and Lake Erie Volunteer Science Network

Present

2023 Lake Erie Watershed Health Field Season Report

Data collected and analyzed by:

Table of Contents

1. Executive Summary
    - 1.1. Mission, Goals, and Program
    - 1.2. Outcomes of 2022 Field Season and Program Year
    - 1.3. How to Use This Document and Supporting Products

2. Approaches and Methods
    - 2.1. Directly Measured Parameters
    - 2.2. Conductivity and Surrogate Measures
    - 2.3. Data Collection and Management
    - 2.4. Analysis and Interpretation

3. Results: Large Rivers and Other Direct Tributaries to Lake Erie
    - 3.1. Cuyahoga River
    - 3.2. Detroit River Tributaries
    - 3.3. Huron River
    - 3.4. Maumee River & Subbasin of Swan Creek
    - 3.5. Ottawa River
    - 3.6. Rocky River
    - 3.7. Buffalo River
    - 3.8. Chappell Creek
    - 3.9. Eighteenmile Creek
    - 3.10. Euclid Creek
    - 3.11. Mills Creek
    - 3.12. Old Woman Creek
    - 3.13. Pipe Creek
    - 3.14. Rush Creek
    - 3.15. Smoke Creek

4. Results: Lake Erie River Basins
    - 4.1. Regional Station Summary
    - 4.2. Regional River Basins Data Summary
    - 4.3. 2023 Regional Findings and Conclusions

5. Summary and Recommendations
    - 5.1. Interpretation of Findings and Corresponding Recommendations
    - 5.2. Limitations of 2023 Monitoring Program and Corresponding Recommendations
    - 5.3. Program and Organizational Outcomes
    - 5.4. Growing the Movement

6. Appendix I - Participating Groups

7. Appendix II - A Word on “Volunteer” vs. Citizen” Science

Section 1 – Executive Summary

1.1 Mission, Goals, and Program

The Lake Erie Baseline Assessment Framework (LEBAF) is a process for standardizing data collection, analysis and communication that empowers volunteer water quality monitoring (often called“volunteer,” “citizen,” or “community” science”) groups to elevate the credibility of their data and tell a regional story about the condition of Lake Erie watersheds. LEBAF was first conceived in 2021 by the Lake Erie Volunteer Science Network (LEVSN), a regional collaboration of local monitoring programs convened by Cleveland Water Alliance, to unlock the potential of volunteer science to address gaps in regional water quality data collection. LEBAF was given structure and life by LEVSN's Standards Working Group, a task force composed of volunteer monitoring programs and external experts from Ohio Sea Grant, The Commons, and Ohio EPA. This Working Group led an iterative process of collaborative standards development that engaged the other LEVSN members as well as additional external partners including Academic and Federal Research Institutions, State Agencies, Local Municipalities, and Natural Resource Managers. This process resulted in the official launch of LEBAF at the inaugural Lake Erie Citizen Science Summit, co-hosted by the Cooperative Institute of Great Lakes Research and Cleveland Water Alliance at the International Association of Great Lakes Researchers' State of Lake Erie conference in March of 2022.

Emerging from the Summit, Eight local monitoring programs from LEVSN volunteered to participate in the first regionally standardized LEBAF sampling season. In exchange for participation, LEVSN Local Hubs received long-term access to equipment (YSI ProQuatro Multiparameter Water Meters), data management and analysis tools (Water Reporter), technical training (from YSI and Water Reporter), and a set of required and recommended best practices for data collection, management and analysis (LEBAF SOP, Data Manager's Manual, and supporting documents). Participation was further supported by monthly cadence meetings and intensive multi-day workshops on data analysis and program evaluation facilitated by Cleveland Water Alliance.

The first output of LEBAF is a set of Standard Operating Procedures (SOP or "Standards") which describe program, technical, information, and evaluation design elements that guide mutually reinforcing activities for volunteer scientists across the Lake Erie Basin. These activities are defined by shared:

- ***Suite of Monitored Parameters -*** LEBAF participants all must directly sample pH, dissolved oxygen, water temperature, and conductivity at least once per month for each monitored site. Direct conductivity measurements are further interpreted as biocondition, total dissolved solids, chloride, and salinity in data analysis.

- ***Monitoring Purpose:*** Collection of a common set of measures that support screening of conditions that support aquatic life as an indicator for the baseline conditions and trends in the health of Lake Erie watersheds at various scales.
- ***Intended Data Use:*** Data collected is intended to be used primarily as a water quality screening tool that drives 1) benchmarking of watershed health, 2) interoperability of results across watersheds, and 3) educating and engaging local communities. It is secondarily intended for use in resource prioritization and decision making (e.g. use support, advocacy, policy, resource management, and adaptive management).
- ***Target Data Users:*** LEVSN and its partners are the primary target users. Use by Federal, State and local decision makers is a priority, but secondary to the needs of the volunteer science groups implementing LEBAF.
- ***Expected Outcomes and Impacts:*** The implementation of LEBAF will 1) provide a regional condition assessment of Lake Erie streams over time, 2) identify potential problem areas to be investigated for impairment identification, 3) establish a shared lexicon to communicate program elements, shared goals, and watershed status to volunteers and the public, 4) demonstrate the capacity of regional volunteer science collaboration, and 5) create an iterative process for expanding the scope of shared standardizations and collaborations over time.

The second output of LEBAF is a "standardization menu" that documents additional parameters and other program elements that could be standardized to tell a more complete story about watershed health. At the end of each field season, LEBAF participants and collaborating partners convene to evaluate that year's programming, using this menu to prioritize adjustments and additions to the SOP for the following season. This annual cycle is intended to guide LEBAF's strategic expansion, using initial wins as a framework on which to build, over iterations, towards greater collective impact.

1.2 Outcomes of 2023 Field Season and Program Year

During the second LEBAF field season, ten participating groups collected, analyzed, and interpreted data from over 1300 samples originating at over 100 stations in 20 local watersheds across the Lake Erie Basin (Table 1 and Figure 1). Building on participant engagement during 2022, the inaugural year, LEVSN added two participating groups and collected nearly double the samples from a greater number of rivers and streams. Use of the collaboratively developed LEBAF SOP enabled comparable data collection by all participants, allowing groups from as far afield as Ann Arbor and Buffalo to compile an increasingly representative snapshot of Lake Erie watersheds. This shared structure empowered participants to refine a standardized data analysis and interpretation process that provides a robust screening of watershed health across monitored areas and the Lake Erie basin as a whole.

Table 1. Characterization of the 2023 Lake Erie Volunteer Science Network

Monitoring Region	Participating Group	Waterbody (# of stations)
Southeastern Michigan	**Huron River Watershed Council**	**Large Rivers:** ● Huron River (12) ● Detroit River (5) - only sites on direct tributaries of river
Northwest Ohio	**Community Water Action Toledo**	**Large River:** Maumee River (6) - some sites on one tributary of the river ● Swan Creek (9) **Direct Tributary:** Ottawa River (4) - some sites on one tributary of the river ● Tenmile Creek (1)
North central Ohio	**Firelands Coastal Tributaries Watersheds**	**Direct Tributaries**: ● Mills Creek (7) ● Old Woman Creek (10) ● Pipe Creek (7) ● Chappel Creek (6)
Northeast Ohio	**Summit Soil and Water Conservation District**	**Large River:** Cuyahoga River - only sites on tributaries of the river ● Yellow Creek (9) ● Furnace Run (8)
	Cleveland Metroparks	**Direct Tributary:** Euclid Creek (1) **Large River:** Rocky River (1)
	Tinker's Creek Watershed Partners	**Large River:** Cuyahoga River - only sites on tributary of the river ● Tinkers Creek (11) ● Brandywine Creek (5)
Buffalo Area (New York)	**Buffalo Niagara Waterkeeper**	**Large River:** Buffalo River (2) **Direct Tributaries:** ● Eighteen Mile Creek (2) ● Rush River (1) ● Smoke Creek (1)

Figure 1. Map of Large Rivers and Direct Tributaries (blue shades) and monitoring stations (green) participation in the 2023 LEBAF Program.

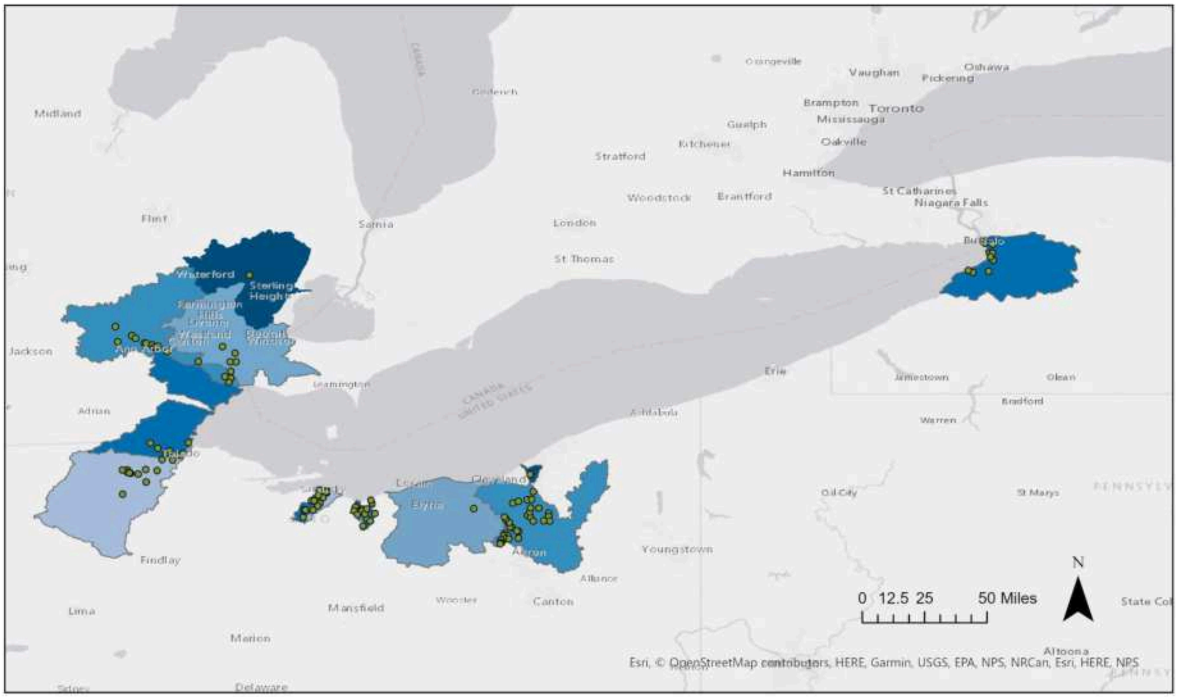


Figure 2. Southeastern Michigan Large Rivers & Monitoring Stations. There is no data included in the Clinton River in this 2023 report, but there are LEVSN participants monitoring in this watershed.

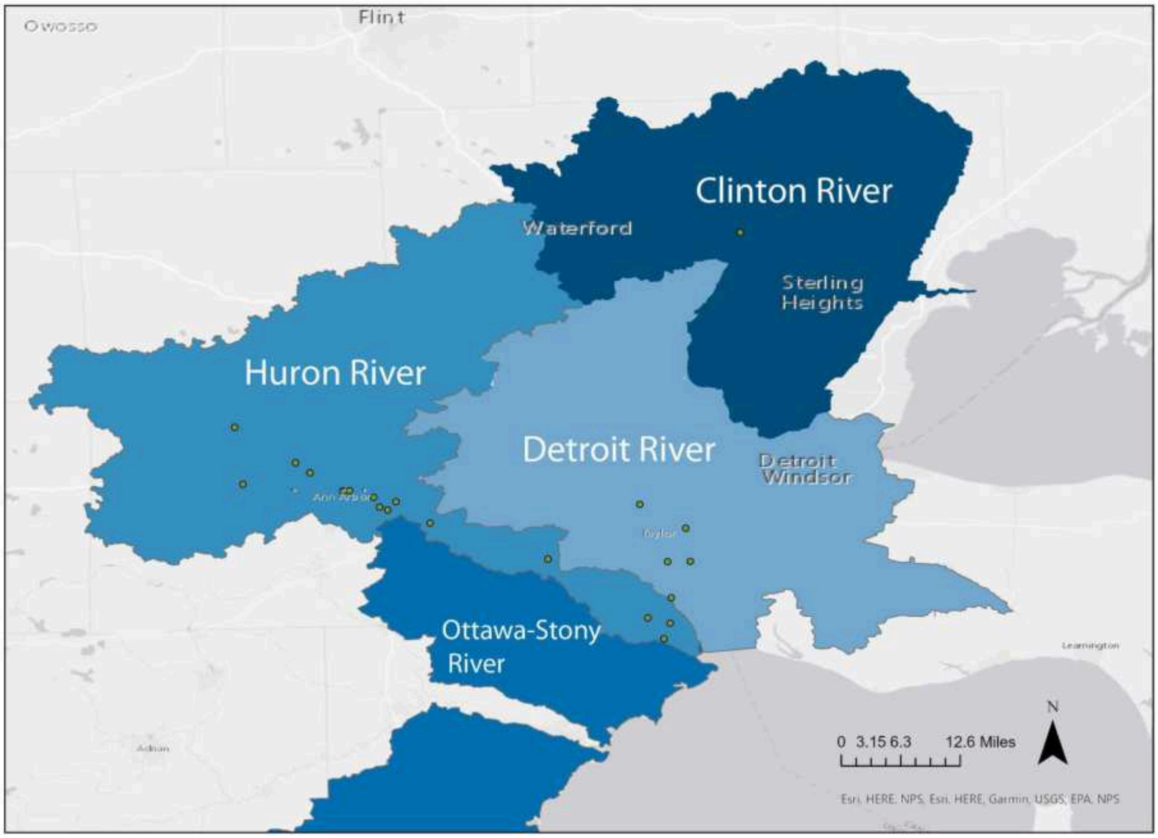


Figure 4. Northwest Ohio Large Rivers & Monitoring Stations

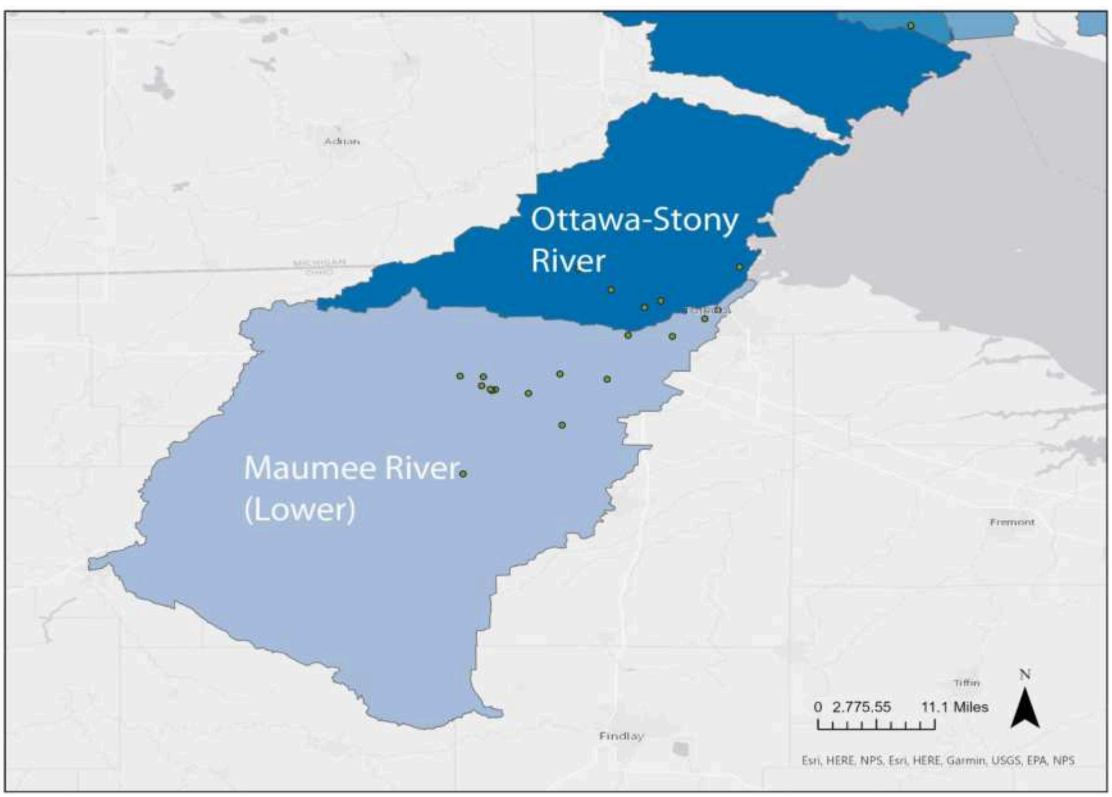


Figure 3. North Central Ohio Direct Tributaries & Monitoring Stations

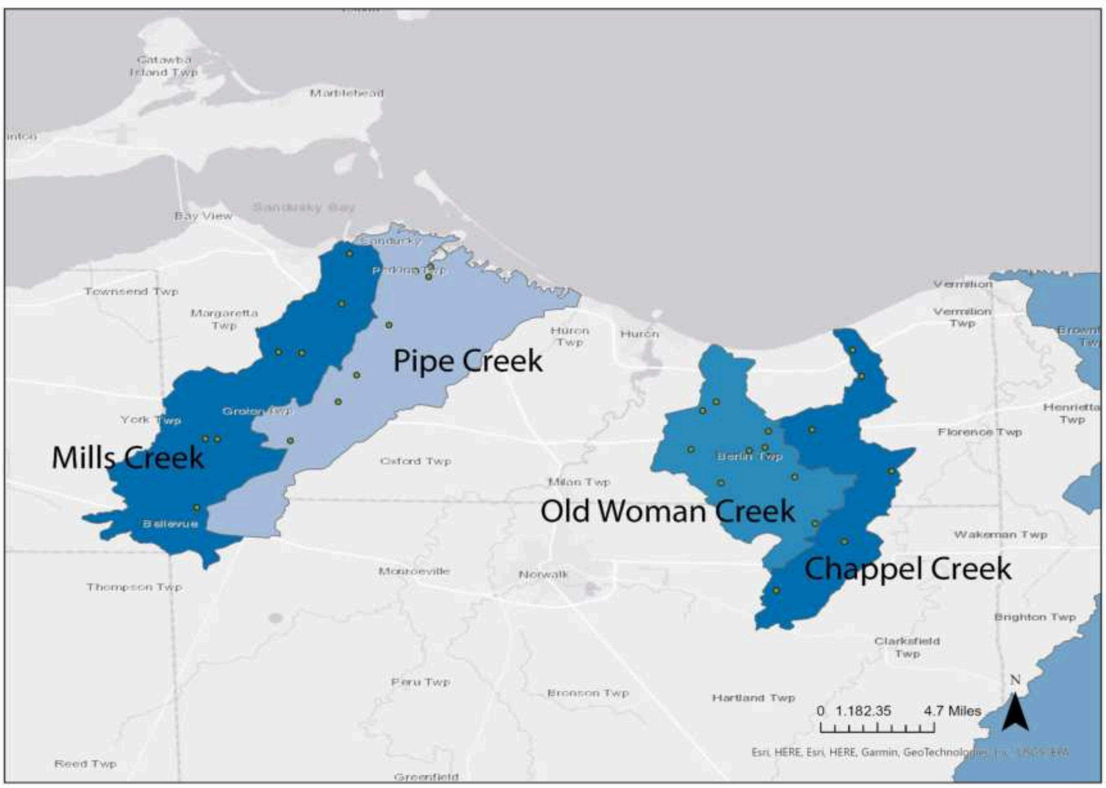


Figure 4. Northeast Ohio Large Rivers, Direct Tributaries, & Monitoring Stations

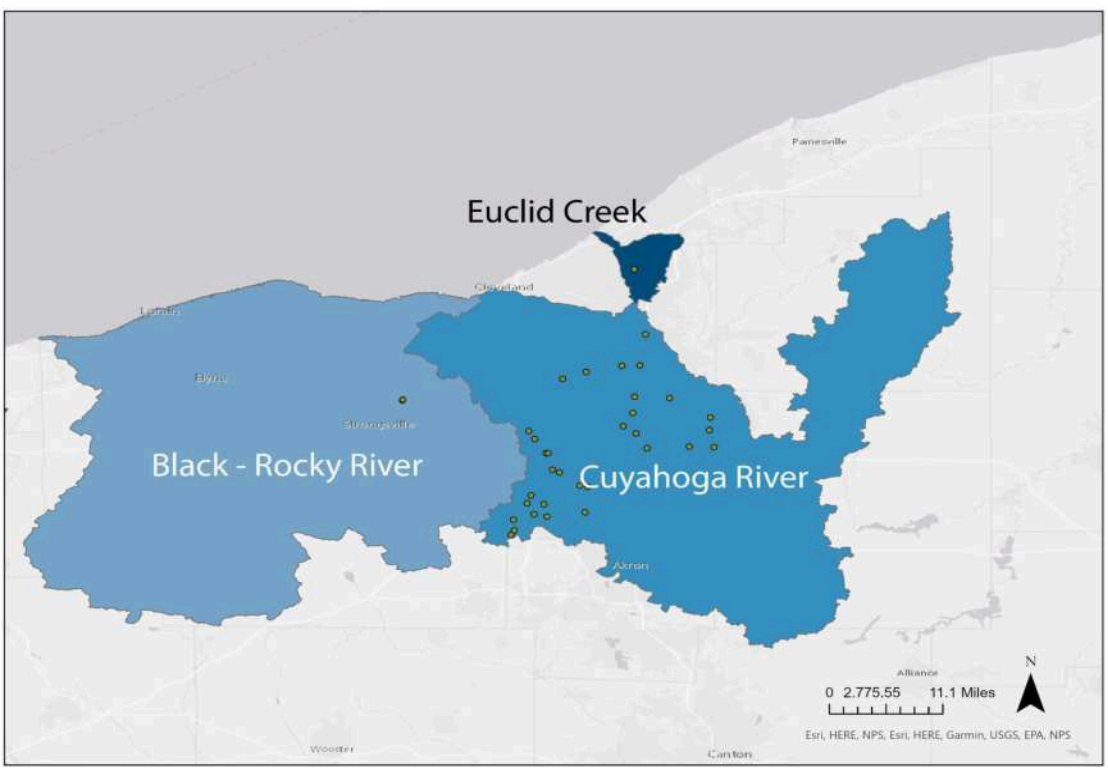
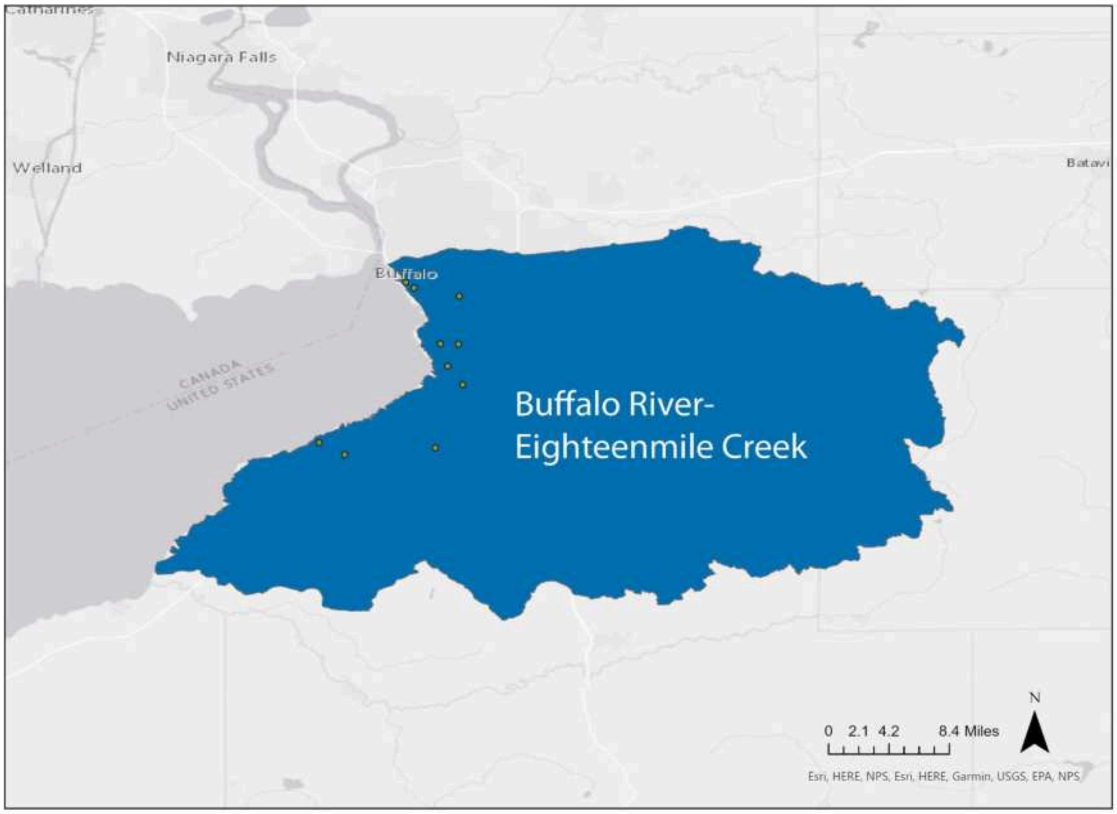


Figure 4. New York Buffalo Area Large Rivers & Monitoring Stations



Through expanded use of this rigorous and standardized assessment, LEVSN can present a regional volunteer-driven perspective on the condition of watersheds that feed Lake Erie and refine benchmarks against which continued monitoring can be compared. Using the definition of health laid out in the LEBAF SOP, 2023 field measurements support 2022 outcomes that suggested Lake Erie's watersheds are generally healthy and able to support aquatic life. These conclusions are again supported by participants' direct measurement of pH and dissolved oxygen as well as expressions of conductivity as TDS, salinity and chloride, although there is some indication that negative impacts may be present regionally.

For the second year in a row, exceedances of the conductivity macroinvertebrate biocondition gradient suggested that all waterways sampled are currently experiencing, or at risk of experiencing, degraded conditions; across all sampling sites, the exceedance rate is above 95%. This parameter is an indicator that looks at stream health through the lens of potential impacts to aquatic life from dissolved substances, chemicals, and minerals present in the water. This could mean that elevated conductivity levels are directly impacting aquatic life in many Lake Erie streams or are associated with other processes and pollutants interacting to limit macroinvertebrate community structure and function. In some cases, it may also reflect localized geology or processes that our assessment macroinvertebrate database does not represent with equal sensitivity. Longer-term monitoring of this parameter will help determine the scope of this potential impact. Aquatic macroinvertebrate community data exists for some sites, and this will help to offer clarity when comparing trends over time.

Analysis of 2023 LEBAF data and sampling design, especially with the added context of local knowledge, highlighted some limitations. In considering the 2023 results, it is essential to note that LEBAF, even with continued growth, has spatial and temporal gaps within currently monitored watersheds as well as underrepresentation of cold water streams, absence of monitoring for some major watersheds to the Lake, and lack of Canadian participants. Two years of standardized data collection does not allow for definitive statements about the overall health of any watershed regardless of how much data was collected. Before drawing any actionable conclusions, it is critical to consider long term variations that provide better context for each season's observations. As a result, ***all observations and interpretations described in each water body's aggregated summary, and in the Recommendations and Conclusions should be taken as heavily qualified by a range of limitations that face this monitoring program, particularly in these early years of operation.***

Further, with few stations located on Lake Erie itself, it is important to recognize that assessment of aquatic life conditions on the open water is not currently possible through LEBAF. With this in mind, LEVSN determined that this report will only include analysis, interpretation, and recommendations for Lake Erie river basins. Exploration of water quality of Lake Erie based on results of basin sampling will be included on a bi-annual basis, beginning in 2025.

The second year of standardized volunteer monitoring continued progress towards LEBAF's intended monitoring purpose, data use, and desired impacts. LEVSN improved its use of industry-standards sensor technology, a cloud data platform, training opportunities, and updated SOPs to maintain standardized, credible volunteer monitoring. Participating groups were able to collaboratively screen for and benchmark the health of their local watersheds, identifying data gaps to guide future monitoring priorities and potential problem areas to be further investigated. Many hours of work from partners across the Lake Erie Basin led to improved analysis and reporting methods. During Spring 2024, a second evaluation of LEBAF's SOP and processes will be conducted by its participants to further refine program elements and shared analyses. LEVSN has realized its aim to build on 2022's successes to expand the number of samples collected, geographic coverage, and confidence in its interpretation over future sampling years.

As LEBAF monitoring continues, the standardized, credible, volunteer-collected data will allow LEVSN to provide a regional condition assessment of Lake Erie streams over time to inform local, and potentially regional, restoration and protection activities. While a more comprehensive picture is not yet clear, the network is demonstrating the capacity of a regional volunteer network to generate credible and useful science. Participants have shared knowledge, positively impacted their communities, and expanded access to volunteer monitoring around Lake Erie. The movement will continue to build momentum in pursuit of better water quality and quality of life for all Lake Erie Basin communities.

1.3 How to Use This Document and Supporting Products

This document is the 2023 annual LEBAF report of data collected from rivers and tributaries within the Lake Erie Basin. This is the second annual report that provides a *detailed analysis* of data collected by the Lake Erie Volunteer Science Network (LEVSN). The report includes two different assessments of 2023 LEBAF data.

1. **Local Rivers and Lake Erie Tributary Assessments:** An analysis of individual river or tributary 2023 datasets using a standardized assessment described in Section 2 - Approach and Methods. The assessments for each river and tributary are provided alphabetically in Section 3 - Results: Large Rivers and Other Direct Tributaries to Lake Erie. Each river or tributary subsection provides 1) monitoring organization information, 2) a description of monitoring stations, 3) results, and 4) a summary of recommendations and data limitations. Only elements of importance for data screening of ecosystem health are presented in these assessments. Participating organizations have more information on their monitoring programs and data as well as their own information products available on their websites (linked in Appendix 1).
2. **Lake Erie Basin Assessment:** An assessment of all the collected data by the Lake Erie Volunteer Network (LEVSN) through a Lake Erie Basin-wide lens. This assessment follows the same analysis approach described in Section 2, but aims to identify overall spatial and temporal trends or differences across the entire Lake Erie Basin. The results for each of the four directly measured, core parameters - 1) pH, 2) dissolved oxygen, 3) temperature, and 3) conductivity - are shared in Section 4 - Results: Lake Erie Watershed and overall findings are summarized in Section 5 - Summary and Recommendations. The parameter results in Section 4 include further information on the 1) data assessment and thresholds, 2) parameter expectations, 3) data characterization, 4) water quality exceedances, 5) factors influencing exceedances, 6) a data summary, 7) data limitations, and 8) recommendations.

This LEBAF report serves as a standardized assessment and report of 2023 data across the Lake Erie Basin. Secondarily the report also provides local (Section 3) and regional (Section 4) recommendations for addressing water quality concerns and ecosystem harm. These recommendations are summarized in Section 5.1 Interpretation of Findings and Corresponding Recommendations and serve as a guide for resource prioritization and decision making (e.g. use support, advocacy, policy, resource management, and adaptive management) for Federal, State, and local decision makers. Additional communication tools with more concise language as well as all the 2023 and 2022 data are available on the LEVSN Website.

Section 2 – Approach and Methods

2.1 Directly Measured Parameters

The LEBAF SOP presents standards for the direct collection, management, and analysis of basic chemical parameters that indicate watershed conditions using a multiparameter water meter or a set of single parameter water sensors. This section provides basic information about each core parameter measured and the use of each parameter as an indicator of water quality and ecosystem health. Each parameter includes a link to a relevant section of the LEBAF SOP which includes more information on the impact this parameter can have on an aquatic ecosystem, its natural fluctuations, common external factors that influence its dynamics, and LEBAF's standardized method for sampling it.

pH: A measure of hydrogen and hydroxyl ion activity in water or a measure of water acidity/basicity. pH affects many chemical and biological processes in surface water such as the solubility, biological availability, and transport of heavy metals (cadmium, copper, lead), nutrients (carbon, nitrogen, phosphorus), and other aquatic pollutants. pH levels that are either too low or too high are not conducive to aquatic life.

Dissolved Oxygen (DO): The amount of gaseous oxygen (O_2) in the water. DO is governed by temperature, salinity, and atmospheric pressure. DO concentrations are typically near or at saturation for a given temperature. Waters with DO levels at or near the respective temperature saturation are capable of supporting aquatic life adapted to those conditions. The necessary amount of DO, however, varies with species, age and activity, and includes a lower and higher supportive range.

Temperature (Temp): The average kinetic energy of water molecules also known as the degree or intensity of thermal energy in water. Temperature affects the chemical and physical properties of water, and in turn, other elements within an aquatic system. Aquatic temperature regimes drive metabolism, growth, behavior, and reproduction of aquatic biology, determining the type and quantity of aquatic life present in waterbodies. Supportive temperatures include cold, warm and transitional temperatures as well as seasonal ranges within each temperature category.

Conductivity: Conductivity is a measure of the collective amount of dissolved ions (salts and other primarily inorganic chemicals) in a waterbody. Since conductivity quantifies a broad range of chemicals, conductivity serves as a general indicator of water quality. Natural rivers and streams tend to be low in ionic content, but the amount of dissolved ions varies with geology, precipitation, and other localized variables. The range of conductivity values, however, tends to be consistent. Thus, if conductivity falls above baseline conditions, it indicates potential pollution from salts, nutrients, or metals that may directly or indirectly affect aquatic life or habitat. Further investigation is needed to identify the specific dissolved ions contributing to the high conductivity.

2.2 Conductivity and Surrogate Measures

As described above, conductivity is a widely used screening parameter rather than a measure of specific constituents. Conductivity is highly correlated with a number of other water quality parameters including total dissolved solids (TDS), salinity, and chloride. As such, surrogate parameters can be mathematically calculated from conductivity measurements. LEBAF calculates the three surrogate measures - TDS, salinity, and chloride - using the equations described in the LEBAF SOP and Table 3. These surrogate parameters can be used to help interpret high conductivity (> 850 µS cm^{-1}) results and suggest further investigation. As the LEBAF SOP is expanded over time, LEVSN hopes to include standardized direct observations of these parameters, as opposed to surrogate values calculated from conductivity measurements. LEBAF also hopes to use direct measurements for comparison to test the local correlations of calculated values whenever possible. Surrogate parameters from conductivity measurements are explained in more detail below.

Conductivity Biocondition: LEBAF participants assessed directly measured conductivity results against a macroinvertebrate community condition gradient based on conductivity levels provided by Ohio EPA. As conductivity increases it begins to impact aquatic life. The gradient identifies conductivity levels that correlate to *healthy* macroinvertebrate communities, *declining or degrading* communities and *already degraded* communities (see thresholds in Table 3). Comparison of conductivity results to a large temporally, geographically and ecologically relevant macroinvertebrate biocondition dataset allows for interpretation of the degree to which conductivity may be impacting overall aquatic health.

Total Dissolved Solids (TDS): A measure of all solids dissolved in water, including minerals, salts, metal, cations, anions and organic molecules. Very similar to conductivity, TDS doesn't measure specific ions but a combination. The scientific and mathematical relationship between conductivity and TDS is very well established and has a high use confidence for multiple purposes including screening. In fact, the surrogate calculation used by LEBAF is the same equation TDS meters employ automatically converting conductivity to TDS. Most states have well established Clean Water Act standards for TDS to protect drinking water or water supply, but not for aquatic life. Ohio has a TDS aquatic life standard but uses it with caution as it is underprotective and requires local context to interpret, but it can provide a useful screening threshold. An initial use of Ohio's aquatic life TDS standard of 1500 mg L^{-1} was applied to determine if conductivity levels were high enough to exceed even this underprotective standard. If so, it would suggest that aquatic life is most likely impacted.

Chloride: A measure of the concentration of dissolved salts resulting from the combination of chlorine with a range of positively charged elements such as hydrogen, sodium or magnesium. Elevated concentrations of chloride in streams have been determined to be toxic to some aquatic life. Additionally, the presence of chloride increases the corrosivity of the water, potentially threatening drinking water infrastructure and quality. The relationship between conductivity and chloride is strong and consistent across watersheds, since chloride salts include highly charged ions. State chloride standards to protect drinking water or water supply are well established, but those for aquatic life are relatively new. Where conductivity values were high, they were compared to aquatic life thresholds to determine if chloride itself should be investigated as a potential source.

Salinity: A measure of the concentration of total dissolved salts (not just chlorides) in water. Higher salt concentrations can impact stream biota and reduce biodiversity in streams as well as increase corrosivity of water. Conductivity is also highly correlated to salinity, and well established. Salinity standards for freshwater are lacking in states' Clean Water Act standards, but the USGS provides a continuum of salinity concentrations for fresh to highly saline water. Using those thresholds, a general level of conductivity can be deduced to serve as screening levels for elevated salinity.

2.3 Data Collection and Management

Participating members of the Lake Erie Volunteer Science Network are expected to adhere to the technical requirements and minimum performance criteria of this regional framework, which is designed to synergize with, rather than replace, their pre-existing sampling plans. The specifications below provide guidance on the minimum technical and programmatic elements required for participation. For more detail, please reference the LEBAF SOP.

- *Monitoring Stations:* Participants are required to monitor at least one station from April to October. Ideally, participants should monitor at least one station on each major tributary across their coverage area. More stations are always encouraged. Participants identify stations that are representative of location and flow within the stream and ensure safety and accessibility.
- *Monitoring Frequency:* Participants are expected to monitor all established stations at least one time per month from April to October. More frequent visits are encouraged and date/time flexibility is allowed depending on weather conditions and equipment availability.
- *Data Management:* LEVSN employs Water Reporter (WR), an online data sharing platform, to standardize collection, storage, management, analysis, and reporting of LEBAF data. A regional monitoring dashboard hosted by CWA features all data collected across the region and a custom data analysis script generates standardized metrics, graphs, and maps.
- *QA/QC:* Network participants must collect four aquatic chemistry parameter readings using YSI multiparameter water quality meters or equivalent sensor technology, along with required information as detailed in the LEBAF SOP. Sensors must be calibrated and maintained following the procedures prescribed by the device manufacturer and align with the minimum specifications outlined below. All data must undergo QA/QC at point of entry and during the final field season analysis.

Table 2. LEBAF Collection Parameter Information

Parameter	Conductivity	Dissolved Oxygen	pH	Temperature
Resolution	0.001 mS (0 to 0.500 mS) 0.01 mS (0.501 to 50.00 mS) 0.1 mS (>50.0 mS)	≦ 0.01 mg/L	≦ 0.01	≦ 0.1° C
Accuracy	±0% to ±1%	For 0 to 200% Saturation: Between ±0% and ±2% of the reading OR between ±0% and ±2% air saturation. For 200% to 500% Saturation: Between ±0% and ±6% For 0 to 20 mg/L: Between ±0% and ±2% OR between ±0 mg/L and ±0.2 mg/L For 20 mg/L to 50 mg/L: Between ±0% and ±6%	±0% and ±0.2	±0° to ±0.3° C
Range	At Least 0 to 200 mS/cm	At Least 0 to 50 mg/L [OR] 0 to 500% Saturation	0-14	At Least 0° to 50° C

2.4 Analysis and Interpretation

To meet the data objectives, monitoring purpose, and intended data uses for targeted data users in 2023, LEBAF evaluated the data on three scales.

1. Individual Site Analysis
2. Analysis of Large Rivers and Direct Tributaries to Lake Erie
3. Lake Erie Basin

Automated data analysis produced standardized summary statistics (total sample size, maximum, minimum and median result, number and percent exceedance of respective standards) as well as standardized graphs and maps at each scale (see LEVSN webpage). Data analysis focused on evaluating water quality concerns related to the four core parameters measured by the LEVSN network within each Large River and Direct Tributary to Lake Erie and across the Lake Erie Basin as a whole. Parameter exceedances were determined using referenced benchmarks (Table 3) defined by LEBAF for each parameter based on United States Federal and State Clean Water Act (CWA) criteria. Where possible all assessment criteria are focused on the health of aquatic life communities in lotic or running waters. More detail on each criteria, source, and rationale can be found in LEBAF SOP.

Table 3. LEBAF Screening Assessment Criteria (Benchmarks) Details and Sources

Parameter	Benchmark(s)	Source/Comments
pH	6.5.-9.0 pH Units	Most commonly used Lake Erie CWA pH use assessment standards. Assessed exceedances below 6.5 and above 9.0.
Dissolved Oxygen (DO)	Cold water ≤ 7 mg/L Warm water ≤ 5 mg/L	Adopted EPA warm and cold water system DO standards.
Temperature (Temp)	Warm and Cold monthly values between states daily max/mean. LEBAF developed a conservative set of monthly temperature ranges for warm and cold waters as a screening benchmark (Table 43) based on accepted standards.	Lake Erie CWAs all agree that water temperatures should exist within a +/- 5°C range for warm and cold rivers.
Conductivity	**1) Survey Evaluation:** LEBAF conductivity results are compared to a reference and survey conductivity dataset to evaluate data consistency and relevancy. This dataset provides statistical values for two ecoregions and three watershed sizes (Table 46).	Ohio EPA maintains the robust conductivity reference and stream survey dataset used for this comparison. Each station and watershed are compared with the respective ecoregion and watershed size.
	2) Biocondition Evaluation: LEBAF uses the minimum threshold of 412 µS cm^{-1} to define a healthy macroinvertebrate community. LEBAF has built out a set of conductivity criteria based on other biocondition metrics and reference data to better describe	LEBAF adopted the minimum biocondition threshold from Ohio EPA and built out the combined conductivity criteria based on additional Great Lakes States' conductivity guidance and the Ohio EPA ecoregion reference and survey dataset. Unlike the other parameters, the LEBAF conductivity criteria is a continuum that

	macroinvertebrate health that is outlined in Table 47. The macroinvertebrate community at sites and watersheds with average or median conductivity values ≥ 850 µS cm^{-1} are likely degrading and warrant further investigation into conductivity surrogate measures.	helps to diagnose various stages of ecosystem health that guide recommendations. LEBAF conductivity results should be compared to other measures when available and appropriate to better diagnose sources contributing to high conductivity and evaluating the in situ macroinvertebrate community.
Conductivity Surrogate Measures		
Chloride	Aquatic life toxicity levels: Acute = 640,000 µg L^{-1}, 640 mg L^{-1} Maximum = 320,000 µg L^{-1}, 320 mg L^{-1} Chronic = 150,000 µg L^{-1}, 150 mg L^{-1}	LEBAF adopted the Michigan EGLE chloride standards for aquatic life use protection. Calculation of Chloride from Conductivity: $[Cl^-]$ = 4.928 EC. This relationship has a 94% R-value. In addition, Ohio EPA provided a large river specific correlation regression for 11 large rivers, LEBAF applied that equation for respective rivers that have better correlation than the above equation. Each river's equation is in the SOP.
Total Dissolved Solids (TDS)	An aquatic life standard of 1500 mg L^{-1}, but is used cautiously, with local context because it can be underprotective.	LEBAF adopted this TDS aquatic life threshold from the Ohio EPA. Calculation of TDS from Conductivity: TDS = k EC (in 25 °C). Based on literature for freshwater and low end natural waters, the k-value is 0.55. LEBAF Is evolving is measurement of TDS and assessment methods.
Salinity	● Freshwater: < 1,000 parts per million (ppm) or 1 g L^{-1} ● Slightly saline water: 1,000 ppm – 3,000 ppm or 1 - 3 g L^{-1} ● Moderately saline water: 3,000 ppm – 10,000 ppm or 3 - 10 g L^{-1}	LEBAF adopted these salinity benchmarks from literature and the United States Geological Survey (USGS). Great Lakes States do not yet have salinity water quality standards.

	● Highly saline water: 10,000 ppm – 35,000 ppm or 10 - 35 g L^{-1}	LEBAF uses these criteria to identify patterns and potential salt sources contributing to high conductivity and not as a standard assessment. This parameter is most important to assess when conductivity values are > 850 µS cm^{-1} and where road salts and other practices occur. Calculation of Salinity: salinity = 0.4665 x ([Conductivity]$^{1.0878}$) Conductivity concentrations must be in mS m^{-1}. Results are expressed in g L^{-1}. To compare with standards in ppm results need to be multiplied by 1000.

Important to notes about the conductivity assessment:

All directly measured conductivity data was assessed against a conductivity database of reference and survey data filtered by two ecoregions and three watershed sizes (Table 46). The reference and survey data was summarized and provided by the Ohio EPA. This dataset provides the respective conductivity population distribution identifying the minimum, 25th, 50th, 75th percentile and maximum levels. LEBAF compared conductivity result distributions to the respective ecoregion and watershed size to validate that results aligned with the respective conductivity distribution in the database. This assessment was not to determine if conductivity was elevated, but to confirm and validate if results resemble conductivity data from a larger database. Such validation provides confidence to use conductivity for further analyses such as assessment against a conductivity macroinvertebrate biocondition and surrogate expressions of chloride, salinity and total dissolved solids.

LEBAF also conducted a conductivity biocondition assessment. This assessment differed slightly from the 2022 assessment and differed between the Large River and Direct Tributary Assessment in Section 3 and the Lake Erie Basin assessment in Section 4. In Section 3, individual conductivity data points and statistical data was compared to the Ohio EPA Biocondition Criteria. The Ohio EPA minimum criterion of 412 µS cm^{-1} was used to determine conductivity exceedances (Table 3). The Ohio EPA biocondition bins of 412 - 655 µS cm^{-1} and > 655 µS cm^{-1} were used to determine if observed values suggested the macroinvertebrate community was declining or degraded, respectively. Then the overall conductivity statistical data for the watershed was compared to LEBAF's combined conductivity criteria (Table 47) to describe the state of the macroinvertebrate community within the Large River or Direct Tributary and provide additional recommendations. This second evaluation evaluates the data based on a four bin continuum of health that takes into account the naturally high conductivity of sites in LEVSN due to the geology of the region. Only this combined biocondition criteria was used to evaluate ecosystem health and provide recommendations for the full Lake Erie Basin data assessment in Section 4.

Additionally, expressions of conductivity calculated from mathematical relationships for chloride, salinity and total dissolved solids (TDS) were employed again in the 2023 LEBAF evaluation to provide additional context on the size and implication of exceedance.

Assessment and resulting interpretation of the data at the Local River and Tributary levels included consideration of available ancillary information, alongside the standardized summary statistics, at each level by each corresponding sampling group. At the Lake Erie Basin level, all participating groups participated in a full day workshop to discuss overall basin trends and develop the basin story. The output from this workshop was synthesized into Section 4. All final results were reviewed and edited by the LEBAF Standards Working Group with feedback from all LEBAF participants. Details on LEBAF's Analysis process can be found in the SOP.

Section 3 – Results: Large Rivers and other Direct Tributaries to Lake Erie

This section represents the summaries of large rivers and direct tributaries to Lake Erie submitted by monitoring groups participating in the LEVSN in 2023. For additional data and visualization tools visit the Lake Erie Volunteer Science Network webpage for an interactive map of basins monitored in 2022 and 2023.

3.1 Cuyahoga River

3.1.1 Monitoring Organizations: Two groups monitor four sub-basins within the Cuyahoga River basin, but none monitor the mainstem directly. We provide a sub-basin analysis and potential implications for Cuyahoga in this report. The two entities and four sub-basins include the following:

Tinker's Creek Watershed Partners (TCWP) monitors the Tinker's Creek and Brandywine Creek Subbasins. TCWP's mission is to protect and restore the water quality and habitats of the Tinker's Creek and Brandywine Creek watersheds through community partnerships, education, and outreach. This is their second year contributing to the LEBAF network. With the help of TCWP volunteers, data was gathered at 16 stations along both creeks. TCWP will make statements about the health of their stations within its two sub-watersheds of the Cuyahoga to help tell the story of the larger Cuyahoga basin.

Summit Soil and Water Conservation District (SSWCD), monitors the Yellow Creek and Furnace Run sub-basins. SSWCD provides leadership and advocates for the stewardship of our natural resources and responsible land use through the provision of education, technical assistance, and partnerships in Summit County, Ohio. SSWCD's relatively new stream volunteer monitoring program utilizes community members as citizen scientists to gather real-time data about their local watershed. During the 2023 monitoring season, data for the LEBAF network was successfully collected for 17 stations in two Cuyahoga River subwatersheds, Furnace Run and Yellow Creek, with the help of 12 volunteers. While none of SSWCD's monitoring locations are directly on the Cuyahoga River, inferences regarding the health of this large river can be made through the assessment of its subwatersheds.

3.1.2 Station Summaries:

Tinker's Creek - Tinker's Creek is the largest tributary to the Cuyahoga River. The main stem of Tinker's Creek is approximately 30 miles long and flows through four counties: Portage, Summit, Geauga, and Cuyahoga. Tinker's Creek joins the Cuyahoga River in Bedford Reservation and is classified as a warm water system. In 2023, 11 stations were monitored along Tinker's Creek and its direct tributaries. The land surrounding these monitoring stations can be characterized as 44.1% developed, 31.0% forest, 15.0% grass/pasture, 5.4% row crop and 4.5% other (water).

Brandywine Creek - Brandywine Creek is approximately 11 miles long, with headwaters that are located in Hudson and its confluence with the Cuyahoga River located in the Cuyahoga Valley National Park. Brandywine Creek is a warm water tributary and supports a warmwater habitat. Five stations were monitored along Brandywine Creek and its direct tributaries (i.e. Indian Creek) in 2023. The land surrounding these monitoring stations can be characterized as 65.4% developed, 27.3% forest, 4.9% grass/pasture, 0.3% row crop and 2.10% other (water).

Yellow Creek - Yellow Creek is a basin of the Lower Cuyahoga River Watershed, located in the Erie Drift Plain ecoregion. This watershed is 1 of 26 named tributaries of the Cuyahoga River and is considered one of the most high-quality tributaries entering the Cuyahoga River. Yellow Creek is designated Warmwater Habitat and Primary Contact Recreational use per Ohio Water Quality Standards (OAC Chapter 3745-1). In 2023, 9 stations were monitored along Yellow Creek. Low to high density developed and impervious area is the predominant land use, covering almost 40% of the watershed. About 45% of the watershed is primarily mature deciduous and evergreen forest, and approximately 15% of the watershed is cultivated crop and pastureland.

Furnace Run - Summit Soil and Water Conservation District monitors 8 stations throughout the Furnace Run watershed, all of which are located along the mainstem of this Cuyahoga River tributary. Stations are numbered sequentially from the confluence with the Cuyahoga River to the headwaters (ie. FR1 is located at the confluence, while FR22 is in the tributary headwaters). Much of this watershed (32%) is protected lands that are managed by Summit Metroparks, Cleveland Metroparks, and the Cuyahoga Valley National Park. This watershed contains five valuable, cold water habitat streams and was recently given an EPA health score of 0.67 (scale of 0-1, with 1 being healthiest).

3.1.3 Summary of 2023 Findings and Analysis

Table 4. Cuyahoga River Summary Statistics and Exceedances - 126 total samples, 33 stations

Summary Statistics and Exceedances Basin - Cuyahoga

Parameter	Mean Reading	Median Reading	Min. Reading	Max. Reading	Sample Count	N. Exceeded	Pct Exceeded
Conductivity Biocondition	973.65	945.00	4.60	3,687.00	126.00	120.00	96.00
Dissolved Oxygen	13.53	7.80	2.10	721.00	126.00	8.00	6.45
pH	7.82	7.93	2.28	8.95	126.00	3.00	2.44
Water Temperature	18.59	19.35	8.20	26.80	126.00	5.00	4.03

Tinkers Creek - *42 samples, 11 stations*

pH - Site TC001 experienced a low pH value (i.e. 6.4) that occurred on a day with low base flow. These stations that presented exceedance are located in extensively regulated land areas, including a bus garage site which may have contributed to the low pH levels**.** Sites Un002 and TC003 experienced high pH just above the threshold (i.e. 9.1 and 9.2) on cold temperature days.

DO - Stations UnHw001, TC006, and PB001 exceeded LEBAF DO standards twice during the monitoring season. These stations lie in the suburban areas of Hudson and Twinsburg that Tinker's Creek runs through. All but one PB001 monitoring day occurred during below base flow drought days including a day that experienced heavy wildfire smoke.

Temperature - Overall, water temperatures for Tinker's Creek were found to be acceptable in relation to LEBAF standards.

Conductivity - All observations for Tinker's Creek stations exceeded the comparison values to the Ohio EPA's reference and stream survey conductivity database (see section 2). To quantify the magnitude of exceedance: Tinker's Creek data exceeded the minimum survey values by ~300-700 µS cm^{-1}; the median survey values by ~200-900 µS cm^{-1}; all but two stations exceeded the maximum survey value (990 µS cm^{-1}). It is possible that this extreme exceedance is not an accurate representation of Tinker's Creek because the Ohio EPA survey values were for the Cuyahoga River and not the Tinker's Creek tributary.

Elevated average conductivity suggests an investigation into chloride and salinity could be beneficial. Tinker's Creek is a very urban watershed that frequently receives a significant amount of stormwater discharge that may be inflating TDS. Stations with conductivity exceedances were likely affected by high ambient air temperatures, low base flow conditions, and runoff pollutants from adjacent land. Those stations with high exceedances are located in urban areas near major road systems and are likely impacted by runoff pollution. All stations with severe salinity exceedances also exhibited below base flow conditions. It's likely that dissolved salt in the water is more concentrated due to this reduced flow, resulting in the extreme highs that were observed at Un001, Un002, and UnHw001. All these stations exist in urban areas where stormwater runoff is a likely contributor to the water salinity.

Brandywine Creek - *17 samples, 5 stations*

pH - All observations were within LEBAF standards, and generally within the range of 7.5-8.5. One potential outlier (~6.5) was observed, but it did not cross below the threshold.

DO - Measurements collected in Brandywine Creek do not indicate a potential DO impairment based on LEBAF standards. Data points that were collected during low base flow conditions tended to be lower, but none fell below healthy values.

Temperature - All observations were within LEBAF standards, suggesting that there is no concern with water temperatures.

Conductivity - 2023 Brandywine Creek conductivity values exceeded representative values for streams in the Cuyahoga basin (see section 2). Conductivity values were higher than the Ohio EPA headwater reference and survey for both the minimum and median values: roughly 550 µS cm^{-1} higher than the minimum and roughly 425 µS cm^{-1} higher than the median. Conductivity only exceeded the maximum Ohio EPA headwater survey value (by roughly 200 µS cm^{-1}), and did not exceed the Ohio EPA headwater reference value. This may not be a good representation of Brandywine Creek since the Ohio EPA Survey was created for the Cuyahoga River and not for Brandywine Creek.

All stations exceeded LEBAF framework standards for conductivity biocondition criteria (see section 2) throughout 2023. Data exceeded the healthy range by approximately 100-400 µS cm^{-1}. Stations of extreme exceedance occurred during low base flow conditions and warmer months of the year.

Chloride values generally decreased over time, with a few exceptions of spikes in September, likely brought on by drought. It is possible that the equation calculations are not accurate due to no Brandywine Creek sites actually being on the Cuyahoga River.

Brandywine Creek monitoring stations are located in urban high density areas. In addition to the contribution of stormwater runoff pollution to salinity concentrations, drought conditions occurred during two months (May and September) which may have amplified saline concentrations in water bodies where water levels were low.

Yellow Creek - ***44 samples, 9 stations***

pH - Measurements collected in Yellow Creek do not indicate a potential pH impairment based on LEBAF standards.

DO - One site in Yellow Creek, YC13, experienced DO concentration exceedances. This site has a small drainage area (20 square miles or less) and is downstream of Bath Pond discharge location. Throughout the sampling season, water at this site was observed to be relatively clear with little suspended solids. All but one measurement was taken at base flow conditions; one was taken with little to no flow. The temperature of the water was around 20°C during all but one sampling occasion. The lowest DO concentration was reported when the water temperature was 20.8 °C, the stream at base flow condition, and having rained the previous night. This suggests DO concentration exceedances at this site may be driven by anthropogenic factors or upstream eutrophic conditions.

Temperature - Measurements collected in Yellow Creek meet the prescribed LEBAF seasonal temperature thresholds.

Conductivity - Conductivity data was compared to Ohio EPA reference and survey data with respect to ecoregion and stream size. While the Yellow Creek sampling stations are located within the Erie Drift Plain ecoregion, station data were compared to data for the Erie/Ontario Lake Plain ecoregion, as no data is currently available for the Erie Drift plain ecoregion. In 2023, headwater sites of Yellow Creek had conductivity values that ranged from 370.60 to 1490 µS cm^{-1}, with a 50th percentile value of 783.50 µS cm^{-1}. This median value is closer to the 75th percentile for headwater survey sites within the Erie/Ontario Lake Plain ecoregion. Conductivity values for the stream sites of Yellow Creek had a smaller range between 621 µS cm^{-1} and 1054 µS cm^{-1}; however, the stream site median value (919 µS cm^{-1}) is closer to the 95th percentile for stream survey sites within the Erie/Ontario Lake Plain ecoregion.

Conductivity values were also compared to Ohio EPA macroinvertebrate bio-condition thresholds as a way to predict the status and quality of macroinvertebrate communities in the watershed; values less than 412 µS cm^{-1} suggest a healthy/functioning macroinvertebrate community, 412 - 655 µS cm^{-1} suggests a declining or degrading community, and those greater than 655 µS cm^{-1} suggest a degraded community. Overall, Yellow Creek conductivity values ranged from 370.60 to 1490 µS cm^{-1}. The minimum recorded result suggests that some sites may support a healthy macroinvertebrate community, while the maximum result suggests that some sites may be exposed to conductivity conditions that support a declining or degraded macroinvertebrate community. Mean conductivity for all stations was 822.67 µS cm^{-1}, which suggests that the macroinvertebrate community in Yellow Creek may be declining or degraded.

Macroinvertebrate data was collected by volunteers at 5 of the 9 sampling stations during the 2023 field season using the Pollution Tolerant Index (PTI) assessment. Of these stations, 80% received a "fair" rating and 10% were rated as "excellent". These results support the biocondition suggestion that macroinvertebrate communities in Yellow Creek are declining or degraded. Further analysis of macroinvertebrate communities is needed to determine if the community is stressed due to conductivity levels, or if other factors (like habitat condition) are affecting macroinvertebrate abundance and biodiversity.

Furnace Run - ***23 total samples, 8 stations***
pH - The pH data collected in 2023 does not indicate any potential pH impairments along the Furnace Run tributary based on LEBAF standards. One total pH exceedance (pH=2.28) was observed at FR7, a site with heavy land use and low flow at the time of collection.

DO - The DO data collected in 2023 does not indicate any potential DO impairments along the Furnace Run tributary, as all measurements were within LEBAF standards.

Temperature - Four temperature exceedances were observed across three monitoring stations in Furnace Run (FR6, FR7, FR13). Each of these sites has a small drainage area of <20 sq miles and all are located near the midpoint of the Furnace Run waterway. All three of these stations are cold water habitats; however, all the exceedances were within 1-2 degrees of the standard . Additionally, these exceedances occurred at times of elevated ambient temperature and low flow velocity. While the percentage of temperature exceedances (17%) is within an acceptable limit, special attention should be paid to these cold water habitats to assess their ability to withstand rising temperatures.

Conductivity - Conductivity values for a given waterbody should ideally be compared to the standards of its region, given that conductivity values vary between ecoregions. All Furnace Run stations occur in the Erie Drift Plain ecoregion; however, as no data is available for this region, station data was compared to standards for the Erie/Ontario Lake Plain ecoregion. In 2023, conductivity values ranged from 548 to 1914 µS cm^{-1} with a 50th percentile value of 1037 µS cm^{-1}. This median value is closer to the 95th percentile value of 1114 µS cm^{-1} for the EPA Erie/Ontario Lake Plain stream survey.

The Ohio EPA also sets a conductivity threshold for evaluating macroinvertebrate health: < 412 µS cm^{-1} promotes a healthy community, between 412 and 655 µS cm^{-1} suggests a declining community, and > 655 µS cm^{-1} indicates a degraded community. All 23 conductivity measurements from 2023 exceeded the threshold for a healthy macroinvertebrate community. The median conductivity value of 1037 µS cm^{-1} suggests likely habitat degradation and impacts to the macroinvertebrate community. Additionally, as no site returned a value <548 µS cm^{-1}, the data would suggest that aquatic life in the Furnace Run tributary is degraded and likely impaired.

In response to the elevated conductivity values, chloride and salinity were also examined for this tributary. Every monitored station returned at least one exceedance in 2023. The EPA standard limit for chronic exposure to chloride is 150-320 mg L^{-1}. Except for stations FR6 and FR7, maximum chloride values were slightly over the lower limit for chronic exposure with an average value of 161 mg L^{-1}. The two stations with the consistently highest values, FR6 and FR7, are located near heavily modified terrain and returned average values of 238 mg L^{-1} and 389 mg L^{-1}, respectively. These two locations also exceeded acceptable salinity values of 1000 ppm in 75% of their samples, indicating that these urban areas may be approaching a change from fresh to brackish water systems.

3.1.4 Summary of 2023 Conclusions, Recommendations, Actions

Table 5. Tinkers Creek Water Quality Summary

pH	*Temperature*	*DO*	*Conductivity*
Concerning	Acceptable	Acceptable	Likely threats, impacts

Overall, LEBAF standards for pH, temperature and DO suggest that the Tinker's Creek tributary can support a healthy ecosystem. The compilation of additional station metadata (e.g. site characteristics, if they are shaded, the width and depth of the stream, etc.) would aid in narrowing down potential causes for inconsistencies. TCWP currently reports on the water level and the moisture level of the riverbanks, however, additional station information would be useful for future analysis.

The pH of Tinker's Creek was expected to be in the neutral range given historical data (~7.5 range). Sites TC001 and BRC-DS experienced low pH on below base flow days. These stations are located in extensively regulated land areas, including a bus garage site which may have contributed to the low pH levels. Sites Un002 and TC003 experienced high pH values just above the threshold (i.e. 9.1 and 9.2) on cold temperature days. TCWP may benefit from enhancing volunteer training, making sure procedures are standardized, and making certain samples are being taken from identical sampling locations each time.

Conductivity did not follow a consistent pattern throughout the monitoring year. To aid in a more complete analysis, it is advised to conduct a general assessment of the land use at all stations, as well as noting any station anomalies during data collection that may indicate pollution that is not normally present. Site assessments may also help determine any potential causes of chloride pollution. Additionally, current estimates of chloride may incorrectly portray the state of Tinker's Creek since it is not located directly on the Cuyahoga River, which was used to generate these estimates. The implementation of winter chloride assessments using the Salt Watch protocol may enhance the data set. Volunteers will be instructed to take note of unusual conditions when conducting water quality monitoring in subsequent years, as this may provide insight into potential pollution sources. Additionally TCWP will continue to educate the public about sensible salting practices, as decreased saline concentrations during icy months will help to lessen the concentrations throughout the rest of the year.

Table 6. Brandywine Creek Water Quality Summary

pH	*Temperature*	*DO*	*Conductivity*
Acceptable	Acceptable	Acceptable	Likely threats, impacts

Overall, LEBAF standards for pH, temperature and DO suggest that the Brandywine Creek tributary can support a healthy ecosystem. However, given the likely threats and impacts from elevated conductivity values, it is advisable to start conducting macroinvertebrate surveys at stations throughout the watershed. A more robust macroinvertebrate database will help to reinforce statements made about water chemistry. It is recommended to conduct site assessments while taking samples; these may include noting conditions that are out of the ordinary, any macroinvertebrate sightings, and any clues that might help to determine causes of exceedances. Conducting winter chloride assessments through Salt Watch may enhance the data set. Past staff turnover has presented issues with properly communicating past data and expectations to volunteers in the field collecting water samples. With a dedicated staff, future data collection and analysis can become more robust and exact.

Table 7. Yellow Creek Water Quality Summary

pH	***Temperature***	***DO***	***Conductivity***
Acceptable	Acceptable	Acceptable	Concern for biota

Overall, LEBAF standards for pH, temperature and DO suggest that the Yellow Creek tributary can support a healthy ecosystem, however, conductivity values for the creek are concerning. High conductivity measurements are likely the result of anthropogenic influences from urbanization. Urbanization and development can lead to various environmental challenges such as increases in pollutant availability, surface water runoff, peak flows, stream instability and flashiness. Calculated concentrations of salinity suggest conditions where evaporation may be high, or when road salt or wastewater may be present. Further investigations are necessary to fully characterize the contaminants contributing to these conductivity values.

Table 8. Furnace Run Water Quality Summary

pH	***Temperature***	***DO***	***Conductivity***
Acceptable	Acceptable	Acceptable	Likely threats

Overall, LEBAF standards for pH, temperature and DO suggest that the Furnace Run tributary can support a healthy ecosystem. As this creek contains several high value, cold water habitats, it would be beneficial to conduct additional monitoring of these areas to assess if they are experiencing greater temperature variability relative to their warm water counterparts. As extreme weather events (e.g. elevated ambient temperatures and periods of extended drought) increase, parts of Furnace Run may become more vulnerable to systemic fluctuations in temperature, DO and pH. The high conductivity values observed are likely the result of anthropogenic influences in this system. Excessive inputs of nutrients, including chloride from nearby highways and nitrogen from highly manicured developments, is likely impacting this waterway. Furthermore, the equation used to calculate the chloride exceedances for Furnace Run uses the Cuyahoga River as a benchmark; as none of the monitored stations are situated on the Cuyahoga River but are in the Cuyahoga basin, it is possible that the calculations are not representative of chloride levels on the Furnace Run tributary.

While this sampling season provided SSWCD and LEBAF with valuable data regarding the Furnace Run watershed, it is difficult to draw conclusions regarding the health of this Cuyahoga River tributary with such a limited data set. Additional sampling over the coming years will help better identify trends and patterns within this waterbody. Adding macroinvertebrate data in the 2024 season will also aid in a better understanding of the communities present in this environment and their tolerances to the parameters that are monitored. Additionally, FR7 has already been identified as a “problematic location”. Its proximity to both a major highway interchange and a heavily manicured residential development assuredly contributes to its continued exceedances. SSWCD intends to investigate restoration and remediation measures to help rehabilitate this location. Finally, to obtain a more accurate assessment of chloride levels along Furnace Run, SSWCD will also take direct chloride measurements via quant tabs rather than deriving them indirectly.

Combined Sub-basin Conclusion, Recommendations, and Actions for Cuyahoga River

Table 9. Cuyahoga River Tributaries Water Quality Summary

pH	*Temperature*	*DO*	*Conductivity*
Acceptable	Acceptable	Acceptable	Likely threats

While none of the monitoring locations in the Cuyahoga River watershed are located directly on the Cuyahoga River, inferences regarding the health of this large river can be made through the assessment of its subwatersheds. As such, this report is a summary of the subwatersheds within the Cuyahoga River, not the Cuyahoga river itself.

This sampling season provided valuable insight into the health of the Cuyahoga River watershed. However, as two of the four subwatersheds were sampled for the first time in 2023, it is difficult to draw robust conclusions regarding the overall health of this area with such a limited data set. Overall, the Cuyahoga River basin can support a healthy ecosystem based on LEBAF standards for pH, temperature and DO. There were several site-specific pH exceedances in the basin which exhibited acidic pH measurements during low base flow periods. These sites are situated in heavy land-use areas and should be investigated to determine if remediation measures can offer improvement. Many of the temperature exceedances for the basin occurred in valuable, cold-water habitats, during times of low baseflow and elevated ambient temperatures. These cold-water areas should be given special attention to assess their ability to withstand rising temperatures. DO exceedances for the basin occurred at times of low baseflow, like many of the other exceedances. Flow appears to be a valuable indicator of stream quality and as such should be added as a quantifiable value in subsequent monitoring seasons. Currently, flow is estimated via observation of the monitor and therefore is subject to interpretation. By adding a more precise measurement of this variable, a more accurate understanding of factors relating to the exceedances will be obtained.

Conductivity readings were high throughout the basin with a 96% exceedance rate and an average value of 973 µS cm^{-1} which may indicate a degraded aquatic community. These high conductivity measurements are likely the result of anthropogenic factors. Excessive use of chloride containing agents (e.g. road salt or nitrogen from fertilizer) can increase these values exponentially. It is advised that surface deicing protocols, both municipal and residential, be evaluated and education be provided on how to minimize this impact on our waterways. Additionally, the implementation of macroinvertebrate surveys in these sub-basins will provide a better understanding of these communities and their tolerance to the measured parameters.

3.2 Detroit River Tributaries

3.2.1 Monitoring Organizations: Multiple watershed groups and government agencies conduct water quality monitoring within the Detroit River Watershed. Two of those organizations are members of LEBAF: the Clinton River Watershed Council (CRWC) and the Huron River Watershed Council (HRWC). In 2022, the CRWC reported on water quality within the Clinton River which drains into the Detroit River via Lake St. Clair. Due to the complexity of the Detroit River Watershed, that data was presented only in the context of the Clinton River. In this 2023 report, the HRWC is the only LEBAF organization monitoring 4 creeks that drain into the river south of downtown Detroit, Michigan.

3.2.2 Station Summary: The St. Clair-Detroit River System is complex, draining multiple other river systems in the United States and Canada and acting as a strait between the upper Great Lakes and Lake Erie. HRWC only monitors water quality at 5 stations within 4 creeks located in the most downstream section of the Detroit River watershed: Ecorse Creek (south and north), Frank and Poet Creek, Brownstown Creek, and Blakely Creek. The Frank and Poet, Brownstown, and Blakely Creeks are sometimes referred to as the combined downriver watersheds. **These creeks are all small in comparison to other inputs to the Detroit River and are not representative of the Detroit River main stem.**

All monitoring locations are within the Huron-Erie Lake Plain ecoregion and have bedrock composed of mainly limestone mixed with either shale, sandstone, dolostone, or a combination. The watersheds of these creeks, however, have been highly altered by urbanization. The 5 monitoring locations were chosen based on their use by municipal stormwater partners and capture the extent of urbanization upstream.

The data presented in this report was collected every two weeks throughout the spring, summer, and fall of 2023 as part of the HRWC Chemistry and Flow Monitoring Program that has monitored most of these sites since 2012. The HRWC Chemistry and Flow Monitoring and Biological Monitoring Programs both collect additional data not reported here that provides further context for the interpretation of these results. That data is publicly available on HRWC's Maps Webpage.

3.2.3 Summary of 2023 Findings and Analyses

Table 10. Detroit River Tributaries Summary Statistics and Exceedances

Summary Statistics and Exceedances Basin - Detroit River

Parameter	Mean Reading	Median Reading	Min. Reading	Max. Reading	Sample Count	N. Exceeded	Pct Exceeded
Conductivity Biocondition	996.35	930.00	393.90	2,264.00	65.00	63.00	98.44
Dissolved Oxygen	6.89	6.49	2.60	11.92	65.00	13.00	20.31
pH	7.85	7.76	7.55	8.44	65.00	0.00	0.00
Water Temperature	16.22	17.40	7.60	23.00	65.00	0.00	0.00

pH – Measurements collected in Ecorse Creek and the other downriver watersheds do not indicate a potential pH impairment based on the prescribed LEBAF standards.

DO – DO concentrations in the Ecorse creek and downriver watersheds varied among creeksheds. Ecorse Creek had 4 DO measurements that fell below the 5 mg L^{-1} aquatic life threshold. The exceedances occurred both in the north (2 exceedances) and south (1 exceedance) branch of the creek and account for 17% of the measurements. Blakely Creek (ADW02) DO values followed a normal seasonal trend of high DO in the spring and fall with low DO (slightly below saturation; generally < 8 mg L^{-1}) in the summer, but all values remained above the 5 mg L^{-1} aquatic life threshold. Both Frank and Poet Creek and Brownstown Creek showed similar seasonal trends to Blakely creek, but during the summer months experienced a collective 9 exceedances. Eight of the 9 exceedances occurred at Brownstown Creek (66% of site DO), a site with notoriously low water levels and slow flow. The median DO concentration at Brownstown Creek was 5.45 mg L^{-1} and the minimum value neared hypoxic levels at a recorded 2.6 mg L^{-1}.

Temperature – In 2023, all recorded temperature values in Ecorse creek and the other 3 downriver watersheds met the prescribed LEBAF seasonal temperature thresholds.

Conductivity –All monitored creeks are located in the Huron-Erie Lake Plain ecoregion, which is associated with naturally high conductivity values. In 2023, these 4 tributaries of the Detroit River had highly variable conductivity values between 394 and 2264 µS cm^{-1}, with a median concentration of 930 µS cm^{-1}. These values were high even by the creeks' ecoregion standards with the 2023 median value nearing the Ohio EPA Huron-Erie Lake Plain 90th percentile stream reference value of 952 µS cm^{-1}. The range of 2023 conductivity values still overlap with the expected range for the Huron-Erie Lake Plain ecoregion, but most of the 2023 measurements fall within the upper end of the range. This provides some additional confidence in using our conductivity results, while also suggesting that there are other factors contributing to the high conductivity concentrations in these creeks.

The Ohio EPA also sets conductivity standards for assessing macroinvertebrate community health. The lower limit of 412 µS cm^{-1} was exceeded all, but twice in 2023 within these 4 creeks. The upper limit of 655 µS cm^{-1}, which suggests a degrading macroinvertebrate community, is already near the Ohio EPA Huron-Erie Lake Plain stream median conductivity reference value of 653 µS cm^{-1}. More than 75% of the 2023 data (78.5%) fell above this bio-condition threshold. The highest values were recorded in both the south and north branches of Ecorse Creek. The remaining 18.5% of data fell between the 412 and 655 µS cm^{-1} bio-condition thresholds with most of these data points, including the 2 values below 412 µS cm^{-1}, recorded in Blakely Creek. Together, this data suggests that Ecorse, Frank and Poet, and Brownstown creeks have highly degraded macroinvertebrate communities. The community at Blakely creek is declining, but spring and summer conductivity values are not yet consistently high. Supplemental macroinvertebrate sampling in these creeks further suggests that all four creeks have highly degraded macroinvertebrate populations, despite Blakely Creek having lower conductivity values.

The ecoregion of these creeks contributes to some of these high conductivity concentrations, but extreme highs are likely caused by other factors such as anthropogenic influences. All 4 creeks drain highly urbanized residential areas in the Detroit metropolitan area. Even still, only Ecorse, Frank and Poet, and Brownstown creeks had conductivity values in 2023 above the 95^{th} percentile Huron-Erie Lake Plain stream reference value of 1107 µS cm^{-1}. The majority of these values (19 of 20) equated to salinity values above the 1000 ppm freshwater threshold. Salinity exceedances varied from 2 to 8 (15 – 62%) occurrences between creeks with the north branch of Ecorse Creek experiencing the most exceedances. These occurrences of high salinity in Frank and Poet and Brownstown Creek were generally non-consecutive and may allow for aquatic life to seek refuge during these periods of high salinity. The number of occurrences in Ecorse Creek, however, were numerous suggesting ecosystem degradation and a transition to a slightly saline system.

3.2.4 Summary of 2023 Conclusions, Recommendations, and Actions

Table 11. Detroit River Tributaries Water Quality Summary

pH	***Temperature***	***DO***	***Conductivity***
Acceptable	Acceptable	Concerning	Degraded, Likely Threats

In 2023, 65 water samples were collected from 4 tributaries of the Detroit River between April and October. Water quality violations were only observed for 2 of the 4 parameters measured: dissolved oxygen (20%) and conductivity (100%). Blakely Creek was the only creek that did not have occurrences of low DO that threatened aquatic life, although DO was consistently undersaturated during the summer months. Data from these tributaries was not reported on in the 2022 LEBAF report, but historical data collected by HRWC shows similarly high conductivity values and intermittent periods of low DO in these 4 creeks. While high conductivity is partially a natural phenomenon, extreme conductivity values and instances of low DO recorded in 2023 often corresponded to extreme weather events that disrupted stream flow.

Conductivity values for all four streams tended to be much higher than the expected *Huron-Erie Lake Plain* ecoregion reference. The landscape that drains into these creeks does not resemble the natural landscapes of this ecoregion, but rather consists of large residential areas with some interspersed commercial and industrial locations. This shift in land use and subsequent channelization of these streams drastically altered the flow regimes. Flashy flows with little or no baseflow increases physical weathering and land-based inputs of nutrients and salts during storms and decreases or ceases in flow between wet weather events. Consistent with this flow regime, the highest conductivity values in all four creeks were observed on June 1st during a period of moderate drought in southeast Michigan. On this same day, 4 violations of low dissolved oxygen occurred with the lowest recorded value reaching near hypoxic levels in a stagnant pool of water at Brownstown Creek (ADW03). About a month later when a large storm event occurred, the conductivity values plummeted, though still above 800 µS cm^{-1}, only to recover to their usual highs by the subsequent sampling. Again, this reflects the pulse of stormwater that diluted the contaminants and the quick return to low flow post storm.

The altered flow regime of these urbanized creeksheds wreaks havoc on the ecosystems of these 4 tributaries. While the ecosystems are healthy by LEBAF pH and temperature standards, the intermittent low DO and consistently high conductivity pose threats to aquatic life. Low DO does not pose a threat at Blakely Creek and is rare at Frank and Poet Creek. Aquatic life, however, is likely affected at Brownstown and Ecorse creeks due to some extended periods of low DO and low water levels in the case of Brownstown creek. All four creeks may become more vulnerable to low DO in the future as climate change increases the frequency of drought, a weather phenomenon that worsened DO conditions in these creeks in the spring of 2023. Conductivity values in all creeks also exceeded the LEBAF bio-condition suggesting that the macroinvertebrate communities are highly degraded. Further investigation into the sources of contaminants, such as nutrients and salts, contributing to these conductivity values is needed to help with restoration efforts. Additional data and analysis of these four creeksheds is available on HRWC's maps page and Wayne County results page.

3.3 Huron River

3.3.1 Monitoring Organizations: The Huron River Watershed Council (HRWC) is the only LEBAF organization monitoring the Huron River and its tributaries. HRWC's Chemistry and Flow Monitoring Program was developed in 2002 as a response to community interest in increasing available data on nutrient contributions to the middle section of the Huron. Over the years the Program has grown to include stations throughout the Chain of Lakes, middle, and lower sections of the river.

3.3.2 Station Summary: The HRWC Monitoring Program collected data from 15 stations that were selected based on feedback from municipal stormwater partners, HRWC's biological monitoring program sites, likelihood of significant sub-watershed phosphorus loading based on modeling, and capturing the range of sub-watershed and upstream conditions. Of all stations, 3 stations are located within the main stem of the Huron River and 12 are in the tributaries near the confluence with the river. Most of these stations (2 main stem and 9 tributary sites) are situated in the middle section of the Huron River Watershed in Washtenaw County, Michigan. The other 4 sites (1 main stem and 3 tributary sites) are in the lower section of the watershed in Wayne County, Michigan, with the main stem sampling location near the mouth of the river, Lake Erie confluence.

The Middle and Lower Huron River Watershed sections fall within two distinctly different ecoregions and geological regions. The Middle Huron falls within the Eastern Corn Belt Plains (Ecoregion 55) and has bedrock comprised of sandstone. The Lower Huron section, however, falls within the Huron-Lake Erie Plains (Ecoregion 57) and has bedrock comprised of a mix of limestone and sandstone. These differences may contribute to some natural variations between sites. Further, each sub-watershed drains upstream areas with differing land use and cover. The Middle Huron sampling stations drain a variety of different dominating land uses with highly urbanized (4 sites), agricultural (3 sites), commercial (1 site), and natural woodland (3 sites) areas all represented within this section of the watershed. The Lower Huron sites drain primarily urban areas except for 1 tributary station that drains primarily natural woodlands.

The data presented in this report was collected every two weeks throughout the spring, summer, and fall of 2023. The data expands upon the 2022 LEBAF Field Season Report with measurements from the same 12 stations and 3 additional stations (all tributary sites in the lower-Huron). The HRWC Chemistry and Flow Monitoring Program and Biological Monitoring Program collect additional data not reported here that provides further context for the interpretation of these results. That data is publicly available on HRWC's Maps Webpage.

3.3.3 Summary of 2023 Findings and Analyses

Table 12. Huron River Summary Statistics and Exceedances - 206 total samples, 15 stations

Summary Statistics and Exceedances Basin - Huron

Parameter	Mean Reading	Median Reading	Min. Reading	Max. Reading	Sample Count	N. Exceeded	Pct Exceeded
Conductivity Biocondition	910.17	780.00	444.00	2,222.00	206.00	205.00	100.00
Dissolved Oxygen	8.62	8.56	3.80	15.92	206.00	6.00	2.93
pH	8.05	8.04	7.64	8.59	206.00	0.00	0.00
Water Temperature	16.84	17.00	5.80	25.80	206.00	1.00	0.49

pH – Consistent with 2022 findings, pH data collected in 2023 does not indicate any potential pH impairment in the Huron River based on the prescribed LEBAF standards.

DO – Of the 205 DO measurements in 2023, 4 measurements from 1 tributary (ADW08) and 1 river (ADW23) station in the lower-Huron and 1 measurement from a tributary (MH09) in the Middle Huron fell below the 5 mg L^{-1} DO aquatic life impairment threshold. While this is 5 more measurement violations compared to the data collected in 2022, the majority (98%) of DO values remained above the threshold or high enough to sustain aquatic life. Further, these 6 violations were non-consecutive and corresponded with extreme weather events or observed slow flow. The short duration of low DO events may allow aquatic life to seek refuge in the short-term and remain unharmed by the events.

Temperature – In 2023, a single temperature violation was observed at the most downstream river station (ADW23) on May 31st during a flash drought in Michigan. The recorded temperature of 22.9°C was 1.9°C above the prescribed LEBAF standard for the month of May. Since 99% of 2023 data and 100% of 2022 data meet LEBAF seasonal temperature thresholds, there is little to no indication that the Huron River is impaired due to temperature nor is it contributing to a potential Lake Erie temperature impairment.

Conductivity – Natural conductivity values differ between ecoregions and geological areas. While the Middle and Lower Huron sections fall within two different ecoregions, both are compared with the Huron-Erie Lake Plain ecoregion data because no data is available for *Eastern Corn Belt Plain* ecoregion. In 2023, conductivity values in the Huron River tributaries ranged from 444 µS cm^{-1} to 2222 µS cm^{-1}, with a 50th percentile value of 789 µS cm^{-1}. This median value is closer to the 75th percentile value of 778 µS cm^{-1} for the *Huron-Erie Lake Plain* streams reference. Consistent with 2022 data, much of the spring conductivity values fell below this 75th percentile reference value except for 4 tributary sites that drain highly urbanized areas (MH04, MH07, MH08B, and MH09). Still, most of the 2022 and 2023 stream conductivity values fell above this stream reference value. Huron River conductivity values had a smaller range between 522 µS cm^{-1} and 919 µS cm^{-1}, but again the median value of 745 µS cm^{-1} was close to the 75th percentile *Huron-Erie Lake Plain* river reference value of 744 µS cm^{-1}. This comparison with the ecoregion references shows some overlap with our dataset and provides some additional confidence in using our conductivity results. When our dataset strays above these references, it suggests some of the variation in conductivity is unexplained by ecoregion and helps inform protection recommendations.

The Ohio EPA also sets a conductivity threshold for evaluating macroinvertebrate health: < 412 µS cm^{-1} promotes a healthy community, between 412 and 655 µS cm^{-1} suggests a declining community, and > 655 µS cm^{-1} indicates a degraded community. All 205 conductivity measurements in 2023 exceeded the healthy macroinvertebrate threshold of 412 µS cm^{-1}. The upper biocondition threshold of 655 µS cm^{-1} is near the 50th percentile reference values for

Huron-Erie Lake Plain streams and river reference. Thus, it is expected that 50% of data collected in this ecoregion would exceed this threshold. Only 28% (57 samples) of Huron River and tributary conductivity measurements fell between 412 and 655 µS cm^{-1} and 72% (148 samples) were > 655 µS cm^{-1}. These findings are consistent with 2022 data, which found 98% of conductivity values were > 412 µS cm^{-1} with most values exceeding 655 µS cm^{-1}. The minimum (444 µS cm^{-1}) and maximum (2222 µS cm^{-1}) conductivity values in 2023, however, were higher than those values in 2022 (352 and 2035 µS cm^{-1}, respectively). Overall, this data suggests that most of the macroinvertebrate communities in the Huron River and its tributaries are declining or degrading and macroinvertebrate sampling by HRWC corroborates this finding.

While natural influences may contribute to some of the observed high conductivity values, anthropogenic influences cause further exceedances. A total of 39 measurements (19%) from tributaries of the Huron River had conductivity values above 1107 µS cm^{-1}, the 95th percentile of Huron-Erie Lake Plain streams. All these measurements were taken from sites (MH07, MH08B, MH09, MH04, and ADW09) draining highly urbanized creeksheds. Most of these measurements (38 of 39) equated to salinity values above the acceptable freshwater limit of 1000 ppm, which indicates that these urban streams may be approaching a change over to a slightly saline water system.

3.3.4 Summary of 2023 Conclusions, Recommendations, and Actions

Table 13. Huron River Water Quality Summary

pH	*Temperature*	*DO*	*Conductivity*
Acceptable	Acceptable	Acceptable	Degraded, Concern for Biota

Between April and October of 2023, HRWC measured pH, dissolved oxygen, temperature, and conductivity in 205 water samples collected from 15 sites within the Huron River and its tributaries. Water quality violations occurred for 5 dissolved oxygen, 1 temperature, and all 205 conductivity measurements. Results in 2022 were similar with slightly fewer violations for dissolved oxygen and conductivity and no violations for temperature. Consistent with 2022 findings, high conductivity values were influenced by the natural ecology and geology of the area and further exacerbated by the anthropogenic influence of urbanization. In 2023, however, extreme conductivity values in urbanized watersheds and most of the other observed water quality violations (2 low DO occurrences and 1 temperature violation) also corresponded to extreme weather conditions such as drought or extreme precipitation events.

The high conductivity values observed in both 2022 and 2023 are partially attributed to the ecoregion and geology of the Huron River watershed. As mentioned in this report and the 2022 report, much of the Huron River watershed falls within an ecoregion for which the Ohio EPA does not have a reference. Our interpretation of this natural variation might be skewed by comparisons of middle-Huron data with the *Huron-Erie Lake Plain* reference values rather than the *Eastern Corn Belt Plain* ecoregion for which there is no reference data. Based on the geology of the region, it would be expected that conductivity would increase moving downstream, both due to a shift in bedrock from sandstone to limestone and an increasingly larger drainage area. This trend holds true in both 2022 and 2023 for the river sites located on the main stem, but the highest tributary conductivity values are recorded in middle Huron creeks.

The extremely high conductivity values tend to correspond with increased urbanization and extreme weather events that alter flow. All the tributaries located in the middle-Huron with median conductivity values above 1000 µS cm^{-1} in 2022 and 2023 – MH07: Mallets Creek, MH08B: Millers Creek, and MH09: Swift Run – drain highly urbanized areas. The highest recorded conductivity value of 2222 µS cm^{-1} was observed at Swift Run (MH09) on June 3, 2023 during a flash drought in Michigan. Dissolved oxygen at MH09 during this time also dropped below saturation and near the 5 mg L^{-1} aquatic life limit, but never dropped below the threshold. The maximum value of 1955 µS cm^{-1} in Mallets Creek was recorded three weeks later as the drought continued. In the lower Huron during this flash drought there were also two violations of low dissolved oxygen in ADW08: Woods Creek and ADW23: Huron River at Fort Rd. Concurrently, the only temperature violation within the Huron River in 2023 was recorded in the Huron River at Fort Rd. (ADW23).

Severe storms during the 2023 monitoring season also influenced conductivity at the three middle Huron sites with the highest conductivity values (MH07, MH08B, and MH09) by diluting contaminants with a pulse of rainwater. All three sites saw a drastic decline in conductivity reaching their site minimums on July 27th, the day after a severe storm. In all instances conductivity values rebounded to their normal high values by the subsequent sampling suggesting highly flashy flow regimes at these sites. This drastic swing in conductivity values was not observed for two other major storm events that occurred on June 25th and August 24th, each dropping more than 2 inches of rain. This is likely due to a lack of data collected from these sites after those events, since a similar drop in conductivity at the most downstream river site with a more stable flow regime, ADW23, was observed after the August 24th rain event.

Overall, the Huron River and its tributaries can support a healthy ecosystem based on the LEBAF standards for pH, DO, and temperature. Extreme weather events, specifically periods of high heat and low precipitation, however, may cause intermittent periods of stress that cause aquatic life to relocate for short periods of time. Since the occurrence of these extreme weather events are only expected to increase with climate change, parts of the Huron River may become more vulnerable to DO and temperature impairments in the future. These periods of drought also seem to further exacerbate the already high conductivity values that may cause macroinvertebrate communities to decline or in some cases degrade. High conductivity is likely the result of anthropogenic influences from urbanization including increased or flashy flows, increased physical weathering, and the input of more contaminants from land such as nutrients or salts. Calculated concentrations of salinity suggest some inputs of salts possibly from the application of road salts in urbanized areas during winter. Further investigations are necessary to fully characterize the contaminants and help restoration efforts, especially in the urbanized creeks of Mallets, Millers, and Swift Run. Additional information and data for these HRWC sites is available via HRWC's map webpage and Washtenaw County Results Page.

3.4 Maumee River & Subbasin Swan Creek

3.4.1 Monitoring Organizations: Currently only one organization in the LEBAF Network is monitoring the Maumee River Watershed and Subbasin Swan Creek Watershed, Community Water Action Toledo (CWAT). CWAT aims to increase understanding of water quality in Lake Erie tributaries and drive improvement of water quality across Northwest Ohio by aligning our sampling protocols with LEBAF, harnessing the existing strengths of our collective programs, and engaging a wide range of volunteers in citizen science. 2023 members included Metroparks Toledo, Partners for Clean Streams, the Toledo Zoo, and TMACOG. Monitoring began in 2023. All data was collected this season with trained staff members present. Meters were calibrated monthly throughout the field season. Limitations include sampling frequency; stations were sampled 1-2 times monthly, April-October. On Swan Creek, 2 samples were included from stations that were not fully monitored according to LEBAF standards of a minimum of once per month.

3.4.2 Station Summary:
Maumee River Main Stem - LEBAF monitoring at 6 stations on the Maumee (CWAT-6*, CWAT-7*,CWAT-8*, CWAT-9, CWAT-10, and CWAT-11) began in 2023; CWAT-6 is the most upstream site monitored, moving numerically downstream with CWAT-11 being the most downstream. Stations with an (*) have been monitored by Metroparks Toledo for macroinvertebrate data since 2021. CWAT-9, CWAT-10 and CWAT-11 are within the lacustrine zone on the river, and are in urbanized areas, with no buffers and residential or commercial adjacent land use. CWAT-6 and CWAT-7 have primarily agricultural adjacent land use, with wooded buffers; CWAT-8 has agricultural and residential adjacent land use.

The Maumee River is 140 miles long and is the largest direct tributary to Lake Erie, draining parts of Michigan, Indiana, and Ohio. Most of the watershed (~ 73 %) is in Ohio, draining 5,024 square miles over 107.8 river miles. Monitored stations are all on the Lower Maumee. Land Use Information from Ohio EPA 2014 Report for the Lower Maumee: "Aggregated land use across the Lower Maumee River watershed is approximately 75.82% agricultural and 14.64% developed for urban or residential use. Other land uses include 6.61% forest, 1.36% open water, 0.94% grassland, 0.50% wetland, and 0.13% other."

Swan Creek Subbasin - All stations on Swan Creek for 2023 were upstream of the city of Toledo. CWAT-13, CWAT-15, CWAT-18, CWAT-19, and CWAT-21 are all located within Oak Openings Metropark, a 5,000 acre preserve of natural lands and ecosystems managed by Metroparks

Toledo and the most upstream sites monitored. CWAT-16 and CWAT-17 are in the middle of the monitored stretch of the stream, and have primarily residential and agricultural row crop adjacent land use, with wooded buffers. CWAT-12 is the most downstream and urban site monitored, located in a preserve in an urban area.

Land use information from Ohio EPA: “The watershed drains 204 square miles. The lower reaches of Swan Creek run through the southern portion of the City of Toledo until joining with the Maumee River in downtown Toledo. Overall, the land use in the Swan watershed is 55 percent row crop and pasture land, 21 percent urban/residential, and 18 percent forest.” (Swan Creek TMDL Report, 2010) “Land use within the Swan Creek watershed changes significantly from rural agricultural lands in the headwaters to the creek’s confluence with the Maumee River in the City of Toledo. A significant area of natural lands in the Oak Openings region have been preserved by Metroparks Toledo. The region’s primary airport (Eugene F. Kranz Toledo Express Airport) and rural residential properties dot this significant natural resource. Continued urban sprawl into the upper reaches of the watershed is a concern.” (STEM 2017 Report).

3.4.3 Summary of 2023 Findings and Analysis

Table 14. Maumee River Summary Statistics and Exceedances – 57 total samples, 6 stations

Summary of Exceedances by Waterbody and Parameter

Basin	Sample Run..	Parameter	Mean Reading	Median Reading	Min. Reading	Max. Reading	Sample Count	N. Exceeded	Pct Exceeded
Maumee River	2023	Conductivity Biocondition	608.67	563.00	293.50	1,102.00	57.00	53.00	96.36
		Dissolved Oxygen	10.19	9.70	3.42	24.31	57.00	6.00	10.53
		pH	8.32	8.42	7.15	10.12	57.00	5.00	8.93
		Water Temperature	21.65	22.70	8.80	30.00	57.00	7.00	12.28

Maumee River Main Stem

pH – 5 exceedances out of 57 samples (8.93%) were observed. Exceedances occurred on July 11, August 15, September 12, September 24, and October 28. All exceedances were slightly above pH 9, and 3 of 4 occurred at CWAT-8 Sidecut. Per Ohio EPA, alkalinity in the basin can be expected due to the geology of the watershed. Sidecut is located in the middle of sampled stations; given the lack of a difference between pH values observed at stations upstream versus downstream of this site, the high pH values observed at Sidecut likely reflect local site conditions. Sidecut sampling occurred in a side channel from the main stem of the River, where low-flow conditions are more common over the summer. Data collected do not indicate pH as a cause for concern for impairment in the Maumee River based on LEBAF standards.

DO – 6 exceedances out of 57 samples (10.53%) were observed. Low readings occurred at CWAT-10 Middlegrounds and CWAT-11 Glass City stations, and were sustained through the end of August into September 2023. Both of these stations fall within the zone of lacustrine influence on the Maumee, and the exceedances may reflect the influence of the harmful algal bloom/nutrient pollution present in Lake Erie during that time. 90% of DO values recorded on the Maumee River during the 2023 season were within LEBAF standards; therefore DO levels in the river are expected to support aquatic life throughout most of the year.

Temperature – 7 exceedances out of 57 samples (12.28%) were observed. Exceedances occurred on May 10, May 28, June 20, 2023, July 11, July 25, October 3; all except October 3 occurred at a single station while other stations sampled on those days had temperatures within range. No consecutive exceedances occurred at the same stations. All exceedances were close to the threshold limit, only slightly above benchmark.

Conductivity - The Maumee River watershed falls in the Huron-Erie Lake Plain ecoregion, which serves as the reference for our observed values. In 2023, conductivity values in the Maumee River ranged from 293.50 to 1102 µS cm^{-1} with a 50th percentile value of 563 µS cm^{-1}. The median and maximum values are comparable to the 50th percentile value of 659 µS cm^{-1} and 95th percentile value of 1043 µS cm^{-1} for Huron-Erie Lake Plain rivers reference. This comparison with the ecoregion references shows good overlap with our dataset and provides additional confidence in using our conductivity results.

Conductivity results can be used to evaluate how well a stream supports aquatic life: Ohio EPA sets conductivity thresholds of < 412 µS cm^{-1} to denote a healthy macroinvertebrate community, values between 412 and 655 µS cm^{-1} indicate a degrading macroinvertebrate community, and those > 655 µS cm^{-1} indicate a degraded community. In 2023, 2/57 samples fell under 412 µS cm^{-1}, 39/57 samples fell in the degrading range, and 16/57 samples were > 655 µS cm^{-1}. Overall, this data suggests that macroinvertebrate communities in the Maumee River are degrading or degraded; however, supplemental data collected by Metroparks Toledo at 3 of the 5 sites suggest some resilience within the macros community. Salinity and chloride analyses, calculated parameters based on directly measured conductivity values, did not show any exceedances. The Maumee River watershed drains a heavily agricultural area, with extensive field tiling and drainage system alterations; nutrient pollution is a known issue within the watershed, and high conductivity values likely reflect some of that influence.

Table 15. Swan Creek Summary Statistics and Exceedances – 61 total samples, 8 stations

Summary of Exceedances by Waterbody and Parameter

Basin	Sample Run..	Parameter	Mean Reading	Median Reading	Min. Reading	Max. Reading	Sample Count	N. Exceeded	Pct Exceeded
Swan Creek	2023	Conductivity Biocondition	681.48	668.50	316.80	1,331.00	61.00	55.00	91.67
		Dissolved Oxygen	8.07	8.24	2.04	13.69	61.00	7.00	11.67
		pH	7.83	7.83	7.13	8.63	61.00	0.00	0.00
		Water Temperature	17.55	18.70	7.80	24.60	61.00	4.00	6.67

Swan Creek Subbasin

pH – Data collected in 2023 do not indicate pH as a cause for concern for impairment in Swan Creek based on LEBAF standards.

DO – 7 exceedances out of 61 samples (11.67%) were observed. Low readings occurred on May 31, June 27, August 30 (CWAT-18), September 27 (CWAT-16, CWAT-19), October 5 (CWAT-17), and October 29 (CWAT-16). Exceedances occurred throughout the sampling season at different stations, and none on consecutive sampling dates at the same station. Overall, DO varied as expected seasonally and temporally. Single exceedances at a site are likely more reflective of time of sampling rather than conditions on the stream as a whole. Low levels at CWAT-15 Evergreen Lake are likely reflective of low/stagnant water at time of sampling, a reoccurring site-specific condition. 89% of DO values recorded on Swan Creek during the 2023 season were within the LEBAF analytical benchmark of >=5 mg L^{-1}.

Temperature – 4 exceedances out of 61 samples (6.67%) were observed. Exceedances occurred on May 31, at CWAT-13, CWAT-14, CWAT-15, CWAT-21. All these sites are located within the Oak Openings Metropark, on headwaters or small stream catchments. Air temperatures peaked that day at 89 degrees, and the measured water temperature exceedances are likely related to the abnormally hot conditions for the season and the susceptibility of smaller catchments to weather extremes. Given the constrained geographic and temporal nature of the measured exceedances, data collected do not indicate temperature as an impairment concern in Swan Creek.

Conductivity – The Swan Creek Subbasin of the Maumee River Watershed falls in the Huron-Erie Lake Plain ecoregion, which serves as the reference for our observed values. In 2023, conductivity values in Swan Creek ranged from 317 to 1331 µS cm^{-1} with a 50th percentile value of 669 µS cm^{-1}. The median and maximum values are comparable to the 50th percentile value of 653 µS cm^{-1} and 95th percentile value of 1107 µS cm^{-1} for Huron-Erie Lake Plain streams reference. While the collected maximum value exceeds the reference, this comparison with the ecoregion references shows good overlap with our dataset and provides additional confidence in using our conductivity results.

Conductivity results can be used to evaluate how well a stream supports aquatic life: Ohio EPA sets conductivity thresholds of < 412 µS cm^{-1} to denote a healthy macroinvertebrate community, values between 412 and 655 µS cm^{-1} indicate a degrading macroinvertebrate community, and those > 655 µS cm^{-1} indicate a degraded community. In 2023, 9/61 samples fell under 412 µS cm^{-1}, 21/57 samples fell in the degrading range, and 25/57 samples were > 655 µS cm^{-1}. Overall, this data suggests that macroinvertebrate communities in Swan Creek are degrading or degraded. Upstream sites appeared to have lower average conductivity readings relative to downstream sites, with headwater sites in Oak Openings Metropark, a large natural preserve, having the lowest readings, and more urbanized sites downstream having the highest readings. Salinity and chloride analyses, calculated parameters based on directly measured conductivity values, showed 2/61 exceedances for salinity (3.33% exceedance rate), both at CWAT-12 Swan Creek, the most downstream and urban site sampled. The Swan Creek watershed drains a heavily agricultural area, with extensive field tiling and drainage system alterations upstream, and downstream runs through a heavily urbanized area with stormwater inputs; nutrient pollution is a known issue within the watershed, and high conductivity values may reflect some of that influence.

3.4.4 Summary of 2023 Conclusions, Recommendations, Actions

Table 16. Maumee River Main Stem Water Quality Summary

pH	*Temperature*	*DO*	*Conductivity*
Acceptable	Acceptable	Acceptable	Concern for biota, degrading

Table 17. Swan Creek Subbasin Water Quality Summary

pH	*Temperature*	*DO*	*Conductivity*
Acceptable	Acceptable	Acceptable	Concern for biota, degrading

Overall, 2023 data suggest that the Maumee River and Swan Creek support aquatic life based on LEBAF benchmarks for water temperature, pH, and DO. Persistently high conductivity values in the watershed are a cause for concern due to potential impacts on aquatic life, and based on LEBAF standards both waterways are considered degraded with a concern for biota. We recommend continuing LEBAF monitoring to gain a fuller picture of stream health and baseline conditions over time. At sites that seem to have local conditions with exceedances in a specific parameter (CWAT-8, CWAT-10, CWAT-11, CWAT-18), we recommend increased monitoring where feasible, specific to the parameter of concern, and in response to climate events as reasonable. For DO, this would look like capturing a 24-hour cycle if possible and/or monitoring on consecutive days when an exceedance is noted; for pH, monitoring on consecutive days, multiple times a day, and/or capturing multiple locations within the channel; for temperature, monitoring on consecutive days.

At all sites where feasible and suitable, we recommend initiating macroinvertebrate monitoring several times during the sample season using ODNRs SQM method. Regular monitoring of the macroinvertebrate community, along with continued monitoring of conductivity per LEBAF standards, will expand understanding of the effect of conductivity in the watershed.

3.5 Ottawa River

3.5.1 Monitoring Organizations: Currently only one organization in the LEBAF Network is monitoring the Ottawa River/Tenmile Creek Watershed, Community Water Action Toledo (CWAT). CWAT aims to increase understanding of water quality in Lake Erie tributaries and drive improvement for water quality across Northwest Ohio through aligning our sampling protocols with LEBAF, harnessing the existing strengths of our collective programs, and engaging a wide range of volunteers in citizen science. 2023 members included Metroparks Toledo, Partners for Clean Streams, the Toledo Zoo, and TMACOG. Monitoring began in 2023. All data were collected this season with trained staff members present. Meters were calibrated monthly throughout the field season. Limitations include sampling frequency; stations were sampled 1-2 times monthly, April-October. On the Ottawa River, two samples were included from a station that was not fully monitored according to LEBAF standards of a minimum of once per month.

3.5.2 Station Summary: LEBAF monitoring at 4 stations began in 2023. The most upstream site, CWAT-1, is located on Tenmile Creek, a headwater of the Ottawa River, in Sylvania, with urban/residential adjacent land use and grassy buffers. CWAT-2 and CWAT-4 are in the middle stretch of the monitored stretch of the stream, both located in parks and with wooded buffers, and urban/residential adjacent land use. CWAT-5 is within the zone of lacustrine influence, with no buffers and urban/residential adjacent land use. All but CWAT-1 are located in the city of Toledo. We combined analyses for Tenmile Creek and the Ottawa River. All summary information includes both Ottawa River and Tenmile sample results, referred to collectively as the Ottawa River throughout the remainder of the report.

Land Use and Geological Data for the Ottawa River/Tenmile Creek Watershed per OEPA 2015 Report: “Agriculture prevails in the western third of the area on Lake Plain glacial till deposits overlying Devonian bedrock. Rural and suburban development exists in the central third largely occupying the Sand Plains of the Oak Openings on top of a Devonian or Silurian base. The eastern third is an urban area on Lake Plain lacustrine fine sand, silt, and clay deposits over Silurian bedrock. Area bedrock is dense, offering little ground water storage or contribution to surface flows. Soils throughout the basin are poorly drained.”

3.5.3 Summary of 2023 Findings and Analysis

Table 18. Ottawa River Summary Statistics and Exceedances- 45 total samples, 4 stations

Summary of Exceedances by Waterbody and Parameter

Basin	Sample Run..	Parameter	Mean Reading	Median Reading	Min. Reading	Max. Reading	Sample Count	N. Exceeded	Pct Exceeded
Ottawa River	2023	Conductivity Biocondition	953.32	984.50	584.00	1,384.00	34.00	34.00	100.00
		Dissolved Oxygen	8.91	7.90	4.75	18.14	34.00	1.00	2.94
		pH	8.03	7.99	7.40	8.65	34.00	0.00	0.00
		Water Temperature	18.51	19.65	8.10	29.90	34.00	2.00	5.88
Ten Mile Creek	2023	Conductivity Biocondition	1,039.91	1,119.00	656.00	1,351.00	11.00	11.00	100.00
		Dissolved Oxygen	10.71	10.66	7.21	14.02	11.00	0.00	0.00
		pH	8.20	8.15	7.60	8.72	11.00	0.00	0.00
		Water Temperature	18.60	19.80	9.90	25.50	11.00	0.00	0.00

pH – Data collected in 2023 do not indicate pH as an impairment concern in the Ottawa River based on LEBAF standards.

DO – 1 exceedance out of 45 samples (2.22%) was observed. There was a single exceedance at CWAT-4 on June 13; this likely reflects a site-specific condition, and given that it was not sustained, an isolated event. Overall, DO varies as expected seasonally/temporally. 98% of DO values recorded on the Ottawa River during the 2023 season were within the LEBAF analytical benchmark of >=5 mg L^{-1}.

Temperature – 2 exceedances out of 45 samples (4.44%) were observed. Exceedances occurred on May 28 and July 4, at CWAT-5, Howard Pinkley Landing. This station experiences lake influence, and both late May and early July experienced air temperatures at or above average leading up to these sampling dates. The majority (~95%) of collected data fell within LEBAF standards, indicating that temperature is not an impairment concern on the Ottawa River in 2023.

Conductivity – The Ottawa River Watershed falls in the Huron-Erie Lake Plain ecoregion, which serves as the reference for our observed values. In 2023, conductivity values in the Ottawa River ranged from 584.80 to 1384 µS cm^{-1} with a mean value of 974.63 µS cm^{-1}. The mean and maximum values are comparable to the 50th and 95th percentile values of 653 µS cm^{-1} and 1107 µS cm^{-1}, respectively, for Huron-Erie Lake Plain streams reference. The minimum value observed is more comparable to the 50^{th} percentile of the reference, and the mean value observed is comparable to the 90^{th} percentile reference value of 952 µS cm^{-1}. This comparison with the ecoregion references shows some overlap with our dataset and provides additional confidence in using our conductivity results, but also suggests that the Ottawa River is exceeding and/or at the top end in comparison to reference streams for the ecoregion.

The Ohio EPA also sets a conductivity threshold for evaluating macroinvertebrate health: < 412 µS cm^{-1} promotes a healthy community, between 412 and 655 µS cm^{-1} suggests a declining community, and > 655 µS cm^{-1} indicates a degraded community. In 2023, all samples exceeded 412 µS cm^{-1}, with 4/45 samples falling in the degrading range, and 41/45 samples > 655 µS cm^{-1}. There was no clear upstream/downstream pattern to the exceedances, and no clear seasonal pattern. Salinity analysis, a calculated parameter based on directly measured conductivity values, indicated a 17% exceedance rate in the Ottawa River, with the highest exceedance rate at the most upstream station, CWAT-1. All sites measured on the Ottawa River fall within urbanized areas. Analysis of local weather data during the 2023 sampling season indicated that high salinity results coincided with prolonged dry periods and in some cases, abnormally high air temperatures leading up to the sampling date. Overall, this data suggests that macroinvertebrate communities in the Ottawa River are primarily degraded, and that conductivity is a concern in the Ottawa River watershed.

3.5.4 Summary of 2023 Conclusions, Recommendations, Actions

Table 19. Ottawa River Water Quality Summary

pH	***Temperature***	***DO***	***Conductivity***
Acceptable	Acceptable	Acceptable	Likely threat, impacts; Degraded

Overall, data collected in 2023 suggest that the Ottawa River supports aquatic life based on LEBAF benchmarks for water temperature, pH, and DO. Persistently high conductivity values in the watershed are a cause for concern due to potential impacts on aquatic life, and based on LEBAF standards the Ottawa River is considered degraded, with likely threats and impacts to ecosystems. We recommend continuing LEBAF monitoring, which will give a more complete picture of stream health and baseline conditions over time. At sites that seem to have local conditions with exceedances in a specific parameter (CWAT-1, CWAT-2, CWAT-5), we recommend increased monitoring where feasible, specific to the parameter of concern, and in response to climate events when possible.

At all sites where feasible and suitable, we recommend initiating macroinvertebrate monitoring several times throughout the sample season using ODNR's SQM method. Regular monitoring of the macroinvertebrate community where possible, along with continued monitoring of conductivity per LEBAF standards, will expand understanding of the effect of conductivity in the watershed. For CWAT-1 and CWAT-2, where multiple salinity exceedances were noted, increased monitoring at these locations should be considered, as well as direct sampling of salinity in addition to the calculated metric. Coordination with groups involved in research on salinity and chlorides in the watershed should also be explored.

3.6 Rocky River

3.6.1 Monitoring Organizations: The Watershed Volunteer Program (WVP) is a Cleveland Metroparks Natural Resources department led volunteer program supported by the Northeast Ohio Regional Sewer District. WVP is an effort to engage community members in an array of active management projects to improve watershed conditions. WVP promotes stewardship through learning opportunities, monitoring activities, restoration projects, and community outreach. Over the last ten years, more than 2,200 volunteers contributed 27,000+ hours and 270 became Certified Watershed Stewards.

The WVP works with the Cuyahoga Soil and Water Conservation District to manage a joint volunteer water chemistry monitoring program. Staff and volunteers monitor 53 stations within three watersheds: Euclid Creek, Rocky River, and Cahoon Porter. 25 WVP volunteers help test water chemistry at sites on a monthly basis from January to December. In 2023, the Cleveland Metroparks designated two of its stations for regional standards collection using the Lake Erie Baseline Assessment Framework (LEBAF). One of those stations is in the Rocky River watershed.

3.6.2 Station Summary: Bonnie Park Below is a station located on the East Branch of the Rocky River downstream of a removed dam. 21 sampling events were made between January - November 2023 by four volunteers. This is a warmwater site located along the East Branch of the Rocky River upstream of the convergence with the West Branch of Rocky River. This site has a 60.3 square mile drainage area that is approximately 54% forested and 41% developed. The 2011 National Land Cover Dataset (NLCD) data indicates an 8.54% impervious area in the drainage area to Bonnie Park.

3.6.3 Summary of 2023 Findings and Analysis

Table 20. Rocky River Summary Statistics and Exceedances - 21 samples, 1 station

Summary Statistics and Exceedances Basin - Rocky

Parameter	Mean Reading	Median Reading	Min. Reading	Max. Reading	Sample Count	N. Exceeded	Pct Exceeded
Conductivity Biocondition	649.35	661.00	412.00	893.00	21.00	21.00	100.00
Dissolved Oxygen	9.07	9.00	5.61	13.34	21.00	0.00	0.00
pH	8.19	8.15	7.85	8.68	21.00	0.00	0.00
Total Dissolved Solids	357.14	363.55	226.60	491.15	21.00	21.00	100.00
Water Temperature	16.10	19.20	1.80	24.60	21.00	1.00	4.76

pH - Data collected in 2023 do not indicate pH as an impairment concern in the Rocky River based on LEBAF standards, as we found 0% exceedances for this parameter. This finding is consistent with data collected in 2022.

DO - Data collected in 2023 do not indicate DO as an impairment concern in the Rocky River based on LEBAF standards, as we found 0% exceedances for this parameter. This finding is consistent with data collected in 2022.

Temperature - In 2023, a single temperature exceedance was observed on May 30, 2023 at 2:48 pm. The recorded temperature of 24.50 °C was 3.5 °C above the prescribed LEBAF standard for the month of May. Since 95% of 2023 data and 100% of 2022 data met LEBAF seasonal temperature thresholds, there is little to no indication that the Rocky River at Bonnie Park is impaired due to temperature nor is it contributing to a potential Lake Erie temperature impairment.

Conductivity - Natural conductivity values differ between ecoregions and geological areas. The Rocky River watershed lies in the Erie Drift Plain ecoregion. In 2023, conductivity values at Bonnie Park ranged from 412 to 893 $\mu S\ cm^{-1}$ with a 50th percentile of 649 $\mu S\ cm^{-1}$. While the 50th percentile is slightly above the Erie Drift Plain ecoregion stream reference and survey values, the minimum and maximum observations were below those of the Erie Drift Plain ecoregion. This comparison with the ecoregion references shows some overlap with our dataset and provides some additional confidence in using our conductivity results. When our dataset strays above these references, it suggests some of the variation in conductivity is unexplained by ecoregion and helps inform protection recommendations.

The Ohio EPA also sets a conductivity threshold for evaluating macroinvertebrate health: < 412 $\mu S\ cm^{-1}$ promotes a healthy community, between 412 and 655 $\mu S\ cm^{-1}$ suggests a declining community, and > 655 $\mu S\ cm^{-1}$ indicates a degraded community. At Bonnie Park Below, exceedances were found to occur throughout the year, with the highest exceedance of 893 $\mu S\ cm^{-1}$ occurring on Jan 11, 2023. Field season salinity and TDS data was also reviewed to validate calculated results and exceedance findings at the Bonnie Park sampling site. All 21 conductivity measurements in 2023 exceeded the macroinvertebrate threshold of 412 $\mu S\ cm^{-1}$. The upper biocondition threshold of 655 $\mu S\ cm^{-1}$ is near the 50th percentile reference values for Erie Drift Plain streams and river reference. Thus, it is expected that just under 50% of data collected in this ecoregion would exceed this threshold.

While natural influences may contribute to some of the observed high conductivity values, anthropogenic influences cause further exceedances. Further analysis of conductivity included an analysis of Total Dissolved Solids targets for drinking water and salinity for freshwater. All 21 samples exceeded the TDS drinking water target from Jan - Oct, with the highest exceedance of 491.15 $mg\ L^{-1}$ occurring on Jan 11, 2023.

While all samples exceeded the macroinvertebrate targets for health and the TDS drinking water targets, they did not exceed calculated salinity standards indicating the river is meeting acceptable freshwater limits. Conductivity observed in 2023 was lower than in 2022 indicating a potential improvement in water quality; a mild winter may have resulted in less road salt application which may have led to this trend. No weather, seasonality, or flow condition trends were apparent to explain the range of conductivity readings.

3.6.4 Summary of 2023 Conclusions, Recommendations, Actions

Table 21. Rocky River Water Quality Summary

pH	*Temperature*	*DO*	*Conductivity*
Acceptable	Acceptable	Acceptable	Concern for Biota

Overall the Rocky River at Bonnie Park can support a healthy ecosystem based on the LEBAF standards for pH, DO and temperature. For the purposes of screening, most of the measured LEBAF parameters indicate acceptable or healthy stream conditions. Extreme weather events, specifically periods of high heat and low precipitation, however, may cause intermittent periods of stress that may cause aquatic life to relocate for short periods of time. Since the occurrence of these extreme weather events are only expected to increase with climate change, parts of the Rocky River may become more vulnerable to DO and temperature impairments in the future. High conductivity is likely the result of anthropogenic influences from urbanization including increased or flashy flows causing increased physical weathering within the streams and the input of more contaminants from land such as nutrients or salts. Further investigations are necessary to fully characterize the contaminants comprising the conductivity concentrations. While most field season results indicate a healthy stream, more sampling of the exceeded parameters and incorporation of aquatic life data is needed to make more robust conclusions about the true health of the stream.

3.7 Buffalo River

3.7.1 Monitoring Organizations: One organization in the LEBAF network monitors in the Buffalo River, Buffalo Niagara Waterkeeper.

3.7.2 Station Information: Buffalo Niagara Waterkeeper (BNV) stewards two sites sampled once a month from May - October. Data from 2020, 2021, and 2022 are available for both the Buffalo River at Riverfest Park (BR02 - Coordinates: 42.870881, -78.871138) and Buffalo River at Bailey Peninsula (BR05 - Coordinates: 42.861629, -78.825641) sites.

Buffalo River at Riverfest Park (BR02) is approximately 1 mile upstream of the mouth of the Buffalo River, which feeds directly into Lake Erie. There are multiple Combined Sewer Overflow (CSO) locations upstream and downstream of this site, which is a popular location for both recreational and commercial boats, fishing, and business. It is near a residential area and a contemporary General Mills factory. Historically, this river was used to transport commercial goods. Before flowing into the lake, the Buffalo River passes a constructed ship canal. This site was sampled once a month from May - October between 9:45 am and 11:00 am.

Buffalo River at Bailey Peninsula (BR05) is located near the confluence of the Buffalo River and Cazenovia Creek, approximately 5 miles upstream of station BR02. There are multiple Combined Sewer Overflow (CSO) locations upstream and downstream of this site, including one located on the Bailey Peninsula. It is a popular location for fishing, kayakers, and is close to a busy road. This site was sampled once a month May - October between 10:30 am and 11:30 am.

In August of 2023, additional stations were added to BNW's station list and were monitored using the LEBAF framework. Due to the limited sample size for those additional stations, and lack of historical data, only those stations that were included in the 2022 analysis report are included in the analysis herein.

3.7.3 Summary of 2023 Findings and Analysis

Table 22. Buffalo River Summary Statistics and Exceedances* - 15 total samples, 2 stations.

Summary Statistics and Exceedances Basin - Buffalo

Station Id	Station Na..	Parameter	Mean Reading	Median Reading	Min. Reading	Max. Reading	Sample Count	N. Exceedance	Pct Exceeded
BR02	Buffalo River @ Riverfest Park	Conductivity Bioconditi..	394.69	424.30	81.40	470.50	9.00	6.00	76.47
		Dissolved Oxygen	7.78	7.90	4.76	11.88	9.00	1.00	6.67
		pH	7.75	7.62	7.47	8.47	9.00	0.00	0.00
		Total Dissolved Solids	217.08	233.37	44.77	258.78	9.00	8.00	88.24
		Water Temperature	21.79	23.87	13.43	24.89	9.00	1.00	6.67
BR05	Buffalo River @ Bailey Peninsula	Conductivity Bioconditi..	521.50	512.40	444.50	596.20	6.00	6.00	76.47
		Dissolved Oxygen	8.10	8.31	6.93	9.78	6.00	0.00	6.67
		pH	7.90	7.91	7.71	8.06	6.00	0.00	0.00
		Total Dissolved Solids	286.83	281.83	244.48	327.91	6.00	6.00	88.24
		Water Temperature	20.87	22.46	12.26	25.93	6.00	0.00	6.67

**Due to the removal of one site from this analysis, summary statistics are provided for each station individually instead of in aggregate. Additionally, TDS/DW statistics are included due to high frequency of exceedances*

pH - The lack of exceedances indicates that pH values for the Buffalo River are within the established LEBAF standards (6.5 – 9), suggesting that the Buffalo River has the potential to support aquatic life. This parameter was observed within expected ranges throughout the 2023 sampling season and 2023 measurements were comparable to 2022 for both monitored locations along the river.

DO – 93.3% of DO values recorded on the Buffalo River during the 2023 season were within the LEBAF analytical benchmark of >=5 mg L^{-1} indicating that DO levels in the stream supported aquatic life during the sampled dates and times. The single recorded exceedance occurred on July 15th at station BR02, and was not severe (4.76 mg L^{-1}). Due to its proximity to the mouth of the river, it is possible that this station is more susceptible to lacustrine dynamics than the second station monitored further upstream. This parameter was observed within expected ranges during the sampling season, and measurements in 2023 were comparable to those made in 2022, despite no exceedances being recorded in the previous year.

Temperature - 94.2% of temperature values recorded on the Buffalo River during the 2023 season were within the LEBAF analytical benchmarks indicating that water temperature during the sampled dates and times supported aquatic life. The single exceedance recorded in 2023 occurred on October 5th at station BR02, and was not severe. This was likely driven by the higher than average ambient air temperatures that occurred in the area during the beginning of October. This parameter was observed within expected ranges in 2023, with similar maximum, mean, and minimum values to 2022 measurements, despite no exceedances being recorded in the previous year.

Conductivity - The Ohio EPA also sets a conductivity threshold for evaluating macroinvertebrate health: < 412 µS cm^{-1} promotes a healthy community, between 412 and 655 µS cm^{-1} suggests a declining community, and > 655 µS cm^{-1} indicates a degraded community. Conductivity values recorded along the Buffalo River in 2023 fell roughly between the Ohio EPA reference and survey data, with about 50% of collected data falling below the 50^{th} percentile data for both reference and survey data. Overall, this parameter seems lower than both reference and survey sites. The average conductivity value for the two stations along the Buffalo River were 437.94 µS cm^{-1}, with 12 of 15 samples falling between 412 and 655 µS cm^{-1}, placing the river in the 'concern for biota' category as outlined by LEBAF and suggesting that potentially stressful conditions exist for macroinvertebrate communities along this waterway. Conductivity exceedances continue to be the primary issue for this river, as was the case in 2022. Highly developed land use along the river likely contributes to consistent conductivity exceedances at these sites, with only three measurements falling below the 412 µS cm^{-1} benchmark for an 'excellent/healthy' status for the river.

This parameter decreased from May through October, except for an increase in July which could be influenced by increased presence of recreational boaters and potential associated discharge. Exceedances, while frequent, regularly fall within the range of 'concern for biota', rather than spiking dramatically. Lake dynamics and other pollution inputs could affect measurements on a monthly basis. Conductivity can be expected to be higher in winter and spring months due to runoff from road salts. High flow/storm events can cause spikes in conductivity due to increased runoff from urban, agricultural, or wastewater input sources. Additional factors including limestone bedrock, commercial and industrial inputs, and recreational/commercial boaters could influence conductivity on a seasonal basis.

Limited data are available to determine overall health and diversity of macroinvertebrate communities in the Buffalo River. Sampling of macroinvertebrate communities at both of these sites, and potentially other locations along the river as an additional LEBAF standard, or through cooperation with New York State Department of Environmental Conservation's Watershed Assessment by Volunteer Evaluators program (NYS DEC WAVE) could support future assessments. Other surrogate parameter measurements for salinity, chloride, and TDS/AQ Life do not provide additional context to the exceedances, but analysis of additional metadata might shed light on the source of the exceedances.

TDS - All TDS values recorded along the Buffalo River in 2023 met the aquatic life standard for TDS of 1500 mg L^{-1}.. Measurements recorded at station BR02 in October were sometimes even below drinking water standards of 200 mg L^{-1}. TDS remained consistent throughout the sampling period at both BR02 and BR05, with the exception of the month of October for BR02, suggesting that no abnormal contamination occurred. Concentrations observed in 2023 were lower than 2022 measurements, on average.

3.7.4 Summary of 2023 Conclusions, Recommendations, Actions

Table 23. Buffalo River Water Quality Summary

pH	*Temperature*	*DO*	*Conductivity*
Acceptable	Acceptable	Acceptable	Concern for Biota

Results from the 2023 sampling year suggest that the Buffalo River has generally acceptable conditions for supporting aquatic life. Infrequent and minor exceedances for temperature and dissolved oxygen do not indicate systemic threats to aquatic life along the river, and are suspected to be driven primarily by ambient air temperature. While this driver could continue to present problems for the river in subsequent years, additional sampling at increased frequency, various times of day, and at additional sites could shed light on broader patterns and potential problem areas. Conductivity values were roughly comparable to the Ohio EPA survey and reference datasets with an average of 437.94 µS cm^{-1}. 12 of 15 samples fell between 412 and 655 µS cm^{-1}, placing the river in the 'concern for biota' category as outlined by LEBAF. This parameter continues to be a point of concern for Buffalo River, and concentrations measured in 2023 are comparable to measurements made in 2022. Consistent exceedances throughout the year are likely due to the location of these sites and highly developed surroundings in immediate proximity, with only three measurements falling below the 412 µS cm^{-1} benchmark for an 'excellent/healthy' status for the river. Exceedances, while frequent, regularly fell within the range of 'concern for biota', rather than spiking dramatically. Lake dynamics and other pollution inputs could affect measurements on a monthly basis. Conductivity can be expected to be higher in winter and spring months due to runoff from road salts. High flow/storm events can cause spikes in conductivity due to increased runoff from urban, agricultural, or wastewater input sources. Additional factors including limestone bedrock, commercial and industrial inputs, and recreational/commercial boaters could influence conductivity on a seasonal basis.

Limited data is available to determine overall health and diversity of macroinvertebrate communities in the Buffalo River. Sampling of macroinvertebrate communities at both of these sites, and potentially other locations along the river as an additional LEBAF standard, could support future conclusions. Other surrogate parameter measurements for salinity, chloride, and TDS/AQ Life do not provide additional context to the exceedances, but analysis of additional metadata might shed light on the source of the exceedances.

For all parameters, additional sampling at increased frequency, various times of day, and at additional locations is recommended. Any exceedances that are severe should warrant follow-up sampling and investigation when possible and warranted. Collection of additional metadata, including flow, nutrients, and sediment data, and the exploration of surrogate parameter measurements could help shed light on any future exceedances, and guide conclusions for LEVSN.

3.8 Chappell Creek

3.8.1 Monitoring Organizations: Chappel Creek has been monitored by volunteers of the Firelands Coastal Tributaries (FCT) Watershed Program since 2022. Chappel Creek is a 24 square mile watershed that begins in Huron County and empties into Lake Erie's Central Basin between the City of Huron and the City of Vermilion. The land use of this watershed consists of 58% agriculture, 9% urban, and 33% natural area dominated by forest. The watershed is narrow with a narrow floodplain. Chappel Creek is on the USEPA's impaired waters list for not meeting aquatic life use due to excessive sediment, nutrients, and habitat alteration.

3.8.2 Station Summary: The Firelands Coastal Tributaries Watershed Program collected data from six sites in the Chappel Creek watershed. The watershed crosses two distinct ecoregions: Eastern Corn Belt Plains and Erie-Huron Lake Plain, with Berea sandstone and shale geology underlying the region. Additional sites represent the estuary portion of the watershed but are not included in this analysis since they are within the lake influence zone. More information of the estuary sites can be found at the Firelands Coastal Tributaries Watershed webpage at https://erieconserves.org/watershed-program and National Estuarine Research Reserve System online database https://cdmo.baruch.sc.edu/. Data collection occurs mid-month from April to November; however, our last month was not used in the LEBAF analysis. Overall, 41 observations were made in 2023. Only one sample was not taken during the sampling year due to dry conditions at the site. Chappel Creek was not part of LEBAF in 2022.

3.8.3 Summary of 2023 Findings and Analysis

Table 24. Chappel Creek Summary Statistics and Exceedances - 41 total samples, 6 stations.

Summary Statistics and Exceedances Basin - Chappel Creek

Parameter	Mean Reading	Median Reading	Min. Reading	Max. Reading	Sample Count	N. Exceeded	Pct Exceeded
Conductivity Biocondition	536.88	541.00	372.00	670.00	41.00	39.00	95.12
Dissolved Oxygen	8.72	8.97	3.52	12.78	41.00	3.00	7.32
pH	7.96	7.86	7.35	8.80	41.00	0.00	0.00
Water Temperature	17.74	18.20	11.20	23.30	41.00	6.00	14.63

pH - pH data collected in 2023 was within the acceptable range throughout the sampling period (0% exceedances), indicating that there is no pH impairment in Chappel Creek based on the prescribed LEBAF standards.

DO – Dissolved oxygen data collected in 2023 was within the acceptable range for most of the sampling year, with exceedances occurring at 2 headwater sites in the summer months. These sites frequently experience low base flows during the summer and are more vulnerable to low DO when ambient air temperature is high. Despite the minor exceedance, 2023 data suggests no indication of DO impairment in Chappel Creek based on the prescribed LEBAF standards.

Temperature - Temperature data collected in 2023 were within the acceptable range for most of the sampling period, with the exception of 6 instances that occurred in April. While it is not uncommon for headwater sites to have exceedances in the summer months due to high temperatures and low stream flow, these exceedances occurred at several sites in the watershed in spring. The sites represented both shaded and unshaded sections of Chappel Creek. Average daytime ambient air temperatures observed several days prior to sampling were 70-80 degrees, much higher than the historical average April temperature (≈50°F).

Conductivity - Conductivity in Chappel Creek fell within the Ohio EPA survey and reference datasets (see section 2.2) with an average of 536.88 µS cm^{-1} and a range from 372.00 to 670.00 µS cm^{-1}. Nearly all samples did however, fall within the 50th percentile of value of 629 µS cm^{-1} Erie-Ontario Lake Plain headwater survey.

The Ohio EPA also sets a conductivity threshold for evaluating macroinvertebrate health: < 412 µS cm^{-1} promotes a healthy community, between 412 and 655 µS cm^{-1} suggests a declining community, and > 655 µS cm^{-1} indicates a degraded community. All but two conductivity measurements in 2023 exceeded the healthy macroinvertebrate threshold of 412 µS cm^{-1}. Nearly 92% (38 samples) of Chappel Creek's conductivity measurements fell between 412 and

655 µS cm^{-1} and 0.02% (1 sample) was > 655 µS cm^{-1}. The average conductivity in the stream indicates a concern for biota, meaning there could be impacts to aquatic life. Bedrock, which is dominated by sandstone and shale, should not contribute to elevated conductivity. It is possible that the elevated conductivity may be due to agriculture, which is the dominant land-use in the watershed. No significant exceedances were found in calculated chloride, salinity, or TDS. Monitoring of macroinvertebrates would help to determine if the aquatic community is degrading in Chappel Creek. Additionally, nutrient and sediment monitoring may also help determine if agricultural run-off could be a source elevating the conductivity of the watershed.

3.8.4 Summary of 2023 Conclusions, Recommendations, Actions

Table 25. Chappel Creek Water Quality Summary

pH	*Temperature*	*DO*	*Conductivity*
Acceptable	Acceptable	Acceptable	Concern for biota

Results from the 2023 sampling year suggest that Chappel Creek has acceptable conditions to support aquatic life with no exceedances for pH, and minor exceedances for temperature and dissolved oxygen which corresponded with abnormally high ambient air temperatures. Conductivity was comparable to the Ohio EPA survey and reference datasets with an average of 536.88 µS cm^{-1} and a range from 372.00 to 670.00 µS cm^{-1}. Conductivity appears to be a slight concern for Chappel Creek. As such, further exploration of these sites is recommended to determine if the aquatic biota is being impacted. There was no macroinvertebrate sampling in 2023 for comparison. The stream experiences low summer flows and excessive nutrients and sediment throughout the watershed related to storm events. While most sites in the watershed exhibit acceptable values for supporting aquatic life for LEBAF parameters, additional exploration into flow, nutrients, and sediment would provide a more detailed look at stream health.

3.9 Eighteenmile Creek

3.9.1 Monitoring Organizations: The Eighteen Mile Creek basin is monitored by Buffalo Niagara Waterkeeper.

3.9.2 Station information: Buffalo Niagara Waterkeeper (BNW) has two stations that are monitored once per month from May - October along Eighteenmile Creek. Data from 2020, 2021, and 2022 are available for both sites, including Eighteenmile Creek at Old Lakeshore Road (EMC01 - Coordinates: 42.712208, -78.966392) and at Gowanda State Road Bridge (EMC03 - Coordinates: 42.706475, -78.849177).

Eighteenmile Creek at Old Lake Shore Road Bridge (EMC01) is approximately 840.5 meters upstream of the mouth of the creek, which feeds directly into Lake Erie. It is located south of the city of Buffalo in Derby, NY. This creek is fast moving, cool, and can be affected by lake seiche and heavy agricultural use and upstream runoff. There are no nearby Combined Sewer Overflows (CSOs), although the upstream agriculture and its popularity as a boating, fishing, and recreation site could affect parameter measurements. This site is close to a residential area. This station was monitored once per month May - October between 10:15 am and 10:45 am.

Eighteenmile Creek at Gowanda State Road Bridge (EMC03) is located approximately 14.89 km upstream of the previous station, and south of the city of Buffalo in the town of Hamburg. This station is near a cemetery, a busy commercial district, and along a busy state road, all of which could affect parameter measurements. Heavy agricultural use and runoff upstream of this site could also affect measurements. This station was sampled once per month May - October between 10:45 am and 11:15 am.

In August of 2023, additional stations were added to BNW's station list, and were monitored using the LEBAF framework. Due to the limited sample size for those additional stations, and lack of historical data, only those stations that were included in the 2022 analysis report are included in the analysis herein. For more information on those sites, view the station map here.

3.9.3 Summary of 2023 Findings and Analysis

Table 26. Eighteenmile Creek Summary Statistics and Exceedances* - 14 total samples, 2 stations.

Summary Statistics and Exceedances Basin - Eighteenmile Creek

Station Id	Station Name (..	Parameter	Mean Reading	Median Reading	Min. Reading	Max. Reading	Sample Count	N. Exceedance	Pct Exceeded
EMC01	Eighteenmile Creek @ Old Lake Shore Rd Bridge	Conductivity Bioconditi..	517.49	516.65	327.70	704.50	8.00	7.00	87.50
		Dissolved Oxygen	10.75	10.84	9.28	12.20	8.00	0.00	0.00
		pH	8.28	8.21	8.11	8.48	8.00	0.00	0.00
		Total Dissolved Solids	284.62	284.16	180.24	387.48	8.00	7.00	87.50
		Water Temperature	18.21	18.31	11.83	23.17	8.00	4.00	57.14
EMC03	Eighteenmile Creek @ Gowanda St. Rd Bridge	Conductivity Bioconditi..	539.75	579.55	349.80	602.60	6.00	5.00	87.50
		Dissolved Oxygen	10.80	10.81	10.00	11.78	6.00	0.00	0.00
		pH	8.28	8.27	8.17	8.46	6.00	0.00	0.00
		Total Dissolved Solids	296.86	318.76	192.39	331.43	6.00	5.00	87.50
		Water Temperature	16.31	17.25	11.74	21.14	6.00	2.00	57.14

**Summary statistics and exceedances are shown only for stations EMC01 and EMC03. An aggregated summary table is excluded, as it includes data from a station that is not included in analysis. TDS/DW statistics are included due to high frequency of exceedances.*

pH - All 2023 pH values fell within established LEBAF standards (6.5 – 9), indicating the potential to support aquatic life. This parameter was observed within expected ranges in 2023, based on observations made in 2022.

DO – 100% of DO values recorded on Eighteenmile Creek during the 2023 season were above the LEBAF analytical benchmark of >5 mg L^{-1}, suggesting that DO concentrations supported aquatic life during the sampled dates and times. This parameter was observed within expected ranges in 2023, based on observations made in 2022, with no exceedances recorded in either year.

Temperature - 57.14% of temperature values recorded on Eighteenmile Creek during the 2023 season were within the LEBAF analytical benchmarks, indicating that water temperatures in the stream could potentially present challenges to supporting aquatic life, particularly during the warmer summer months. Both stations along the creek experienced regular exceedances in the warmer months of the sampling season, with July and August recording the highest exceedances. The combined three exceedances between these two months could be cause for concern, but additional measurements that were taken two days after the August 17^{th} exceedance showed a significant decrease in water temperature. Results for this parameter in 2023 followed a similar overall trend when compared to 2022, with a few notable exceptions. While overall average temperature for both stations was lower in 2023, both stations recorded significantly higher minimum temperatures, and a slightly higher maximum temperature at EMC01. Exceedances for this parameter are likely being driven by ambient air temperature.

Conductivity - 2023 conductivity values observed in Eighteenmile Creek fell roughly between the Ohio EPA reference and survey data, with collected data falling between the 50th percentile of reference and survey data, and both max and minimum recorded values falling below the respective reference and survey values. Overall, results suggest lower overall conductivity compared to both reference and survey results. Average conductivity for the two stations along Eighteenmile Creek was 528.62 µS cm^{-1}, with 11 of 14 samples falling between 412 and 655 µS cm^{-1}, and one recorded exceedance of 655 µS cm^{-1}, placing the creek in the 'concern for biota' category as outlined by LEBAF. Observations from 2023 suggest the existence of potentially stressful conditions for macroinvertebrate communities along this waterway, with seasonal spikes. No clear pattern could be established between the upstream (EMC03) and downstream stations (EMC01), although the downstream site exhibited lower overall conductivity values and is potentially more susceptible to lacustrine dynamics. Fluctuations outside of the 412 – 655 µS cm^{-1} range, particularly at the downstream station, indicate that this creek could be susceptible to incidental and dramatic changes in conductivity values. While conductivity exceedances remained frequent in 2023, as in 2022, there was more variance in 2023 for this parameter, with lower overall mean, minimum, and median values, and a slightly higher maximum reading. Erosion, agriculture inputs, and nearby residential/commercial runoff could influence conductivity within the stream on a seasonal basis.

This parameter was observed within expected ranges, with results generally decreasing from May through October, except for an increase in July which could be due to increased presence of recreators. Exceedances were frequent and regularly fell within the range of concern for biota, rather than spiking dramatically. Lake dynamics and other pollution inputs could affect measurements on a monthly basis. Conductivity can be expected to be higher in winter and spring months due to runoff from road salts. High flow/storm events can cause spikes in conductivity due to increased runoff from urban, agricultural, or wastewater input sources. Additional factors including erosion, agriculture inputs, and nearby commercial/residential runoff could influence conductivity on a seasonal basis. Limited data is available to determine overall health and diversity of macroinvertebrate communities in Eighteenmile Creek. Sampling of macroinvertebrate communities at both of these sites, and potentially other locations along the river as an additional LEBAF standard, or through cooperation with New York State Department of Environmental Conservation's Watershed Assessment by Volunteer Evaluators program (NYS DEC WAVE) could support future conclusions. Other surrogate parameter measurements for salinity, chloride, and TDS/AQ Life do not provide additional context to the exceedances, but analysis of additional metadata may shed light on the source of the exceedances.

TDS - All TDS values recorded along Eighteenmile Creek in 2023 met the aquatic life threshold of 1500 mg L^{-1} as established by LEBAF. Some sites had values that fell below even the drinking water standard of 200 mg L^{-1}. Results for this parameter, on average, are lower in 2023 than in 2022, but less stable.

3.9.4 Summary of 2023 Conclusions, Recommendations, Actions

Table 27. Eighteenmile Creek Water Quality Summary

pH	*Temperature*	*DO*	*Conductivity*
Acceptable	Degrading	Acceptable	Concern for Biota

Results from the 2023 sampling year suggest that conditions along Eighteenmile Creek could present challenges for supporting aquatic life based on the above parameters when compared to LEBAF standards. Frequent exceedances in water temperature and conductivity measurements could indicate regularly stressful conditions for aquatic life, and more information will be required to determine driving factors for exceedances, although ambient air temperature is suspected to be the likely driver of exceedances in water temperature. While this driver could continue to present problems for the river in subsequent years, additional sampling at increased frequency, various times of day, and at additional sites could shed light on broader patterns and potential problem areas. Conductivity values recorded along Eighteenmile Creek in 2023 fall roughly between the Ohio EPA reference and survey data, with collected data falling between the 50th percentile of reference and survey data, and both max and minimum recorded values falling below the respective reference and survey values. Overall, results suggest lower overall conductivity compared to both reference and survey results. The average conductivity value for the two stations along the Eighteenmile Creek was 528.62 µS cm^{-1}, with 11 of 14 samples falling between 412 and 655 µS cm^{-1}, and one recorded exceedance of 655 µS

cm^{-1}, placing the creek in the 'concern for biota' category as outlined by LEBAF. Observations in 2023 suggest potentially stressful conditions for macroinvertebrate communities along this waterway, with seasonal spikes. There is no clear trend that can be established between the upstream (EMC03) and the downstream station (EMC01), although the downstream location recorded lower overall conductivity values and is potentially more susceptible to lacustrine dynamics. Fluctuations outside of the 412 µS cm^{-1} – 655 µS cm^{-1} range, particularly at the downstream station, indicate that this creek could be susceptible to incidental and dramatic changes in conductivity values.

The number of exceedances at this site in 2022 (and previous monitoring) are similar to the number of exceedances in 2023. Conductivity to Biocondition and TDS continue to be issues at this site, likely due to hot weather, wastewater inputs, runoff, and geology/erosion. Temperature exceedances were less frequent and severe than in 2022, indicating that fluctuations are likely the result of seasonal changes and weather patterns (rather than due to any persistent point/non-point source contaminants).

Limited data is available to determine the overall health and diversity of macroinvertebrate communities in Eighteenmile Creek. Sampling of macroinvertebrate communities at both of these sites, and potentially other locations along the river as an additional LEBAF standard, or through cooperation with NYS DEC WAVE program could support future conclusions. Other surrogate parameter measurements for salinity, chloride, and TDS/AQ Life do not provide additional context to the exceedances, but analysis of additional metadata might shed light on the source of the exceedances.

For all parameters, additional sampling at increased frequency, various times of day, and at additional locations is recommended. Any exceedances that are severe should warrant follow-up sampling and investigation when possible and warranted. Collection of additional metadata, including flow, nutrients, and sediment data, and the exploration of surrogate parameter measurements could help shed light on any future exceedances, and guide conclusions for LEVSN.

3.10 Euclid Creek

3.10.1 Monitoring Groups: The Watershed Volunteer Program (WVP) is a Cleveland Metroparks Natural Resources Department led volunteer program supported by the Northeast Ohio Regional Sewer District. WVP is an effort to engage community members in an array of active management projects to improve watershed conditions. WVP promotes stewardship through learning opportunities, monitoring activities, restoration projects, and community outreach. Over the last ten years, more than 2,200 volunteers contributed 27,000+ hours and 270 became Certified Watershed Stewards.

The WVP works with the Cuyahoga Soil and Water Conservation District to manage a joint volunteer water chemistry monitoring program. Staff and volunteers monitor 53 stations within three watersheds: Euclid Creek, Rocky River, and Cahoon Porter. 25 WVP volunteers monitor stations on a monthly basis from January to December. In 2022, the Cleveland Metroparks designated three of its stations for regional standards collection using the LEBAF monitoring protocol. One of those stations is in the Euclid Creek watershed.

3.10.2 Station information: Schaefer Park was the only station within the Euclid Creek watershed that was monitored using LEBAF protocols. This station was monitored 13 times between January to November 2023 by four volunteers and one staff member. Euclid Creek has two main branches (east and west) and drains directly to Lake Erie with a drainage area of 24 square miles; it lies on the eastern border of Cuyahoga County and the western border of Lake County. Schaefer Park is a channelized, warmwater site with a confined floodplain. It is located along a small unnamed tributary to the West Branch of Euclid Creek. The station is in Lyndhurst, Ohio and drains 1.91 square miles. Much of the stream network is underground in pipes, but the stream is daylighted at this monitoring location. The station is 100% developed and primarily residential land use. The site is directly downstream of a community park with ball fields. A common trend at the station is high phosphate levels.

3.10.3 Summary of 2023 Findings and Analysis

Table 28. Euclid Creek Summary Statistics and Exceedances - 13 total samples, 1 station.

Schaefer Park							
Parameter	**Mean Reading**	**Median Reading**	**Min. Reading**	**Max. Reading**	**Sample Count**	**N. Exceedance**	**Pct Exceeded**
Conductivity/Biocondition	543.71	500.00	344.40	682.00	9.00	7.00	77.78
Dissolved Oxygen	8.76	8.44	2.38	12.00	13.00	1.00	7.69
pH	8.02	8.15	7.29	8.60	13.00	0.00	0.00
Water Temperature	16.88	18.20	10.20	21.60	13.00	0.00	0.00

pH - In 2022 there were 5 out of 17 samples that were above 9. Historically pH at this station are mostly between the pH thresholds of 6.5-9. Data collected in 2023 do not indicate pH as an impairment concern in Euclid Creek based on LEBAF standards, as we found 0% exceedances for this parameter.

DO - In 2023, a single dissolved oxygen violation was observed on June 25, 2023. Urban upstream land use can contribute to DO exceedances, however the metadata indicates that heavy smog from Canadian fires on this day combined with extremely low flow likely caused the observed dissolved oxygen exceedance. Since 95% of 2023 data and 100% of 2022 data met LEBAF dissolved oxygen thresholds, there is little to no indication that Schaefer Park tributary is impaired due to dissolved oxygen nor is it contributing to a potential Lake Erie temperature impairment.

Temperature - In 2022 there were 2 out of 17 samples that were above the recommended temperature target. Data collected in 2023 do not indicate temperature as an impairment concern in Euclid Creek based on LEBAF standards, as we found 0% exceedances for this parameter.

Conductivity - Natural conductivity values differ between ecoregions and geological areas. The Euclid Creek watershed lies in the Erie Drift Plain ecoregion. In 2023, conductivity values at Schaefer Park ranged from 344 to 682 µS cm^{-1} with a 50th percentile of 500 µS cm^{-1}. While the 50th percentile is slightly above the Erie Drift Plain ecoregion stream reference value, the minimum and maximum observations were below those of the Erie Drift Plain ecoregion. This comparison with the ecoregion references shows some overlap with our dataset and provides some additional confidence in using our conductivity results. When our dataset strays above these references, it suggests some of the variation in conductivity is unexplained by ecoregion and helps inform protection recommendations.

The Ohio EPA also sets a conductivity threshold for evaluating macroinvertebrate health: < 412 µS cm^{-1} promotes a healthy community, between 412 and 655 µS cm^{-1} suggests a declining community, and > 655 µS cm^{-1} indicates a degraded community. 78% of the samples exceeded 655 µS cm^{-1}. Field season salinity and TDS data was also reviewed to validate calculated results and exceedance findings at the Bonnie Park monitoring station. All 21 conductivity measurements in 2023 exceeded the macroinvertebrate threshold of 412 µS cm^{-1}. The upper biocondition threshold of 655 µS cm^{-1} is near the 50th percentile reference values for Erie Drift Plain streams and river reference. Thus, it is expected that just under 50% of data collected in this ecoregion would exceed this threshold.

Historic conductivity values at this station from 2006 – 2021 fluctuate throughout a yearly cycle without predictable trends. A general pattern of high conductivity during the summer and lower conductivity towards colder months can be seen in 2023, albeit temperatures were only mildly cooler in late September and October. This behavior is expected; however, not unusual considering that historic high conductivity values have been observed season-round.

While natural influences may contribute to some of the observed high conductivity values, anthropogenic influences cause further exceedances. Further analysis of conductivity included an analysis of Total Dissolved Solids targets for drinking water and salinity for freshwater. 8 of 9 samples exceeded the TDS drinking water target.

While 78% of the samples exceeded the macroinvertebrate targets for health, they did not exceed calculated salinity standards indicating the streams are still meeting acceptable freshwater limits. Conductivity observed in 2023 was lower than in 2022 indicating a potential improvement in water quality; a mild winter may have resulted in less road salt application which may have led to this trend. No weather, seasonality, or flow condition trends were apparent to explain the range of conductivity readings.

3.10.4 Summary of 2023 Conclusions, Recommendations, Actions

Table 29. Euclid Creek Water Quality Summary

pH	*Temperature*	*DO*	*Conductivity*
Acceptable	Acceptable	Acceptable	Concern for Biota

Overall, the unnamed tributary to Euclid Creek at Schaefer Park can support a healthy ecosystem based on the LEBAF standards for pH, DO and temperature. For the purposes of screening most of the measured LEBAF parameters indicate acceptable or healthy stream conditions. Extreme weather events, specifically periods of high heat and low precipitation, however, may cause intermittent periods of stress that may cause aquatic life to relocate for short periods of time. Since the occurrence of these extreme weather events are only expected to increase with climate change, parts of the Euclid Creek watershed may become more vulnerable to DO and temperature impairments in the future. High conductivity is likely the result of anthropogenic influences from urbanization including increased or flashy flows causing increased physical weathering within the streams and the input of more contaminants from land such as nutrients or salts. Further investigations are necessary to fully characterize the contaminants comprising the conductivity concentrations. While most field season data indicates a healthy stream, more monitoring of the exceeded parameters and incorporation of aquatic life data is needed to make conclusions about the true health of the stream. After reviewing the goals of LEBAF, Cuyahoga SWCD and Cleveland Metroparks recommend moving away from monitoring Schafer Park and focusing efforts on stations along the mainstem of Euclid Creek to obtain a more robust understanding of the watershed.

3.11 Mills Creek

3.11.1 Monitoring Organizations: One entity in the LEBAF network is Mills Creek, which has been monitored by volunteers of the Firelands Coastal Tributaries (FCT) Watershed Program since 2011. Mills Creek is a 42.4 square mile watershed with headwaters that begin in the community of Bellevue and empties into Sandusky Bay on the west end of the City of Sandusky. Most of the watershed is rural/agricultural land use (67%) with more than a quarter being urbanized development and less than 7% natural area. The watershed is located within the Karst geological region and has high interaction between the ground and surface water. The watershed has two large industrial discharges, one being a limestone quarry and the other a wastewater treatment plant. Both discharges occur in the upper portion of the watershed.

3.11.2 Station information: The Firelands Coastal Tributaries Watershed Program collected data from 7 station sites in the Mills Creek watershed that are representative of the stream proper portion of the watershed. Five station locations are spaced from headwaters to mouth along a main channel, with two additional stations on side tributaries. The watershed is located in Erie-Huron Lake Plain Ecoregion with unique limestone/karst geology. Data collection occurs mid-month from April to November; however, our last month was not used in the LEBAF analysis. Overall, 49 observations were made in 2023.

3.11.3 Summary of 2023 Findings and Analysis

Table 30. Mills Creek Summary Statistics and Exceedances - 49 total samples, 7 stations.

Summary Statistics and Exceedances Basin - Mills Creek

Parameter	Mean Reading	Median Reading	Min. Reading	Max. Reading	Sample Count	N. Exceeded	Pct Exceeded
Conductivity Biocondition	879.89	857.00	382.40	2,127.00	49.00	47.00	95.92
Dissolved Oxygen	8.91	8.88	5.83	12.84	49.00	0.00	0.00
pH	7.97	8.00	6.60	8.71	49.00	0.00	0.00
Water Temperature	16.53	17.00	8.50	22.50	49.00	1.00	2.04

pH - Consistent with 2022 findings, pH data collected in 2023 was within the acceptable range throughout the sampling period, as we found 0% exceedances for this parameter. As such, we conclude that there is no indication of pH impairment in Mills Creek based on the prescribed LEBAF standards.

DO – Similar to 2022, dissolved oxygen data collected in 2023 was within the acceptable range with no exceedances occurring throughout the sampling year. Therefore, the current data suggests no indication of DO impairment in Mills Creek based on the prescribed LEBAF standards.

Temperature - A slight increase from 2022 findings, temperature data collected in 2023 were still within the acceptable range for most of the sampling period, with the exception of one instance that occurred in April. Average daytime ambient air temperatures observed several days prior to sampling were 70-80 degrees, much higher than the historical average April temperature (≈50°F). We feel the current data suggests no indication of DO impairment in Mills Creek based on the prescribed LEBAF standards.

Conductivity – Similar to 2022, conductivity continues to show highly elevated values in Mills Creek compared to the Ohio EPA survey and reference datasets with an average of 879.89 µS cm^{-1} and a range from 382.4 to 2,127.0 µS cm^{-1}. Conductivity results distributions provided some overlap between median and maximum values with the Ohio EPA reference stream and survey data. However, a comparison of medians suggests that Mills Creek tends to have a conductivity much higher than the Ohio data set. The limestone geology and high groundwater input within the watershed influence higher conductivity levels compared to other watersheds of similar size sampled by the Ohio EPA in the Huron Erie Lake Plain region. However, there is a marked difference at several sites in Mills Creek, where industrial discharges of quarry and wastewater treatment effluent enter the system. Stations immediately downstream of these industrial discharges (Strecker Rd West and Miller West) resulted in large departures compared to the Ohio data set. More than 50% of the data exceeded the 75th percentile of value of 821 µS cm^{-1} Huron-Erie Lake Plain headwaters survey suggesting impacts to conductivity is a concern for the entire watershed.

The Ohio EPA also sets a conductivity threshold for evaluating macroinvertebrate health: < 412 µS cm^{-1} promotes a healthy community, between 412 and 655 µS cm^{-1} suggests a declining community, and > 655 µS cm^{-1} indicates a degraded community. All but two conductivity measurements in 2023 exceeded the healthy macroinvertebrate threshold of 412 µS cm^{-1}. Only 12% (6 samples) of Mills Creek conductivity measurements fell between 412 and 655 µS cm^{-1} and 84% (41 samples) were > 655 µS cm^{-1}. The average conductivity in the stream indicates a degraded, and threatened habitat, meaning impacts to aquatic life are probable.

Macroinvertebrate communities sampled in this watershed ranged from poor to excellent with the lowest score occurring at the site of highest average conductivity. The highest readings consistently occurred at headwater sites where drainage alternation for agricultural land use and small watershed size may play a role in degraded community and conductivity metrics. No significant exceedances were found in calculated chloride, salinity, or TDS. The stream experiences low summer flows at several headwater sites and excessive nutrients throughout the watershed may be a significant contributor to the degradation of stream biota.

3.11.4 Summary of 2023 Conclusions, Recommendations, Actions

Table 31. Mills Creek Water Quality Summary

pH	***Temperature***	***DO***	***Conductivity***
Acceptable	Acceptable	Acceptable	Likely Threats, Impacts

Results from the 2023 sampling year suggest that Mills Creek has acceptable values to support aquatic life for temperature, pH, and dissolved oxygen. This is an improvement for dissolved oxygen, which previously had exceedances at one headwater site in 2022. Conductivity continues to show elevated values compared to the Ohio EPA survey and reference datasets with an average 879.89 µS cm^{-1} and a range from 382.4 to 2,127.0 µS cm^{-1}. The highest readings consistently occurred at the Strecker Rd West site, which is downstream of two permitted industrial discharge outfalls. Limestone geology and high groundwater likely contribute to elevated values; however, there is a marked difference for several sites on the mainstem and middle portion of the watershed downstream of the two industrial discharges. High conductivity in the stream suggests impacts on the aquatic biota, which is consistent with 2023 macroinvertebrates sampling results of fair to good at most sites. No significant exceedances were found in calculated chloride, salinity, or TDS. The stream experiences low summer flow at several headwater sites and excessive nutrients throughout the watershed, which may also contribute to the degradation of stream biota.

Conductivity appears to be the greatest concern for Mills Creek. As such, further exploration of these sites is recommended to determine factors that are increasing the conductivity and lowering aquatic biota. While most sites in the watershed exhibit acceptable values for supporting aquatic life for LEBAF parameters, we feel additional exploration into flow, nutrients, and sediment will reveal a more detailed look at stream health.

3.12 Old Woman Creek

3.12.1 Monitoring Groups: One entity in the LEBAF network is Old Woman Creek, which has been monitored by volunteers of the Firelands Coastal Tributaries (FCT) Watershed Program since 2008. Old Woman Creek is a 27 square mile watershed that flows from the headwaters in Huron County through Erie County and empties into the west end of the central Lake Erie basin. The watershed begins as two branches that merge into a central channel upstream of a naturally functioning freshwater estuary. Land use in the watershed is mostly row crop agriculture (66%) followed by natural areas (20%) and rural development with a small village at the center of the watershed. The watershed geology consists of shale and sandstone with the Berea Escarpment separating the upper and lower watershed at the Village of Berlin Heights.

3.12.2 Station information: The Firelands Coastal Tributaries Watershed Program collected data from 10 stations sites in the Old Woman Creek watershed that are representative of the stream proper portion of the watershed. Station locations were in the east and west branches of the creek with one site located at the confluence that represents 83% the watershed's drainage basin. The watershed crosses two distinct ecoregions: Eastern Corn Belt Plains and Erie-Huron Lake Plain, with Berea Sandstone and shale geology. Additional sites represent the estuary portion of the watershed but are not included in this analysis since they are within the lake influence zone. Data collection occurs mid-month from April to November; however, our last month was not used in the LEBAF analysis. Overall, 58 observations were made. No samples were taken twice during the sampling year due to dry conditions at the site.

3.12.3 Summary of 2023 Findings and Analysis

Table 32. Old Woman Creek Summary Statistics and Exceedances - 58 total samples, 10 stations.

Summary Statistics and Exceedances Basin - Old Woman Creek

Parameter	Mean Reading	Median Reading	Min. Reading	Max. Reading	Sample Count	N. Exceeded	Pct Exceeded
Conductivity Biocondition	597.90	576.00	335.20	988.00	69.00	66.00	95.65
Dissolved Oxygen	9.19	9.17	5.00	13.20	69.00	1.00	1.45
pH	7.91	7.97	6.74	8.58	69.00	0.00	0.00
Water Temperature	17.14	18.10	9.90	23.50	69.00	6.00	8.70

pH - Consistent with 2022 findings, pH data collected in 2023 was within the acceptable range throughout the sampling period, as we found 0% exceedances for this parameter. As such, we feel there is no indication of pH impairment in Old Woman Creek based on the prescribed LEBAF standards.

DO – A slight improvement from 2022, dissolved oxygen data collected in 2023 was within the acceptable range for most of the sampling year, with only one minor exceedance in June. In the previous year, exceedances occurred at a headwater site during the summer at a time of higher than normal ambient air temperatures and low base flows in the stream. We feel the current data suggest no indication of DO impairment in Old Woman Creek based on the prescribed LEBAF standards.

Temperature - A slight increase from 2022 findings, temperature data collected in 2023 were still within the acceptable range for most of the sampling period, with the exception of 6 instances that occurred in April. While it is not uncommon for headwater sites to have exceedances in the summer months due to high temperatures and low stream flow, these exceedances occurred at several sites in the watershed all in spring. The sites represented both shaded and unshaded sections of Old Woman Creek. Average daytime ambient air temperatures observed several days prior to sampling were 70-80 degrees, much higher than the historical average April temperature (≈50°F).

Conductivity – Similar to 2022, conductivity continues to show slightly elevated values in Old Woman Creek compared to the Ohio EPA survey and reference datasets with an average of

597.90 µS cm^{-1} and a range from 335.20 to 988.00 µS cm^{-1}. Most samples did however, fall within the 75th percentile of value of 629 µS cm^{-1} Erie-Ontario Lake Plain streams survey.

The Ohio EPA also sets a conductivity threshold for evaluating macroinvertebrate health: < 412 µS cm^{-1} promotes a healthy community, between 412 and 655 µS cm^{-1} suggests a declining community, and > 655 µS cm^{-1} indicates a degraded community. All but three conductivity measurements in 2023 exceeded the healthy macroinvertebrate threshold of 412 µS cm^{-1}. Nearly 75% (52 samples) of Old Woman Creek's conductivity measurements fell between 412 and 655 µS cm^{-1} and 20% (14 samples) were > 655 µS cm^{-1}. The average conductivity in the stream indicates a concern for biota, meaning there could be impacts to aquatic life. Macroinvertebrate communities sampled in this watershed ranged from poor to excellent with the lowest score occurring at the site of highest average conductivity. The highest readings consistently occurred at headwater sites where drainage alternation for agricultural land use and small watershed size may play a role in degraded community and conductivity metrics.

3.12.4 Summary of 2023 Conclusions, Recommendations, Actions

Table 33. Old Woman Creek Water Quality Summary

pH	***Temperature***	***DO***	***Conductivity***
Acceptable	Acceptable	Acceptable	Concern for biota

Results from the 2023 sampling year suggest that Old Woman Creek has acceptable values to support aquatic life with little to no exceedances for pH, and dissolved oxygen. This is an improvement for dissolved oxygen, which previously had exceedances at two headwater sites in 2022. Conductivity continues to show slightly elevated values compared to the Ohio EPA survey and reference datasets with an average of 597.90 µS cm^{-1} and a range from 335.20 to 988.00 µS cm^{-1}. The highest readings consistently occurred at headwater sites. The average conductivity in the stream indicates a concern for biota meaning there could be impacts to aquatic life. Macroinvertebrate communities sampled in this watershed ranged from poor to excellent, with the lowest score occurring at the site of highest average conductivity. No significant exceedances were found in calculated chloride, salinity, or TDS. The stream experiences low summer flows and excessive nutrients and sediment throughout the watershed related to storm events, which may also play a significant factor in degraded stream biota at some sites.

Conductivity appears to be the greatest concern at the headwater sites of Old Woman Creek. As such, further exploration of these sites is recommended to determine factors that are increasing the conductivity and lowering aquatic biota. While most sites in the watershed exhibit acceptable values for supporting aquatic life for LEBAF parameters, we feel additional exploration into flow, nutrients, and sediment will reveal a more detailed look at stream health.

3.13 Pipe Creek

3.13.1 Monitoring Organizations: One entity in the LEBAF network is Pipe Creek, which has been monitored by volunteers of the Firelands Coastal Tributaries (FCT) Watershed Program since 2008. Pipe Creek is a 48.5 square mile watershed that combines three separate direct tributaries: Pipe Creek, Hemminger Ditch, and Plum Brook. All three subbasins empty into East Sandusky Bay, which is located in the western basin of Lake Erie. The watershed is nearly equal in agriculture and urban land uses with less than 15% in natural areas. This watershed has the highest rate of urbanization with the highest development located at the lower portion of the watershed. The watershed also has 2 limestone quarry discharges and is part of the karst geological region.

3.13.2 Station Information: The Firelands Coastal Tributaries Watershed Program collected data from 10 stations sites in the Pipe Creek watershed that are representative of the stream proper portion of the watershed. Six station locations are spaced from headwaters to mouth along a main channel, with one station located on a side tributary. The watershed is located in Erie-Huron Lake Plain Ecoregion with unique limestone/karst geology. Data collection occurs mid-month from April to November; however, our last month was not used in the LEBAF analysis. Overall, 49 observations were made in 2023.

3.13.3 Summary of 2023 Findings and Analysis

Table 34. Pipe Creek Summary Statistics and Exceedances - 49 total samples, 10

Summary Statistics and Exceedances Basin - Pipe Creek

Parameter	Mean Reading	Median Reading	Min. Reading	Max. Reading	Sample Count	N. Exceeded	Pct Exceeded
Conductivity Biocondition	870.77	822.00	321.80	1,650.00	49.00	48.00	97.96
Dissolved Oxygen	8.49	8.44	4.07	11.65	49.00	2.00	4.08
pH	8.05	8.06	7.62	8.83	49.00	0.00	0.00
Water Temperature	17.21	17.00	11.20	24.20	49.00	4.00	8.16

pH - Consistent with 2022 findings, pH data collected in 2023 was within the acceptable range throughout the sampling period, as we found 0% exceedances for this parameter. As such, we feel there is no indication of pH impairment in Pipe Creek based on the prescribed LEBAF standards.

DO – Similar to 2022, dissolved oxygen data collected in 2023 was within the acceptable range with two exceedances in June and July of the sampling year. As in the previous year, exceedances occurred at a headwater site during the summer at a time of higher than normal ambient air temperatures and low base flows in the stream. We feel the current data suggest no indication of DO impairment in Pipe Creek based on the prescribed LEBAF standards.

Temperature - A slight increase from 2022 findings, temperature data collected in 2023 were still within the acceptable range for most of the sampling period, with the exception of four exceedances that occurred in April. Average daytime ambient air temperatures observed several days prior to sampling were 70-80 degrees, much higher than the historical average April temperature (≈50°F). We feel the current data suggest no indication of DO impairment in Pipe Creek based on the prescribed LEBAF standards.

Conductivity - Similar to 2022, conductivity continues to show highly elevated values in Pipe Creek compared to the Ohio EPA survey and reference datasets with an average of 870.77 µS cm^{-1} and a range from 321.4 to 1,650.0 µS cm^{-1}. Conductivity results distributions provided some overlap between median and maximum values with the Ohio EPA reference stream and survey data. However, a comparison of medians suggests that Pipe Creek tends to have a conductivity much higher than the Ohio data set. The limestone geology and high groundwater input within the watershed influence higher conductivity levels compared to other watersheds of similar size sampled by the Ohio EPA in the Huron Erie Lake Plain region. However, there is a marked difference at two sites (Portland Rd and Oakland Ave), where industrial limestone quarry discharge enters the system. The highest readings consistently occurred at the Oakland Ave site which is located on a small tributary to Pipe Creek within one mile of the quarry discharge. Nearly 50% of the data exceeded the 75th percentile of value of 821 µS cm^{-1} Huron-Erie Lake Plain headwaters survey suggesting impacts to conductivity is a concern for the entire watershed. The average conductivity in the stream also suggests impacts on the aquatic biota, which is consistent with 2023 macroinvertebrates sampling results of fair rating at the Oakland Ave site. Other sites in the watershed not influenced by industrial discharges received good and excellent ratings. No significant exceedances were found in calculated chloride, salinity, or TDS. The stream experiences low summer flows at several headwater sites and excessive sediment and nutrients related to storm events, which may also contribute to the degradation of stream biota.

The Ohio EPA also sets a conductivity threshold for evaluating macroinvertebrate health: < 412 µS cm^{-1} promotes a healthy community, between 412 and 655 µS cm^{-1} suggests a declining community, and > 655 µS cm^{-1} indicates a degraded community. All but one conductivity measurement in 2023 exceeded the healthy macroinvertebrate threshold of 412 µS cm^{-1}. Only 12% (6 samples) of Pipe Creek's conductivity measurements fell between 412 and 655 µS cm^{-1} and 86% (42 samples) were > 655 µS cm^{-1}. The average conductivity in the stream indicates a degraded, and threatened habitat, meaning impacts to aquatic life are probable.

Macroinvertebrate communities sampled in this watershed ranged from poor to excellent with the lowest scores occurring at 2 sites with the lowest drainage size. One site was a headwater for the stream where drainage alternation for agricultural land use and small watershed size may play a role in degraded community and conductivity metrics. The other site, while also small drainage, was within the urbanized area and downstream of a quarry discharge. No significant exceedances were found in calculated chloride, salinity, or TDS. The stream experiences low summer flows at several headwater sites and excessive nutrients throughout the watershed may be a significant contributor to the degradation of stream biota.

3.13.4 Summary of 2023 Conclusions, Recommendations, Actions

Table 35. Pipe Creek Water Quality Summary

pH	***Temperature***	***DO***	***Conductivity***
Acceptable	Acceptable	Acceptable	Likely threats, impacts

Results from the 2023 sampling year suggest that Pipe Creek has acceptable values to support aquatic life with no exceedances for temperature, pH, and dissolved oxygen. This is an improvement for dissolved oxygen, which previously had exceedances at one headwater site in 2022. Conductivity continues to show elevated values compared to the Ohio EPA survey and reference datasets with an average of 870.77 µS cm^{-1} and a range from 321.4 to 1,650.0 µS cm^{-1}. Limestone geology and high groundwater likely contribute to elevated values; however, there is a marked difference for the Oakland Ave site, which consistently has the highest levels compared to other sites in the watershed. The Oakland Ave site is on a small tributary to the Pipe Creek mainstem and is downstream of a permitted industrial discharge outfall from a local limestone quarry. The average conductivity in the stream also suggests impacts on the aquatic biota, which is consistent with 2023 macroinvertebrate sampling results of fair rating at the Oakland Ave site. Other sites in the watershed not influenced by industrial discharges received good and excellent ratings in comparison. No significant exceedances were found in calculated chloride, salinity, or TDS. The stream experiences low summer flows at several headwater sites and excessive nutrients throughout the watershed, which may also contribute to the degradation of stream biota.

Conductivity appears to be the greatest concern for Pipe Creek. As such, further exploration of these sites is recommended to determine factors that are increasing the conductivity and lowering aquatic biota. While most sites in the watershed exhibit acceptable values for supporting aquatic life for LEBAF parameters, we feel additional exploration into flow, nutrients, and sediment will reveal a more detailed look at stream health.

3.14 Rush Creek

3.14.1 Monitoring Groups: One entity in the LEBAF network monitors in the Rush River Basin, Buffalo Niagara Waterkeeper (BNW).

3.14.2 Station information: Rush Creek is a small tributary south of the City of Buffalo that flows into Lake Erie at Woodlawn Beach, one of Buffalo's popular swimming beaches. There are often beach closures, limiting contact recreation with the Lake. Buffalo Niagara Waterkeeper - Riverwatch Citizen Science volunteers monitor one site on Rush Creek, Rush Creek @ Milestrip (RUSH01 - Coordinates: 42.790250, -78.837000). This site is on the main branch of Rush Creek, about 1 mile inland from Lake Erie. This site is sampled once per month from May to October in between the hours of 9:00 am and 11:00 am, and has been monitored since 2018. This is a 17 mile stream (class C).

In August of 2023, additional stations were added to BNW's station list, and were monitored using the LEBAF framework. Due to the limited sample size for those additional stations, and lack of historical data, only those stations that were included in the 2022 analysis report are included in the analysis herein.

3.14.3 Summary of 2023 Findings and Analysis

Table 36. Rush Creek Summary Statistics and Exceedances* - 8 total samples, 1 station.

Summary Statistics and Exceedances Basin - Rush Creek

Station Id	Station Na..	Parameter	Mean Reading	Median Reading	Min. Reading	Max. Reading	Sample Count	N. Exceedance	Pct Exceeded
RUSH01	Rush Creek @ Milestrip	Conductivity Bioconditi..	1,005.36	952.30	739.30	1,560.00	8.00	8.00	100.00
		Dissolved Oxygen	9.77	9.84	8.96	11.03	8.00	0.00	0.00
		pH	8.14	8.14	8.04	8.26	8.00	0.00	0.00
		Total Dissolved Solids	552.95	523.77	406.62	858.00	8.00	8.00	100.00
		Water Temperature	16.68	16.88	11.96	19.93	8.00	3.00	55.56

**Aggregated summary table is excluded, as it includes data from a station that is not being included in analysis. TDS/DW statistics are included due to high frequency of exceedances.*

pH - The lack of exceedances indicates that pH values for Rush Creek are within the established LEBAF standards (6.5 – 9). It is assumed that pH will continue to follow the trends established by previous data sets, and that these values indicate potential to support aquatic life. This parameter behaved as expected throughout the 2023 monitoring season, and results are comparable to 2022 measurements for the monitored location along the creek, with one fewer exceedance in 2023 compared to 2022. Its location directly under a major thruway and proximity to an adjacent railyard likely make it subject to multiple sources of runoff. Rush Creek, though small, impacts Lake Erie, especially localized at Woodlawn Beach. Urban stormwater runoff, Sanitary Sewer Overflows (SSOs) and other municipal and sanitary inputs are impacting this Creek. This impacts recreational access and aesthetics of Lake Erie. Elevated levels of phosphorus have been measured through previous studies.

DO – 100% of dissolved oxygen values recorded along Rush Creek during the 2023 season were within the LEBAF analytical benchmark of >5 mg L^{-1}. Based on this, we can expect that during the sampled dates and times the DO levels in the stream supported aquatic life, and this is an indicator of good stream health. This parameter behaved as expected for the sampling season, and results are comparable to the 2022 sampling season, with no exceedances observed in either year, and a slightly higher average DO level in 2023.

Temperature - 37.5% of temperature values recorded on Rush Creek during the 2023 season fell outside of LEBAF analytical benchmarks. Based on this, we expect that water temperature in the stream could potentially present challenges to supporting aquatic life, particularly during the warmer summer months. Exceedances occurred in July, August, and September, and could be of concern to the overall health of the creek. An additional measurement taken in August resulted in a non-exceedance, indicating fluctuations outside of the established trend are possible. Data from 2023 and 2022 (as well as previous years of data) suggest that this site experiences frequent and severe exceedances of temperature.

Conductivity - Conductivity values recorded along Rush Creek in 2023 fell significantly outside of the Ohio EPA reference and survey data, with collected data exceeding both minimum and 50th percentile values for both reference and survey data. Overall, results suggest higher conductivity values along this waterway than both reference and survey locations. The average conductivity along Rush Creek was 1,005.36 µS cm^{-1}, with 100% of samples falling above 655 µS cm^{-1}, placing the creek in the likely impaired category as outlined by LEBAF. Data suggests potentially stressful conditions for macroinvertebrate communities along this waterway, with seasonal spikes. Data from 2023 and 2022 (as well as previous years of data), suggests that this site experiences frequent and severe exceedances of conductivity standards as outlined by LEBAF. While measurements remained elevated throughout the monitoring period, no clear trend could be established, as results showed sudden dips and spikes between sampling events. Rush Creek is on the NYS 2018 303(d) list requiring development of Total Maximum Daily Loads (TMDLs)(pathogens and phosphorus); New York State Department of Environmental Conservation's Priority Waterbodies List (DEC PWL) lists as impaired. Its location directly under a major thruway and proximity to an adjacent railyard likely make it subject to multiple sources of runoff. Rush Creek, though small, impacts Lake Erie, especially localized at Woodlawn Beach. Urban stormwater runoff, SSOs and other municipal and sanitary inputs are impacting this Creek. This impacts recreational access and aesthetics of Lake Erie. Elevated levels of phosphorus have been measured through previous studies.

TDS - Results remained relatively consistent throughout the monitoring period and below the aquatic life standard of 1500 mg L^{-1}, with a dip in July and a sudden, severe spike in September. However, an additional sample collected after the observed September spike showed a substantial decrease in TDS, indicating that sudden fluctuations are possible at this location. Results for this parameter, on average, are higher in 2023 than in 2022, but less consistent.

3.14.4 Summary of 2023 Conclusions, Recommendations, Actions

Table 37. Rush Creek Water Quality Summary

pH	***Temperature***	***DO***	***Conductivity***
Acceptable	Degraded	Acceptable	Likely threats, impacts

Results from the 2023 monitoring year suggest that conditions along Rush Creek could present challenges for supporting aquatic life based on the above parameters when compared to LEBAF standards. Frequent exceedances in water temperature and conductivity could indicate regular stressful conditions for aquatic life, and more information will be required to determine the factors that drive these exceedances, although ambient air temperature is suspected to be the likely driver of exceedances in water temperature. While this driver could continue to present problems for the river in subsequent years, additional monitoring at an increased frequency, at various times of day, and at additional sites could shed light on larger trends and potential problem areas. Consistently elevated conductivity values at this site are a cause for concern in relation to the overall condition of the creek, especially because of its proximity of the monitored station to Lake Erie.

Rush Creek is on the NYS 2018 303(d) list requiring development of TMDL (pathogens and phosphorus); DEC PWL lists as impaired. Its location directly under a major thruway, and proximity to an adjacent railyard likely make it subject to multiple sources of runoff. Rush Creek, though small, impacts Lake Erie, especially localized at Woodlawn Beach. Urban stormwater runoff, SSOs and other municipal and sanitary inputs are impacting this Creek. This impacts recreational access and aesthetics of Lake Erie. Elevated levels of phosphorus have been measured through previous studies. The introduction of more frequent monitoring between the months of August and October of 2023 reduced the average value of individual exceedances from 2022 to 2023, and more data would be useful to understand the seasonal fluctuations in the above parameters. This station's position not only in relation to the mouth of the creek (and to Lake Erie), but in relation to multiple potential sources of commercial runoff will likely continue to present challenges to mitigation strategies in the future.

For all parameters, additional monitoring at increased frequency, various times of day, and at additional locations is recommended. Any exceedances that are severe should warrant follow-up sampling and investigation when possible and necessary. Collection of additional metadata, including flow, nutrients, and sediment data, and the exploration of surrogate parameter measurements could help shed light on any future exceedances, and guide conclusions for LEVSN.

3.15 Smoke Creek

3.15.1 Monitoring Groups: One entity in the LEBAF network monitors in the Smokes Creek Basin, Buffalo Niagara Waterkeeper (BNW).

3.15.2 Station information: Buffalo Niagara Waterkeeper - Riverwatch Citizen Science Program monitors one station on Smoke Creek (SMK04 - Coordinates: 42.81278,-78.8262). This site is along South Smokes creek, approximately 2.3 miles upstream from the mouth of the creek, which flows directly into Lake Erie. It is close to the confluence of south Smoke Creek and the main branch of Smokes Creek. This is approximately 6-7 miles south of the City of Buffalo. The site was monitored once per month from May to October between 9:30 am and 11:30 am. This site has been monitored since 2018.

In August of 2023, additional stations were added to BNW's station list, and were monitored using the LEBAF framework. Due to the limited sample size for those additional stations, and lack of historical data, only those stations that were included in the 2022 analysis report are included in the analysis herein.

3.15.3 Summary of 2023 Findings and Analysis

Table 38. Smoke Creek Summary Statistics and Exceedances* - 6 total samples, 1 station.

Summary Statistics and Exceedances Basin - Smoke Creek

Station Id	Station Na..	Parameter	Mean Reading	Median Reading	Min. Reading	Max. Reading	Sample Count	N. Exceedance	Pct Exceeded
SMK04	South Smokes @ Johnson St	Conductivity Bioconditi..	891.63	922.30	488.40	1,119.00	6.00	6.00	100.00
		Dissolved Oxygen	9.23	9.24	7.89	10.24	6.00	0.00	0.00
		pH	8.03	8.05	7.94	8.09	6.00	0.00	0.00
		Total Dissolved Solids	490.40	507.27	268.62	615.45	6.00	6.00	100.00
		Water Temperature	16.05	16.07	12.46	20.81	6.00	2.00	57.14

**Aggregated summary table is excluded, as it includes data from a station that is not being included in analysis. TDS/DW statistics are included due to high frequency of exceedances.*

pH - The lack of exceedances indicates that pH values for Smokes Creek are within the established LEBAF standards (6.5 – 9). It is assumed that pH will continue to follow the trends established by previous data sets, and that these values indicate potential to support aquatic life. This parameter behaved as expected throughout the 2023 monitoring season, and results are comparable to 2022 measurements for the monitored location along the creek. Any fluctuations could be due to its location within a residential/low intensity urban area.

DO – 100% of dissolved oxygen values recorded along Smokes Creek during the 2023 season were within the LEBAF analytical benchmark of >5 mg L^{-1}. Based on this, we expect that the DO levels in the stream supported aquatic life during the monitoring dates and times, and this is an indicator of good stream health. This parameter behaved as expected for the sampling season, and results are comparable to the 2022 sampling season.

Temperature - 33.33% of temperature values recorded on Smokes Creek during the 2023 season fell outside of the LEBAF analytical benchmarks. Based on this, we expect that water temperatures in the stream could potentially present challenges to supporting aquatic life during the warmer summer months. Exceedances occurred in July, and October, which suggests a potential susceptibility to sudden changes in temperature values along the creek. Compared to 2022 (as well as previous years of data), this site experienced fewer and less severe exceedances for this parameter in 2023, and it is suspected that ambient air temperature is the likely driver of parameter exceedances.

Conductivity - Conductivity values recorded along Smokes Creek in 2023 generally fell outside of the Ohio EPA reference and survey data, with data exceeding the 50th percentile values for both reference and survey data. Minimum and maximum recorded values fell below their respective counterparts in survey and reference data, possibly indicating that this creek is more susceptible to sudden changes in conductivity than other similar waterbodies. The average conductivity along Smokes Creek was 891.63 µS cm^{-1}, with 5 of 6 samples falling above 655 µS cm^{-1}, and one sample falling between the 412 - 655 µS cm^{-1} benchmark, placing the creek in the likely threats/impacts category as outlined by LEBAF. Observations suggest potentially stressful conditions for macroinvertebrate communities along this waterway, with seasonal spikes and noticeable variation between months. Compared to 2022, 2023 observed lower overall values for this parameter, with the minimum value that year being slightly lower than the average value in 2023. The magnitude and frequency of exceedances is concerning for both years, but the overall magnitude has reduced from 2022 to 2023.

TDS - 100% of TDS values recorded along Smokes Creek in 2023 met the aquatic life TDS standard of 1500 mg L^{-1} threshold as established by LEBAF.Results remained relatively consistent throughout the monitoring period, with a noticeable dip in July. Results for this parameter, on average, are lower in 2023 than in 2022, but less consistent.

3.15.4 Summary of 2023 Conclusions, Recommendations, Actions

Table 39. Smoke Creek Water Quality Summary

pH	*Temperature*	*DO*	*Conductivity*
Acceptable	Concerning	Acceptable	Likely threats/impacts

Results from the 2023 sampling year suggest that conditions along Smokes Creek could present challenges for supporting aquatic life based on the above parameters when compared to LEBAF standards. Frequent exceedances in water temperature and conductivity could indicate regularly stressful conditions for aquatic life, and more information will be required to determine the factors that drive these exceedances, although ambient air temperature is suspected to be the likely driver of exceedances in water temperature. While this driver could continue to present problems for the river in subsequent years, additional monitoring at increased frequency, various times of day, and at additional sites could shed light on larger trends and potential problem areas. Consistently elevated conductivity values at this site are a cause for concern in relation to the overall condition of the creek, especially with significant variation in values between certain months.

A biological (macroinvertebrate) assessment of South Branch Smoke Creek in Lackawanna (at South Park Avenue) was conducted as part of the RIBS biological screening effort in 2005. Sampling results indicate slightly impacted conditions. In such samples some replacement of sensitive species by more tolerant species occurs, although the sample also includes a balanced distribution of all expected species. Aquatic life is considered to be fully supported in the stream, however the community composition and nutrient biotic evaluation suggest conditions and levels of enrichment are sufficient to cause some stress to aquatic life. Impact source determination found the fauna to be most similar to communities influenced by nonpoint nutrients and toxins from urban sources and stormwater runoff.

For all parameters, additional monitoring at increased frequency, various times of day, and at additional locations is recommended. Any exceedances that are severe should warrant follow-up sampling and investigation when possible and warranted. Collection of additional metadata, including flow, nutrients, and sediment data, and the exploration of surrogate parameter measurements could help shed light on any future exceedances, and guide conclusions for LEVSN.

Section 4 – Overall Lake Erie River Basins

4.1 Regional Summary

This section provides a Lake Erie Basin-wide analysis of all 2023 LEBAF results by parameter. All 2023 LEBAF data is analyzed together to evaluate spatial and temporal trends or differences across the Lake Erie Basin. Through this analysis LEBAF examines the health of the entire Lake Erie Watershed through the lens of LEBAF standards outlined in Section 2 of this report and further explained for each parameter in Section 4.3, while also outlining limitations in the dataset and approach. To help summarize some data and trends within the watershed, LEBAF often refers to different regions or waterbodies within the Lake Erie Watershed as defined in Section 1 Table 1 and Figure 1. A more detailed analysis and interpretation of individual direct tributary and large river data is provided in the previous section (Section 3). All the data is also accessible through the LEVSN webpage Water Reporter Widget.

4.2 Regional River Basins Data Summary

Table 40. Lake Erie Basin Cold and Warm Water Summary Statistics.

All LEBAF Stations Summary Table - 111 stations						
Parameter [unit]	**mean**	**median**	**minimum**	**maximum**	**N exceedances**	**% exceedances**
pH	7.99	8.06	2.28	10.12	8	1%
Water Temperature [°C]	17.7	18.6	1.8	30	55	6%
Cold Water	17.5	17.3	11.74	23.78	21	54%
Warm Water	17.7	18.7	1.8	30	34	4%
Dissolved Oxygen [mg L^{-1}]	8.6	8.5	2.04	24.31	49	6%
Cold Water	9.85	9.74	7.34	12.2	0	0%
Warm Water	8.52	8.45	2.04	24.31	49	6%
Conductivity [µS cm^{-1}]	823	745	81.4	3687	812	97%

Table 41. Summary of Exceedances by Waterbody and Parameter. Exceedances are represented by percentages and the max and median values for each parameter are displayed in parentheses. Watersheds with cold water sites are shaded.

Watershed	pH	Temp [°C]	DO [mg L^{-1}]	Conductivity [µS cm^{-1}]
Buffalo River	**0%** (8.5, 7.8)	**7%** (25.9, 23.6)	**7%** (11.9, 8)	**76%** (596, 445)
Chappel Creek	**0%** (8.8, 7.9)	**15%** (23.3, 18.2)	**7%** (12.8, 9)	**95%** (670, 541)
Cuyahoga River	**2%** (9, 7.9)	**4%** (26.8, 19.4)	**6%** (11.36, 7.8)	**96%** (3687, 945)
Detroit River	**0%** (8.4, 7.8)	**0%** (23, 17.4)	**20%** (11.9, 6.5)	**98%** (2264, 930)
Eighteenmile Creek	**0%** (8.6, 8.3)	**57%** (23.8, 18.2)	**0%** (12.2, 10.9)	**87.5%** (705, 532)
Euclid Creek	**0%** (8.6, 8.2)	**0%** (21.6, 18.2)	**9%** (12, 8.4)	**50%** (682, 449)
Huron River	**0%** (8.6, 8)	**0.5%** (25.8, 17)	**3%** (15.9, 8.6)	**100%** (2222, 780)
Maumee River	**9%** (10.1, 8.4)	**12%** (30, 22.7)	**11%** (24.3, 9.7)	**96%** (1102, 563)
Mills Creek	**0%** (8.7, 8)	**2%** (22.5, 17)	**0%** (12.8, 8.9)	**96%** (2127, 857)
Old Woman Creek	**0%** (8.6, 8)	**9%** (23.5, 18.1)	**1%** (13.2, 9.2)	**96%** (988, 576)
Ottawa River	**0%** (8.7, 8)	**6%** (29.9, 19.7)	**3%** (18.1, 7.9)	**100%** (1384, 985)
Pipe Creek	**0%** (8.8, 8.1)	**8%** (24.2, 17)	**4%** (11.7, 8.4)	**98%** (1650, 822)
Rocky River	**0%** (8.7, 8.2)	**5%** (24.6, 19.2)	**0%** (13.3, 9)	**100%** (893, 661)
Rush Creek	**0%** (8.3, 8.2)	**56%** (21, 18.7)	**0%** (11, 9.8)	**100%** (1560, 952)
Smoke Creek	**0%** (8.3, 8)	**57%** (23.1, 16.6)	**0%** (10.2, 9.1)	**100%** (1119, 872)
Swan Creek	**0%** (8.6, 7.8)	**7%** (24.6, 18.7)	**12%** (13.7, 8.2)	**92%** (1331, 669)
Ten Mile Creek	**0%** (8.7, 8.2)	**0%** (25.5, 19.8)	**0%** (14, 10.7)	**100%** (1351, 1119)

4.3 2023 Regional Findings and Conclusions

4.3.1 pH

Thresholds: While pH may fluctuate daily, seasonally or along a river continuum, there is an acceptable range in which aquatic life thrives. The U.S. Environmental Protection Agency suggests a pH range of 6.5-9 for freshwater systems and LEBAF has adopted this range as the standard threshold.

Parameter Expectation: The expectation for pH is that all sites would be within the LEBAF standard range. Even with naturally occurring fluctuations, healthy streams should have relatively stable pH throughout the year that does not fall outside the LEBAF threshold.

Table 42. pH Data Characterization

	# Samples	# Stations	Minimum	Maximum	Median	Exceedance
LEBAF sites	**890**	**135**	**2.28**	**10.12**	**8.06**	**0.9%**

Exceedance Locations: 8 total exceedances were recorded across the LEBAF network in 2023. These exceedances were concentrated in two large river basins: the Cuyahoga River (with 3 exceedances) and the Maumee River (with a total of 5 exceedances).

Figure 2. pH exceedances in 2023. Red dots indicate the sampling locations of pH exceedances.

Factors Influencing Exceedances:

- Adjacent high intensity land use
- Low stream flow

Story: While aquatic organisms can tolerate some fluctuations in dissolved oxygen and temperature, pH requirements need to remain consistent throughout their life stages. However, if the exceedance is acute in duration, aquatic life may be able to find refuge in a different part of the stream, thus limiting harm. There were fewer pH exceedances across the LEBAF network in 2023 compared to the data from 2022 and none of the monitoring groups experienced an increase in pH exceedances. In 2023, eight exceedances were recorded within the network representing 0.8% of the overall observations. These exceedances were limited to two river basins: the Cuyahoga (2.44% of total samples) and the Maumee (8.93% of total samples). All exceedances in the Cuyahoga River basin were obtained from two direct tributaries of the Cuyahoga – Furnace Run (1) and Tinker's Creek (2) – and occurred between July 13 and18th, 2023.

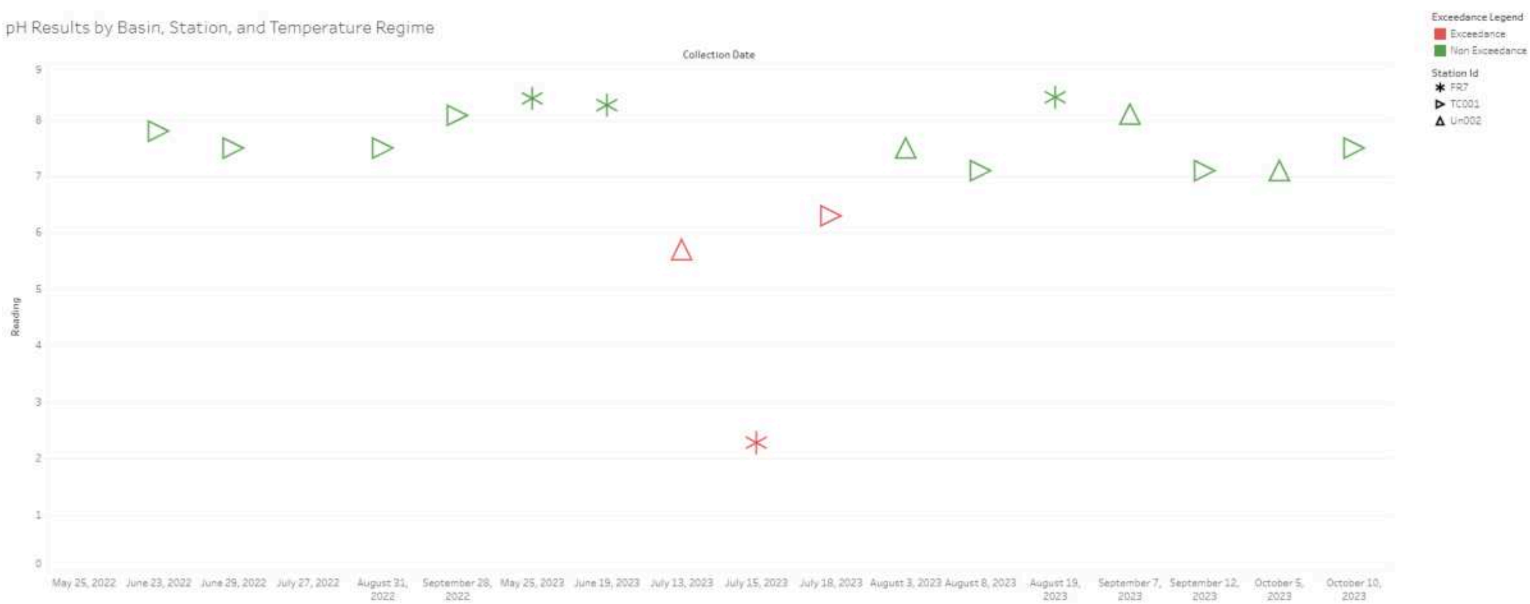


Figure 3. 2023 pH in the Cuyahoga Basin. Tinkers Creek samples are marked with triangles and Furnace Run samples are marked with asterisks. Red data points indicate pH exceedances.

According to the U.S. drought monitor, these three exceedances occurred during an abnormally dry to moderate drought period. The lack of precipitation directly contributed to the low base flow in the monitored tributaries, which was noted at the time of sampling. Furthermore, the sites with exceedances in the Cuyahoga Basin are situated near highly urbanized areas with altered drainage systems and increased impervious surfaces – all of which can have negative impacts on a waterbody and contribute to a low pH.

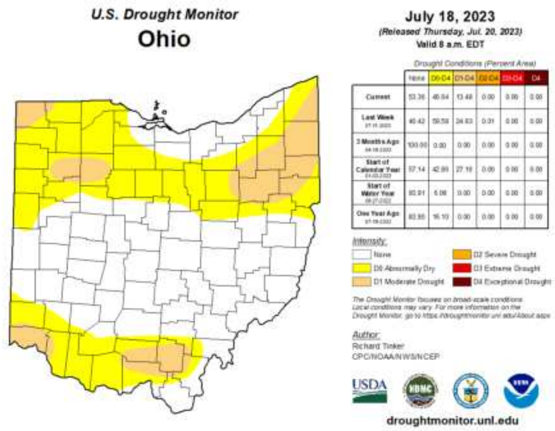


Figure 4. Furnace Run sampling location (FR7) ***Figure 5. U.S. Drought Monitor, Ohio 7/18/23***

The five exceedances in the Maumee were from two monitoring sites which typically display more alkaline conditions due to the geology of the watershed. These variations were just above the upper limit for pH ranging from 9.04-10.12 and correspond with lower water conditions at the sampling locations. Additionally, these exceedances appear to be site-specific as pH improves bidirectionally along the Maumee.

Figure 6. 2023 pH in the Maumee River. pH data from five sites monitored in the Maumee river. Only sites CWAT-6, marked with plus signs, and CWAT-8, marked with asterisks, experienced exceedances, which are colored in red.

Data Limitations: The data herein appear to show site-specific instances of pH exceeding the acceptable range. However, the frequency and duration of data collection makes identifying trends and patterns difficult. A continuous measurement of pH, or multiple measurements taken at different points throughout the day may help better capture temporal variation. Additionally, flow is measured as a subjective variable, by visual assessment only, and therefore may vary with each individual monitorer. As many of the pH exceedances were correlated to times of low flow at the monitoring location, a precise, objective measurement of flow may depict a more accurate interpretation of site conditions. The Maumee River and Furnace Run tributaries were sampled by LEBAF for the first time in 2023. Without historical data to assess, it is difficult to determine the degree to which these variations are typical. Additional sampling over the coming years will allow us to better identify trends and patterns within the LEBAF network.

Recommendations: To achieve a more accurate understanding of pH across the LEBAF network, it is recommended that pH sampling occur at different times of day and across consecutive days at sites with current pH exceedances. This will help to determine if pH exceedances are a regular occurrence or derived from an infrequent source. Since the sites with exceedances in the Cuyahoga Basin appear to be correlated with high urbanization, it is recommended that additional mitigation measures be looked into for improving the overall watershed health of these locations. Finally, the addition of flow as a quantifiable variable, as well as sampling of the macroinvertebrate communities, across the LEBAF network will improve our assessment of ecosystem health.

4.3.2 Temperature

Thresholds: Maximum temperature limits change for each month to adjust for natural seasonal variation and seasonality of biological stressors (Table 43).

Table 43. LEBAF Temperature Thresholds. Maximum limits in both fahrenheit and celsius for cold water habitat streams (blue) and warm water habitat streams (red).

April	May	June	July	August	September	October
52 F	58 F	64 F	66 F	66 F	63 F	54 F
11 C	14 C	17 C	18 C	18 C	17 C	12 C
61 F	70 F	82 F	85 F	85 F	82 F	70 F
16 C	21 C	27 C	29 C	29 C	27 C	21 C

Parameter Expectation: The expectation for temperature is that all sites would not exceed the monthly maximum LEBAF value established in either cold water or warm water streams. In addition to seasonality, temperature can also vary spatially based on groundwater inputs, factors like impervious surface cover and canopy cover, and stream morphology (slow or stagnant locations should warm more than areas where water flows faster). Thus, some sites may be expected to get closer to threshold maxima than others, but, to maintain a healthy, diverse aquatic biological community, temperatures should be below thresholds.

Table 44. Water Temperature Data Characterization

	# Samples	# Stations	Minimum	Maximum	Median	Exceedance
Cold Water Sites	**39**	**10**	**11.74℃**	**24.51℃**	**20.03℃**	**53.84%**
Warm Water Sites	**801**	**101**	**1.8℃**	**30℃**	**18.7℃**	**3.87%**

Exceedance Locations: 52 total exceedances (6.5% of samples) were observed across the network of warm and cold water streams (see Figure 7). Those exceedances were observed in the following cold water streams: Buffalo River, Eighteen Mile Creek, Rush Creek, and Smoke Creek and in the following warm water streams: Huron River, Maumee River, Swan Creek, Ottawa River, Mills Creek, Pipe Creek, Chappel Creek, Old Woman Creek, Cuyahoga River, and Rocky River. All samples were lower than the threshold maxima at sites in the following streams: Euclid Creek, Old Woman Creek, Pipe Creek, and Mills Creek. Overall, there was an equal number of streams that observed either increases or decreases of exceedances compared to 2022 resulting in no net change for this parameter for the network. However, the cold water stations of the Buffalo River area did see a decline in the number of exceedances for temperature compared to 2022.

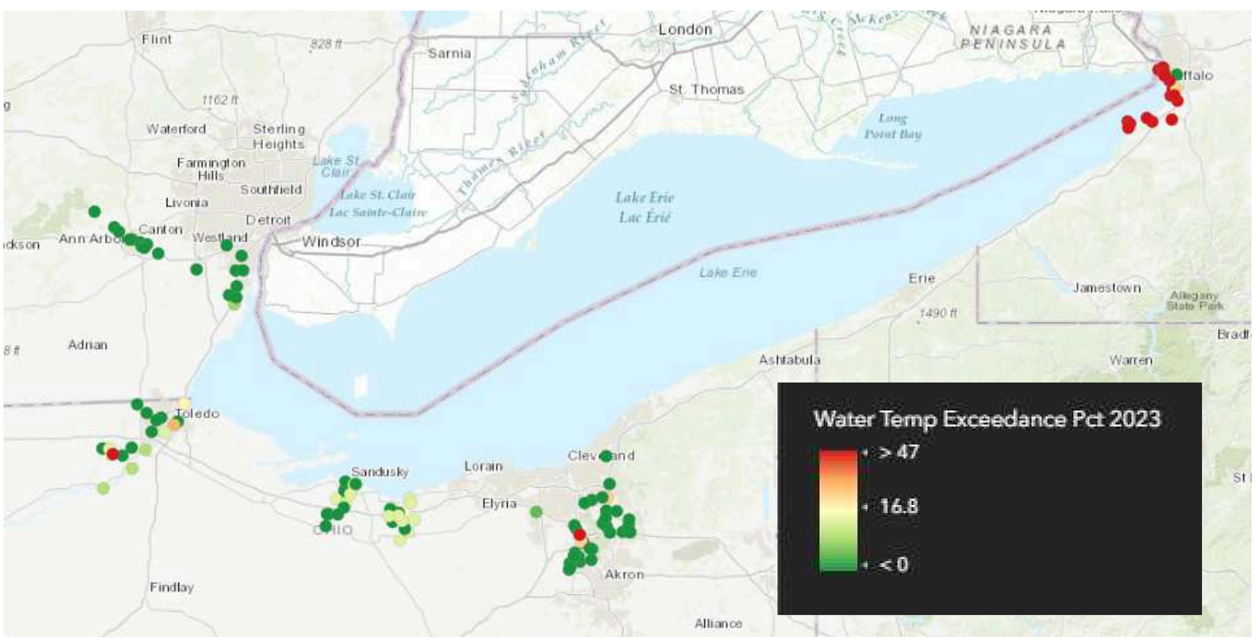


Figure 7. 2023 Temperature exceedances.

Factors Influencing Exceedances:

- Ambient air temperature
- Stream flow
- Drainage area of site (stream/headwater)

Story: Stream temperature is important for sustaining aquatic life and can be a critical factor impacting sensitive species living in streams. While water temperature naturally varies due to time of day, seasonal air temperature, and groundwater input, elevated temperatures can create inhospitable conditions that can negatively impact aquatic life. In 2023, fifty two exceedances were observed across the network representing about 6.5% of observations made. Exceedances occurred in less than 15% of the samples for most streams except for three Buffalo area streams: Smoke Creek (33.33%), Eighteenmile Creek (57.14%) and Rush Creek (37.5%). The 4 stations monitored along these waterways are all considered 'cold water' streams, which have a considerably lower maximum temperature threshold than warm water sites. While these exceedances seem high, the sample size of these streams were low. Overall most streams experienced 4 or less elevated temperature observations throughout the sampling season that largely correlated with high ambient air temperatures and low stream flow. Each individual exceedance was only slightly higher than thresholds set for each month in both warm and cold water systems.

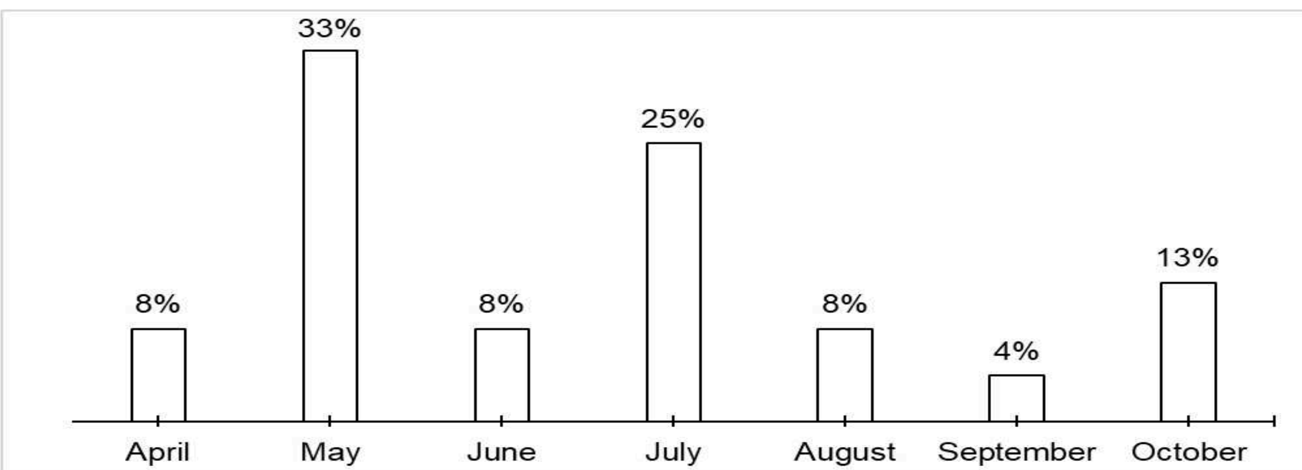


Figure 8. Percent of temperature exceedances by month.

More than 50% of streams with observed exceedances occurred in May and July of the sampling year – mostly occurring in Northwest (Maumee/Ottawa) and Northeast (Cuyahoga/Rocky) Ohio. Sampling events from these months occurred at times when ambient air temperatures were at or above 80 F. While these temperatures are typical for July, they are about 10 F higher than the average temperature for the month of May. A similar occurrence was also observed in April for Chappel Creek in North Central Ohio, which also aligned with abnormally high air temperature periods around sampling. In addition to abnormally high temperatures in Spring, precipitation was well below average, which contributed to portions of Michigan, Ohio, and New York being listed as abnormally dry on the US Drought Monitor (see Figure XX). This lack of precipitation contributed to low base flow in streams, which was consistent with condition observations made at the time of sampling.

Site drainage was another contributing factor that seemed to align with most exceedances. Headwater sites experienced more temperature exceedances at times when ambient air temperatures were high. These sites also were mostly lacking in riparian tree cover; however this was not true at every site. Sites in Furnace Run, Maumee River, Ottawa River, Tinkers Creek noted heavy land use and lack of woody riparian cover at the sites where exceedances occurred. Heavy land use refers to development and altered drainage systems, which can also contribute to higher storm flow and lower stream baseflow. In watersheds where developed land use is dominant, streams can become very flashy and have increased temperature in stormwater from paved surfaces that absorb heat. Low flow conditions combined with lack of riparian shading reduce the ability of a waterbody to be resilient to fluctuations in air temperature.

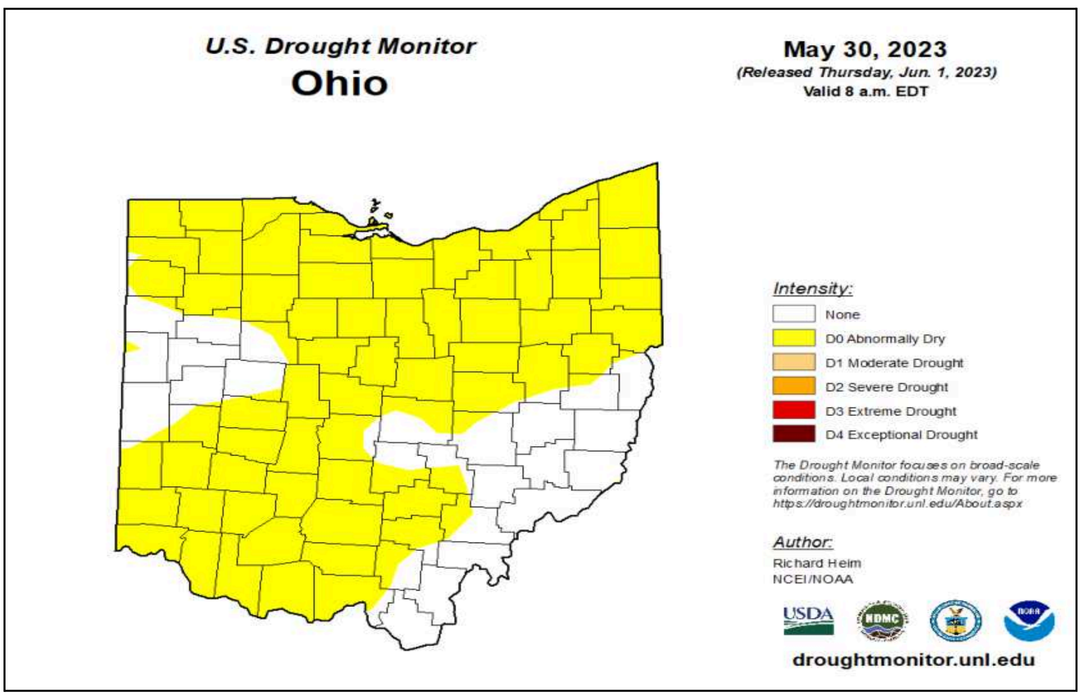


Figure 9. U.S Drought Monitor Report during several May sampling events.

Although a limited number of cold water stations around the Lake Erie basin are monitored using the LEBAF framework, temperature exceedances for cold water stations seem to be primarily located in the eastern Lake Erie Basin/Western New York area (see Figure XX). High frequency exceedances along Rush, Smokes, and Eighteenmile Creek could be a cause for concern, but the magnitude and timing of exceedances indicate that they are driven primarily by ambient air temperature anomalies. However, temperature trends in these waterways followed similar patterns in 2023 as they did in 2022, which suggests that annual high

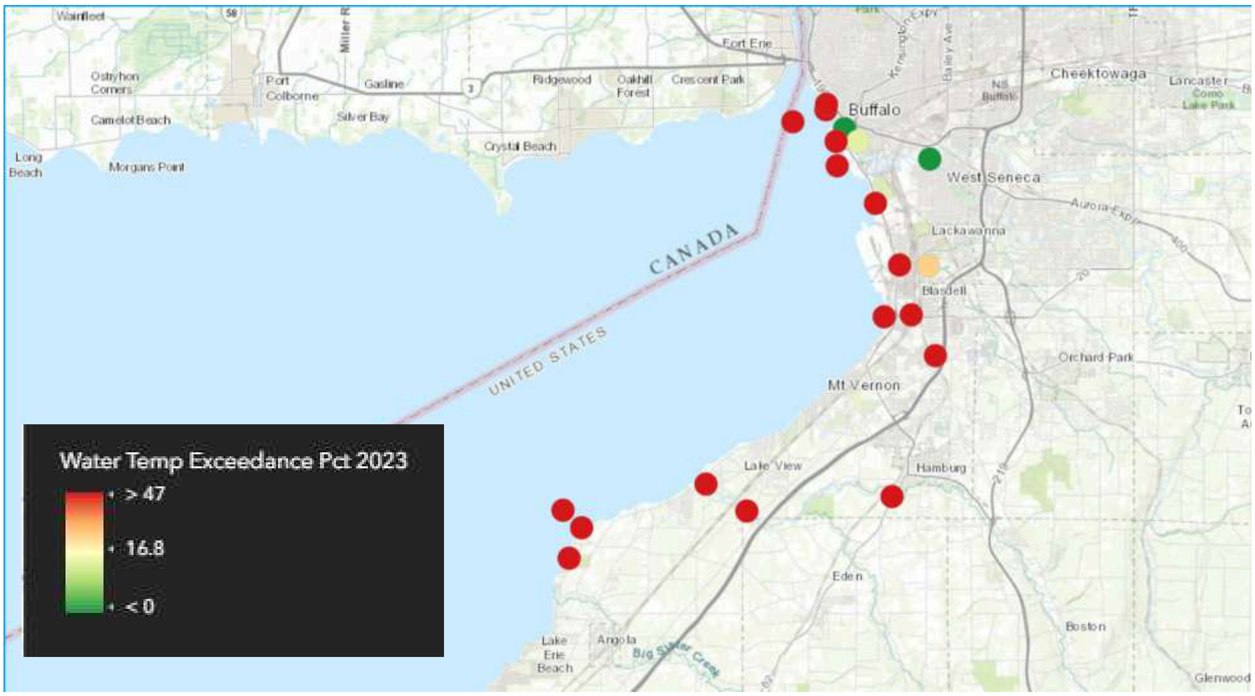


Figure 10. Average water temperature exceedances in the Buffalo Area

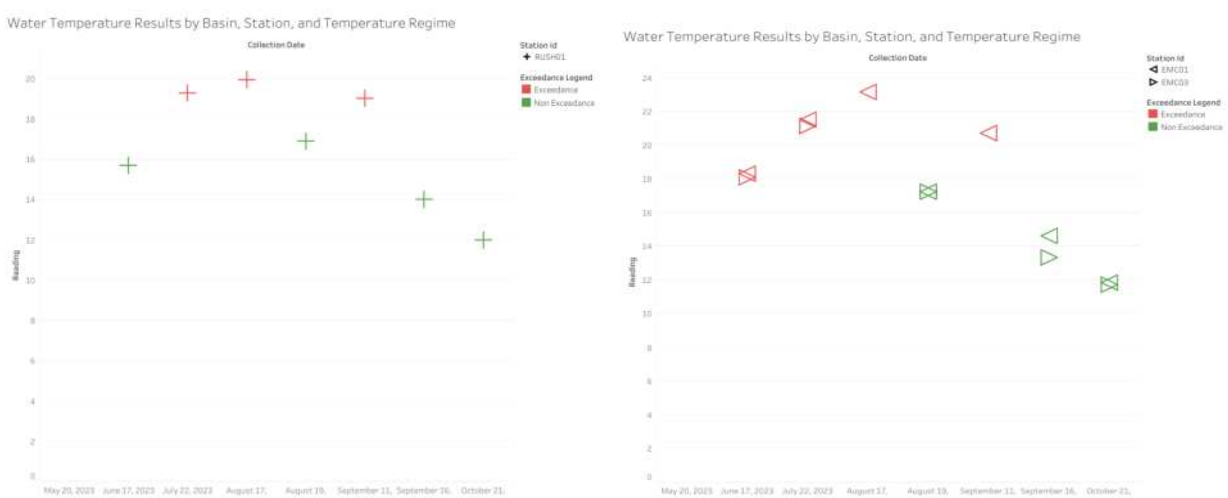


Figure 11. 2023 Temperature in Rush Creek and Eighteenmile Creek. Rush Creek temperature data points are displayed as plus signs in the left plot. Eighteenmile Creek temperature data from two stations, EM01 (left pointing triangles) and EM03 (right pointing triangles), are displayed in the right plot. All red data points indicate temperature exceedances.

temperatures could be impacting resident biota. Collection of additional data at increased frequency, various times of day, and additional stations could shed light on other drivers of water temperature exceedances. Collection of metadata including flow, ambient air temperature, nutrients, and sediment could support any future conclusions about exceedance drivers and overall impact on Lake Erie.

Data Limitations: The current frequency of samples taken presents challenges for establishing trends. Each sample was taken at one point in time and often during a similar time of day, so it does not represent the temporal variations in temperature during the daily periods outside of a singular sampling event. Moreover, while the current data can help to determine the magnitude of an exceedance, it fails to determine the duration over which it occurs. A continuous measurement may be able to indicate more consistent trends with data. Flow was also identified as another limitation with this parameter. Many exceedances occurred at headwater sites and were associated with observed low flow. The measurement of flow is visual and subjective. More precisely (and numerically) measured flow coupled with increased temperature sampling would provide a greater data set to determine duration of exceedance and related factors contributing to it. In addition to increasing the sampling frequency within a sampling event and over a sampling year, several years of data may also need to be established before this data can be used as a sentinel tool for observing stream response to climate change.

Recommendations: To improve the understanding of temperature at sites currently experiencing exceedances it is recommended that additional sampling efforts with increased frequencies (e.g. continuous measurements) should focus on months where previous exceedances have occurred. For all sites, it is recommended sampling take place in the afternoon when daytime temperatures are at their highest. Finally, the addition of quantified flow measurements should be considered for key sites.

4.3.3 Dissolved Oxygen (DO)

Thresholds: The concentration of dissolved gasses in water, such as dissolved oxygen (DO), is dependent on temperature. The colder the water the higher the concentration of DO. Thus, cold and warm water streams have different DO thresholds.

Cold-water streams: $\geq$ 7 mg L^{-1} DO

Warm-water streams: $\geq$ 5 mg L^{-1} DO

Parameter Expectation: All site measurements are expected to be within the LEBAF standard range with some anticipated fluctuations due to daily, seasonal, spatial, and stream condition factors.

> **Diurnal -** Daily fluctuations of DO concentrations are a result of photosynthesis (production of oxygen) during daytime and respiration (consumption of oxygen) at night.

Seasonal - The concentration of DO in water fluctuates seasonally as DO levels vary with water temperature. During the winter, higher DO levels should be expected; during summer, lower DO levels should be expected.

Spatially - Smaller streams with higher gradients should have higher DO due to greater mixing. Downstream locations with lower gradients and lower velocity should also have lower DO.

Stream Habitat - Unaltered stream channels have meanders, riffles, and woody debris, which can produce turbulent water. Turbulent water pulls oxygen from the atmosphere and mixes into the water. Higher DO concentrations could be expected in unaltered channels, while lower DO concentrations could be expected in altered stream channels as the water is less turbulent due to the lack of meanders, riffles, and woody debris.

Stream Productivity - Low DO concentrations may be present if oxygen consumers dominate the aquatic system. Oxygen consumers include aquatic animals, decomposition, and various chemical reactions. If oxygen consumption exceeds production, dissolved oxygen levels will decline. High levels of DO may result from an abundance of oxygen producers within the water. This includes plants and algae which produce oxygen as a byproduct of photosynthesis.

Table 45. Dissolved Oxygen Data Characterization

	# Samples	# Stations	Minimum	Maximum	Median	% Exceedance
Cold Water Sites	**43**	**10**	**7.34 mg L^{-1}**	**12.2 mg L^{-1}**	**9.74 mg L^{-1}**	**0%**
Warm Water Sites	**800**	**100**	**2.04 mg L^{-1}**	**24.31 mg L^{-1}**	**8.45 mg L^{-1}**	**5.74%**

Exceedance Locations:

Summary of basins with Dissolved Oxygen Exceedances, (number of exceedances), in warm water streams:

Buffalo River (1)
Chappel Creek (3)
Cuyahoga River (8)
Detroit River (13)
Euclid Creek (1)
Huron River (6)
Maumee River (6)
Old Woman Creek (1)
Ottawa River (1)
Pipe Creek (2)
Swan Creek (7)

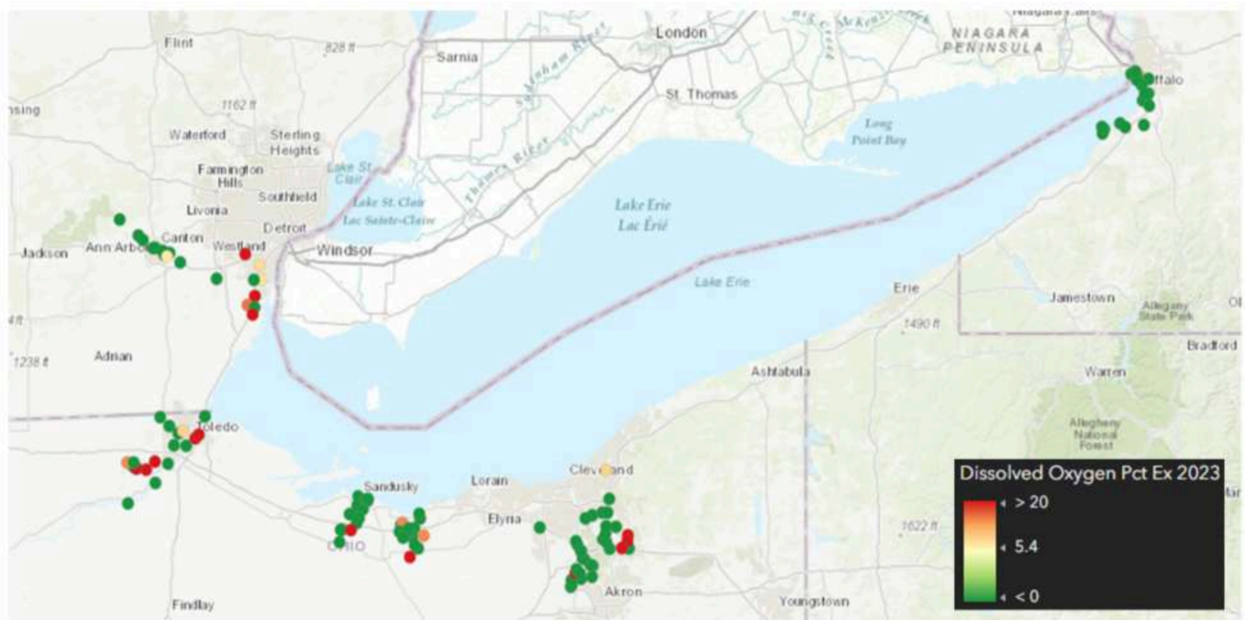


Figure 12. DO Exceedances by LEVSN Monitoring Locations. The color of the data points represents the percentage of DO exceedances. All non-green points are locations with at least one exceedance.

Factors Influencing Exceedances:

- Flow Conditions
- Ambient Air Temperature
- Watershed Land Use
- Drainage Area Size
- Other
- Stream Buffer

Story: In 2023, none of the cold-water samples fell below the cold-water DO concentration threshold value of 7 mg L^{-1}. This trend is consistent with the 2022 data, which also reports no cold-water sample data under the 7 mg L^{-1} threshold. In 2023, 5.74% of warm water samples fell below the warm water DO concentration threshold of 5 mg L^{-1}. This trend is consistent with 2022 data, which reports 5.5% of warm water samples below parameter threshold. The 2023 low DO warm water samples were found in 11 of the 14 warm water basins monitored, meaning 78.57% of the basins monitored experienced low DO concentrations in warm water streams at some point during the 2023 monitoring season. The percentage of exceedances in the monitored basins range from 1.45–20.31%, with the highest percentage occurring in the Detroit River Basin. Maximum DO concentrations range from 10.24–24.31 mg L^{-1}, suggesting 100% saturation conditions may be present.

Flow conditions and ambient air temperature tended to contribute to low DO concentrations, as well as land use. For example, Detroit River Tributary sites with low DO concentrations were all located in highly urbanized areas with flashy flow regimes and the site with persistent low DO, ADW03, had consistently low, even stagnant water conditions (Figure 12). DO exceedances at other Detroit Tributary locations were observed primarily in May and June when southeast Michigan was experiencing above average temperatures and below average precipitation. Other factors that may be affecting DO concentrations include influence from algal blooms on Lake Erie (Figure 14) and possible eutrophication from upstream inputs (Figure 15).

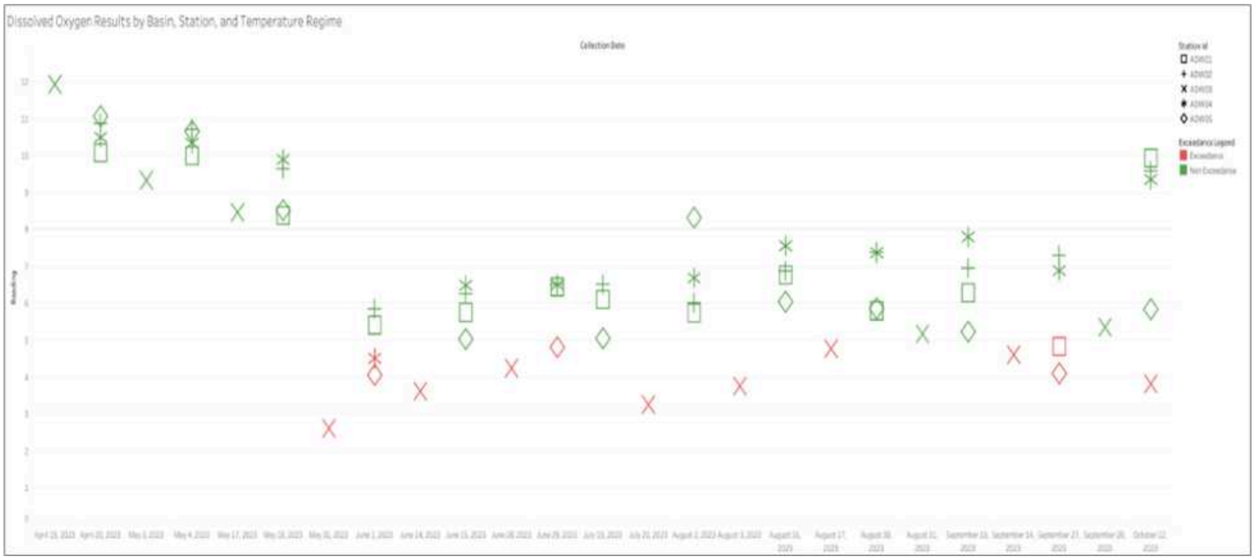


Figure 13: DO over time at 5 Detroit Tributary sites. *ADW01 (squares), ADW04 (asterisk), and ADW05 (diamonds) all experienced intermittent low DO, marked in red. ADW03 ('x') persistent low DO concentrations. ADW02 (plus signs) was the only Detroit Tributary with no DO exceedances.*

Sample size is relatively small and is not yet sufficient to draw conclusions on daily and seasonal patterns, temperature influences, etc. There are also spatial limitations to the data that have yet to be investigated. Considering the distribution of exceedances, DO impacts to aquatic life at these sites is possible. Evaluation of the exceedance sites and surrounding land uses could help determine likely causes. At sites below the minimum threshold, there may be impacts to aquatic life, especially if DO levels are low for an extended period. Understanding the quality of macroinvertebrate communities would help draw conclusions in DO patterns and fluctuations.

Data Limitations: Sample size is relatively small and is not yet sufficient to draw conclusions on daily and seasonal patterns, temperature influences, etc. There are also spatial limitations to the data that have yet to be investigated. Considering the distribution of exceedances, DO impacts to aquatic life at these sites is possible. Evaluation of the exceedance sites and surrounding land uses could help determine likely causes. At sites below the minimum threshold, there may be impacts to aquatic life, especially if DO levels are low for an extended period. Understanding the quality of macroinvertebrate communities would help draw conclusions in DO patterns and fluctuations.

Figure 14: Western Lake Erie Basin algal bloom influence. Satellite image (Sept. 4, 2023) of Lake Erie algal bloom extending into Maumee Bay that may have influenced DO exceedances in the Maumee River.

Figure 15: Yellow Creek Sampling Site, YC13, Drainage Basin. Aerial imagery of discharge from Bath Pond, a possible source of low oxygenated water upstream of the YC13 sampling site.

Recommendations: Low oxygen levels are less than optimal for most aquatic life including macroinvertebrates and fish. This can result in loss of species diversity and overall presence of aquatic life species in our waterways. It's recommended that macroinvertebrate communities be sampled next season to determine the effects of DO concentrations. If low DO concentrations are constant, biological communities should begin to decline.

The current protocol requires DO measurement once a month. Though, given daily, seasonal, and other factors affecting DO, continuous diurnal data collection is suggested. Continuous monitoring or monitoring at a wider range of times may give more insight to variability and potential issues. Since dissolved oxygen is a function of water temperature, which varies temporally, a greater sampling frequency would also be beneficial to capture seasonal trends. Also, issues affecting DO, such as the algal blooms, occur seasonally, so a greater spatial and temporal extent of data collection would be helpful. Focus should be paid to areas where exceedances occurred as these are likely localized issues that may require local remediation.

4.3.4 Conductivity

Thresholds: Conductivity is a measure of all the dissolved ions (salts and other primarily inorganic chemicals) in a waterbody. Conductivity quantifies a broad range of chemicals; thus, conductivity is used as a *general* indicator of water quality. Since waterbodies tend to have a consistent range of conductivity, baseline, or reference conductivity values such as the Ohio EPA ecoregion and stream size specific reference and survey data (Table 46) are used by LEBAF as a comparator for assessing both the **(1)** validity of conductivity measures and **(2)** water quality. Most watersheds evaluated by LEBAF fall within one of two bioregions: *Erie-Ontario Lake Plains* (EOLP, Ecoregion 83) and *Huron-Lake Erie Plains* (HELP, Ecoregion 57). A few watersheds (e.g. parts of the Huron River, Ten Mile Creek, Old Woman Creek, and Chappel Creek) have sites that fall within other ecoregions, primarily the *Eastern Corn Belt Plains* (Ecoregion 55), that do not have reference or survey data and were instead compared to either the EOLP or HELP ecoregion that was most like the ecoregion of the watershed.

Table 46. Ohio EPA Ecoregion and Stream Size Specific Conductivity Reference and Survey Data for Erie-Ontario Lake Plains (EOLP) and Huron-Lake Erie Plains (HELP)

Ecoregion	Stream Size	Stream Type	Min	x.25%	x.50%	x.75%	x.90%	x.95%
EOLP	Headwaters	**Reference**	**90**	**351**	**462**	**611**	**702**	**825**
EOLP	Streams	**Reference**	**167**	**405**	**489**	**549**	**643**	**766**
EOLP	Rivers	**Reference**	**183**	**348**	**456**	**602**	**803**	**883**
EOLP	Headwaters	Survey	316	466	629	886	1245	1654
EOLP	Streams	Survey	375	437	568	774	942	1114
EOLP	Rivers	Survey	304	416	585	780	1019	1201
HELP	Headwaters	**Reference**	**510**	**588**	**707**	**875**	**1119**	**1151**
HELP	Streams	**Reference**	**166**	**529**	**653**	**778**	**952**	**1107**
HELP	Rivers	**Reference**	**142**	**543**	**659**	**744**	**877**	**1043**
HELP	Headwaters	Survey	500	570	680	821	1074	1345
HELP	Streams	Survey	248	491	633	740	836	959
HELP	Rivers	Survey	152	573	679	808	1039	1275

LEBAF also evaluates conductivity based on the Ohio EPA minimum biocondition criterion of **412 μS cm^{-1}**. Values above this criterion are considered exceedances and were further evaluated using LABAF's combined conductivity criteria screening, which expands on the Ohio EPA

Table 47. LEBAF Combined Conductivity Criteria Thresholds

Threshold [μS cm^{-1}]	Condition	Action
≤ 412	Excellent, healthy	Protection activities
413-850	Concern for biota	Investigate biota diversity. Identify potential sources.
851-2000	Likely threats, impacts	Investigate chloride and salinity, and possibly other contaminants. Identify and investigate potential sources. Remediate sources
≥ 2001	Likely impaired	Work with state agency to determine further actions.

biocondition criteria to further describe the condition of the macroinvertebrate community and suggest appropriate actions for restoration (Table 47).

Several other measures including total dissolved solids, salinity, and chloride concentrations can be calculated from conductivity, as they are highly correlated. When observed conductivity concentrations are **> 850 µS cm^{-1},** LABAF uses these surrogate measures to better deduce potential sources of pollution and further specify aquatic life protective actions. The criteria used to evaluate these surrogate measures are outlined in Section 2.4 Analysis and Interpretation Table 3. LEBAF Screening Assessment Criteria (Benchmarks) Details and Sources.

Parameter Expectations: LEBAF expected watershed ambient conductivity values to overlap with the respective Ohio EPA ecoregion and stream size reference and survey data. LEBAF expected the alignment to vary between watersheds with no watershed data being in perfect alignment, but the overlap would provide additional confidence in the LEBAF conductivity results. Since both the EOLP and HELP reference and survey data have median values above the biocondition criterion of 412 µS cm^{-1}, it was anticipated that at least half of all the conductivity would naturally exceed this criterion. High conductivity values are also expected **(1)** after snow melt in the early spring that flushes anthropogenic sources of salts, **(2)** with warmer water temperatures in the summer months, **(3)** during low flow events that concentrate minerals and pollutants, and **(4)** in smaller streams that contain smaller volumes of water or less diluent.

Table 48. Conductivity Data Characterization

	# Samples	# Stations	Minimum	Maximum	Median	Exceedances
All LEBAF Sites	838*	111	81.4* µS cm^{-1}	3687 µS cm^{-1}	745* µS cm^{-1}	812
Cold Water Sites	43	10	327.7 µS cm^{-1}	1914 µS cm^{-1}	831.8 µS cm^{-1}	41
Warm Water Sites	795*	101	81.4* µS cm^{-1}	3687 µS cm^{-1}	742* µS cm^{-1}	771

*6 samples from warm water sites were removed from the data characterization statistics because they were lower than acceptable conductivity values (< 50 µS cm^{-1})
-a couple of the cold and warm water sites were not sampled every month between April and October

Exceedance Locations: 813 (97%) of the samples were above the 412 µS cm^{-1} biocondition criterion with every LEBAF monitoring site experiencing at least one exceedance. Conductivity in 4 watersheds – Buffalo River, Chappel Creek, Eighteenmile Creek, and Euclid Creek – never exceeded 850 µS cm^{-1}. Most other watersheds never had conductivity values that exceeded 2000 µS cm^{-1}. Only 4 creek sites within 4 different watersheds had measured conductivity above 2000 µS cm^{-1}: the Brandywine Creek East Twinsburg in the Cuyahoga watershed, Ecorse Creek North at Beech Daly Rd. in the Detroit watershed, Swift Run at Shetland Dr. in the Huron River watershed, and Strecker Rd. W station in the Mill Creek watershed. The Brandywine Creek East

Twinsburg station draining to the Cuyahoga River had the highest conductivity value of 3687 µS cm^{-1}, but was only monitored four times throughout the season.

Factors Influencing Exceedances:

- Differing adjacent and upstream land use
- Flow conditions such as volume, velocity, and mixing
- Geology

Story:

Conductivity measures were generally high compared to all standards evaluated by LEBAF. Conductivity ranged from 81.4 to 3687 µS cm^{-1} with a median value of 743 µS cm^{-1} (Table 48). About half of the monitored watersheds (i.e. Buffalo River, Chappel Creek, Eighteenmile Creek, Euclid Creek, Maumee River, Old Woman Creek, Rocky River, and Swan Creek; Table 49) had median values in close alignment with the respective Ohio EPA ecoregion survey and reference median values. The other half of the watersheds had median values that exceeded the respective ecoregion and stream size median values. Medians recorded in these watersheds were more closely aligned with the 75^{th} percentile values or in some cases even the 90^{th} percentile values (i.e. tributaries of the Detroit River, Ottawa River, Rush Creek, and Ten Mile Creek; Table 49). The differences in alignment among watershed datasets were expected. It was also unsurprising that over half of the watershed datasets were skewed toward the high end of baseline datasets since most LEBAF monitoring sites are in anthropogenically altered

Table 49. Summary Statistics of Conductivity by Watershed. Watersheds with the full dataset minimum and maximum conductivity values are bolded and highlighted in a light and dark shade of gray, respectively.

Watershed	% Exceeded	N. Exceeded	Sample Count	Maximum	Minimum	Median	Mean
Buffalo River	**76%**	**13**	**17**	**596.2**	**81.4**	**444.5**	**437.9**
Chappel Creek	95%	39	41	670	372	541.0	536.9
Cuyahoga River	**96%**	**120**	**126**	**3687**	**N/A**	**945.0**	**973.6**
Detroit River	98%	63	65	2264	393.9	930.0	996.4
Eighteenmile Creek	88%	14	16	704.5	327.7	532.0	534.0
Euclid Creek	78%	7	9	682	344.4	500.0	543.7
Huron River	100%	205	206	2222	444	780.0	910.2
Maumee River	96%	53	57	1102	293.5	563.0	608.7
Mills Creek	96%	47	49	2127	382.4	857.0	879.9
Old Woman Creek	96%	66	69	988	335.2	576.0	597.9
Ottawa River	100%	34	34	1384	584	984.5	953.3
Pipe Creek	98%	48	49	1650	321.8	822.0	870.8
Rocky River	100%	21	21	893	412	661.0	649.4
Rush Creek	100%	10	10	1560	739.3	952.3	994.4
Smoke Creek	100%	8	8	1119	488.4	871.6	856.1
Swan Creek	92%	55	61	1331	316.8	668.5	681.5
Ten Mile Creek	100%	11	11	1351	656	1119.0	1039.9

watersheds with variability unexplainable by ecoregion alone. The comparison with the Ohio EPA baseline datasets still, however, provides additional confidence in the LEBAF conductivity data.

A total of 97% of all LEBAF conductivity data exceeded the 412 µS cm^{-1} Ohio EPA biocondition criterion (Table 48). This was unsurprising as it was consistent with 2022 data and since 50% of the data was expected to exceed this criterion based on the natural variability of conductivity within the ecoregions. The known natural variability above this threshold stresses that conductivity alone is not a limiting factor for life since it is a non-specific measure. Even still, the vast majority of LEBAF conductivity data exceeding the biocondition criterion suggests that the conductivity values were indeed high and may be composed of some unnatural or excess inputs that may impact the biological community. When comparing medians, seven watersheds (i.e. Cuyahoga River, Detroit River, Mills Creek, Ottawa River, Rush Creek, Smoke Creek, and Ten Mile Creek) had median values above the likely threatened or impacted 850 µS cm^{-1} combined conductivity criterion. An additional two watersheds (i.e. Huron River and Pipe Creek) fall above this threshold when means were evaluated. All nine of these watersheds had maximum conductivity values that reached over 1000 µS cm^{-1}.

The watersheds characterized by high conductivity did not have uniformly high conductivity across all monitoring sites (Table 49 and Figure 16). Generally, only a few sites located in each watershed had consistently high values or event-based spikes. The sites with prolonged elevated conductivity (> 850 µS cm^{-1}) tended to be in smaller creeks and streams draining anthropogenically disturbed land – especially urbanized areas. The sites with conductivity routinely at or above 850 µS cm^{-1} in southeast Michigan, the Greater Buffalo Area, and Cleveland area drained urban and suburban areas with high percentages of impervious surfaces. Examples include ADW04: Reeck Rd and ADW05: Beech Daily Rd in tributaries of the Detroit River (Figure 17A); MH09: Shetland Dr. and MH08B: Huron Pkwy in tributaries of the Huron River (Figure 17A); SMK04: South Smoke at Johnson St. and RUSH01: Rush Creek at Milestrip in Buffalo (Figure 17B); and sites in Yellow creek and Brandywine creek in Cleveland. Sites with consistently high conductivity in the Greater Toledo area drained rural, agricultural row crop land such as CWAT-1: Sylvania Northview in Ten Mile Creek and CWAT-19 along Oak Openings in Swan Creek (Figure 17D). A few sites in Sandusky (e.g. MC-7: Strecker Rd. W, PC-5: Oakland Ave., and PC-7: Perkins Ave; Figure 17C) drain a mix of land uses, but sampling organizations attribute the high conductivity to adjacent industrial or wastewater outfalls.

Anthropogenic disturbances or changes to upstream land use were most often associated with conductivity exceedances. Such disturbances often alter natural flow regimes to more flashy systems. Drastic changes in flow coincided with spikes and troughs in conductivity data. For example, some sites in flashy, urbanized systems with high conductivity saw drastic declines to levels nearing the 412 µS cm^{-1} biocondition criterion following storm events (Figure 17A; Troughs in MH09 and MH08B data), while others saw spikes (Figure 17B; Peak at RUSH01). This

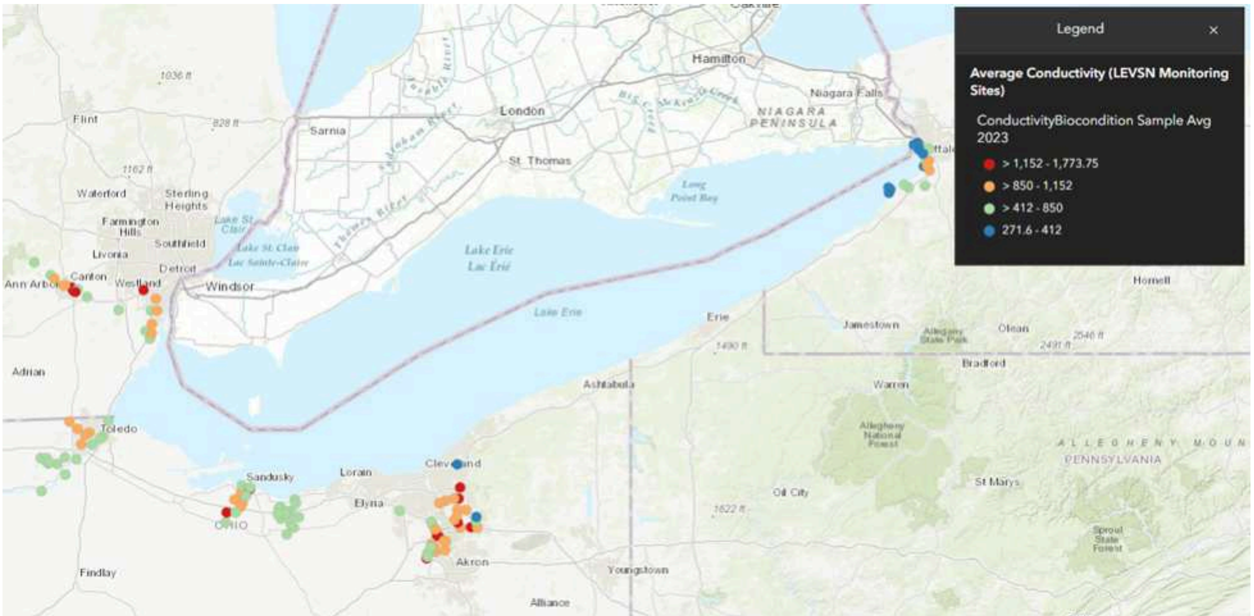


Figure 16. Lake Erie Watershed Average Conductivity Exceedance Map. All circles represent a LEVSN sampling location. All stations marked in non-green colors had average conductivity values that exceeded the Ohio EPA biocondition (> 412 µS cm^{-1}). Sites with orange and red colors had average conductivity values that likely have impacts on the biological community.

suggests different inputs contributed to conductivity at these sites. When conductivity decreases as flow rate increases, it suggests a constant flow or point source. When conductivity and flow rate increase together, it suggests pollutants in runoff.

Extreme flow conditions were further exacerbated by extreme weather conditions in 2023 including record storms throughout the summer months and a flash drought between late May and early June for much of southeastern Michigan and northern Ohio. The flash drought brought hot temperatures and little to no precipitation that left some streams with lower-than-normal baseflow or even stagnant water conditions that corresponded with the three highest recorded conductivity values recorded in southeast Michigan (Figure 17A; MH09: Shetland Dr. and ADW05: Beech Daily Rd.) and Cleveland (BC-ET1: Brandywine Creek East Twinsburg). Extreme weather events are only expected to increase with climate change and may make aquatic systems with already flashy flow regimes more vulnerable to poor water quality or even dry conditions.

No clear seasonal trends nor consistent differences between stream temperature groups (Table 48) emerged when evaluating the full dataset, which further points to potential pollutant sources rather than natural variability. LEBAF calculated three surrogate measures– total suspended solids (TDS), chloride, and salinity – based on the directly measured conductivity to better understand potential pollutant sources contributing to conductivity. Despite consistently high conductivity above aquatic life thresholds, all LEBAF calculated TDS values measured below

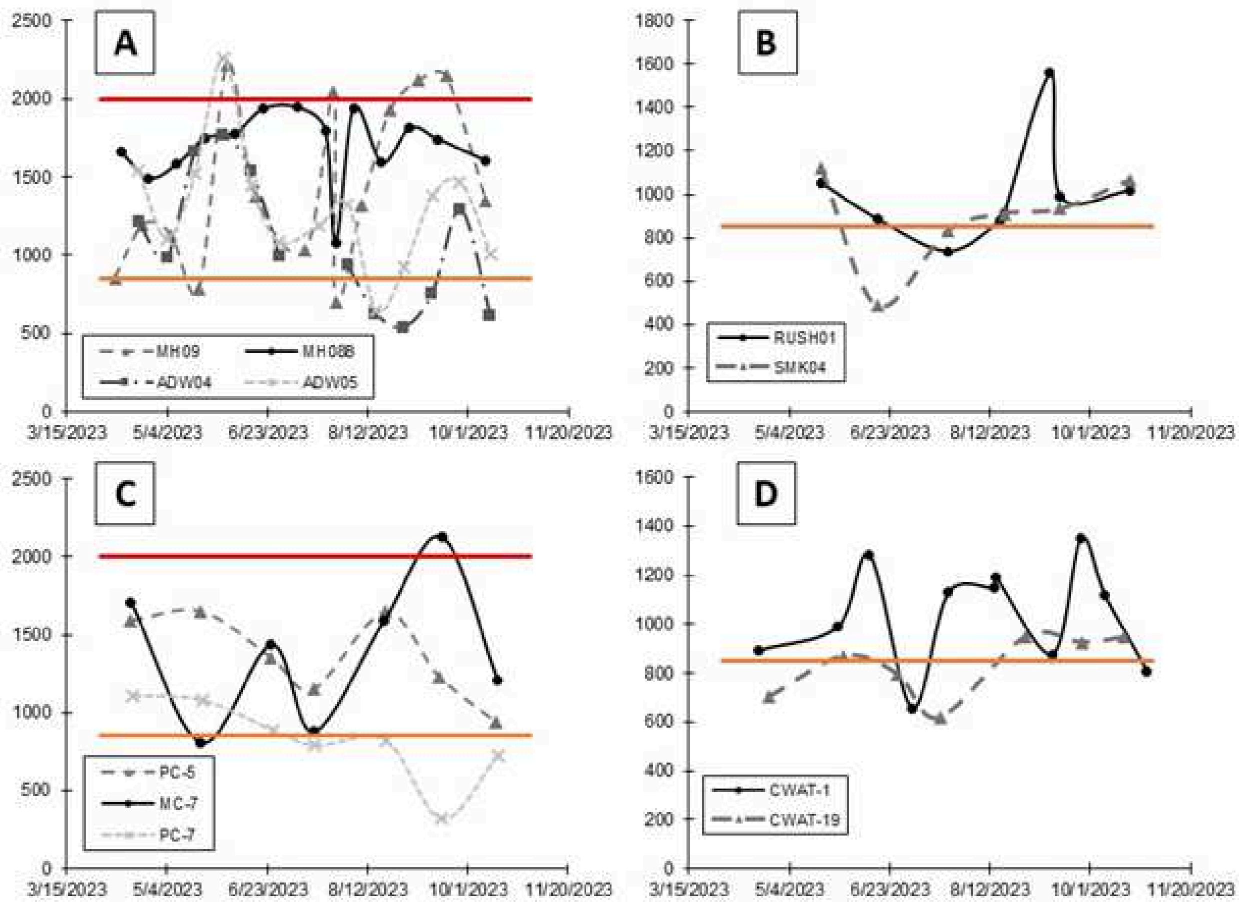


Figure 17. Example Sites in (A) Southeast Michigan, (B) the Buffalo area, (C) Sanduscky area, and (D) Toledo area with High Conductivity Over the 2023 LEBAF Monitoring Period. All orange lines mark the 850 µS cm^{-1} likely impacts combined criteria threshold and the red lines in A and C mark the 2000 µS cm^{-1} impaired combined criteria threshold. Y-axis scales vary.

the aquatic life threshold of 1500 mg L^{-1}. Additionally, watersheds had relatively few conductivity values that resulted in high calculated chloride (86 exceedances; 10%) and salinity (111 exceedances; 13%; Figure 18). Generally high chloride and salinity values were only observed when conductivity values neared 1000 to 2000 µS cm^{-1}. High calculated chloride concentrations were rare except in the Cuyahoga River Watershed (81 exceedances). These observations were often inconsistent with calculated salinity values and any directly measured chloride concentrations reported by a select few LEBAF groups. Thus, calculated LEBAF chloride values and their interpretation may not reflect true chloride concentrations or trends. For most sites, high salinity and some high chloride concentrations were event based or occurred non-consecutively. These fleeting spikes may allow aquatic life to seek temporary refuge during the exceedances. A few sites, however, within watersheds with the highest observed conductivity readings (e.g. Huron River, Detroit River, and Cuyahoga River; Figure 16 and Figure 18), had extended periods (months) with calculated salinity above the 1000 ppm freshwater limit that may suggest these streams are transitioning to slightly saline systems. Such a transition could impair aquatic life.

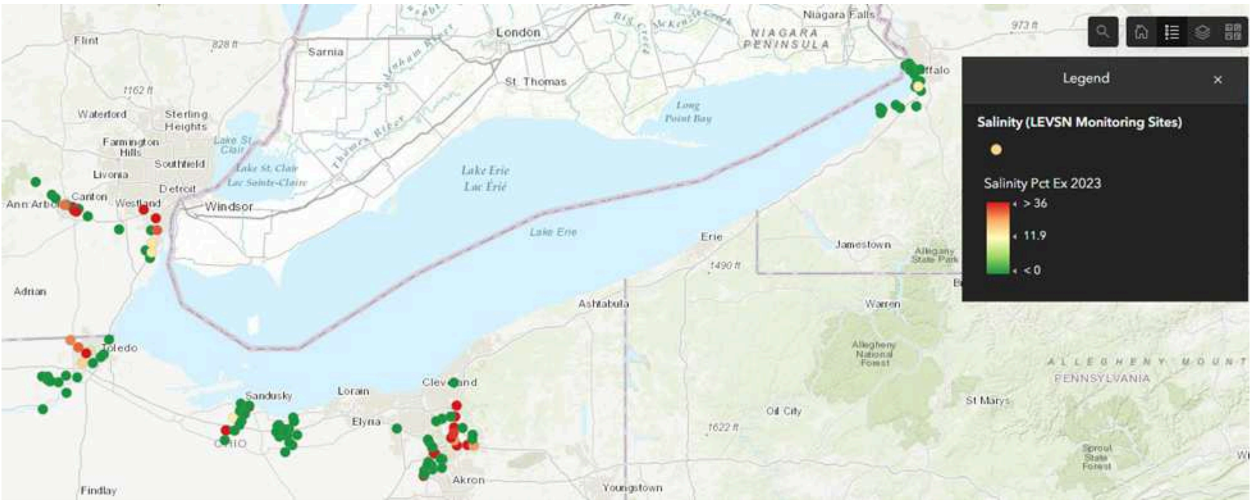


Figure 18. Lake Erie Watershed Salinity Exceedance Map. All non-green point mark sites with at least one salinity exceedance in 2023.

Data Limitations: Existing conductivity data limitations include: the limited number of cold water stations and sites; spatial data gaps including in areas of lower Michigan, tributary rivers and streams along the southeastern edge of Lake Erie, and the entire Canadian side of the Erie basin; and temporal limitations such as a seasonal gap in data between November and April and fine scale frequency gaps (i.e. between biweekly or monthly sampling points) that capture changes in flow especially in flashy systems.

The analysis of the surrogate measures of chloride, salinity, and TDS are also limited by the fact that they are implied and not directly measured parameters. LEBAF calculated these values based on the equations specified in LEBAF Standard Operating Procedure. While these equations are scientifically defensible, LEBAF does not account for the *in-situ* temperature and rather assumes standard room temperature of 25°C. Thus, the salinity, chloride, and TDS calculations may not reflect the actual concentrations found in each stream. Comparisons between direct measures of these parameters and the calculated values also show some discrepancies, but require further comparison and analysis to apply potential corrections.

Recommendations: Much of the Lake Erie Watershed experienced higher than expected conductivity in 2023. The range of values and trends observed were similar to those observed in 2022. Based on the LEBAF conductivity analysis, 10 of the monitored watersheds (i.e. Buffalo River, Chappel Creek, Eighteenmile Creek, Euclid Creek, Huron River, Maumee River, Old Woman Creek, Pipe Creek, Rocky River, and Swan Creek) have median conductivity values that are of concern for the macroinvertebrate community and warrant further investigation and direct surveys of macroinvertebrate biodiversity. The other 7 monitored watersheds (i.e. Cuyahoga

River, Detroit River, Mills Creek, Ottawa River, Rush Creek, Smoke Creek, and Ten Mile Creek) have median conductivity values that suggest the biological community is already impacted and warrants further investigation into pollution sources. Further, LEBAF recommends remediation efforts, especially in the 7 highly impacted watersheds, to prevent further impacts or future degradation of the biological community due to high conductivity. Sites with highly anthropogenically altered sub-watersheds that experience flashy flows are high priority sites for remediation. The conductivity analysis at these sites showed the highest values during periods of low flow such as the flash drought conditions experienced in Southeast Michigan and Ohio in late May and early June. Due to conductivity being a non-specific parameter and the limitations in the spatial and temporal data coverage, further investigations are needed within all monitored watersheds to better understand the specific pollution sources contributing to this high conductivity at each monitoring location.

LEBAF stations with conductivity values that exceeded 1000 $\mu S\ cm^{-1}$ were primarily in urbanized areas. High conductivity in urbanized areas is often compounded by increased point and non-point sources of pollution and flashy flows due to impervious surface coverage that may increase both natural weathering and non-point source pollution. For example, in the Sandusky area (e.g. Pipe Creek and Mills Creek) high conductivity values were observed at sites downstream of industrial outfalls. LEBAF recommends that watershed groups and community members review and comment on the industrial and wastewater permits issued in LEBAF watersheds to ensure state environmental agencies require reductions in pollutants that may contribute to conductivity exceedances detrimental to aquatic life. Other urbanized sites in Southeast Michigan are in highly channelized tributaries that can mobilize large quantities of minerals and pollutants that may contribute to non-point sources of conductivity in addition to documented point sources. Increased sample frequency is needed to better understand the influence of flow on conductivity, especially during both high and low flow events such as droughts or storms. LEBAF also aims to incorporate standardized flow measurements into the network’s monitoring protocol to help watershed groups better diagnose flow related water quality issues and provide specific flow related recommendations.

Further analysis and surrogate measurement investigations also suggest potential salt inputs from ground water sources at some urbanized LEBAF sites. Some sites with measured conductivity values > 850 $\mu S\ cm^{-1}$ experienced stark declines in conductivity after storm events, which suggest a possible flushing or dilution effect of a constant salt source such as ground water. Concurrently high calculated salinity and rare occasions of high calculated chloride at these sites further support a possible groundwater salt source likely from winter road applications. An evaluation of flow corrected concentrations or load calculations as well as direct measures of salinity and chloride, especially at LEBAF sites during the winter months and in the early spring, would strengthen this claim. Even still, LEBAF recommends municipalities consider more efficient and less frequent salt applications during the winter months as a preemptive remediation step to improve water quality across the Lake Erie Watershed.

In some cases, high conductivity was observed at sites draining agricultural or natural areas. Some agricultural products introduce salts as well as inorganic nutrients to streams that increase conductivity. Inorganic nutrient pollution is of particular concern for the health of the Western Lake Erie Basin but warrants a separate investigation of conductivity sources. High conductivity in agricultural and natural areas may also be influenced by environmental and geological factors, some of which may not influence aquatic life as evidenced by the Ohio ecoregion survey and reference dataset (Table 46). To better understand both natural and anthropogenic influences on conductivity, LEBAF hopes to expand its spatial coverage across the Lake Erie Watershed by engaging Canadian volunteer monitoring groups and continuing the expansion of the U.S. based network.

Section 5 – Recommendations

5.1 Interpretation of Findings and Corresponding Recommendations

In 2023, LEBAF participants monitored over 100 stations across 20 rivers and tributaries located in the Lake Erie Basin. LEBAF participants were required to sample once per month from April to October. A few participating groups sampled more frequently while a couple groups were unable to collect measurements until later in the season resulting in fewer data points at a handful of stations. This resulted in data collection during 842 sampling events. Data included the four core parameters – pH, DO, temperature, and conductivity – and three surrogate parameters – TDS, salinity, and chloride. LEBAF evaluated all data, even data collected from sites with fewer than 6 sampling points to increase the spatial coverage, in the overall analysis. Any sites with sparse data were caveated in the interpretation of results, especially if the data deviated from basin-wide temporal trends. LEBAF also recognizes its short 2-year history and hopes continued sampling at all LEVSN sites in future years will help to better characterize site, watershed specific, and Lake Erie Basin-wide temporal variability.

Based on the 2-year LEVSN dataset and the LEBAF definition of health, as previously described in Section 2, the rivers and tributaries situated in the Lake Erie Basin are generally healthy and support aquatic life, particularly with respect to pH, temperature, and DO. Conductivity measurements are cause for concern in some sections of the rivers and tributaries, but do not suggest that the rivers and tributaries are unhealthy overall. Some rivers and tributaries are healthier than others based on different parameter exceedances. Unhealthy conditions were most often event based (e.g. during periods of drought), short-lived (i.e. observed during a single sampling) and occurred in smaller tributaries of larger systems that drained highly altered land, primarily urban areas or in some cases row crop farmland.

The pH, temperature, and DO data all showed exceedances in less than 10% of the data collected in 2023 (Table 40), which is similar to 2022 findings. Cold water sites experienced more temperature exceedances, but fewer DO and pH exceedances than warm water sites in both years (Table 40). Fewer cold water sites were monitored than warm water sites, which may contribute to some of the differences observed. Many of the temperature and DO exceedances in both warm and cold water systems as well as several of the pH exceedances were observed when atmospheric temperatures were above average (generally ≥ 80°F/26.7°C) and there was below average precipitation. Those two factors led to low stream baseflow or even stagnant conditions (Section 4.3). In fact, most of these exceedances occurred from late May through early July when the United States Drought Monitor confirmed moderate drought conditions in southeast Michigan, abnormally dry to moderate drought conditions in Northwest, North central, and parts of Northeast Ohio, and abnormally dry conditions in the Buffalo area (Figures 5 and 9). Such extreme weather conditions are only expected to become more frequent and intense with climate change. Thus, LEBAF recommends the following protective actions: increase riparian buffer zones to increase river and stream shading and expand the implementation of green stormwater infrastructure (e.g. vegetative swales and rain gardens) to help restore more natural flow regimes. Both recommendations also help to reduce the urban heat island effect that further exacerbates high temperatures in aquatic systems within urban areas.

The conductivity data showed the greatest concern for ecosystem health, with 97% of all LEVSN data exceeding the Ohio EPA biocondition criterion adopted by LEBAF for evaluating ecosystem health (Table 40 and 48). LEBAF recognizes that this criterion is difficult to meet when compared to Ohio EPA's natural reference and survey conductivity data for aquatic systems in the geological regions that encompass the LEVSN sites (Table 46). Most conductivity data overlapped with the reference and survey data, but more of the 2023 conductivity data fell on the upper end of the reference and survey datasets (Table 49). This was also observed in 2022, which suggests many of the monitored rivers and tributaries in the Lake Erie Basin tend to have conductivity measures above natural levels. The data from nine of the 16 watersheds suggested there were likely threats and impacts to the biological community based on the combined conductivity criteria employed by LEBAF (Table 49). The data from the other seven watersheds suggest some concern for biota, but data primarily aligned with natural reference and survey data for the appropriate geological region. LEBAF recommends that all LEVSN participants begin to incorporate macroinvertebrate surveys into their monitoring programs to better diagnose biological health. LEBAF aims to develop standard guidance for conducting macroinvertebrate surveys into the LEBAF SOP.

The nine watersheds with likely threats and impacts due to conductivity included the Cuyahoga River Tributaries, Detroit River Tributaries, Huron River, Ottawa River, Mills Creek, Pipe Creek, Rush Creek, Smoke Creek, and Ten Mile Creek (Table 49 and Figure 16). These watersheds generally did not have uniformly high conductivity across all monitoring sites, but rather only at a few sites that drained highly altered land: primarily urban areas. These sites had consistently high values or event-based spikes. Some of the event-based spikes were associated with extreme weather events, like drought conditions, that also led to many of the other parameter exceedances. Therefore, the rivers and direct tributaries in the Lake Erie Basin overall are deemed to be relatively healthy with respect to conductivity and have locations where aquatic life can seek temporary refuge during conductivity exceedances. Furthermore, despite high conductivity, none of the calculated TDS values exceeded the aquatic life threshold and less than 15% of both the calculated salinity and chloride data exceeded LEBAF thresholds.

Even still, due to the number of sites and watersheds with average conductivity concentrations above 850 µS cm^{-1}, LEBAF recommends that all LEVSN participants conduct additional investigative sampling for sources contributing to high conductivity values. Since conductivity is a broad pollutant indicator, sources may differ across sites and watersheds. Some initial source evaluations based on calculated salinity and chloride suggest salts as a potential source contributing to high salinity especially at the sites within the Huron River, Detroit River tributaries, and Cuyahoga River tributaries that had the highest conductivity values (Figure 18). LEBAF recommends municipalities consider more efficient and less frequent salt applications during the winter months, particularly in Southeast Michigan and Northeast Ohio, but also as a preemptive remediation step to improve water quality across the Lake Erie Basin. LEBAF noted discrepancies in calculated, surrogate measures of salinity and especially chloride compared to some measured values. LEBAF recommends participating groups directly measure these parameters in future years, especially at sites with conductivity values exceeding 850 µS cm^{-1}, to better evaluate these potential sources of conductivity and better refine LEBAF calculations of these parameters. LEBAF aims to incorporate standard guidance for measuring these parameters in an updated LEBAF SOP and include the data in future LEBAF annual reports.

Finally, most exceedances and parameter extremes (i.e. maximums and minimums) for all 4 core parameters tended to occur at sites with flashy flow regimes. Flashy flows often occur in streams draining urban areas with lots of impervious surfaces or in highly channelized streams. These flashy flow regimes result in lower than normal baseflow conditions and pulses of fast flows during rain events that mobilize large quantities of pollutants. These drastic changes in flow and water levels may pose a bigger threat to aquatic life than chemical exceedances. The LEBAF protocol currently only characterizes flow through visual observations, but based on these observations, plans to add quantitative flow measurements to the core measurements of the LEVSN network. The addition of standardized flow measurements will help to characterize pollutant loads and quantitatively describe flow regimes that will allow LEBAF to provide more specific flow-related recommendations in future reports.

Overall, the second year of data collection was a success. The report shows a snapshot of data collected over a two-year time frame that suggests the rivers and direct tributaries to Lake Erie have generally healthy ecosystems that support aquatic life. More detailed analyses of the data that supports this conclusion can be found in Sections 3 and 4 of this report. The data collected and presented supports the LEBAF monitoring purpose, data use of screening for primary data users, and the participating organizations.

5.2 Limitations of 2023 Monitoring Program and Corresponding Recommendations

As described in the introduction, all observations and interpretations described in each water body's aggregated summary, and in the Recommendations and Conclusions should be taken as qualified by a range of limitations that face this monitoring program currently, particularly in these early years of operation.

In 2022, the first year of the program, we noted 4 key limitations: Lack of Historical Record, Low Monitoring Frequency, Underrepresentation of Key Components, and Difficulty Pinpointing Exceedance Sources.

LEBAF's 2023 conclusions are also limited by a number of factors with primary limitations stemming from gaps in the sampling frequency of some of our data. Consequently, some of the recommendations described below explore options to begin to fill these gaps as much as possible

All of the interpretations and recommendations presented in this report have been refined by member groups that bring significant knowledge regarding their local water bodies to the table. LEBAF trusts each group's local wisdom will help inform any use of the data in their outreach, education, restoration and protection efforts. Any groups seeking to leverage LEBAF data or information products outside this local context are heavily encouraged to engage with the relevant participating groups to ensure accurate interpretation. This is particularly true for all stakeholders outside of LEVSN including researchers, agencies, and community members.

Here are the 2023 Monitoring Program's limitations, and corresponding recommendations. We've also noted whether these limitations were also found last year, in the first year of operation.

Key limitations of the 2023 monitoring season include -

Sampling frequency - Sampling frequency was a limitation reported by Maumee River and Swan Creek, and by Ottawa River; in these cases, stations were sampled 1-2 times monthly, April-October. In Swan Creek, 2 samples were included from stations that were not fully monitored according to LEBAF standards of a minimum of once per month. On the Ottawa River, two samples were included from a station that was not fully monitored according to LEBAF standards of a minimum of once per month. The recommendations here are for these stations to be sampled a minimum of once per month, according to LEBAF standards. Low sampling frequency was flagged in the 2022 list of key limitations. Last year, recommendations were to require all participants to sample 1x/month from April to October in future years (some groups were not equipped to do so in 2022, but now are). For those groups who have the capacity, LEBAF will recommend increasing sampling to 2x/month beginning in 2024.

Sampling frequency was also raised as a parameter-specific limitation, for dissolved oxygen and temperature, and specifics on those limitations and associated recommendations are detailed below.

Parameter Specific Limitations

Temperature data limitations: The current frequency of samples taken presents challenges for establishing trends in temperature. Each sample was taken at one point in time and often during a similar time of day, so it does not represent the temporal variations in ambient water temperature during the daily periods outside of a singular sampling event. Moreover, while the current data can help to determine the magnitude of a temperature exceedance, it fails to determine the duration over which it occurs. A continuous measurement may be able to indicate more consistent trends in temperature.

Flow was also identified as another limitation with this parameter. Many temperature exceedances occurred at headwater sites and were associated with observed low flow. The measurement of flow is visual and subjective. More precisely (and numerically) measured flow coupled with increased temperature sampling would provide a more complete data set to use in determining duration of exceedance and related contributing factors. In addition to increasing the monthly and annual sampling frequency, several years of data may also need to be established before temperature can be used as a sentinel tool for observing stream response to climate change.

To improve the understanding of temperature at sites currently experiencing exceedances, it is recommended that additional sampling efforts with increased frequencies (e.g. continuous measurements, if possible) should focus on months where previous exceedances have occurred. For all sites, it is recommended sampling take place in the afternoon when daytime temperatures are at their highest. Finally, the addition of quantified flow measurements should be considered for key sites.

Dissolved oxygen data limitations: Sample size is relatively small and is not yet sufficient to draw conclusions on daily and seasonal patterns, temperature influences, etc. There are also spatial limitations to the data that have yet to be investigated. Considering the distribution of exceedances, DO impacts to aquatic life at these sites is possible. Evaluation of the exceedance sites and surrounding land uses could help determine likely causes. At sites below the minimum threshold, there may be impacts to aquatic life, especially if DO levels are low for an extended period. Low oxygen levels are less than optimal for most aquatic life including macroinvertebrates and fish; this can result in loss of species diversity and overall presence of aquatic life species in our waterways. Understanding the diversity and tolerances of macroinvertebrate communities would help draw conclusions about DO patterns and fluctuations. It is recommended that macroinvertebrate communities be sampled next season to determine if low DO concentrations are affecting biota. If low DO concentrations are constant, biological communities should begin to decline.

The current protocol requires DO measurement once a month. Given daily, seasonal, and other factors affecting DO, continuous diurnal data collection is also suggested. Continuous monitoring or monitoring at a wider range of times may give more insight to variability and potential issues. Since dissolved oxygen is a function of water temperature, which varies temporally, a greater sampling frequency would also be beneficial to capture seasonal trends. Issues affecting DO, such as the algal blooms, also occur seasonally, so a greater spatial and temporal extent of data collection would be helpful. Focus should be paid to areas where exceedances occurred as these are likely localized issues that may require local remediation.

pH data limitations: The pH data herein appear to show site-specific instances of pH exceeding the acceptable range. However, the frequency and duration of data collection makes identifying trends and patterns difficult. A continuous measurement of pH, or multiple measurements taken at different points throughout the day may help better capture temporal variation. Additionally, flow is measured visually as a subjective variable, and therefore may vary with each individual monitorer. As many of the pH exceedances were correlated to times of low flow at the monitoring location, a precise, objective measurement of flow may depict a more accurate interpretation of site conditions. The Maumee River and Furnace Run tributaries were sampled by LEBAF for the first time in 2023. Without historical data to assess, it is difficult to determine the degree to which these variations are typical. Additional sampling over the coming years will allow us to better identify trends and patterns within the LEBAF network. To achieve a more accurate understanding of pH across the LEBAF network, it is recommended that pH sampling occur at different times of day and across consecutive days at sites with pH exceedances. This will help to determine if pH exceedances are a regular occurrence or derived from an infrequent source. Since the sites with exceedances in the Cuyahoga River Basin appear to be correlated with high urbanization, it is recommended that additional mitigation measures be considered for improving watershed health around these locations. Finally, the addition of flow as a quantifiable variable, as well as sampling of the macroinvertebrate communities, across the LEBAF network will improve our assessment of ecosystem health.

Conductivity data limitations, with road salt monitoring recommendations: Much of the Lake Erie Watershed experienced higher than expected conductivity in 2023. The range of values and trends observed were similar to those observed in 2022. Existing conductivity data limitations include: the limited number of cold water stations and sites; spatial data gaps including in areas of lower Michigan, tributary rivers and streams along the southeastern edge of Lake Erie, and the entire Canadian side of the Erie basin; temporal limitations such as a seasonal gap in data between November and April and fine scale frequency gaps (i.e. between biweekly or monthly sampling points) that capture changes in flow especially in flashy systems.

The analysis of the surrogate measures of chloride, salinity, and TDS are also limited by the fact that they are implied and not directly measured parameters. LEBAF calculated these values based on the equations specified in LEBAF Standard Operating Procedure. While these equations are scientifically defensible, LEBAF does not account for the *in-situ* temperature and rather assumes standard room temperature of 25°C. Thus, the salinity, chloride, and TDS calculations may not reflect the actual concentrations found in each stream. Comparisons between direct measures of these parameters and the calculated values also show some discrepancies, but require further comparison and analysis to apply potential corrections. Since surrogate parameters are based on singular transformation equations, direct parameter measurement could validate or improve local application of these equations.

Due to conductivity being a non-specific parameter and the limitations in the spatial and temporal data coverage, further investigations are needed within all monitored watersheds to better understand the specific pollution sources contributing to this high conductivity at each monitoring location.

LEBAF recommends that, where feasible and appropriate, watershed groups and community members review and comment on the industrial and wastewater permits issued in LEBAF watersheds to ensure state environmental agencies require reductions in pollutants that may contribute to conductivity exceedances detrimental to aquatic life. Other urbanized sites in Southeast Michigan are in highly channelized tributaries that can mobilize large quantities of minerals and pollutants that may contribute to non-point sources of conductivity in addition to documented point sources. Increased sample frequency is needed to better understand the influence of flow on conductivity, especially during both high and low flow events such as droughts or storms. LEBAF also aims to incorporate standardized flow measurements into the network's monitoring protocol to help watershed groups better diagnose flow related water quality issues and provide specific flow related recommendations.

Further analysis and surrogate measurement investigations also suggest potential salt inputs from ground water sources at some urbanized LEBAF sites. Some sites with measured conductivity values > 850 µS cm^{-1} experienced stark declines in conductivity during or after storm events, which suggests a possible flushing or dilution effect of a constant salt source such as ground water. Concurrently high calculated salinity and rare occasions of high calculated chloride at these sites further support a possible groundwater salt source likely from winter road applications. An evaluation of flow corrected concentrations or load calculations as well as direct measures of salinity and chloride, especially at LEBAF sites during the winter months and in the early spring, would test this conclusion. Even still, LEBAF recommends municipalities consider more efficient and less frequent salt applications during the winter months as a preemptive remediation step to improve water quality across the Lake Erie Watershed.

In some cases, high conductivity was observed at sites draining agricultural or natural areas. Some agricultural products introduce salts as well as inorganic nutrients to streams that increase conductivity. Inorganic nutrient pollution is of particular concern for the health of the Western Lake Erie Basin but warrants a separate investigation of conductivity sources. High conductivity in agricultural and natural areas may also be influenced by environmental and geological factors, some of which may not influence aquatic life as evidenced by the Ohio ecoregion survey and reference dataset (Table 46). To better understand both natural and anthropogenic influences on conductivity, LEBAF hopes to expand its spatial coverage across the

Lake Erie Watershed by engaging Canadian volunteer monitoring groups and continuing the expansion of the U.S. based network.

5.3 Program and Organizational Outcomes

From a program and organizational perspective, the 2023 LEBAF sampling season was extremely successful. Now in its second year of fully standardized monitoring, LEBAF participation grew substantially as LEVSN's movement to amplify the credibility and power of community water quality action continued to gain momentum. Participants engaged deeply in the highly structured process of collecting, analyzing, and communicating data to support their own local information needs and tell a shared regional story about the health of Lake Erie watersheds.

Participation highlights include -

- Six 2022 participants returned for the 2023 season (Buffalo Niagara Waterkeeper, Cleveland Metroparks, Erie Soil & Water Conservation District, Huron River Watershed Council, Tinker's Creek Watershed Partners, and Old Woman Creek NERR).
- Two additional 2022 participants returned but faced technical and/or logistical difficulties that prevented them from completing the 2023 season (Clinton River Watershed Council and SUNY Fredonia). Both intend to resume participation in 2024.
- Five new participants adopted LEBAF standards for the first time (Metroparks Toledo, Partners for Clean Streams, Summit Soil & Water Conservation District, Toledo Metropolitan Area Council of Governments, and Toledo Zoo & Aquarium).
- Six participants and seven external partner organizations (New York DEC, NEORSD, NOACA, Ohio EPA, Organic Connects, Watershed Management Association of Ohio, and Water Rangers) took increased ownership over the network in at least one of three subject matter focused working groups (Steering, Standards, and Equity & Justice)
- The eleven active 2023 participating organizations leveraged their combined 1,335 data points (collected monthly at over 100 sites) and LEBAF's standardized analysis tools to conduct individual assessments of the health of 20 local watersheds, a collaborative evaluation of the health of the Lake Erie Basin, and documentation of these analyses in a shared field season report (this document).

In addition to collecting, analyzing, and reporting 2023 data, the network worked hard to leverage learnings from 2022 to refine its processes and deepen its capacity. A rigorous evaluation process conducted following the first LEBAF field season resulted in the documentation of key gaps, limitations, and opportunities for improvement in a shared action plan. The LEVSN Standards Working Group used this plan to lead the network in updating its processes, tools, and supporting documentation to fine tune LEBAF in preparation for Information Design (data analysis and reporting) in the Fall and Winter of 2023/2024.

Key program improvements integrated into the 2023 field season -

- Kicking off monitoring into the Maumee River Basin, a key contributor of agricultural runoff to Lake Erie, and expanding monitoring in the Cuyahoga River Basin, a key contributor of industrial and urban runoff to Lake Erie
- A better defined and documented QA/QC process for collecting and validating data
- An updated SOP and User Guide that increases the accessibility of key documentation
- An improved data analysis tool with more mapping, graphing, and automation options
- A refined Information Design process, including -
    - A more appropriately weighted approach to analyzing Conductivity and its surrogate parameters that improves interpretation and the framing of results
    - A more streamlined individual analysis process that makes it easier for participants to consistently and rigorously evaluate their local watersheds
    - A more collaborative Lake Erie Basin Watershed analysis process that allows the full network to discuss and come to consensus on regional insights
    - A more refined reporting process that improves templates and engages participants to more efficiently compile and share results

It is worth noting that the identification, prioritization, and execution of these improvements was driven by participant engagement. The issue areas that guided this work was determined by participants feedback from the 2022 field season evaluation process and the development of updated documentation, processes, and tools was delegated by the participant-driven Standards Working Group. This phenomena shows the continued commitment of Local Hubs to not only the standardized implementation of LEBAF, but its continued growth and refinement.

This process of continuous improvement continued after the 2023 field season with a rigorous, program evaluation conducted in February of 2024. While some program limitations are difficult to address due to capacity or technical challenges, many can be rapidly resolved over iterations of the program and still others will become opportunities for growth over longer timescales as the network continues to build momentum. In the meantime, any known limitations will continue to shape the qualifications communicated in Section 5.2 each year and serve as target development opportunities for future years.

Key program improvements proposed for development during the 2024 field season -

- Expand LEBAF participation across the basin, with particular focus on Michigan, New York, and Ontario, to work towards addressing gaps in geographic coverage
- Continue refinement of data analysis tools and methods with a particular focus on creating even more user friendly documentation to support participants
- Developing non-mandatory guidance to support participants in setting up their sampling plans, site selection, volunteer management, and other best practices that amplify the support provided by required standards
- Bringing technical trainings fully in-house (rather than relying on vendors) to ensure relevance and completeness of the guidance provided

- Develop approach for incorporating in-situ sensors for high-frequency sampling at stations with persistent exceedances to address temporal resolution issues
- Refining approach for engaging K-12 schools in LEBAF to grow participation and expand community impact through youth engagement.
- Evaluate opportunities to standardize and incorporate additional parameters to advance LEBAF's monitoring purpose and intended data uses

Of particular focus is driving continued growth in LEBAF participation, which will help address spatial gaps in data collection as well as build the network's capacity to manage and refine LEBAF. We plan to continue to leverage our reserve of YSI sensors and Water Report licenses, as well as our robust training and onboarding process, to empower both existing groups and new monitoring programs to join the movement. Eight new groups are in the process of being onboarded to the network for the 2024 field season as this report is being published.

We are highly encouraged by the continued positive feedback from LEBAF participants as we wrap up the program's second year. When asked about the benefits to their staff, volunteers and programs, they consistently spoke about how productive and educational it was to participate in a regional effort of this scope for the first time. Participants appreciated the support provided by sensor loading, data platform licenses, and SOP documentation provided by the network and are getting increasingly more proficient in the annual as their experience grows and the process regines. On average, participants rated their ease of implementing LEBAF protocols as 4.35 out of 5 (with 5 being "Very Easy"), up from 3.9 in the program's first year

Participants also enjoyed the opportunity to refine their capacities via standardized data collection, management, and analysis technologies employed as well as to learn from and refine the collaborative process of data analysis, synthesis, and interpretation. They also appreciated learning about each other's programs and water bodies, sharing best practices and expanding each other's knowledge about the Lake Erie Basin. On average, 2023 groups rated LEBAF's effect on the impact of their individual programs as 4.5 out of 5 (with 5 being "greatly amplified impact"). The group's dedication to this work is reflected in their budgets - in 2023 LEBAF groups spent almost $420,000 staffing and equipping their volunteer monitoring programs.

Perhaps most of all, participants see the tremendous potential of standardized, interoperable data being collected at the regional level - the capacity to integrate their work with that of their peers to build a data asset that is bigger than any one community or organization could do by themselves. The potential impacts of this standardized approach is hard to understate. The analytical capability and programmatic credibility it allows for each participating group is complimented by the new capacity they have to build a unified and effective screening tool at the scale of a Great Lake Basin. This process, now shown to be technically and organizationally possible, promises to produce significant value for the Lake Erie region and its communities as it grows and builds a unique historical record that can be used to understand trends over time. As

LEBAF evolves and matures, LEVSN aims to tie its recommendations more closely to specific conservation, restoration, and other beneficial actions for various stakeholders, in their relevant localities and at the regional level. For example:

- Residents near impacted streams could be advised to not mow to the edge of their yard and incorporate other best practices into their daily lives.
- Agricultural Landowners and Developers could be advised to use best management practices to mitigate adverse watershed impacts from their land use.
- Municipalities could be encouraged to make changes to land use, integrate data into planning activities, amend zoning codes, and support pollution source identification.
- Watershed Management Groups could receive support in pinpointing locations for streambank stabilization and other restoration projects.
- Environmental Agencies could investigate problem areas with further monitoring or leverage LEBAF data to target restoration investments or educational signage.

Further, the alignment and activation engendered by the standardization process has transformed the Lake Erie volunteer science ecosystem from a constellation of disparate local groups into a highly organized movement. This shift enables a host of possibilities, ways that the network can build on LEBAF to meet data needs and address water quality issues. LEVSN's Steering Committee and Standards Working Group are exploring ways to leverage the network's momentum to expand LEBAF, as well as LEVSN's broader work, for greater collective impact. In order to position the capacity for such action as well as other forms of collaboration such as adding new partners or working with agencies on specific monitoring objectives, LEBAF will communicate the conclusions, recommendations, and organizational accomplishments of the 2023 field season to key stakeholders using a variety of products and channels. The primary information product from 2023 will be this report and its more succinct local and Lake Erie iterations which will be shared by Cleveland Water Alliance and each LEBAF participant respectively as a press and web release. LEVSN also plans to put on a public webinar covering the same core content and update its shared webpage on the Cleveland Water Alliance site. Finally, LEVSN will continue to refine its shared data hub (Water Reporter) and work to publicize and connect this hub to end users via a web app on the shared webpage, local collaborations, and API connection to other data hubs.

In conclusion, LEBAF participants are passionate about their work and desire to keep the collaborative moving forward to create collective impact for Lake Erie waters and the communities they support. LEVSN aims to grow and refine the LEBAF process to build up the effectiveness of its work, the value of its data repository, and the depth of its engagement with decision makers. In 2024, the network will focus on further refining the operation and maintenance of existing protocols, tools, documentation, and workflows with emphasis on more exchanges between groups and the sustainability of the network. Moving forward, it aims to build on existing standards to improve the credibility of its work and broaden our understanding of the Lake Erie Basin. If you are interested in supporting or participating in LEVSN or want more information, please refer to section 5.4 below.

5.4 Growing the Movement

Since 2020, LEVSN participation has tripled to include over 20 participating organizations, and the network has partnered with professional scientists and decision makers to create a robust program that can fill data gaps and inform management efforts across the Lake Erie Basin. In 2023 alone, LEVSN participants engaged 143 volunteers in 3196 hours of service which resulted in collection of over 1,300 standardized samples across over 100 sites in 20 local watersheds.

The network has already demonstrated the capacity of volunteer science to generate powerful scientific and community impact and we will continue to build momentum as our movement continues to grow. LEVSN invites communities, organizations, and individuals to join us in pursuing better water quality and quality of life for all Lake Erie Basin communities by:

- **Funding the Network** - Direct contributions to the network enable us to retain and grow critical functions such staff capacity, equipment upkeep, and data infrastructure.
- **Funding a Local Hub** - Direct contributions to your local volunteer science program enables their capacity to collect data, address local challenges, and participate in LEVSN.
- **Participation -** Bringing a new or existing volunteer program into LEBAF expands our capacity to collect data for impact and helps fill critical data gaps.
- **Leadership** - Participation in Working Groups or on our Steering Committee grows our organizational capacity to expand and evolve the network to address new challenges.
- **Technical Resources** - In-kind contributions of equipment, data tools, and technical support ensure that the network remains at the forefront of water data technology.
- **Scientific Expertise** - Collaborations with researchers, agency scientists, and water resource managers ensures that our movement remains scientifically rigorous.
- **Data User Relationships** - Leveraging our data helps the network build the partnerships and funding relationships needed to scale impact and ensure long-term sustainability.

If you are interested in supporting or partnering with LEVSN, please reach out to Max Herzog with Cleveland Water Alliance at mherzog@clewa.org. Together, we can ensure a healthier future for all Lake Erie Basin communities. With your help, the story has just begun.

Appendix I – Participating Groups

Buffalo Niagara Waterkeeper has been the guardian of Western New York's fresh water since 1989. Its mission is four-fold: PROTECT the water, RESTORE both the waterways and the surrounding ecosystems, CONNECT people to their waterways, and INSPIRE both economic activity along the waterways and community engagement. Their long-standing water quality monitoring program, Riverwatch, and other staff-led water quality data collection efforts provides a regular stream of data and information allowing us to maintain a strong understanding of our local waterways conditions and threats. This data is used to educate volunteers, community members, and elected officials and advocate for water quality improvements.

Cleveland Metroparks is home to 18 park reservations, eight lakefront parks, over 300 miles of all-purpose, hiking, biking, and bridle trails, eight golf courses, five nature centers, dining, retail, and the nationally acclaimed Cleveland Metroparks Zoo. The organization serves a mission to protect nature, connect communities, and inspire conservation of our world. The Watershed Volunteer Program (WVP), established in 2012, is offered through Cleveland Metroparks with funding support from Northeast Ohio Regional Sewer District. Its mission is to connect community members concerned with the health of local watersheds and includes water quality monitoring.

Firelands Coastal Tributaries Watershed Program was created in 2006 and is currently operated through a partnership between the Old Woman Creek National Estuarine Research Reserve and the Erie Soil and Water Conservation District. The program acts as a community lead for watershed planning, stewardship education, grant funded watershed improvement projects, and the development of citizen-based stream monitoring.

Huron River Watershed Council (HRWC) is southeast Michigan's oldest environmental organization dedicated to river protection. HRWC protects and restores the river for healthy and vibrant communities. HRWC monitors the Huron River, its tributaries, lakes, and groundwater, and leads programs on pollution prevention and abatement, wetland and floodplain protection, public education, and natural resource and land-use planning.

Metroparks Toledo is a public agency serving the citizens of Lucas County by providing a regional system of clean, safe, natural parks. Metroparks engages volunteers in a host of activities including multiple programs centering the monitoring of natural resources. Historically, their water quality monitoring program has centered on biological monitoring to determine the water quality of streams and rivers in and near Metroparks. Now, through LEBAF and the Clean Water Action Toledo (CWAT) partnership, water chemistry monitoring has been added to the program.

Partners for Clean Streams (PCS) is striving for abundant open space and a high-quality natural environment, adequate floodwater storage capacities and flourishing wildlife, stakeholders who take local ownership in their resources, and rivers, streams, and lakes that are clean, clear, and safe. PCS was established in 2007 as a 501c3 non-profit watershed organization. PCS programs focus on engaging the community in caring for and learning about the streams and rivers in northwest Ohio and our everyday connection to Lake Erie. Since 2021 PCS has led the Clean Water Action Toledo (CWAT) partnership, a collaboration with Metroparks Toledo, TMACOG, and Toledo Zoo focused on integrating and growing volunteer water quality monitoring across the greater Toledo area with a focus on implementing LEBAF.

Summit Soil and Water Conservation District (SSWCD) was established to address conservation needs in Summit County, providing local leadership for soil and water resources conservation and water quality enhancement. LEVSN supported SSWCD in developing a Stream Monitoring Volunteer Program to enhance the stewardship of Summit County watersheds by increasing knowledge of local water quality. By participating in LEBAF, SSWCD provides credible water quality data to drive necessary stewardship changes that support watershed health both locally and regionally. In addition, SSWCD documents water quality trends over time and uses the data as an evaluation tool for improvement projects.

Tinker's Creek Watershed Partners' water quality monitoring program teaches volunteers how to monitor a stream, show what conditions to look for that are cause for concern, and who to contact with questions and data. The data will be compiled and logged online and shared with partners to monitor the health of the creek and to find sites for future restoration projects. Volunteers are encouraged to adopt a site where they take on the sampling every month for their favorite spot in the watershed. These data help prioritize work and track pollution.

Toledo Metropolitan Area Council of Governments (TMACOG) is a regional planning partnership made up of members in northwest Ohio and southeast Michigan. Together, TMACOG members work on transportation, water quality, and economic development endeavors that affect quality of life for everyone in our region. For 34 years, TMACOG has involved hundreds of students and dozens of classrooms in annual water quality testing and analysis in area waterways through their Student Watershed Watch program. Each year, students sample, study, and report on water quality issues, giving them hands-on scientific experience and insight into the importance of protecting our natural resources. Now, through LEBAF and the Clean Water Action Toledo (CWAT) partnership, sensor-based water chemistry monitoring has been added to the program.

Toledo Zoo is a recognized conservation leader that conducts research, participates in animal rehabilitation, and implements conservation programs throughout Northwest Ohio and across the globe, seeking to better the lives of animals and ecosystems. Its ZOOTeen program offers volunteer opportunities to students ages 13-17 who have a strong interest in education, animal science and conservation. LEBAF and Clean Water Action Toledo (CWAT) has partnered with the Zoo to provide opportunities for its ZOOTeen program to engage with water quality monitoring.

Appendix II – A Word on “Volunteer” vs. “Citizen” Science

Since its inception, the movement of scientific research led or supported by nonprofessional volunteers has been referred to by many names. Over the years, this movement has contributed significant findings in fields as diverse as ornithology, epidemiology, and art history. The advent of modern digital tools has dramatically expanded the movement, prompting increased interest from professional researchers, government officials, and private industry. Increased institutional engagement has resulted in exciting opportunities for growth across the movement, as well as a growing consensus around the term “Citizen Science,” which became enshrined in US federal law by the “Crowdsourcing and Citizen Science Act” of 2016.

Given the charged nature of citizenship in US public discourse, many participants in the movement have begun to criticize the term “Citizen Science” as a barrier to inclusive participation, resulting in a growing trend of rebranding the work as “Community Science”. This debate was further complicated by the 2021 publication of “Inclusion in Citizen Science: The Conundrum of Rebranding” which observes that "Community Science" is already an established term that refers to research that is not only executed by local residents, but is directly led by them and shaped by their priorities/challenges (for example a health study precipitated by grassroots activism in response to a local environmental injustice). This draws a critical distinction between "Community Science" and our movement, which is typically organized by an institution, whether academic, nonprofit, or governmental.

While there is no “correct” approach to naming our movement, the members of LEVSN feel it is important to approach branding with intentionality, both signaling our commitment to equity and ensuring we are not co-opting terms used by more grassroots work. For these reasons, we have opted to refer to our work as “Volunteer Science” and the participants in the work as “Volunteer Scientists.” We assert that this work is fully aligned with common definitions of “Citizen Science” used in existing policy, programs, and funding opportunities. We also acknowledge that branding, no matter how well positioned, is far from sufficient to ensure a truly community-centric movement. For this reason, LEVSN commits to creating an “Equity Working Group” that will explore how we can more substantively center the needs and voices of marginalized communities in our programming and decision making. Our goal is to contribute to a more just, equitable, and inclusive future for all Lake Erie residents.