, the lake was at the same monthly mean level in July, August, and September, but rose in October by less than an inch.

By the end of 2019, Lake Superior had been above its monthly LTA levels every month since May 2014, a period of 68 months. Over the final 3 months of 2019, Lake Superior monthly average levels were 13 to 15 inches above LTA and three inches below its monthly record high water levels.

Lake Michigan-Huron

Lake Michigan-Huron's 2019 levels are shown in Figure 6. Lake Michigan-Huron's monthly mean level in January was 20 inches above its monthly LTA and 3 inches above its January 2018 level. Catapulted by NBS that was above average for 9 months in 2019, by December 2019, the lake's level was 36 inches above LTA and 17 inches above its level of a year ago. Figure 6 also shows water levels from 2012 when the lake fell to a record low December level. Lake Michigan-Huron's mean level in December 2019 was 65 inches higher than its record low in 2012.

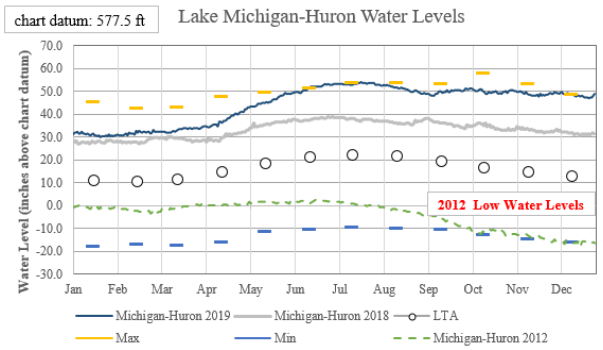

Figure 6: Lake Michigan-Huron Water Levels

The water level of Lake Michigan-Huron has been above average every month since November 2014, a streak of 62 consecutive months. Unlike all of the other Lakes, Michigan-Huron did not meet or exceed any record high levels in 2019, although the lake came within an inch of its record high monthly levels in June, July, and December.

Lake Michigan-Huron's seasonal rise of 22 inches in 2019 eclipsed its 2018 seasonal rise of 10 inches and its historical average seasonal rise of 12 inches. The NBS to the lake in April, May, and June ranged from 50-75% above average, according to provisional statistics. The lake peaked in July at a monthly mean level of 581.92 feet. This level was its 2nd highest July level since 1918, its 6th highest overall monthly level since 1918, and its highest monthly level since November 1986. The lake's monthly mean levels from June through December were all their 2nd highest monthly means in their respective months.

Another notable occurrence was the modest seasonal decline after its 22 inch rise. The lake's average water level decline from July to December is around 9 inches, but in 2019, the lake only fell only 5 inches. Within that timeframe, the lake's monthly mean level rose slightly from September to October after falling from July to September. This relatively short water level decline was due to above average NBS over the final 4 months of the year. Contributing to that stretch of above average NBS was over 30% above average precipitation in

September and October, and substantially below average evaporation in September and December.

Figure 7 shows monthly residual net basin supply relative to its monthly LTA NBS. In 2019, Lake Michigan-Huron received a remarkable amount of water supplies. According to preliminary statistics, the monthly NBS in April, May, September, and December were amongst the four highest NBS the lake has received in those months since 1900. Precipitation was over 30% above average in 3 of those 4 months, and was 8% above average for the year. Moreover, NBS was above average in 7 of the last 9 months of the year. Preliminary results show that the lake's annual NBS, which is the sum of all of its monthly NBS in a year, was larger in 2019 than in any year since 1900. Figure 8 shows a summary of the annual NBS over the past 7 years.

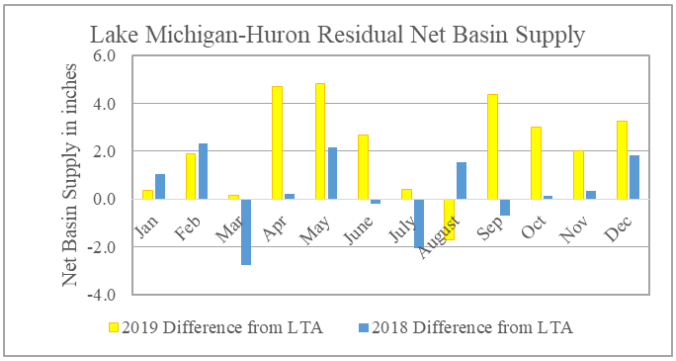

Figure 7: Lake Michigan-Huron Residual Net Basin Supply, difference from Long-Term Average

Year	Percent of Average Annual NBS (based on Coordinated Period of Record, 1900-2008)
2019	177%
2018	120%
2017	137%
2016	89%
2015	100%
2014	150%
2013	126%

Figure 8: Lake Michigan-Huron's Annual NBS in 2019 compared to Annual NBS over the past 7 years and its Average Annual NBS

Lake St. Clair

Figure 9 shows the water levels of Lake St. Clair in 2019 compared to 2018 and the LTA levels. Lake St. Clair started the year 22 inches above LTA and was at least 30 inches above its Long-Term Monthly Average levels the final 7 months of 2019. In addition, the lake has been above its monthly LTA every month since March of 2015.

Lake St. Clair was 15 inches below its record high water levels in January and February. However, 4 consecutive months of above average NBS to start the year led to a February-to-July seasonal rise of 25 inches, topping the prior year's 19-inch rise and its historical average rise of 16 inches, and notably dwarfing the preceding 12-inch seasonal decline. This 25-inch surge propelled the lake to eclipse its record high monthly mean water levels for five consecutive months in 2019 – May, June, July, August, and September – by a range of 1 to 4 inches.

According to preliminary results, the lake reached a monthly mean level of 577.40 feet in June, the highest monthly mean level it had achieved for any month dating back to the start of its period of record (1918). This level was 3 inches above its previous June record high and an inch above the previous record high monthly level set in October 1986. This record high level was surpassed the

very next month when the lake's mean level rose 2 inches to its seasonal peak of 577.56 feet.

Net basin supplies to Lake St. Clair were near average or below average the remaining eight months of the year. The lake's monthly NBS is summarized in Figure 10. The lake's decline from its July peak to December was 14 inches, slightly higher than its average July-to-December decline of 11 inches, resulting in Lake St. Clair being 4 to 8 inches below record highs during the final 3 months of the year. The lake's considerable inflow from the St. Clair River, driven by near-record Lake Michigan-Huron levels, sustained Lake St. Clair's elevated levels despite below average monthly NBS in the final 8 months of the year.

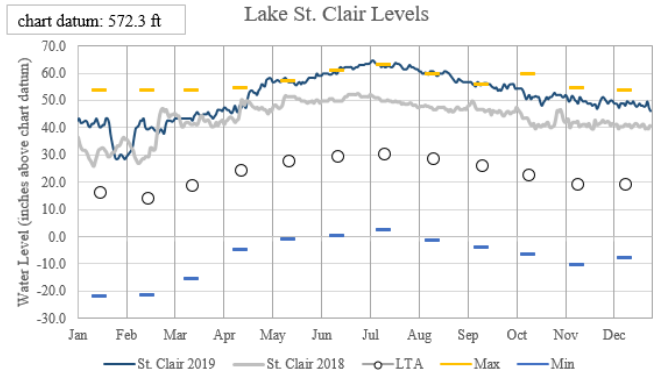

Figure 9: Lake St. Clair Water Levels

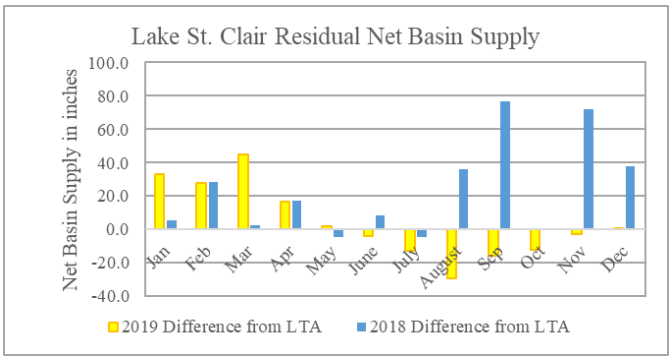

Figure 10: Lake St. Clair Net Basin Supplies

Lake Erie

Record breaking high water levels characterized Lake Erie water levels in 2019, as displayed in Figure 11. The lake's level has been above its monthly LTA since June 2015, a period of 55 consecutive months. According to preliminary data, Lake Erie surpassed its monthly mean level record high in May and continued to set monthly mean level record highs in June, July, August, and September. These new record high levels ranged from 2 to 4 inches above the previous record high levels reached in 1986. Lake Erie's monthly mean level in June, 574.61 feet, is the lake's highest monthly level in its period of record dating back to 1918.

The level of Lake Erie in January 2019 was about 10 inches above its 2018 January level, 25 inches above LTA, and 9 inches below its record high January level. In March, the lake was even an inch below its March 2018 level. However, Lake Erie experienced a 21-inch seasonal rise in 2019, exceeding its historical average climb of 14 inches. This seasonal rise resulted in the lake's monthly mean level in July being 12 inches above its 2018 levels, and 31 inches above LTA.

Lake Erie's 21-inch rise can be attributed to net basin supplies to the lake that were above average in 4 of the 5 months from February to June. Its NBS in June was 2.5 times the average for that month. Contributing to the NBS were runoff and precipitation that were above average in April, May, and June, according to preliminary estimates. In fact, Lake Erie was the only Great Lake in 2019 to experience above average precipitation in 4 consecutive months, April to July.

The lake's monthly NBS in 2019 is shown in Figure 12. In the second half of the year, – November was the only month Lake Erie experienced above average NBS. Lake Erie's monthly mean levels remained 3 to 7 inches above the previous year's levels, and 7 to 8 inches below record high levels, over the final 3 months of 2019.

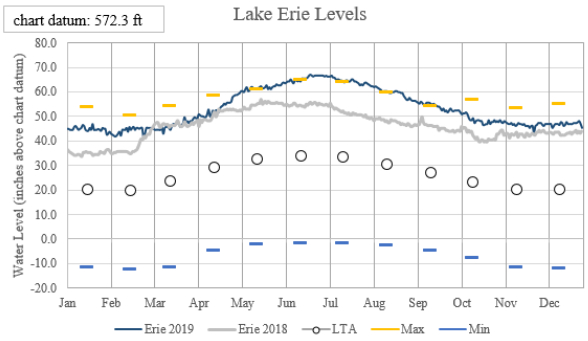

Figure 11: Lake Erie Water Levels

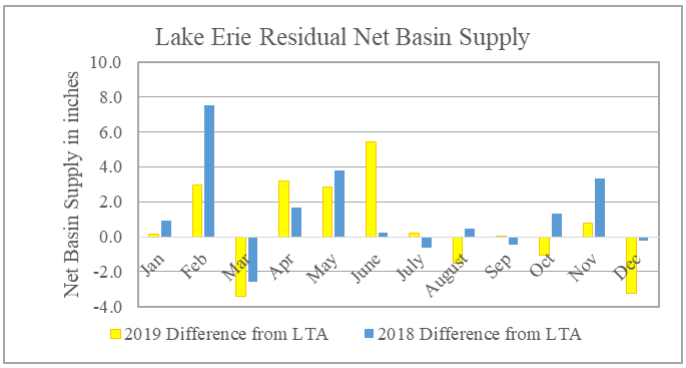

Figure 12: Lake Erie Residual Net Basin Supply, deviation from Long-Term Average

Lake Ontario

Figure 13 shows Lake Ontario water levels relative to the chart datum of 243.3 feet. The lake began 2019 as it began 2018 – 11 inches above LTA and 13 inches below its record high January level. Unlike the other Great Lakes, which have been above average in every month since at least late 2015, Lake Ontario's current streak of above average water levels began in October 2018.

The lake's seasonal rise in 2019, was 51 inches, substantially more than the lake's 2018 seasonal rise of 19 inches, and its average seasonal rise of 21 inches. Lake Ontario's monthly Net Basin Supply, shown in Figure 14, was above average for every single month of 2019. In fact, its May and June net basin supplies were around 70% above normal. Preliminary results suggest precipitation and runoff were well above average those 2 months.

While in January 2019, Lake Ontario was at the same level it was in January 2018, by July, Lake Ontario's mean level was 29 inches above what it was 12 months before, and 31 inches above average. In addition, the lake's meteoric rise of 51 inches resulted in surpassing the record high water levels in June and July that had been set just two years earlier in 2017. Lake Ontario peaked in June at 249.05 feet, 4 inches above its record high June mean level. This level, which was 33 inches above LTA, is also the highest monthly mean level recorded on Lake Ontario since the lake's period of record began in 1918.

The lake's 2019 seasonal decline of 36 inches occurred from June to December. This is much larger than the lake's average June-to-December decline of 21 inches and brought Lake Ontario down to 11 inches above its 2018 monthly mean level, and 19 inches above LTA, in December. According to provisional statistics, record and near-record high monthly Lake Ontario outflows through the St. Lawrence River occurred from June through December, contributing to the lake's above average decline. In 2019, the lake's annual NBS - the sum of all of its monthly NBS in a calendar year - was the lake's 5th highest since 1900, according to provisional data.

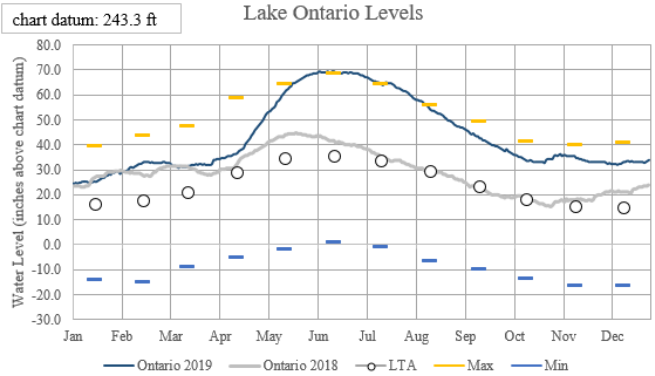

Figure 13: Lake Ontario Water Levels

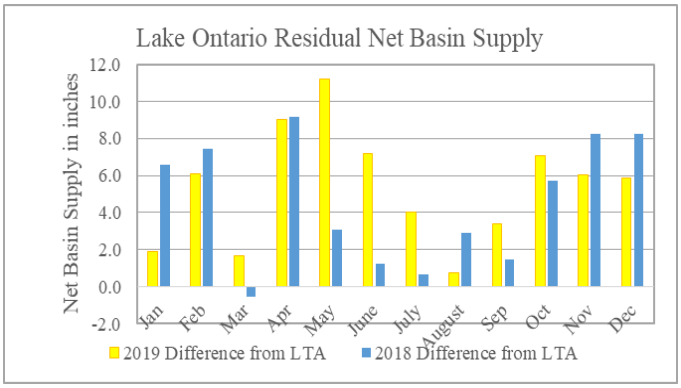

Figure 14: Lake Ontario Residual Net Basin Supply, deviation from Long-Term Average

Emergency Management Rises to the Occasion

The U.S. Army Corps of Engineers (USACE) Emergency Management is authorized by Public Law 84-99 to support local, county, and state efforts during flood emergencies. USACE support comes in two forms, Technical Assistance and Direct Assistance. Technical Assistance allows USACE to provide data, recommendations and solutions to the community's flooding concerns. Additionally, under Technical Assistance, USACE can deploy a skilled flood fight team during a flood event in order to bring expertise into a community, and train local communities how to properly fill and place sandbags and other temporary flood protection measures. Under Direct Assistance, USACE can provide materials and equipment to communities during a flooding event. These materials include sandbags, plastic sheeting, and HESCO barriers. All materials provided must be returned if not used or reimbursed back to USACE, unless a Presidential Disaster is declared. Additionally, flood fight supplies provided under Direct Assistance are solely for the protection of critical public infrastructure. USACE cannot directly assist individual homeowners or commercial interests.

2019-2020 Great Lakes High Water

Due to the rising water level on the Great Lakes, USACE Detroit District activated their Emergency Operations Center (EOC) in early May 2019. This Great Lakes high water event has persisted since then and Emergency Management is currently providing Technical Assistance to six counties in Wisconsin, twelve counties in Michigan, and one tribe in Michigan. Typical Technical Assistance for this event has included reviewing areas of concern and providing flood fighting recommendations, and educating/training in proper sandbag filling and placement. In addition to Technical Assistance, USACE Detroit District has provided over 290,000 sandbags to communities.

Preparedness is a key principle in Emergency Management, and USACE Detroit District Emergency Management has been engaged with many communities in Michigan and Wisconsin to provide outreach regarding the ongoing threat from the Great Lakes high water levels. These engagements range from one-on-one meetings with local/county government agencies, to public meetings/presentations on Great Lakes water levels, USACE Emergency Management authorities, and the Detroit District response to the Great Lake high water level event.

Case Study: City of Detroit Flood Fight

Figure 15: Flood Fighting Staging Area in Jefferson-Chalmers community, Detroit, MI, May 2019

Figure 16: Sandbagged property in Jefferson-Chalmers community, Detroit, MI, May 2019

During the spring and summer of 2019, the City of Detroit experienced substantial flooding along the shore of Lake St. Clair. Flooding caused damage to numerous homes, streets to become impassible, and evacuation routes to be blocked. During this event, the USACE Detroit District Flood Fight Team (FFT) was deployed to support the Jefferson-Chalmers community. The FFT's first initiative was to establish a flood fighting staging area in that neighborhood. Then, the FFT helped train the community in sandbag filling and placement techniques. In addition, the FFT evaluated areas of concern throughout the community that were vulnerable to flooding and provided recommendations to mitigate the flooding. This flooding was a community-wide issue, and was tackled with a community-wide effort.

Who Can You Contact?

If you are in need of assistance in your community, please contact your local or county emergency management agency. USACE support is supplemental to local efforts and it is important that the county and state are aware of the need in their area of responsibility. If you have any questions for USACE Detroit District, please contact Emergency Management at CELRE-EOC@usace.army.mil or visit our dedicated Great Lakes High Water webpage at https://www.lre.usace.army.mil/About/Great-Lakes-High-Water/

More Information

Update articles are included periodically in the *Monthly Bulletins* highlighting topics and explanations relevant to Great Lakes water levels. Nearly all past Update Articles dating back to 1985 can be accessed here:

https://www.lre.usace.army.mil/Missions/Great-Lakes-Information/News-and-Information/Great-Lakes-Update-Articles/

The *Monthly Bulletin* is sent by postal mail. To be added to the postal mailing list, please send an email to hhpm@usace.army.mil or call 1-888-694-8313 and select option 1. Alternatively, the Monthly Bulletin can be viewed on our website. The home page is: http://www.lre.usace.army.mil. In addition to the *Monthly Bulletin*, the Detroit District issues the *Weekly Great Lakes Water Level Update* and the *Weekly Great Lakes Connecting Channels Water Levels and Depths*. Both products are updated at the end of each week. Additionally, a one year *Great Lakes Water Level Outlook* is produced once every three months. All forecast products are located here:

http://www.lre.usace.army.mil/Missions/GreatLakesInformation/GreatLakesWaterLevels/WaterLevelForecast.aspx

The Detroit District also has a Facebook page which can be found here:
https://www.facebook.com/USACEDetroitDistrict/
Please email questions and comments to hhpm@usace.army.mil. To contact the District by phone call toll free 1-888-694-8313 and select option 1. The Detroit District's mailing address is:

Department of the Army
Detroit District Corps of Engineers
ATTN: CELRE-EHW
477 Michigan Avenue
Detroit, MI 48226