Watershed Assessment of Detroit River Phosphorus Loads to Lake Erie

FINAL REPORT | MAY 2019

EXECUTIVE SUMMARY

1. PROJECT INTRODUCTION

The rivers flowing into Lake Erie carry phosphorus and other nutrients that can lead to harmful algal blooms in its western basin and hypoxic (low oxygen levels) conditions in its central basin. Despite nutrient management efforts, algal blooms and hypoxia that impact drinking water, tourism, swimming and fishing have become more extensive in recent years. In 2012, the US and Canada signed a revised *Great Lakes Water Quality Agreement* which, in 2016, led to the adoption of new phosphorus loading targets and the development of action plans to meet those targets. The plans were released in 2018.

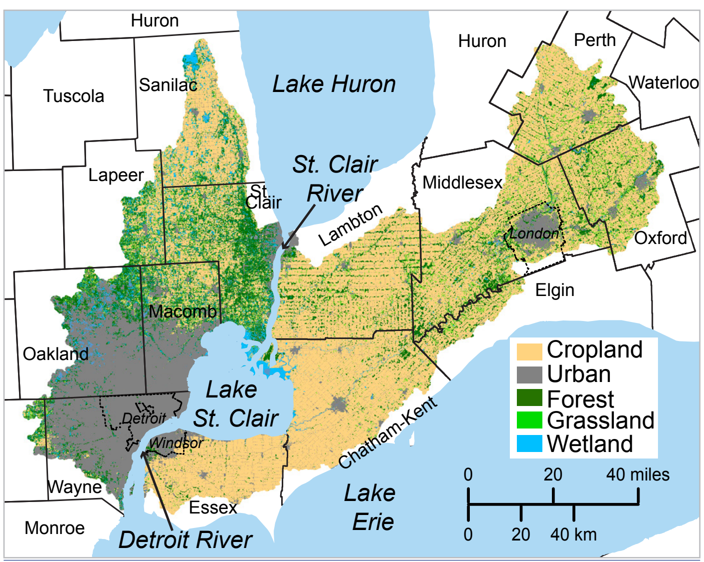

Figure A. ***Project study area.*** This map shows the land use in the St. Clair-Detroit River System watershed. The watershed contains both highly urbanized areas, including the city of Detroit and its large metro area, and extensive agricultural areas, including some of Canada's most productive cropland.

The Detroit River provides approximately 80% of the flow and 25% of the phosphorus entering Lake Erie; however, the sources of this load have been somewhat uncertain. In 2016, the Erb Family Foundation provided support to a project team based at the University of Michigan to characterize sources and evaluate management options for the St. Clair-Detroit River System watershed (Figure A). The team developed four models to simulate the dynamics of this complex, binational watershed that includes extensive urban and agricultural environments as well as the large, shallow, productive Lake St. Clair, which receives and processes inputs from upstream of the Detroit River. A diverse project advisory group provided feedback on the policy context, planned research approach, and resulting products.

2. OVERVIEW OF PHOSPHORUS SOURCES

To characterize sources of phosphorus, we compiled and analyzed data from US and Canadian water quality monitoring programs and point sources between 1998 and 2016, and estimated loads from tributaries to the St. Clair River, Lake St. Clair, and the Detroit River. Our calculations show that Detroit River phosphorus loads to Lake Erie declined by 37% since 1998 and by 19% since 2008.

We found that phosphorus from Lake Huron makes up about half of the load that the Detroit River delivers to Lake Erie, which is substantially higher than most prior estimates. Further analysis of satellite imagery suggests that storms are causing shoreline erosion and resuspension of nearshore Lake Huron bottom sediments, and this sediment is getting transported into the St. Clair River episodically, evading most current monitoring programs.

After Lake Huron, the largest contributors of phosphorus to the Detroit River are the regional Water Resources Recovery Facility in Detroit, and the Thames River in Ontario, which receives runoff from its highly productive agricultural watershed (Figure B). Excluding Lake Huron, the watershed contributions of phosphorus to the Detroit River can be broken down as follows: point sources from Michigan

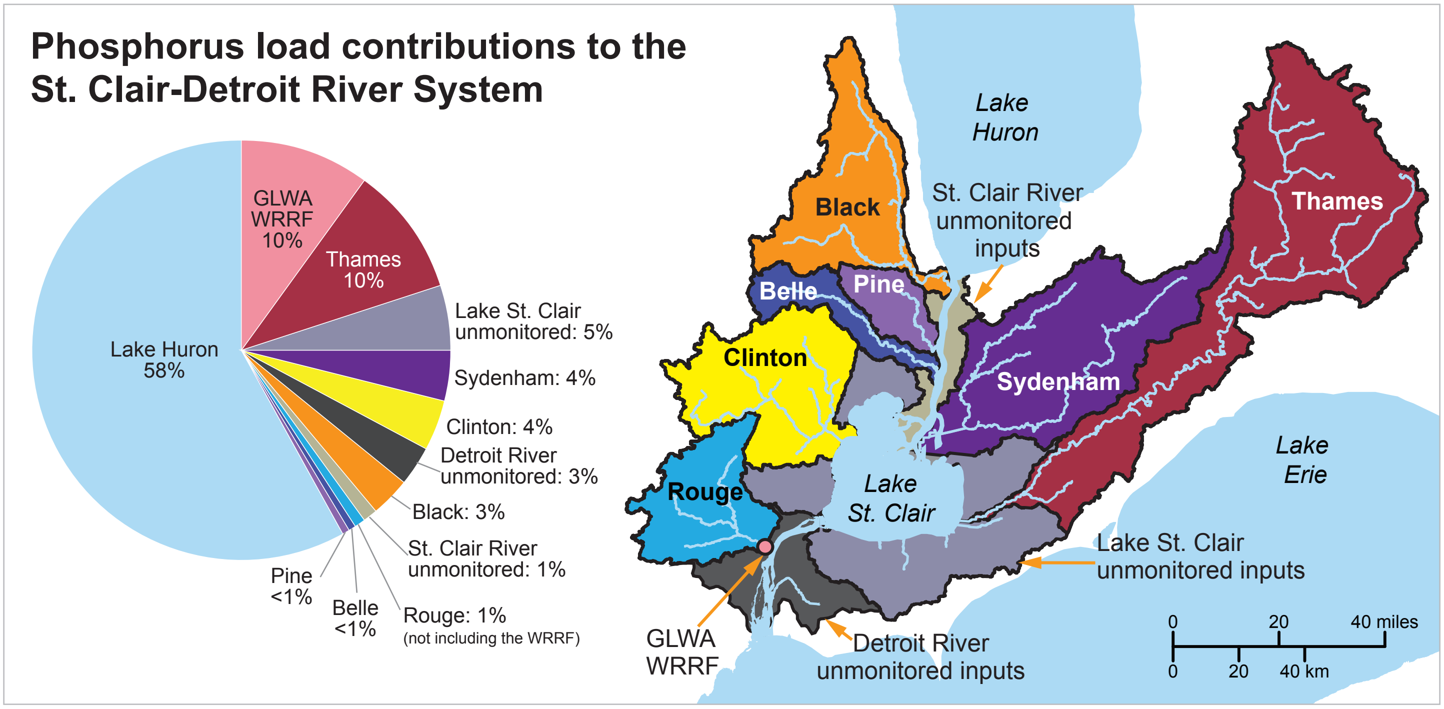

Figure B. *Where is phosphorus coming from?* The pie chart shows the relative amounts of phosphorus that come from different parts of watershed. Colors in the pie chart correspond to the map at right. The Thames and Sydenham river watersheds are primarily agricultural, while the Clinton and Rouge are mostly urban. The Great Lakes Water Authority's Water Resource Recovery Facility (GLWA WRRF) in Detroit is one of the largest wastewater treatment facilities in North America and serves 77 communities. Some of the phosphorous inputs that flow through Lake St. Clair are retained and removed from the water, which is not accounted for in this figure. Accounting for retention in Lake St. Clair slightly increases the relative contribution of downstream sources, such as the WRRF in Detroit, that do not pass through Lake St. Clair before entering Lake Erie.

(43% of watershed inputs), non-point sources from Ontario (31%), nonpoint sources from Michigan (19%), point sources from Ontario (7%). This analysis provides the backdrop for assessing potential approaches to reduce the Detroit River's phosphorus contribution to Lake Erie.

3. NUTRIENT PROCESSING IN LAKE ST. CLAIR

Lake St. Clair receives water and phosphorus from the upper Great Lakes via the St. Clair River, many tributaries, including the Clinton, Thames, and Sydenham rivers, and point sources that discharge directly into the lake. To better understand how this lake processes phosphorus, we analyzed long-term records of flow and nutrient input to and output from the lake and developed a detailed biogeochemical lake model.

Through both analytical approaches, we found that Lake St. Clair is a net sink for phosphorus; a portion of the phosphorus that enters the lake remains there. Our long-term data analysis indicated that the lake retains, on average, 20% of its total phosphorus input, but retention of dissolved reactive phosphorus is likely much lower than that. While the introduction of zebra and quagga mussels and the production of aquatic plants could account for much of the retention, sediment accumulation is possible in the 30% of the lake bottom that is deeper than 15 feet. Wind-induced resuspension over the remaining 70% could explain the year-to-year variability in retention rates in the lake.

We compared retention rates of flows and sediments from the lake's major tributaries and found lower retention rates of inputs from the Thames River. This suggests that changes in the Thames River load are likely to result in larger changes in the load leaving the lake, compared to changes in the Sydenham or Clinton river loads. However, changes are likely to be small compared to the overall load to the lake which is dominated by the St. Clair River.

4. URBAN SOURCES ASSESSMENT

Twenty percent of land area in the St. Clair-Detroit River System watershed is urban. The largest urban areas are around Detroit, Michigan and London and Windsor, Ontario. These three urban areas together contribute 24% of the phosphorus load carried by the Detroit River to Lake Erie. We found that point sources, which include wastewater treatment plants and, to a lesser extent, industrial facilities, are responsible for 80% of the phosphorus from urban areas. The Water Resources Recovery Facility in Detroit treats sewerage from 77 communities and is the largest urban source of phosphorus, representing about 63% of the load from the Michigan urban study area and about 13% of the Detroit River's load to Lake Erie. Our analysis found that the plant has reduced its load by 44.5% since 2009 by improving treatment. Stormwater runoff accounts for 10% of urban phosphorus contributions. The remainder of the urban load comes from treated (7%) and untreated (2%) combined sewer overflows (CSOs). While contributions to the Detroit River load from runoff and CSOs are relatively minor, even as a percentage of the urban load, efforts to reduce these events can have environmental benefits beyond phosphorus reduction.

5. OPTIONS FOR REDUCING LOADS FROM AGRICULTURAL SOURCES

We used the Soil and Water Assessment Tool (SWAT) to model the entire St. Clair-Detroit River System watershed and to explore options for reducing phosphorus loads. Although the model is of the entire study area, including all point sources, it is particularly well suited to evaluate how changes in agricultural land management practices could impact runoff, nutrient losses and downstream water quality. Several land management practices were found to be effective in reducing total and dissolved forms of phosphorus from agricultural watersheds; however, no practice implemented alone could achieve a 40% reduction.

The biggest reductions in phosphorus loads were achieved by combining three of the following practices: planting cover crops, adding filter/buffer strips, creating or restoring wetlands, and placing fertilizer and manure into the soil. These combinations resulted in greater than 50% reductions in phosphorus from the agricultural watersheds and suggest that a flexible approach, where practices can be combined to match the needs and preferences of farmers, will be most successful. Our analysis suggests that focusing these practices on 55% of the land with the highest per acre losses of phosphorus could achieve reductions on the order of the *Great Lakes Water Quality Agreement* targets. For the Thames River, we found that the practices that meet the annual target loads also meet the spring targets. Compared to similar areas in Michigan, the Ontario watersheds had higher modeled phosphorus loss yields per acre of agricultural land, especially for dissolved reactive phosphorus, most likely because they receive more rainfall.

6. OPTIONS FOR REDUCING LOADS FROM URBAN AND SUBURBAN SOURCES

To explore options for reducing urban loads, we calibrated a Storm Water Management Model (SWMM) for the large combined sewer area in and around Detroit. This fine-resolution urban model focused on metro Detroit, but the strategies explored are relevant to London, Windsor, and other cities that experience wet weather discharges from a combined sewer system.

Because the load from the regional Water Resources Recovery Facility (WRRF) in Detroit is the largest urban phosphorus source, improvements in treatment efficiency at this facility could help reduce loads to Lake Erie. However, significant additional treatment improvements beyond what has already been done over the past decade could become expensive. SWMM results suggest that reducing combined sewer overflows could be difficult by relying solely on efforts to reduce the cover of impervious surfaces such as pavement. While CSOs higher in the sewer collection system can be addressed to an extent through approaches such as green infrastructure, downstream overflows are caused by water coming from many upstream subcatchments and thus are difficult to address locally. SWAT modeling results for the highly urban Clinton and Rouge watersheds indicate that creating vegetated pervious surfaces is more effective for reducing phosphorus loads than creating pervious surfaces without vegetation such as permeable pavement.

7. OPTIONS FOR MEETING PHOSPHORUS LOADING TARGETS

Through this report and referenced journal articles, we have provided a more complete understanding of the relative contributions of different sources of phosphorus within the St. Clair-Detroit River System watershed, including Lake Huron, point sources, combined sewer overflow events, and runoff from both agricultural and urban lands. We have documented some significant reductions in phosphorus inputs over time due to ecological and climatic changes in Lake Huron and improvements at the regional Water Resource Recovery Facility in Detroit, but additional work is needed to reach phosphorus targets (Figure C).

As the US and Canada adaptively manage their Domestic Action Plans for reducing loads to Lake Erie, findings from this project may help them reevaluate the basis for load reductions from the St. Clair-Detroit River System watershed.

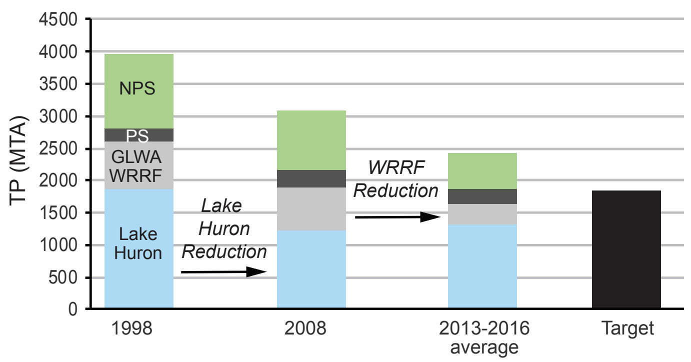

Figure C. ***How have inputs changed over time?*** This bar chart shows the annual amount of phosphorus input to Lake Erie from the Detroit River during three time periods. The colors represent four sources of phosphorus: (1) flow from Lake Huron; (2) discharge from the Great Lakes Water Authority Water Resource Recovery Facility (GLWA WRRF) in Detroit; (3) discharge from other point sources (PS) in the watershed; and (4) runoff from nonpoint sources (NPS) in the watershed. The target represents a 40% reduction from the 2008 load.

For example, our new understanding of the contribution from Lake Huron suggests that reaching Lake Erie loading targets may require larger reductions from the watershed than previously thought, and attention to Lake Huron sources. We also identified a need to enhance monitoring around the outlet and southeastern shore of Lake Huron to better understand the phosphorus load from the lake. This report identifies several pathways for reaching load reduction targets, including placing a combination of agricultural land management practices on lands with higher losses of phosphorus, and strategies to capture and manage wet weather flows in combined sewer systems, including strategic use of green infrastructure for CSO retention basins with smaller collection areas.

Most climate models predict that this region will experience warmer temperatures and greater precipitation in the future, including more frequent and intense storms in the spring and summer. Our watershed modeling indicates that these precipitation changes will lead to more runoff and greater phosphorus loading from agricultural areas as well as from the already stressed combined sewer systems. The projected warmer temperatures are expected to mitigate these impacts somewhat through a longer growing season, more evapotranspiration by plants, and smaller snowmelt events. Climate change is likely to make nutrient reduction efforts more challenging, but knowledge of future climate impacts can inform action now, for example, by elevating the need for water management strategies to accompany nutrient management. In summary, this modeling-based project integrated and analyzed extensive datasets to develop results that can be used to guide policies and practices as the countries work within the *Great Lakes Water Quality Agreement* adaptive management framework.

This project was managed by the University of Michigan Water Center, Graham Sustainability Institute, and funded by the Fred A. and Barbara M. Erb Family Foundation. For more information on this project and to download the full report, please go to: myumi.ch/detroit-river

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