Western Lake Erie Basin Science Panel Report

A report submitted to
Michigan's Quality of Life Agencies
by the Western Lake Erie Basin Science Panel

November 2023

Table of Contents

Executive Summary..4

Summary Recommendations.. 4

Detailed Responses to the Charge Questions...8

Overarching Question 1: Review the DAP's "Priority Objectives" to meet target reductions in nonpoint source P and offer suggestions to refine existing or suggest different objectives...........8

Overarching Question 2: Will the adaptively managed set of projects, when taken together, provide the necessary elements for a TP and SRP (when set) reduction strategy that will achieve the reduction targets set by the state? If not, what additional activities, projects or programs are needed?.. 13

Overarching Question 3: Is the DAP Team asking the right questions about NPS pollution?........ 13

Overarching Question 4: How should the conceptual adaptive management process and support structure be adjusted in order to implement an effective process? What additional resources or steps should we consider?.. 14

Overarching Question 5: Referencing the list of uncertainties below:.. 17

a. Which of these uncertainties will affect each adaptive management project?................. 17

b. Are there additional uncertainties not currently being accounted for in the AMP?........... 17

c. Identify strategies to reduce them over time if possible (e.g., effectiveness, costs, and relationships)..17

Which of these uncertainties will affect each adaptive management project? Are there additional uncertainties not currently being accounted for in the AMP? Identify strategies to reduce them over time if possible (e.g., effectiveness, costs, and relationships).................. 19

Watershed Practices..19

1. What are cost effective methods for detecting changes in water quality (i.e., TP and SRP) resulting from the implementation of agricultural best management practices (BMPs) and landscape infrastructure.. 19

2. How will warmer winter temperatures and changing precipitation patterns impact:...............20

a. The efficacy of agricultural BMPs and landscape infrastructure across the Watershed?.... 21

b. The implementation of agricultural BMPs?.. 22

3. Do you predict shifts in agricultural nutrient management practices as climate conditions change and as population size and density grows in Michigan? Have these shifts occurred in other states? If so, what can be learned from them?.. 22

Land Management Practices.. 22

1. Would additional wetlands assist in the reduction of P delivery to Lake Erie?.........................22

a. What are the siting considerations for these types of BMPs?...23

b. Are there existing examples of effective approval (permitting) approaches that can expedite implementation in other states?.. 24

c. What effective approaches could be used to engage landowners and agricultural producers in wetland restoration or creation on agricultural lands?..................................... 24

2. Is there existing work [in Michigan or other states] related to drains or other riparian areas that would be beneficial for P reduction? How much of that work would need to occur to see a

measurable reduction? 24
3. Are there actions that other land managers, private landowners, or municipalities could be doing to also help achieve the NPS P reduction? 25
4. What should drain commissioners consider when implementing two-stage drainage ditches, including infrastructure limitations, assessment, and long-term operations and maintenance? 25
Agricultural Practices 25
1. What is the suite of in-field and edge-of-field BMPs that are effective at addressing TP and SRP combined that could be implemented as sets of stacked practices? Can these practices be ranked from least to most effective? 25
2. How do we overcome barriers to adoption of BMPs in the agricultural community? 27
a. What examples can we draw on from other states that have already overcome these barriers? 27
3. What level of implementation is required to detect the impact of agricultural land management changes in Lake Erie water quality? 29
Research 30
1. What are the next steps for the current edge-of-field research evaluating drain tile flow management? 30
2. What other areas of research regarding management practices need to be conducted to inform decision making? 30
3. How should legacy P in the watershed be addressed, measured, or managed as a matter of reducing P loading in the WLEB? 31
Annotated Bibliography 33
Appendix A: Charge to the Science Panel from Michigan's Domestic Action Plan Team on behalf of the Quality of Life Agencies 42
Appendix B: Responses to overarching questions broken down by Priority Objective Subtasks 46
Priority Sub-tasks 3f, 3h, 6e: MAEAP - track progress and set goals in Bean Creek, St. Joseph River, and River Raisin Watersheds to increase enrollment 46
Priority Sub-tasks 3i and 6g: Conduct Agricultural Inventories in priority HUC-12 sub-watersheds in the Bean Creek and River Raisin Watersheds 47
Priority Sub-task 4f: Point Source Loading Reductions - EGLE and GLWA evaluate soluble reactive phosphorus discharge quality as a function of the level of municipal treatment 48
Priority Sub-task 5e: Field BMPs: Tile line discharge control study 50
Priority Sub-task 5g: Field BMPs: Reinstate Conservation Reserve Enhancement Program 51
Priority Sub-task 10e: Implement an agricultural wetland restoration pilot project in the WLEB. 53
Appendix C: Key Elements of a Realistic and Effective Adaptive Management Framework 54

Executive Summary

A nine-member Science Panel drafted this report with editing and other support from the University of Michigan Water Center. Panel members include:

- Jeremiah Asher, Institute of Water Research, Michigan State University,
- Rich Batiuk, CoastWise Partners, retired US Environmental Protection Agency,
- Randy Dell, North America Agriculture Program, The Nature Conservancy,
- Greg Dick, Cooperative Institute for Great Lakes Research, University of Michigan,
- Stephen Hamilton, Michigan State University (retired) and Cary Institute of Ecosystem Studies,
- Margaret Kalcic, Department of Biological Systems Engineering, University of Wisconsin-Madison,
- Silvia Newell, Michigan Sea Grant and University of Michigan,
- Adam Reimer, National Wildlife Federation, and
- Fred Sklar, Sklar Environmental Associates.[1]

The Science Panel responded to a charge (Appendix A) from Michigan's Domestic Action Plan (DAP) team on behalf of the Quality of Life (QOL) Agencies to review ongoing research and actions taking place in the Michigan portion of the Western Lake Erie Basin (WLEB) and advise on necessary changes or course corrections to achieve a 40% reduction in total phosphorus loading into the WLEB compared to 2008 levels. Although the 40% target applies to both point sources, which are mainly wastewater treatment facilities, as well as to nonpoint sources, the Panel was charged with focusing on nonpoint source reduction in the Michigan watersheds draining to Lake Erie, particularly the River Raisin and upper Maumee River. This report contains summary recommendations followed by detailed responses to questions outlined in the charge. After being briefed by the DAP Team on August 11th 2023, the Science Panel met in small groups eleven times between August 21st and October 2nd to discuss and respond to the charge. From October 3rd to October 16th, the Science Panel collaboratively wrote this report with writing and organizational support from the Water Center. The Science Panel presented this draft report to the DAP Team for review on October 17th 2023 and met with them to receive feedback on October 24th and 26th. The Science Panel took the DAP Team's comments and questions into consideration while editing, and presented this final report to the DAP Team on November 7th 2023.

Summary Recommendations

Recommendations are not in priority order, which will vary depending on the qualities of sub-watersheds.

Adaptive Management:

1) The State is in between setting goals for specific watersheds and agricultural practices and planning for the adaptive management phase of the diagram in Figure 1. The Panel

[1] Please see bios for each science panelist here.

recommends that the State of Michigan identify and commit the needed resources to sustain an independent scientific advisory panel to help guide and institutionalize adaptive management into the public and private sectors' collaborative efforts to deliver financial and technical support to the agricultural and stormwater management communities.

2) The Panel recommends that the State of Michigan consider this recent report submitted to the International Joint Commission by the Great Lakes Science Advisory Board - Institutional Arrangements of Nutrient Adaptive Management Work Group. The report contains numerous recommendations to improve communication and collaboration among the multiple jurisdictions concerned with the WLEB and charts the way forward for adaptive management. The report's key recommendations that apply to the WLEB include:
    a) Improve communication to link domestic and binational adaptive management processes.
    b) Institutionalize the Lake Erie Nutrient Adaptive Management Framework through dedicated funding and staffing.
    c) Address key research and data gaps.
    d) Explore lessons learned and best practices from other examples of adaptive management.[2]

Adaptive management in outreach and program implementation:
Local outreach, engagement, and program promotion efforts should include ongoing socio-behavioral monitoring and evaluation (including changes in social indicators of behavior, such as attitudes, perceived norms) and designs for future, more enhanced monitoring, as well as evaluation efforts to identify strategies that effectively expand the implementation of conservation behaviors. This includes clear goal and objective setting during the planning phase, implementation of multiple strategies, monitoring and evaluation, and periodic reassessment of outreach goals and objectives.

Accelerating the Adoption of Key Conservation Practices: Scaling up voluntary use of agricultural conservation practices is fundamentally a behavior change challenge. The State of Michigan should increase the capacity of government agencies, local conservation districts, and other conservation partners to leverage social and behavioral sciences, expand use of the Agricultural Inventory process to document current practice adoption, and support locally-led producer and landowner engagement. Specific recommended actions include:

1) The State of Michigan should increase internal capacity, or hire a contractor, to review existing (particularly recent) social and behavioral science research related to the adoption of farming practices and landscape level changes, such as creating wetlands, including in similar settings such as the Maumee River watershed in Ohio.
2) Conservation practice adoption should be an integral part of the adaptive management program. Stakeholders, state and local agencies, and partner organizations should evaluate and discuss the scientific data associated with farming practice impacts on water quality and farm production,

[2] See more here: *Evaluation of Institutional Arrangements to Affect Nutrient Management through Adaptive Management*

social perceptions of practice, and the options for water quality management in order to provide data-backed BMP recommendations to increase adoption of conservation practices.

3) The State of Michigan must increase agency and partner capacity to engage key stakeholders effectively, conduct and evaluate effective outreach strategies, and implement adaptive management. This includes training and support in communications, effective outreach, ongoing outreach evaluation, and monitoring of social indicators of behavior change. Further research is needed to identify successful engagement and outreach strategies within Michigan, including rigorous evaluation of the existing program and practice outreach efforts of state and local agencies and partner organizations.
4) The State of Michigan should expand on current efforts to support local "boots on the ground" agencies and organizations in outreach and engagement planning, coordination of existing programs and efforts between organizations, and increasing local capacity to lead practice promotion and sustained use by producers and landowners.

Support for peer-to-peer farmer networks is a demonstrated model for increasing use of conservation practices. Successful examples include:

1. Wisconsin's producer-led watershed groups,[3] which are supported through grants to locally-led groups of farmers with training and outreach support;
2. Practical Farmers of Iowa,[4] a state-based organization that coordinates on-farm research on conservation and innovative practices;
3. National Wildlife Federation's Conservation Champions program,[5] which provides outreach grants, communications training, and other ongoing support for farmer-led conservation outreach.

Water Quality Monitoring: The State of Michigan should continue its investment in an expanded network of water quality monitoring stations beyond existing sites in the River Raisin and Maumee watersheds. Additional monitoring stations should include both points where rivers flow into the lake and outflows from major sub-basins and be expanded to include the Huron, Rouge, and Detroit rivers. Measurements should be expanded at all existing and future sampling locations to include both discharge and total phosphorus (TP), and soluble reactive phosphorus (SRP)[6], nitrate, total Kjeldahl nitrogen, and ammonium. Suspended sediments and pathogens are also of interest. The sampling design should include targeted sample collection during storm events. The State of Michigan should prioritize maintenance of these stations over time to ensure a long-term water quality data set that can be used to inform adaptive management and other investment decisions by the state and partners. Reacting to these recommendations, Environment, Great Lakes, and Energy (EGLE) staff informed us that monitoring has been expanded in both coverage and measurements in the past few years. The Panel wishes to emphasize the importance of keeping up this expanded sampling for the long term to be able

[3] See Producer-Led Project Summaries from Wisconsin.
[4] See Asprooth et al. in the "Farmer/Landowner Willingness to Adopt Practices" section in the bibliography.
[5] See Bressler el al. in the "Farmer/Landowner Willingness to Adopt Practices" section in the bibliography.
[6] "SRP" is phosphorus in filtered samples that reacts with colorimetric reagents without pre-digestion.

to identify trends, and to ascertain the efficacy of measures to reduce nutrient export from land to water.

Utilizing Spatial Data: The State of Michigan must take full advantage of the rich body of geospatial data being assembled for the Michigan portion of the Western Lake Erie Basin (WLEB) to support management decisions. The state should also access improved spatially explicit models such as the Soil & Water Assessment Tool (SWAT) that estimate nutrient and sediment loss.

Addressing Scientific Uncertainties: Major gaps in our scientific understanding include:

1) Given the accumulating scientific evidence of the effect of nitrogen availability on bloom community composition, toxicity, and duration, the cost/benefit of single (phosphorus) versus dual (nitrogen and phosphorus) nutrient management should be considered;
2) The net effect of conservation tillage[7] practices on phosphorus export to streams is uncertain in the WLEB; and
3) The relative importance of tile drainage vs. overland flow for phosphorus export from cropland is uncertain and needs to be understood to prioritize mitigation actions.

Funding for research to address these scientific uncertainties is likely to come from a combination of federal, state, and non-governmental sources, and is likely to be conducted primarily by academic researchers. The State of Michigan should encourage and support this research to the maximum extent possible.

Collaborative Partnerships:

1) The Panel supports the importance of the State of Michigan gaining access to data from federal agencies such as the Farm Service Agency and the Natural Resources Conservation Service to inform the adaptive management process. This includes current information about the extent and location of practice adoption, program participation, and other forms of action undertaken by land owners and managers. The Panel recommends the State of Michigan reach out to members of the Chesapeake Bay Program Partnership to learn first hand from their experiences and solutions to gaining access to practice implementation data from the U.S. Department of Agriculture's agencies.
2) Michigan's Quality of Life agencies should serve in an agenda-setting and capacity-supporting role for local agencies and conservation partners best positioned to engage local farmers and other stakeholders. These partners include conservation districts, watershed organizations, local citizen groups, farmer-led organizations, and other conservation groups.
3) The Panel sees value in a higher level of collaboration between Michigan and Ohio under the Western Lake Erie Basin Collaborative Agreement process.

[7] Conservation tillage is referred to in this document as any form of reduced tillage that disturbs less soil than conventional tillage.

Detailed Responses to the Charge Questions

Overarching Question 1: *Review the DAP's "Priority Objectives" to meet target reductions in nonpoint source P and offer suggestions to refine existing or suggest different objectives.*[8]

Michigan Domestic Action Plan Priority Objectives

1: Maintain the Phosphorus reductions achieved in the GLWA discharge due, in part, to the more stringent TP effluent limits placed in the NPDES permit in 2013.

2: Achieve reductions in P discharged from the DUWA WWTP and continue reductions at YCUA WWTP.

The Panel agrees that these are important objectives but are not within the scope of this report.

3: Identify priority areas in Michigan's portion of the Maumee River Watershed for P reductions. Identify and implement priority actions to reduce P loads from Michigan's portion of the Maumee River Watershed.

Science Panel Suggests:

- **Access Soil & Water Assessment Tool (SWAT) models developed for the whole Maumee River Watershed to identify the best combination of practices to achieve the 40% phosphorus reduction goal in the Michigan portion of the Maumee.**
- **Strengthen functional working relationships and coordination between local, state, and United States Department of Agriculture (USDA) counterparts** to connect available programmatic resources with "boots-on-the-ground." Given funding limitations, prioritize and guide at the local level. Examples of the potential outcomes of such strengthened working relationships could include development of a shared list of the most cost efficient and pollutant load reducing conservation practices as well as agreement to geographic priority areas within which to collectively target financial and technical support resources.
- **Support the expanded on the ground use of the Agricultural Inventory (field inventory, desktop analysis, and the Agricultural Conservation Planning Framework (ACPF)) by local and partner organizations beyond conservation district offices to identify geographic priority areas for conservation action**. This geographic focus should be developed in conjunction with locally-led outreach and engagement efforts that consider producer's perspectives regarding adoption of priority practices. Leverage local relationships to incorporate producer/landowner understanding of issues, such as taking land out of production, additional costs of implementation and maintenance, and fitting best management practices (BMPs) into existing cropping systems. The Agricultural Inventory is a powerful tool for identifying areas for further action, but given the voluntary nature of agricultural practice adoption, the Agricultural

[8] Italics indicate text from the "Charge to the Science Panel."

Inventory must be used in conjunction with other tools, including social science and local relationships by the "boots-on-the-ground" to make a meaningful difference.

4: Support and invest in research to better understand the causes of HABs, including invasive mussels and SRP, and how these factors increase/decrease HAB events.

Science Panel Suggests:

- The Panel notes the growing scientific evidence that nitrogen is a limiting nutrient for HAB growth, duration, and toxicity, and that dual management of phosphorus (P) and nitrogen (N) may be beneficial.[9]
- While there is a need for research on how N influences harmful algae blooms (HABs) in WLEB, the Panel recommends that Michigan **prioritize monitoring and research to assess the effect of BMPs on N as well as P export from land to water:**
    - What is the potential for N reduction in tandem with P reduction measures?
    - Are special measures needed to address N, or do the measures to reduce P also reduce N sufficiently?
- The Panel was made aware of the paucity of information on soluble reactive P (SRP) vs. total P (TP) for Michigan watersheds,[10] and the need to set standards for nonpoint source SRP in Michigan. Therefore, the Panel suggests that **future monitoring of streams and rivers, as well as wastewater treatment plant effluent, must include SRP as well as TP measurements.**
    - Investigate if and why SRP standards might need to be different in Michigan compared to other parts of the WLEB where data have been deemed adequate to set standards.
- There is a considerable body of published research on the factors that lead to HABs in Lake Erie, as well as the hypothesized roles of invasive mussels. Although scientific uncertainties remain, the Panel recommends that this research should not be a priority for the State of Michigan.
- The state should collaborate with the United States Environmental Protection Agency, United States Geological Survey, and Environment and Climate Change Canada to reinstate monitoring of the Detroit River's P inputs into Lake Erie.

5: Utilize research and field demonstrations to identify the suite of BMPs that work collectively to reduce both TP and SRP at the field implementation level.

Science Panel Suggests:

- **The State of Michigan should focus research on which BMPs are most efficacious** and how to encourage their adoption in the Michigan portion of the WLEB:
    - Conduct research to understand and improve adoption of BMPs specifically in the WLEB (see Research section on page 30),
    - Organize field days to bring producers together to demonstrate how practices work, and

[9] Review the "Nitrogen" section in the bibliography for relevant studies.
[10] The Panel notes that the National Center for Water Quality Research at Heidelberg University has been measuring SRP in the River Raisin upstream of Monroe since 2002.

    - Develop field scale demonstrations for key innovative practices to increase their value for outreach. Examples of field scale demonstrations already underway include the Saline River Watershed Buffer Easement Pilot Project (Sub-task 6k) and the Tile Line Discharge Control Study (Sub-task 5e).
- The State of Michigan should develop a program beyond the Michigan Agriculture Environmental Assurance Program (MAEAP) explicitly to address fertilizer application rates beyond the scope of current nutrient management plans, which even if followed by producers, may not currently result in decreased P application rates and/or reduced P losses.
- Identify high priority fields using the Agricultural Inventory process - then expand application of the Agricultural Inventory process to all HUC-12 watersheds.
- Use spatially explicit modeling in WLEB's specific watershed configuration to identify:
    - Which fields export the most nutrients? (consider tile drainage as well as overland flow)
    - Which BMPs best fit fields of concern?
- **The State of Michigan should set up a structure for funding research** on stacked BMPs.

6: Implement P control actions in the River Raisin Watershed to achieve the target load reductions.

<u>Science Panel Finds:</u>

The recommendations listed above related to scientific uncertainties, the need for research on BMPs best suited to local settings, the challenges of adoption, and communication and collaboration to advance adaptive management all apply to the River Raisin and theMaumee River watersheds.

- The Panel notes that the entire River Raisin watershed has long been a priority for nonpoint source (NPS) measures, therefore spatial prioritization is already well documented and now the challenge is implementation.
- The Panel supports the continued need for the State of Michigan to be able to access Natural Resources Conservation Service (NRCS) and Farm Service Agency (FSA) data to compile full resolution field-scale data on BMP adoption in the River Raisin.

7: Maintain and expand partnerships to provide valuable technical and financial assistance to farmers. Continue expanded Conservation District MAEAP technical assistance levels through 2017 and beyond.

<u>Science Panel Suggests:</u>

- The State of Michigan needs to coordinate with federal programs, particularly NRCS and FSA.
- **This objective makes the assumption that more technical and financial assistance is what is needed to get practices on the ground, but it is imperative to conduct more social science research, including both quantitative (e.g. surveys) and qualitative (e.g. interviews, focus groups) methods in the WLEB to understand how to increase adoption of BMPs, including:**
    - Understand major cognitive and social barriers, such as social norms, funding incentives, new equipment, and decision making/advice by private sector crop advisors, to better understand what limits both voluntary farmer participation in programs (e.g., Michigan

Agriculture Environmental Assurance Program (MAEAP), USDA programs) and adoption of key practices.
    - Mixed methodologies that combine different qualitative and quantitative methods are best suited to understanding complex and dynamic systems, but may require collaborative approaches with multiple partners, including state and local agencies, research institutions, non-governmental organizations, and community groups.
    - Quantitative, survey-based data are needed to get a complete picture of the cultural landscape in Michigan's portion of the WLEB (such as the Social Indicator Planning & Evaluation System (SIPES)). Any research approach has limitations, and survey research can be limited by low response rates. Current best practices in survey methodologies include providing small cash incentives, providing multiple modes of survey completion, and partnering with non-state agencies to conduct surveys.
- The State of Michigan can learn from the existing research on farmer adoption:[11]
    - Look at work in northwest Ohio where some progress has been made along these lines, including understanding landowner motivations for installing wetlands (Soldo et al. 2022) and differences in management decision-making among segments of the farming population (Wilson et al. 2019).
    - There is already momentum to develop a social science community of practice - framework to coordinate across Great Lakes universities - via the Cooperative Institute for Great Lakes Research (CIGLR) Consortium - white paper is under review.[12]
    - Focus should not just be on existing barriers to practice adoption, but also interventions and engagement approaches that can increase adoption of priority practices.

8: Increase and maintain MAEAP practice implementation for long-term water quality improvement.

- The Quality of Life Agencies should work with the state legislature and collaborate with federal partners to **track investments in the WLEB watershed to ensure that investments are strategically directed and complementary rather than redundant.**
- Adoption likely remains a bottleneck. Investments in social science recommended above, including understanding work done in similar places, to understand barriers and pathways to adoption may help MAEAP enroll more farms in their voluntary verification program. While financial incentives are often an important motivation for farmer participation in programs, these incentives alone may be insufficient if program requirements are onerous or participation conflicts with other farm management goals. Gaining a better understanding of farmer perceptions of MAEAP and barriers to participation would inform engagement and outreach by state staff and local partners.

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[11] Please review the "Farmer/Landowner Willingness to Adopt Practices" section of the bibliography for relevant studies.

[12] Until the community of practice report is available see the Great Lakes Visioning Report which calls for a community of practice and defines it as "a group of people who share a common concern, a set of problems, or an interest in a topic and who come together to fulfill both individual and group goals. Communities of practice often focus on sharing best practices and creating new knowledge to advance a domain of professional practice. Interaction on an ongoing basis is an important part of this. (Edmonton Regional Learning Consortium, 2023)."

- **The State of Michigan must increase agency and partner capacity to engage key stakeholders effectively, conduct and evaluate effective outreach strategies, and implement adaptive management.**

9: Improve and increase outreach to the public and farmers to promote understanding of the basin and good conservation practices by initiating new targeted outreach campaigns, workshops, field demonstrations and information sharing.

Science Panel Suggests:

- Apply the 9 step planning approach used in watershed planning, such as the 319 approach used by EGLE's Nonpoint Source Program, to help local partners who may not have the capacity for planning.
- Learn from South Florida Water Management District's interactive, participatory modeling process[13] that involves the interested public in order to:
    - Facilitate information exchange;
    - Understand what the interested public thinks will reduce P;
    - Run models to demonstrate to the public whether their idea(s) will work and explain ecosystem complexity; and
    - Build trust to move forward.

10: Promote wetland restoration and land management initiatives to reduce phosphorus loading.

Science Panel Suggests:

- The state needs to understand why there has been little landowner engagement in wetland restoration in Michigan's portion of the WLEB, such as low response rates from mailings about potential wetland restoration sites.
    - If parties do not already talk to each other, consider recruiting an external facilitator to support state-landowner communication.
    - Robyn Wilson's (Ohio State University) research provides good information about how to identify and communicate with willing landowners regarding wetlands and edge-of-field practices.[14]
- Requirements associated with funding sources and permitting create additional barriers and should be addressed.
    - **The Department of Natural Resources should pursue more flexible wetland funding sources** that do not require landowner sale to the state and are sufficiently attractive to compete with counter-offers.

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[13] See Chapter 3 in Van den Belt, Marjan. 2004. Mediated Modeling: A System Dynamics Approach to Environmental Consensus Building. Washington: Island Press.

[14] Please review the "Farmer/Landowner Willingness to Adopt Practices" section of the bibliography for relevant studies.

What metrics or monitoring are needed to adequately monitor progress on meeting the Priority Objectives?

See Appendix B for responses broken down by Priority Objective Sub-tasks.

Overarching Question 2: *Will the adaptively managed set of projects, when taken together, provide the necessary elements for a TP and SRP (when set) reduction strategy that will achieve the reduction targets set by the state? If not, what additional activities, projects or programs are needed?*

Science Panel Response:

The "adaptively managed set of projects" may represent the best way forward for the time being, but at this time the Panel cannot predict how well they will work given the identified scientific uncertainties, limited funding, and social impediments to adoption. For these reasons, **monitoring, reevaluation, and adjustment of priorities (i.e., adaptive management) in the coming years is crucial.** While local demonstrations and pilot projects are likely necessary to increase interest and adoption of priority practices, these efforts are not currently connected in an actionable way to larger engagement efforts. There is a need for strategic outreach to connect MAEAP with other local, state, and federal conservation program efforts, demonstration and pilot programs, landowner & manager engagement, and spatial planning efforts. Strategic outreach should be supported by ongoing social science research in the planning phase, and outreach program evaluation as part of monitoring, within the adaptive management framework. To achieve this level of planning, research, and evaluation, the state must expand its internal capacity in addition to contracting research and evaluation efforts with academic and private partners.

Greater communication and collaboration with the other jurisdictions in the WLEB watersheds will benefit the state's efforts. **The social science research needed to better understand the barriers to adoption in Michigan** and similar settings, such as Ohio, is particularly important. How all of these projects will affect SRP loads cannot be judged until the Panel has more information on the spatiotemporal patterns of SRP loads in Michigan's rivers and point source effluents flowing to the WLEB.

Overarching Question 3*: Is the DAP Team asking the right questions about NPS pollution?*

Science Panel Response:

- The state should synthesize lessons learned from existing on-field BMP research:
  - Generally look at other heavily tile-drained systems, such as Ohio;
  - H_2Ohio Wetland Monitoring Program;
  - LEARN - Lake Erie Aquatic Research Network;

  - WLEB Regional Conservation Partnership Program (RCPP) in Indiana and Ohio; and
  - SWAT modeling that is currently underway in the Maumee, that extends into Michigan, and could be applied similarly in the River Raisin.
- Focus more on the social science side of BMP adoption in the Michigan context.
- **Create a central place to compile information: work across jurisdictions to compile data/information from across Lake Erie's watershed.** Consider expanding the scope of the Great Lakes Water Management System (GLWMS).
- Find out what would trigger funding support from local, state, and federal policymakers.
- The working hypotheses as presented to the Panel (see Appendix B) are well known measures. The real challenge is how much and how fast can the State of Michigan meet the Priority Objectives in the DAP with the current project methods and limitations in funding?

How could projects better address their associated working hypotheses; or how could these hypotheses be adjusted to address existing projects?

See Appendix B for responses broken down by Priority Objective Sub-tasks.

Overarching Question 4: *How should the conceptual adaptive management process and support structure be adjusted in order to implement an effective process? What additional resources or steps should we consider?*

Science Panel Response:

The Panel has observed that the State of Michigan is in the early stages of building the necessary programmatic infrastructure and institutional working relationships and mechanisms to implement an adaptive management process. The State has some of the key foundational building blocks in place to make progress in the coming years.

Overarching suggestions for moving forward with adaptive management:

- **The State of Michigan should lead coordination, including convening, of all entities collecting and analyzing data and working on models:**
  - Examples for convening diverse stakeholders and relevant organizations, such as local and state agencies, non-governmental organizations, private sector and agricultural retail companies, producers and landowners, municipalities, include:
    - Michigan's Water Use Advisory Council
    - The Collective Impact Forum
- **Agree on one or two systems (from data collection methods to modeling frameworks) to use across every department/agency** and write a proposal for funding it.
  - The agencies must decide who is leading the effort, and
  - Create an institutional structure within the agencies to maintain the effort and include other academic and non-governmental organizations with data analysis and

interpretation expertise to collaborate in the analysis and interpretation of the synthesized data.

- Bring the public, including indigenous populations, into the discussion on a regular basis to review progress.
- Emphasize public health because it is easier to make a case for action when a drinking water supply is threatened, rather than when an ecosystem is threatened.
- Identify triggers to help individuals understand and identify the need for behavior change. Who is drawing connections for decision makers?
    - Establish generally accepted targets and triggers for action;
    - Develop shared numbers collectively to demonstrate when the current strategy is not working and a new strategy is needed.

Examples of tools that could be used in the adaptive management process:

- The Social Indicators Data Management and Analysis Tool (SIDMA) is a validated set of survey questions used to assess a wide range of behavioral and cognitive indicators. The associated handbook also includes guidance for practitioners to apply survey methodologies for pre-post intervention.
- Apply key elements from the Collective Impact Approach including coordinating mutually reinforcing activities, shared measurement systems, and continuous communication to the state's adaptive management model.
- Use the Great Lakes Water Management System (GLWMS) to track progress and report out to stakeholders. Run models on different BMP policy scenarios. Use this modeling tool to carry out a participatory modeling process.
- Develop physical and numeric models to address uncertainties and hypotheses associated with regulatory criteria through a participatory modeling approach.[15] Additional suggestions for such models include:
    - Break up the watershed into sub-basins based on agricultural land use type, e.g., dairy, row crop, grazing;
    - Develop a model for each sub basin - shifting focus away from specific fields;
    - Run an optimization model - estimate the proportion of each agricultural type and level of BMPs necessary to achieve a 40% reduction goal. For example, run a model with and without buffer strips to estimate how much of a difference they would make.

Addressing specific components of adaptive management (see Figure 1):

Research & Modeling Support (planning phase): The state should **integrate data across systems, including water quality data, best management practice (BMP) location data (GLWMS), modeling, etc., to enable data-driven prioritization and action planning.** If incorporating human dimensions research, this is also complicated by the need to make these data spatially explicit so they can be integrated with

[15] See Chapter 3 in Van den Belt, Marjan. 2004. Mediated Modeling: A System Dynamics Approach to Environmental Consensus Building. Washington: Island Press.

other spatial data. Agencies and organizations engaging in producer and landowner outreach need to know where and how to prioritize actions to most effectively target scarce resources.

Programming Support (planning phase): The need to integrate goals, outcomes, and activities across agencies and other conservation partners poses a significant coordination problem for the state. This is complicated by data sharing limitations, such as with some Farm Bill program data. Multiple parallel projects and efforts, such as Farm Bill conservation programs, MAEAP, state efforts, NGOs, farmer-led/community based efforts, create additional challenges to coordination. Internal organizational capacity to facilitate meetings, establish processes, and sustain efforts is critical. Examples of where this capacity provides critical support include:

- Outreach and engagement planning, which is important, challenging, and often under-funded. Watershed-improvement projects typically begin with a planning process, but local conservation districts, new organizations, and organizations with high staff turnover may not have plans in place. Strategic allocation of scarce resources (financial, technical, etc.) can benefit from planning and an adaptive management design.
- Sustaining adoption of BMPs over time, which requires access to research and data sources, coordinated actions and resources between programs, and effective engagement of producers and landowners.
- Effective leveraging of voluntary programs to ensure stakeholder trust and awareness of programs, equitable access to programs, and overall cost-effectiveness across programs.

State agencies can build on current efforts to support local outreach and engagement efforts by providing resources, training, and convening partnerships between conservation organizations engaging with landowners and farm operators on conservation efforts. Engagement efforts are likely to be most effective when led by individuals and organizations with established relationships and trust among relevant audiences, including local conservation districts. State agencies may not be best positioned to be authentic messengers with agricultural stakeholders, but should play an important support role for the front line organizations, including peer-to-peer networks.

Monitoring and Evaluation (evaluation phase): Evaluating outreach and engagement efforts is often lacking in conservation activities. Recognizing behavior change as a sometimes long process, requiring multiple engagements over time and through multiple channels, necessitates ongoing evaluation and monitoring from a socio-behavior change perspective. Understanding and identifying the impacts of outreach activities and overall strategies is challenging, particularly given other structural factors influencing farmer decisions, such as markets, other policies, weather, meta-narratives and socio-political influences from both within and outside of the basin.

- Outreach evaluation requires staff capacity, financial resources (e.g. for ongoing survey work, outside program evaluation), training, and support. Ideally, this type of evaluation should be done within organizations and coordinated across organizations.

Key Elements of a Realistic and Effective Adaptive Management Framework:

Based on the experiences of the Science Panel members who have implemented adaptive management processes in other contexts, the Panel recommends the State of Michigan consider establishing the following key elements of a realistic and effective adaptive management framework. The Panel recognizes that building this adaptive management infrastructure, and the supporting institutional and collaborative working relationships, will take time and resources. While the commitment will be considerable, the resulting benefit to decision making, e.g., increased efficiency and cost-effectiveness, is worth the investment.

Key Elements:

1. Comprehensive and Integrated Monitoring Networks
2. Management-oriented, Linked Models Directed towards Scenario Simulation and Interpretation
3. Tracking, Reporting and Verification of Implemented BMPs
4. Monitoring, Reporting and Loading Trend Analysis of Permitted Municipal and Industrial Dischargers
5. Assessment of Land Use and Land Cover Trends Over Time
6. Collaborative Data Analysis and Interpretation System
7. Elements for Explaining Trends
8. Numerical Goals and Targets Against Which to Assess Progress
9. System for Regular Public Reporting of Progress
10. Recognized Triggers which will Prompt Adapting Public Policies and Management Actions

For detailed recommendations for pursuing each element of adaptive management see Appendix C.

The Panel recommends the State of Michigan continue to work through independent science advisory panels to collaboratively address on what scale (temporal and spatial) and to what extent each element is in place and identify the next steps to build a functional adaptive management framework. The Panel further recommends reaching out to other programs and partnerships across the country who have found varying levels of success (and, therefore, important lessons learned) in building and implementing their own adaptive management frameworks.

Overarching Question 5: *Referencing the list of uncertainties below:*

a. Which of these uncertainties will affect each adaptive management project?
b. Are there additional uncertainties not currently being accounted for in the AMP?
c. Identify strategies to reduce them over time if possible (e.g., effectiveness, costs, and relationships).

AMP p. 36: "Uncertainties are defined as gaps in our knowledge. There are multiple sources of uncertainty that apply to an adaptive management process of this magnitude including:

1) inadequate scientific understanding of phosphorus cycling and climate change impacts,
2) rapidly evolving technologies and information about the relative effectiveness and cost of

various agricultural engineering practices to mitigate phosphorus loss,
3) social and economic factors like changing interstate and binational governance structures, and
4) fluctuating agricultural commodity prices."

Science Panel Response:

Additional Uncertainties:
Nutrients:

- Dual N and P impact on HABs:
    - **To what degree do we need to control N?**
    - If we don't control N will we produce more toxic algae?[16]
- How will changes in nutrient availability and ratios affect composition and species of HABs; will we see a shift to new species (e.g., *Dolichospermum*) and toxins?
- How might the susceptibility of the WLEB to eutrophication change in the face of uncertainties such as new invasive species or climate change (e.g., timing of nutrient loading, water temperature, shifts in wind patterns)? Should we expect a change in the relationship between P load and bloom response?
- The Panel is not sure if a recent estimate by Bocaniov et al. 2023 regarding internal P loading as the residual of a long-term, lake-wide P mass balance comparing inputs to outputs is accurate because it depends on uncertainties in loading numbers. On the other hand, this may be the only way to estimate lake-wide internal loading.
- **What is the importance of SRP, both in the context of wastewater treatment plant effluents and considering the often long flow-paths of water from farm fields to Lake Erie?**
    - SRP is probably not passively transported through river networks. In fact, there may be considerable reactivity and turnover, especially in the headwater streams.
    - Therefore, the state needs to know where most of the SRP at the river mouths originates within the fluvial network in the Michigan watersheds in order to target actions to mitigate SRP loading in those specific river systems.

Policy:

- Future levels of funding and investing are unknown, especially Farm Bill programs and Inflation Reduction Act (IRA) funding which has recently invested ~$18 billion into conservation programs.

Climate Change:

- Climate scientists predict a trend towards greater rainfall intensity and resulting streamflow. Therefore, even if farmers reduced field applications of phosphorus by 50%, increased flow may counteract ecosystem outcomes.
- Does the probability of algal blooms increase with increasing water temperature?
    - The Panel notes here that modeling does not show clear evidence of increasing water temperatures in the western basin in the late summer; neither that water temperature correlates with bloom toxicity or size.

[16] Please review the "Nitrogen" section of the bibliography for relevant studies.

- **Effects of climate change on BMPs are largely unknown.**

Which of these uncertainties will affect each adaptive management project? Are there additional uncertainties not currently being accounted for in the AMP? Identify strategies to reduce them over time if possible (e.g., effectiveness, costs, and relationships).

See Appendix B for responses broken down by Priority Objective Sub-tasks.

Watershed Practices

1. What are cost effective methods for detecting changes in water quality (i.e., TP and SRP) resulting from the implementation of agricultural best management practices (BMPs) and landscape infrastructure.

Science Panel Response:

The Panel emphasizes the importance of an expanded monitoring network, even if it seems expensive, to help determine priorities and track progress. Monitoring the main river channel outflows to Lake Erie is necessary, but does not provide information on the subbasin scale that could show where BMPs are most needed and/or how well they are working to reduce P loads.

Monitoring locations:

- Outflow of whole system is necessary;
- Monitor sub basins with the most concentrated BMPs;
- Monitor sub basins that contribute disproportionately high P loads; and
- Consider N loads.

Balancing Timing vs. Spatial Considerations:

- **The state needs long-term monitoring to evaluate effectiveness: it may take a decade or longer to see the full results of BMPs in stream and lake monitoring trends.**
- More detailed spatial monitoring could be conducted over shorter periods of time.

Learn from Heidelberg's monitoring network:

- Students collect samples on a weekly basis and auto collectors at United States Geological Survey (USGS) stations collect samples three times per day.
- Continuous monitoring with autosamplers allows estimation of loads during high discharge events.
- Updates public database monthly.
- Data are already available from this network for the Maumee and River Raisin in Michigan.

Suggestions:

- Relate auto sampler data to a variety of BMPs in the upstream watershed.
- Auto samples can be compared to field samples for SRP and demonstrate long-term trends and big changes, even if auto sampling misses small changes.
- Manual water sampling and lab analysis will likely still be needed in areas with low P levels because detection limits may not be low enough with currently available/affordable field sensor systems.
- Using macroinvertebrates as bioindicators works in streams with higher gradients and flow but is difficult on flat agricultural terrains which have fine sediment, low summer flow, and grass-filled channels. These conditions make it difficult to find good sites to measure due to sampling difficulties.[17]
- **Utilize citizen science. Community members can collect water samples and send them into a lab for TP.**
- Modeling results that provide estimates about where P originates in a watershed will help given the limitations on how much we monitor. It is important to acknowledge uncertainty in models.

Challenges:

- Cost effective monitoring approaches for attributing changes to BMP implementation vs. changes due to climate variability may be difficult to identify.
- Policy relevance: It is difficult to attribute quantifiable changes in P loading to landscape changes such as implementation of BMPs. It is difficult to draw connections between P loads and BMPs due to concurring weather changes and significant time lags, on the scale of decades.

2. How will warmer winter temperatures and changing precipitation patterns impact:

Changing Precipitation:

- Larger storms will lead to bigger runoff events in the future. **The more water we can retain on the landscape (e.g., in restored or created wetlands, or behind water control structures), the more control we will have over runoff during bigger storms.**
- More precipitation will fall as rain rather than snow in the future, impacting the timing and amount of water moving to streams.
- The prospect of wetter springs encourages the practice of fall tillage. Fall tillage leaves soils more exposed to erosion during the non-growing season, making fields more susceptible to soil erosion and sediment and nutrient losses.
- More saturated conditions, due to larger storms combined with conservation tillage practices and drainage water management, may cause fields to become more susceptible to soil nutrient leaching and export via tile drainage or surface water (overland) flow.

[17] Please review the "Proxies for Water Quality" section of the bibliography for relevant studies.

- Increased precipitation will likely increase the need for tile drain installation to reduce flooding. Michigan has already seen a 17% increase in tile drains from 2012-2017.[18] Tile drains increase runoff, making streamflow flashier, and enhance nutrient export into river networks.

Warmer Temperatures:

- Temperatures are generally trending up.
- Increasing water temperatures reduce ice coverage on Lake Erie.
- Inland HABs may become more toxic. The same nutrient loads may produce more cyanobacteria at higher temperatures.
- Warmer conditions will increase water losses by evapotranspiration, potentially reducing stream flow.

a. The efficacy of agricultural BMPs and landscape infrastructure across the Watershed?

Science Panel Response:

- **Tile drainage control boxes have the potential to manage small storms, but the importance of smaller storms to P export is still unknown.**
- Multiple Maumee watershed SWAT models show mixed results about how climate change would impact water quality and BMP effectiveness:[19]
    - **When running an ensemble of climate model projections through multiple watershed models, the uncertainty was great enough that a clear impact of climate change on hydrology (surface runoff, tile drainage) and water quality (including TP and SRP) could not be detected** (six CMIP5 climate models[20] were used with changes from historical (1996–2015) to mid-century (2046–2065));
    - The models did show that simulated BMPs, such as cover crops, buffer strips, and subsurface application of phosphorus fertilizers, would be effective in a future climate.
- A separate study (Apostel et al. 2021) used a single SWAT model to predict decadal trends in nutrient loading and attribute these to climate and management drivers. This work built on Jarvie et al.'s (2017) work showing that 35% of increased SRP loads were attributed to higher runoff volumes due to climate variation.
- Depending on what model is used, this trend can reverse mid-century due to the interaction between warming and resulting higher rates of evapotranspiration, leaving less water to flow into streams. However, irrigation may be used to compensate for this change.

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[18] United States Department of Agriculture National Agricultural Statistics Service 2017 Census of Agriculture.

[19] Please review the "Climate Change" section of the bibliography for relevant studies.

[20] These (CanESM2; CSIRO-MK3-6-0; CSIRO-MK3-4-0; CSIRO-MK3-10-0; MPI-ESM-LR; NorESM1-M) climate models were chosen because they provided a range of projected change that, compared to all climate models, was near the average for temperature increases, and spanned the range for precipitation changes from slight decreases to considerable increases.

b. The implementation of agricultural BMPs?

Science Panel Response:

- A longer growing season will likely increase the practice of double cropping (e.g., soybeans after wheat during one growing season), which could increase soil compaction due to more passes of heavy equipment on fields and more fertilizer application. There is uncertainty about the impact of these changes on the environment.
- The use of irrigation to reduce risk of drought is already on the rise. Increased irrigation could change stream flow depending on practices and sources of water, and may compensate for the climate-induced increase in evapotranspirative water loss.[21]

3. Do you predict shifts in agricultural nutrient management practices as climate conditions change and as population size and density grows in Michigan? Have these shifts occurred in other states? If so, what can be learned from them?

Science Panel Response:

- Increasing rural populations will increase septic loads.
- Increases in the number of people to be fed (beyond the scope of Michigan) may result in increasing the size/number of CAFOs, resulting in more manure production in the WLEB.
- The redistribution of people, as urbanites move into agricultural landscapes, could put pressure on agriculture to address water quality issues as new residents notice manure applications, stream flow changes, and well contamination. This attention from the general public could influence policies about agricultural nutrient management.
- Florida has seen huge population growth, with land shifting from agricultural to residential. Water from residential land use now goes through treatment plants to remove P.

Land Management Practices

1. Would additional wetlands assist in the reduction of P delivery to Lake Erie?

Science Panel Response:

Passage of stream water through wetlands and floodplains attenuates high flow events, which in turn reduces sediment transport, scouring, and bank erosion. During residence of stream water in wetlands and floodplains, nutrients tend to be removed by sediment trapping as well as biological processes. Based on lessons learned in Ohio, **the Panel suggests that flow-through wetlands (wetlands with a defined inflow and outflow) are by far the easiest to monitor and assess and have proven to be very**

[21] See Michigan State University extension report about irrigation trends in Michigan.

successful at nutrient load reduction. Data on phosphorus load reduction through wetlands in Ohio can be found in Jacquemin et al. 2022.

Critical features make flow-through wetlands both easy to maintain and to monitor to ensure long-term nutrient removal:

1. **A defined outflow,** preferably via a controlled drainage structure or weir using a control box (e.g., *Agri Drain* or similar structure). This allows water volume passing through the wetland to be continuously monitored with an inexpensive water level sensor, which is critical to measure discharge during high flow (when sampling may not be possible), and is required to monitor the nutrient load reduction.
2. **An initial settling pond in which sediment will settle out**. This is critical for P management, as total P includes a large proportion of P bound to iron or aluminum in soils, and the pool can easily and cheaply be dredged when the saturation point is reached. Annual testing of sediment Soil P Sorption Capacity gives an indication of how much additional P the sediment can retain–when it reaches capacity, the wetland will no longer be a sink for P. The timing for P saturation depends on the initial soil properties (sites for P to bind), residence time of the wetland, and the load of P into the wetland.
3. A design that **optimizes residence time of 2-3 days** under base flow conditions.
4. If possible, an **inflow pump to ensure the wetland stays wet** during the summer and that daily water inflow can be turned off in winter after vegetation die-off, although off-channel flow during storm events will still occur.

Floodplain wetlands, including the constructed "two-stage ditch" design,[22] serve to reduce stream energy under high flow and preserve bank stabilization, and are also important for reducing sediment, and therefore phosphorus transport downstream, but are much more difficult to assess for their effects on stream nutrient loads. Monitoring of bank erosion in these cases is more directly conducted by time-lapsed drone images of the banks before and after construction, paired with soil test phosphorus levels to estimate nutrients retained via sediment trapping and bank stabilization.

Floating wetlands treating tile drainage water can also be effective based on a pilot study by Michigan State University (MSU) Institute for Water Research (IWR) showing an average P reduction of 60%. A floating wetland requires monitoring and maintenance as it reaches saturation and requires 3-4 ft deep root systems for capturing sediment. **Floating wetlands serve a potential role in specific locations.**

Coastal wetland restoration along Lake Erie will improve habitat but may not reduce P because of low levels of water exchange with Lake Erie and the fact they attract waterfowl, which add P.

a. What are the siting considerations for these types of BMPs?[23]

Science Panel Response:

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[22] See Kalcic et al. 2018 in the "Edge-of-Field Practices" section of the bibliography.

[23] Consider Bill Currie's species modeling for wetland plant nutrient uptake effectiveness.

- **Topography:**
    - For two-stage ditches, floating vegetative systems, and filtration systems all need elevation drop to direct water flow passively through them. These BMPs require natural elevation gradients to drive water flow.
    - For wetlands, water needs to flow continuously. For example, create equalization basins upstream of stormwater treatment areas to maintain flow even during dry periods.
- Appropriate sites are often problematic for farming due to poor drainage, and can readily be converted back to wetlands by removing drainage structures.
- A residence time of flowthrough water of 2-3 days is optimal for removal of nutrients in wetlands (including floodplain wetlands).

b. *Are there existing examples of effective approval (permitting) approaches that can expedite implementation in other states?*

<u>Science Panel Response:</u>

- DNR's wetland mitigation banking program has developed wetlands of substantial size elsewhere in Michigan.
- Regulated water bodies in Michigan require a permit from EGLE for wetland creation or restoration. Small wetlands may have fewer permitting requirements and lower barriers to implementation, yet still serve to trap nutrients vs. larger wetlands which may take longer to establish. However, larger flow-through wetlands positioned to intercept stream water downstream in the river network may be more effective by "processing" more water compared with an equal area of smaller ones that intercept runoff or headwater stream flow.

c. What effective approaches could be used to engage landowners and agricultural producers in wetland restoration or creation on agricultural lands?

See response below to questions 3 and 4.

2. Is there existing work [in Michigan or other states] related to drains or other riparian areas that would be beneficial for P reduction? How much of that work would need to occur to see a measurable reduction?

<u>Science Panel Response:</u>

- **Ohio is conducting a test in the Maumee by loading a watershed with BMPs and monitoring outcomes against a paired watershed without the BMP emphasis**.
- IWR is working on SWAT + models in the St. Joseph, Bean Creek, and the Ottawa-Stoney sub watersheds and an updated SWAT model for the Maumee. These models include updated climate and weather inputs.

3. Are there actions that other land managers, private landowners, or municipalities could be doing to also help achieve the NPS P reduction?

4. What should drain commissioners consider when implementing two-stage drainage ditches, including infrastructure limitations, assessment, and long-term operations and maintenance?

Science Panel Response:

- The Panel suggests that the state first collect information on what local county drain commissioners are currently practicing.
- The Panel suggests that the Quality of Life Agencies hire a contractor to conduct a literature review on two stage ditches and floodplain wetlands to determine how they can best be configured to maximize sediment and nutrient removal from stream water.

Agricultural Practices

1. What is the suite of in-field and edge-of-field BMPs that are effective at addressing TP and SRP combined that could be implemented as sets of stacked practices? Can these practices be ranked from least to most effective?

Science Panel Response:

While studies show that TP may be reduced through reducing sediment loss, studies are less clear about which practices are effective at reducing SRP. Generally, the most effective practices prioritize soil contact through subsurface P applications.[24] P enriched soils with high loss potential may require engineered edge-of-field P filters.

Approach to choosing site-specific stacked BMPs:

- Place BMP practices into buckets: Prioritize practices for different nutrients (TP, SRP, N) based on existing research.
- Identify suites of practices in different production systems based on site specific characteristics (e.g. soil type, slope) and use to develop scenario based recommendations.
- Address the following stipulations regarding the quality of BMPs:
  - Consider durability and persistence of practices: What maintenance is required?
  - Consider wide variability in cover crop establishment and positive and negative impacts of cover crops on P.
  - Buffer strips may not have been designed with water quality in mind and may not always reduce P (e.g., if biomass is not harvested, P accumulates in the buffer strip).

[24] See Liu et al. 2020 in the "Phosphorus" section of the bibliography.

- Drainage water management could raise the water table, increasing overland flow during storm events.
- There is no established method for modeling the effectiveness of two-stage ditches in SWAT. As more data on two-stage ditches becomes available a model could be developed.
- Conservation tillage practices may reduce P losses via soil erosion while increasing SRP leaching, posing a tradeoff.
- SRP lost at edge-of-field may not translate to SRP entering Lake Erie because the stream network may act as a P sink.

Lessons from watershed modeling (primarily SWAT models) in the Maumee:

- Stakeholder advisory groups select practices to model (an example of Participatory Modeling).
- Evaluate possible scenarios (e.g., stacked practices at lower implementation levels) to show the stakeholder advisory group potential outcomes. Scenario outcomes can then be used to make recommendations and build community support for programs/practices.
- Models account for uncertainty in quality of BMPs leading to a range of potential outcomes by:
  - Simulating heterogeneity in the watershed;
  - Changing model parameters to account for buffer strip efficiency based on elevation and field size;
  - Inputting weather and management (e.g. fertilizer) information into cover crop models to predict establishment rates; and
  - Accounting for a range of tillage types.

Manure from CAFOs and dairies (note that EGLE's 2020 permit is being contested in court):

- Manure application[25] is a significant though not the major P source from the Michigan watersheds draining to the WLEB (fertilizers are the largest source). However, compared to fertilizers, manure application is conspicuous, which results in pressure from the media and general public to address it because of the perceived link to the toxic algae problem.
- Proper management of manure applications can minimize nutrient losses. The Panel is aware that larger livestock operations are required to have nutrient management plans.
- Stormwater treatment basins or other measures to retain or delay water runoff into streams (i.e., increase residence time) can remove nutrients.
- Riparian buffer strips planted with perennial vegetation in key locations downstream of fields receiving fertilizer or manure applications are known to be effective in intercepting P in overland runoff.
  - Native prairie plantings along streams or as "prairie strips" embedded within farm fields are effective in reducing water, soil, and nutrient losses while enhancing biodiversity and aesthetic appeal.[26]

[25] See "Manure" section of the bibliography for relevant studies and this Limnotech Report.
[26] See Schulte et al. 2017 in the "Edge-of-Field Practices" section of the bibliography.

- Non-native vegetation such as grasses that colonize fallow strips can also reduce water, soil, and nutrient losses, and may not need as much maintenance as prairie plantings.

2. How do we overcome barriers to adoption of BMPs in the agricultural community?

a. What examples can we draw on from other states that have already overcome these barriers?

Science Panel Response:

Barrier: Farmers are not inclined to interact with local, state, or federal government agencies.

To reduce this barrier:

- Hire additional staff, build relationships, and enhance technical assistance capacity at the local level.
- Set up local and state programs differently to help conservation districts develop an independent identity. For example, the Washtenaw County Conservation District office is physically separated from the NRCS office. This method can overcome trust barriers relatively quickly.
- Alternatively, administer conservation programs through a third party such as The Nature Conservancy. Encourage and support community-led efforts and organizations, especially peer-to-peer farmer efforts. Look to examples including the Farmer Advocate for Conservation program run by The Nature Conservancy in Ohio, and Conservation Champions program run by National Wildlife Federation across the Midwest (excluding Michigan)).

Barrier: There are socio-cultural barriers to practice adoption, including social norms about farm management, negative perceptions of practices and programs, and lack of supportive social networks.

To reduce this barrier:

- Deeper community engagement is needed by local organizations and agencies, outreach approaches that leverage existing programs (federal Farm Bill programs and MAEAP) while also promoting benefits of practices beyond direct environmental or financial benefits.
- Recent research from the Midwest has emphasized the role of non-production benefits in encouraging adoption of practices such as cover crops and constructed wetlands, including environmental and social amenities (Luther et al. 2020), knowledge of soil health benefits (Guo et al. 2023), and lifestyle benefits (Soldo et al. 2022).[27]
- Outreach and engagement efforts should leverage an understanding of farmer practice adoption motivations, including promoting broad soil health and community benefits, positive social norms, and additional production and compatibility benefits.

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[27] Short descriptions of these articles can be found in the "Farmer/Landowner Willingness to Adopt Practices" section of the bibliography.

To be effective at promoting and supporting farmer adoption of key practices, agency and organization staff engaging farmers need training and professional development in outreach and communications.

- Conservation professionals[28] typically have training and educational backgrounds in natural and agricultural sciences, including soils, agronomy, or natural resource management, and less training in social and behavioral sciences that may be useful in outreach efforts.
- Staff at state agencies, local conservation districts, MSU Extension, and other conservation organizations could benefit from training and professional development in social-behavioral science and communications, such as through National Wildlife Federation's Grow More training program.[29]

Barrier: Edge-of-field (e.g., buffer strip, filter strip, saturated buffer, two-stage ditch) practices are harder to pitch to farmers because they take land out of production and do not add economic value to the farm the way in-field practices can.

To reduce this barrier, programs should consider:

- Flexibility (e.g., width of buffer strips, ability to harvest buffers, reseed)
- Funding should:
  - Reimburse appraisal costs;
  - Ensure payment at least at the annual production value of the land; and
  - Allow edge-of-field practices to be combined with other programs, i.e., applying for more than one funding program for a single practice and location.
  - Alternatively, pay for performance of P reduced at a competitive rate.
- Easement language should clarify:
  - Participation is voluntary.
  - Who has authority to make compliance decisions?
- Long-term management and monitoring of compliance/effectiveness

Barrier: Changing in-field practices requires information, coordination, and equipment. Fertilizer retailers are incentivized to sell as much as possible and extra fertilizer may serve as a form of low cost crop insurance for farmers.

To reduce this barrier:

- Consider who is applying P. For example, is it a joint decision between farmer and custom fertilizer applicator?
- Work with retailers to:
  - Reward fertilizer sales reps for following nutrient management plans;
  - Offer certification programs to demonstrate stewardship;
  - Conduct additional soil sampling to increase variable rate technology adoption.

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[28] See the Soil and Water Conservation Society's Conservation Practitioner Poll 2021
[29] See Espenshade et al. 2022 in the "Farmer/Landowner Willingness to Adopt Practices" section of the bibliography.

Successful examples to draw from:

- Minnesota has a permanent buffer easement program that was founded through a voluntary approach and is now regulated.
- TNC partnered with the stewardship network to explore pay for performance in the WLEB.
- Polk County Ohio - cut out red tape - used mapping tools to identify areas where "batched" buffer strips could be installed. The program pays landowners for temporary easements. This program reduces barriers farmers face when navigating funding structures.
- Saturated buffer data from Grand Lake St Marys in Ohio showing a 27% reduction in TP and a 24% reduction in SRP [30]
- A recent study[31] comparing high cover crop-adopting counties with neighboring low-adopting counties in the Midwest found that high adopting counties had active collaboration between public agencies and the private sector, including crop advisors.

Other considerations:

- Don't assume that practices will persist after initial adoption of BMPs. There is a need to continue producer engagement beyond initial adoption and/or program participation, including providing access to technical assistance, connecting producers with other successful adopters, and other forms of social support.
- Build programs that encourage long-term adoption by sustaining engagement and maintaining relationships with local producers outside of programs.
- Engagement efforts should continue to be led by local agencies (conservation districts, MAEAP technicians) in collaboration with other engaged partners (MSU Extension, NGOs, farmer-led organizations, etc.), with state funding support for outreach and engagement, including resources to support outreach efforts.
- Ongoing monitoring of practice use and connections with water quality outcomes will also require state coordination, resources, and support.

3. What level of implementation is required to detect the impact of agricultural land management changes in Lake Erie water quality?

Science Panel Response:

Measuring impact in Lake Erie may be more difficult than detecting changes in river P export to Lake Erie. The unusually wet conditions in crop fields during the spring of 2019 demonstrated that while reduced P application resulted in less P exported to the lake, there was not a one-to-one link.[32] The Panel suggests that additional TP and SRP monitoring data is needed to answer this question.

[30] See Jacquemin et al. 2023. in the "Edge-of-Field Practices" section of the bibliography.
[31] See Popovici et al. 2023. in the "Farmer/Landowner Willingness to Adopt Practices" section of the bibliography.
[32] See Guo et al. 2021 in the"Phosphorus" section of the bibliography.

Research

1. What are the next steps for the current edge-of-field research evaluating drain tile flow management?

Science Panel Response:

- Controlled drainage may still work on fields with greater slopes than recommended by the USDA. Additional **research should be conducted on control structures** implemented on fields with greater slopes, given that more tile drains are being installed on these fields.
- The combination of tile drains and conservation tillage may increase P saturation along soil flow paths. **Additional research should be conducted to understand more about soluble and sediment-bound P coming out of tile drains in the Maumee and River Raisin as a function of soil and tile drainage under conservation tillage management.**
- Lengthen the MSU IWR edge-of-field research over more years to determine drivers under variable climate conditions and to inform models.
- Optimal timing of water storage in fields with tile line control structures may vary by soil type. Michigan specific **research should be conducted to test how the timing of water storage impacts crop yields and total P and N losses from tile drains vs. overland flow.**
- **Conduct a study to estimate the cost of applying tile drain control structures at scale and then predict the feasibility of implementing this method on the landscape**.

2. What other areas of research regarding management practices need to be conducted to inform decision making?

Science Panel Response:

First, the Quality of Life Agencies should identify internal capacity for, or hire a consultant to, conduct updated literature reviews for each BMP listed in the Domestic Action Plan. The review should include:

- What is expected to happen to TP and SRP;
- Ideal conditions for each practice; and
- Conditions under which the practice wouldn't be wise.

Develop an understanding of farmer attitudes towards adoption of BMPs:

- Compare attitudes in areas where BMPs are already being deployed vs. not, using a paired watershed approach.
- Identify factors such as social, organizational, institutional, and policy context in Southeast Michigan compared to Northwest Ohio and determine what has led to these differences in order to identify unique barriers vs. similar barriers. Apply relevant work already done in Ohio.
- Identify and understand context factors that could reduce opposition to changes, such as improved yields, return on investment, and property values.

- Help farmers become part of the solution instead of the problem.
- Address farm economics of different stacked BMPs: collect actuarial data to support that farms are being profitable from in-field practices including cover crops and variable rate fertilization.

- Apply mental model framework to middle and late adopters:
  - Account for variability in decision-making, including differences in perception of barriers, communication styles, informational deficits, and preferred engagement strategies.
  - Studies in Ohio demonstrate considerable differences between early/current practice adopters and middle/late adopters in these areas.
  - Outreach methods and communication strategies should be crafted to meet the needs of specific audiences.
- Co-produce research with farmers in the WLEB: Look to literature at the intersection of stakeholder engagement with farmers and rural stakeholders and water quality research. Models already exist for how to incorporate stakeholders from the beginning. This collaborative science approach can produce broader and deeper engagement, fostering trust in information and decision making.[33]

Considerations:

- **Draw what we can from research conducted in Ohio and Indiana, but recognize that Michigan specific research is still required,** including farm-level demonstrations that measure effectiveness of BMPs across different soil textures and slopes to understand which BMPs work best in specific sub-watersheds and to inform Michigan specific models with field measurements.
- Nutrient management is challenging to measure from a human dimensions perspective. Producers may not immediately know or be able to accurately report the following data to researchers: rate, timing, placement, and formulation. P decisions, in particular, are often made collaboratively between producers and retailers/agronomists.
- Acknowledge complexity when implementing practices, including how variations in types of tillage impact residue and soil disturbance differently; complexity in cover crops including type, seed mixes, establishment and termination; and other factors that contribute to different levels of practices.

3. How should legacy P in the watershed be addressed, measured, or managed as a matter of reducing P loading in the WLEB?

<u>Science Panel Response:</u>

[33] See the "Stakeholder Engagement" section in the bibliography.

- **Legacy P is defined by the science panel as P from past agricultural activities that has accumulated in soils and sediments, often bound to minerals or organic material.**[34]
- **Not all legacy P is at high risk of loss; it appears to be dependent on soil's susceptibility to erosion as well as changes in water saturation. Identify fields that are hotspots for SRP loss and implement additional BMPs.**
- It is possible to keep legacy P in place by reducing runoff and leaching rates.
- When considering altering the hydrologic regime, consider potential SRP loss under anoxic conditions created by flooding previously unsaturated soils, which can cause release of P through association with iron oxyhydroxide minerals.[35]
- Farmers must create nutrient management plans for P on a field by field basis.
- Fast growing, harvestable biomass (e.g., switchgrass) could be grown to remove P from high P soils with high SRP loss potential.
- Remove legacy P from water body sediments through dredging.
- Add buffers to fields with high P loss potential.

[34] See Sharpley et al. 2013 in the "Phosphorus" section of the bibliography.
[35] See Kinsman-Costello et al. 2014 in the "Phosphorus" section of the bibliography.

Annotated Bibliography

The following articles were recommended by the Science Panel during a series of meetings to address the DAP Team's Charge Letter. Many are referenced in this report with footnotes directing to sections of this annotated bibliography. All articles are linked to PDFs stored in a folder titled "Science Panel" in the "EGLE-Teams-Lake-Erie-Domestic-Action-Plan" *Teams* account. If you do not have access to this *Teams* account and wish to access PDFs of the following articles please contact Alison Bressler at asbressl@umich.edu.

Nitrogen

Baer et al. 2023. The effect of single vs. dual nutrient decreases on phytoplankton growth rates, community composition, and Microcystin concentration in the western basin of Lake Erie. *Harmful Algae* 123.

Chaffin et al. 2013. Nitrogen constrains the growth of lake summer cyanobacteria blooms in Lake Erie. *Advances in Microbiology* 3: 16-26.

Gobler et al. 2016. The dual role of nitrogen supply in controlling the growth and toxicity of cyanobacteria blooms. *Harmful Algae* 54: 87-97.

Hellweger et al. 2022. Models predict planned phosphorus load reduction will make Lake Erie more toxic. *Science* 376: 1001-1005.

Horst et al. 2014. Nitrogen availability increases the toxin quota of a harmful cyanobacterium, *Microcystis aeruginosa*. *Water Research* 54: 188-198.

Paerl et al. 2016. It takes two to tango: when and where dual nutrient (N & P) reductions are needed to protect lakes and downstream ecosystems. *Environmental Science and Technology* 50: 10805-10813.

Schindler et al. 2016. Reducing phosphorus to curb lake eutrophication is a success. *Environmental Science & Technology* 50: 8923-8929.

- All of the above articles speak to the resurgence of interest in whether nitrogen as well as phosphorus needs to be managed to reduce harmful algal blooms.
- Limnologists have hotly debated this since the idea was highlighted in a 2008 review by William M. Lewis, Jr. and Wayne Wurtsbaugh.
- While not everyone has accepted the idea that N must also be controlled (Schindler et al. 2016), and there are practical and cost limitations, very strong evidence points to dual control of N and P as being better than control of P alone in many eutrophic lakes.
- Cyanobacteria such as *Microcystis* that potentially produce toxins appear to develop higher cell quotas of toxins in the presence of excess N in Lake Erie (Horst et al. 2014) and elsewhere (such toxins contain no P but a large number of N atoms).

Phosphorus

Apostel et al. 2021. Simulating internal watershed processes using multiple SWAT models. *Science of the Total Environment* 759: 143920.

- This study tested the effectiveness of an ensemble of models at capturing field-scale dynamics. They found that models performed well at watershed outlets, but that upstream performance varied. Models tended to over-predict discharge through surface runoff and subsurface drainage while underpredicting P loading through subsurface drainage and nitrogen loading through surface runoff.
- This study suggests that care should be taken in applying models to evaluate field-scale management and processes in the absence of field scale data.

Duncan et al. 2017. Linking Soil Phosphorus to Dissolved Phosphorus Losses in the Midwest. *Agricultural and Environmental Letters* 2: 170004.

- Study conducted on 36 fields in Ohio to identify a soil test P (STP) concentration that allows for P application while still meeting recommended Annex 4 loss thresholds. STP was considered a good screening method to identify fields at risk for greater P loss but did not predict risk of dissolved reactive P loss.
- This study suggests that upland management, edge-of-field practices, and in-stream approaches would be required to reduce dissolved reactive P loading.

Guo et al. 2021. Less Agricultural Phosphorus Applied in 2019 Led to Less Dissolved Phosphorus Transported to Lake Erie. *Environmental Science & Technology* 55: 283-291.

- This study was conducted in the Maumee River Watershed in 2019 when fields were left fallow due to spring flooding that prevented planting and led to a 62% reduction in applied P, altered tillage practices, and fallow soils. Precipitation intensity was also lower during this time period.
- Dissolved reactive P loads from March-July were 29% lower than predicted, while total P loads were similar to predicted values.
- These results demonstrate the strong influence of recently applied P on watershed P loading and authors recommend that conservation practices focus on P application techniques and timing.

Jarvie et al. 2017. Increased soluble phosphorus loads to Lake Erie: Unintended consequences of conservation practices? *Journal of Environmental Quality* 46 (1): 123-32.

- This study used empirical regression models to estimate SRP contributions from increased runoff from changing weather and precipitation and increased SRP delivery on elevated riverine SRP loading since 2002 in the Maumee, Sandusky, and River Raisin tributaries to Lake Erie.
- "Findings suggest that changes in agricultural practices, including some conservation practices designed to reduce erosion and particulate P transport, may have had unintended, cumulative, and converging impacts contributing to increased SRP loads that reached a critical threshold around 2002."

Kinsman-Costello et al. 2014. Re-flooding a historically drained wetland leads to rapid sediment phosphorus release. *Ecosystems* 17: 641-656.

- Re-flooding historically drained land can have unintended negative consequences including P release from sediments.
- This study investigates the effects of re-flooding drainage ditches and former wetland soils on P cycling, finding that sediments released substantial amounts of P (previously bound to iron) into the water column after re-flooding, with 20x more SRP and 14x more TP than the much smaller flooded area that existed before re-flooding. Duckweed and filamentous algae proliferated in subsequent summers. SRP concentrations dropped after the first year.

Liu et al. 2020. Best management practices and nutrient reduction: an integrated economic-hydrologic model of the Western Lake Erie Basin. *Land Economics* 96(4): 510-530.

- This study quantifies trade-offs among phosphorus reduction policies using a spatially integrated economic-hydrologic model of WLEB lining economic models of farmer's BMP adoption choices with SWAT to evaluate the cost-effectiveness of nutrient management policies.
- This study finds that "a hybrid policy coupling a fertilizer tax with cost-share payments for subsurface placement [of phosphorus] is the most cost-effective and can achieve the policy goal of 40% reduction in nutrient loadings."

Nazari et al. 2022. Impact of flow pathway and source water connectivity on subsurface sediment and particulate phosphorus dynamics in tile-drained ecosystems. *Agricultural Water Management* 269: 107641.

- This study uses models to assess governing drivers of sediment transport through tile in the Maumee Watershed in Ohio.
- Studies sediment and P in tile drainage under all conditions.
- Findings suggest that reducing preferential transport of new water may be an effective strategy for reducing sediment and particulate P loadings at edge-of-field.

Sharpley et al. 2013. Phosphorus legacy: overcoming the effects of past management practices to mitigate future water quality impairment. *Journal of Environmental Quality* 42: 1308-1326,

- This review paper summarizes our understanding of P legacies (aka time lags) along the watershed "cascade" from upland soils to wetlands and streams to lakes.
- Drivers of P storage and release along surface and subsurface flow paths are evaluated.
- Both physical and biogeochemical mechanisms are involved.
- The efficacy of BMPs and the time delay of response to them are discussed.
- The WLEB is one of the case studies.

Farmer/Landowner Willingness to Adopt Practices

Asprooth et al. 2023. Transforming the Corn Belt: A recipe for collaborative, farmer-driven research and diffusion of innovation. *Journal of Rural Studies* 103.

- This describes the history and role of Practical Farmers of Iowa in developing an innovation and research network of farmers and other agricultural stakeholders in Iowa. PFI generates and shares information about innovative farming practices, provides a supportive community, acts as a network for innovative farmers across the state, and serves as a catalyst for change in the region.
- Farmer participants in PFI credited the organization's diverse membership, autonomous functioning, culture of openness, and non-ideological nature in supporting conservation practice adoption.

Bressler et al. 2021. Cover crop champions: linking strategic communications approaches with farmer networks to support cover crop adoption. *Society and Natural Resources* 34(12).

- This is a case study of National Wildlife Federation's Cover Crop Champions program, a grant and training program supporting farmer-led outreach to support adoption of cover crops and other soil health practices in the Midwest.
- The Champions program changed attitudes and behavior of farmer participants through training in new communication methods, including using simple language to normalize cover cropping, sharing personal success stories, and focusing on tangible benefits of practices.

- The Champions program also facilitates new farmer networks, both by connecting local cover crop farmers and by connecting farmer Champions across the broader region.

Espenshade et al. 2022. Increasing agricultural conservation outreach through social science. *Journal of Soil and Water Conservation* 77 (4): 56A-59A.

- Outreach to farmers must go beyond technical guidance. Outreach should also "frame conservation as a critical part of good farm management and build social norms that encourage adoption of sustainable agriculture practices."
- This study outlines the "Grow More" approach that the National Wildlife Federation developed to provide training for conservation professionals who are traditionally trained in agricultural sciences.
- These trainings "ground conservation outreach in an understanding of decision making and behavior change science" including key lessons: basics of behavior change, culture and social norms, outreach messaging, framing your outreach, outreach planning and preparing speakers, and planning and evaluation tools.

Guo et al. 2023. Scaling up agricultural conservation: Predictors of cover crop use across time and space in the US upper Midwest. *Journal of Soil and Water Conservation* 1-12.

- MSU-led annual survey of farmers in four state study regions (IN, IL, OH, MI).
- Factors predicting cover crop adoption include perceived benefits of cover crops, knowledge of the practice, profitability goals, use of conservation tillage, and rotational diversity. Predictive factors varied depending on the behavior in question, from initial adoption decision, sustained use, and intensity of cover crop use (as a percentage of the farm operation).
- Implications: Outreach efforts should focus on increasing knowledge of cover crops and benefits of soil health, as well as building perceived efficacy of the practice to achieve production and sustainability goals to increase adoption and sustained use of cover crops.

Kast et al. 2021. Evaluating the efficacy of targeting options for conservation practice adoption on watershed-scale phosphorus reductions. *Water Research* 201: 117375.

- This study took place in the Maumee River watershed and found that developing management strategies based on field-level information and human-operator characteristics using SWAT models, stretches resources further while achieving more environmental benefits as compared to managing environmental outcomes solely based on field-level information.

Luther et al. 2020. What drives voluntary adoption of farming practices that can abate nutrient pollution? *Journal of Soil and Water Conservation* 75 (5): 640-650.

- MSU-led annual survey of farmers in four state study region (IN, IL, OH, MI), exploring factors influencing use of cover crops and precision agricultural technologies.
- This research found that objectives other than income significantly predicted adoption of cover crops and precision technologies, including environmental amenities and social status, participation in federal conservation programs, and access to information and technical assistance.
- Implications: Programs and outreach efforts should emphasize a range of benefits of pollution-reduction practices, including environmental and social amenities, and other production benefits beyond income, including compatibility with livestock systems or rotational benefits in crop production.

Palm-Forster et al. 2016. Using conservation auctions informed by environmental performance models to reduce agricultural nutrient flows into Lake Erie. *Journal of Great Lakes Research* 42: 1357-1371.

- This study took place in the Maumee River watershed and explores novel financial incentives for best management practice adoption. Uses SWAT to predict reductions in phosphorus export as a function of type of conservation practice and farm location.
- Farmer participation in research auctions were low due to high perceived transaction costs, especially on rented farmland.
- Implications: efforts to expand use of conservation practices through programs and cost-share payments should seek to minimize complexity and transaction costs for participation.

Palm-Forster et al. 2017. Farmer preferences for conservation incentives that promote voluntary phosphorus abatement in agricultural watersheds. *Journal of Soil and Water Conservation* 72(5): 493-505.

- This study took place in the Maumee River watershed and ranks financial incentive types based on how they affect farmer willingness to adopt BMPs.
- Farmers preferred direct payments for practice adoption (cover crops, conservation tillage, switching from fall to spring fertilization) and tax incentives over price premiums for products grown with conservation practices and BMP insurance. Preferences were lower for these last two options due to high perceived uncertainty with benefits for farmer participants, increasing required payment to compensate for uncertainties and transaction costs.

Popovici et al. 2023. The social factors influencing cover crop adoption in the Midwest: A controlled comparison. *Environmental Management* 72: 614-629.

- This study investigated the "social factors affecting cover crop adoption in Iowa, Illinois, and Indiana" by comparing pairs of neighboring counties with higher and lower adoption levels of cover crops.
- Social factors included "attitudes towards cover crops, conservation agency influence, presence of cover crop experts, advocates, and entrepreneurs, and collaboration between agencies and the private sector" with the latter playing the most important role in explaining adoption of cover crops.
- Other contributing factors included "topography, cattle raising, organic production, and local incentive-based programs."

Reimer et al. 2022. Scaling up conservation agriculture: An exploration of challenges and opportunities through a stakeholder engagement process. *Journal of Environmental Quality* Special Edition: Exploring the Soil Health-Watershed Health Nexus: 1-11.

- Participatory project with farmers and food system stakeholders in Michigan to explore barriers and opportunities for expanding conservation agriculture. Focuses primarily on in-field practices. This work is continuing.
- Identified four broad categories of needed action: 1) markets to support conservation agriculture, 2) expanded conservation programs that support long-term use of practices, 3) strengthened social and professional networks, and 4) improved human capital to successfully implement conservation approaches.

Soldo et al. 2022. Farmer willingness to implement constructed wetlands in the Western Lake Erie Basin. *Journal of Environmental Management* 321: 115928.

- This study took place in the Western Lake Erie Basin and finds that the decision to install a constructed wetland is not entirely dependent on the productivity of the land. Associated

beneficial functions (e.g., aesthetics, hunting opportunities) positively influence willingness for farmers who value conservation.
- Implications: Program providers should emphasize the diverse benefits of constructed wetlands, and target farmers who exhibit stronger conservation identities.

Stakeholder Engagement

Eaton et al. 2022. Farmer perspectives on collaboration: Evidence from agricultural landscapes in Arizona, Nebraska, and Pennsylvania. *Journal of Rural Studies* 94:1-12
- Paper identifying cross-cutting themes from farmer engagement case studies in multiple states. Farmers varied in their view of how included they were in prior participation experiences, how willing they were to learn from others, the degree to which they believed others were open to learning from them, how flexible they believed the process to be, and how much influence they potentially had over agency actions.
- Implications: Agencies and organizations seeking to use participatory engagement processes should be aware of the role of prior experiences in coloring willingness of farmers to participate. Effort should be taken to first understand farmer stakeholder perceptions and past experiences, explore openness to collaboration with non-farmer stakeholders, create opportunities for engagement in agency decision-making to build trust, ensure flexible agendas in collaborative processes, and clarify agency rules and processes.

Jackson-Smith et al. 2018. The road less traveled: Assessing the impacts of farmer and stakeholder participation in groundwater nitrate pollution research. *Journal of Soil and Water Conservation* 73:6.
- This paper describes a stakeholder engagement process used in central Montana to address nutrient pollution challenges in an agricultural watershed. The process included two advisory groups of local stakeholders, including farmers and ranchers, to meet regularly with a team of scientists to develop research questions, structure field research, select management practices, discuss and interpret data, and design outreach efforts.
- The stakeholder engagement process resulted in higher levels of stakeholder confidence in scientific data, greater awareness of and concern with nutrient issues, and more positive impressions of the project. This study was not able to detect changes in conservation behavior within the three-year study period, likely reflecting time lags associated with farming practice change.
- Implications: Community trust is likely to be higher if key stakeholders are involved throughout the process of data collection and interpretation, rather than just as targets of outreach as a result of these activities.

Manure

Kast et al. 2019. Manure management at Ohio confined animal feeding facilities in the Maumee River Watershed. *Journal of Great Lakes Research* 45(6): 1162-1170.
- “Model simulations indicate that inorganic fertilizers contribute a greater proportion of TP (45% compared to 8%) and DRP (58% compared to 12%) discharged from the watershed than manure sources in the March–July period, the season driving harmful algal blooms.”
- “Although inorganic fertilizers contributed a greater mass of TP and DRP than manure sources, the two sources had similar average delivery fractions of TP (2.7% for inorganic fertilizers vs. 3.0% for manure sources) as well as DRP (0.7% for inorganic fertilizers vs. 1.2% for manure sources).”

Long et al. 2018. Use of manure nutrients from concentrated animal feeding operations. *Journal of Great Lakes Research* 44(2): 245-252.

- This study analyzed data from 13 permitted CAFOs in southeastern Michigan including 1187 occurrences of manure application.
- The study found that the overapplication of manure on fields in the study could be redistributed to fertilize 11,800 acres per year.
- "Cost, land availability, crop and soil need, transport logistics, and farmers' reluctance to use manure instead of inorganic fertilizer due to its variable composition" remain barriers to redistribution of manure across the landscape.

Edge-of-Field Practices

Jacquemin et al. 2022. Restored Wetlands in Grand Lake St. Mary's Watershed. Lake Restoration Commission - 2022 Update.

- This fact sheet provides data on P loads for the Coldwater Creek, Prairie Creek, and Beaver Creek Wetlands in the St. Mary's Watershed.
- This is an example of a wetland monitoring project that the State of Michigan could look to as an example.

Jacquemin et al. 2023. Grand Lake St Marys Saturated Buffer Monitoring Summary.

- This fact sheet provides an overview of the St. Charles Center saturated buffer design and provides a successful case study to reduce nutrient runoff from farm fields, based on precipitation, field drainage discharge, nutrient reductions, sediment characteristics, groundwater saturated, and surface runoff potential .

Kalcic et al. 2018. Assessment of beyond-the-field nutrient management practices for agricultural crop systems with subsurface drainage. *Journal of Soil and Water Conservation* 73(1): 62-74.

- "This paper reviews the characteristics, benefits, and drawbacks of agricultural ditches and wetlands, as well as strategies for applying agricultural best management practices (BMPs) at the watershed scale for improving water quality."
- "This synthesis focuses on the Great Lakes Region and the Mississippi River Basin in the United States, and specifically crop production systems in watersheds with subsurface drainage."
- Two-stage ditches and wetlands are considered, and the role of watershed models is discussed.
- Literature on farmer perceptions and adoption of practices in the Great Lakes Region and the Mississippi River Basin is reviewed.

Schulte et al. 2017. Prairie strips improve biodiversity and the delivery of multiple ecosystem services from corn-soybean croplands. *PNAS* 114 (42): 11247-11252.

- This study demonstrates clearly the benefits of strategically located prairie strips planted within or shortly downhill of crop fields where they intercept overland runoff.
- "Prairie strips raised pollinator and bird abundance, decreased water runoff, and increased soil and nutrient retention. These benefits accrued at levels disproportionately greater than the land area occupied by prairie strips"
- "Social surveys revealed demand among both farm and nonfarm populations for the outcomes prairie strips produced."

Proxies for Water Quality

Keitzer et al. 2016. Thinking outside of the lake: Can controls on nutrient inputs into Lake Erie benefit stream conservation in its watershed. *Journal of Great Lakes Research* 42: 1322-1331.

- Agricultural conservation practices hold some potential to improve stream biological conditions in the WLEB, however conservation practices would need to be widespread to achieve watershed conservation goals. Even with widespread conservation efforts, some areas will remain degraded.

Wang et al. 2007. Linkages between nutrients and assemblages of macroinvertebrates and fish in wadeable streams: implication to nutrient criteria development. *Environmental Management* 39: 194-212.

- This study sampled 240 streams in Wisconsin.
- "Twenty-three of the 35 fish and 18 of the 26 macroinvertebrate measures significantly correlated ($P < 0.05$) with at least one nutrient measure."
- "Selected biological measures showed clear trends toward degradation as concentrations of phosphorus and nitrogen increased, and some measures showed clear thresholds where biological measures changed drastically with small changes in nutrient concentrations."

Climate Change

Kujawa et al. 2020. The hydrologic model as a source of nutrient loading uncertainty in a future climate. *Science of the Total Environment* 724: 138004.

- This study characterized uncertainty from both climate models and hydrologic (SWAT) models in predicting riverine discharge and nutrient loading in the Maumee River watershed.
- Multiple models of both kinds help to indicate the uncertainties in model projections.
- There was no clear agreement on the direction of change in future nutrient loadings or discharge.
- Variation among climate models was the dominant source of uncertainty in predicting future total discharge, tile discharge (i.e. subsurface drainage), evapotranspiration, and total nitrogen loading
- Variation among hydrologic models was the main source of uncertainty in predicted surface runoff and phosphorus loadings.

Kujawa et al. 2022. Using a multi-institutional ensemble of watershed models to assess agricultural conservation effectiveness in a future climate. *Journal of the American Water Resources Association* 58 (6): 1326-1340.

- "This study investigates the combined impacts of climate change and agricultural conservation on the magnitude and uncertainty of nutrient loadings in the Maumee River Watershed."
- Used an ensemble of five Soil and Water Assessment Tools (SWAT) models driven by six climate models.
- Increased conservation resulted in statistically significant reductions in annual loads of total phosphorus (41%), dissolved reactive phosphorus (18%), and total nitrogen (14%) under the highest emission climate scenario (RCP 8.5).

Past MAEAP Evaluation

Stuart et al. 2014. Evaluating the use of an environmental assurance program to address pollution from United States cropland. *Land Use Policy* 39: 34-43.

- This study examines MAEAP and "explores how it might serve to reduce nutrient pollution associated with intensive corn production."
- Data was collected through interviews with corn farmers to explore why they participated in MAEAP, the extent of their management changes, and opinions regarding MAEAP's effectiveness.
- The study found that most farmers had already satisfied a majority of MAEAP requirements before enrolling and few changes were made that would result in environmental improvements demonstrating the limitations of voluntary programs to address environmental problems.

Appendix A: Charge to the Science Panel from Michigan's Domestic Action Plan Team on behalf of the Quality of Life Agencies

Problem: The Western Lake Erie Basin (WLEB) is shallow, making it vulnerable to harmful algal blooms (HABs) from excessive nutrient runoff from the WLEB watershed.

Focus: Nutrient management, focusing on nonpoint source (NPS) contributions to reduce total phosphorus (TP) loading into the WLEB by 40% (in combination with point source reductions) as compared to 2008 levels (Table 1).[36] Soluble reactive phosphorus (SRP) reduction levels are yet to be set.

Table 1: Phosphorus load reduction goals (AMP p. 9). [37]

Priority Objective (4)	2008 TP Target Baseline Load (1)	20 Percent Reduction Amount (by 2020)	40 Percent Reduction Amount (by 2025)	Target Load
Detroit River TP load (at mouth)	1,261	252	504	756
River Raisin TP Load (at monitoring location) (5)	172 (0.157 mg/l)	34 (0.031)	69 (0.063)	103
River Raisin Spring TP load (at monitoring location)	83 (0.148 mg/l)	17 (0.030)	33 (0.059)	50 (0.089)
River Raisin Spring SRP Load (3)	N/A	N/A	N/A	N/A
MI Maumee TP Load (2)	267	53	107	160
MI Maumee SRP Load (3)	N/A	N/A	N/A	N/A
Total Michigan Load Allocation	1,883	377	753	1,130

1. Based on 2008 load estimated by Annex 4. The 2008 TP Target Baseline Load numbers for the Raisin come from Heidelberg University's River Raisin monitoring station data.

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[36] More detail on the 2015 phosphorus loading targets can be found in Annex 4 Objectives and Targets Task Team (May 11, 2015) *Recommended Phosphorus Loading Targets for Lake Erie: Final Report to the Nutrients Annex Subcommittee.*

[37] State of Michigan, 2021. *Michigan's Adaptive Management Plan to Reduce Phosphorus Loading into Lake Erie.* Prepared by Michigan Department of Agriculture and Rural Development; Michigan Department of Natural Resources; and Department of Environment, Great Lakes, and Energy, 45 p.

2. Based on percentage of land use in Michigan's portion of the Maumee River.
3. No Soluble Reactive Phosphorus (SRP) loading estimate for the River Raisin or the Maumee River. Research is needed and concentrations may currently be low for the River Raisin.
4. Concentration in parenthesis is a flow weighted mean concentration.
5. Values at monitoring location on the River Raisin will be used to provide an entire watershed value.

Adaptive Management: The Domestic Action Plan (DAP) Team, consisting of senior management staff from the Michigan departments of Agriculture and Rural Development (MDARD); Natural Resources (DNR); and Environment, Great Lakes, and Energy (EGLE), understands that it will take longer than 2025 to achieve nutrient reduction goals set for the WLEB. The DAP Team believes that "active adaptive management provides for the use of scientific outcomes and experimentation to guide the best direction for achieving the phosphorus reductions in the basin." The goal of the adaptive management process is to help align funding, resource needs, and research with agency management commitments (Adaptive Management Plan [AMP], p. 3). The adaptive framework seeks to "evaluate the outcomes of deliberate, measured actions taken to reduce phosphorus, and to develop and implement scientifically driven projects to address gaps and uncertainties in current approach" (AMP p. 7). ***The DAP Team acknowledges the value of the adaptive management framework and is in the initial set-up phase of the process, which will take some time to fully implement (AMP p. 5).***

Charge to the Science Panel: Provide input and advice to the DAP Team that focuses primarily on agriculture NPS contributions of phosphorus (P). The Panel is asked to review ongoing research and actions taking place in the Michigan portion of the WLEB and assess results, progress and advise on necessary changes or course corrections to achieve P reductions. The Science Panel is asked to:

- provide advice on developing realistic, tangible, and science-based goal(s) and objectives for advancing the adaptive management process;
- address the questions below relating to the projects the state has initiated action on to meet the goals of the DAP; and
- provide input on what information is required to implement an effective adaptive management process.

Overarching Questions:

1. Review the DAP's "Priority Objectives" to meet target reductions in nonpoint source P and offer suggestions to refine existing or suggest different objectives.
    a. What metrics or monitoring are needed to adequately monitor progress on meeting the Priority Objectives?
2. Will the adaptively managed set of projects, when taken together, provide the necessary elements for a TP and SRP (when set) reduction strategy that will achieve the reduction targets set by the state?
    a. If not, what additional activities, projects or programs are needed?
3. Review working hypotheses and associated projects:
    a. Is the DAP Team asking the right questions about NPS pollution?
    b. How could projects better address their associated working hypotheses; or how could these hypotheses be adjusted to address existing projects?
    c. If necessary, propose alternative hypotheses.

4. How should the conceptual adaptive management process (Figure 1) and support structure be adjusted in order to implement an effective process? What additional resources or steps should we consider?

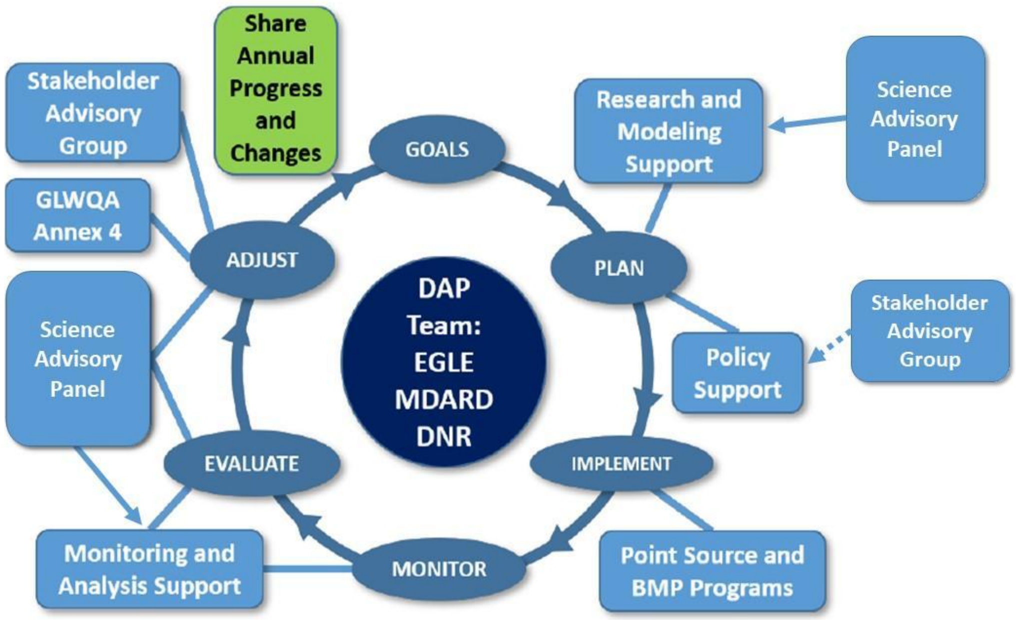

Figure 1. Adapted from Figure 11 in the Adaptive Management Plan. Proposed conceptual governance and support structure for Michigan DAP adaptive management cycle. Note that some support and advisory components, roles, and commitments are currently under development and subject to change. (AMP p. 21)

5. Referencing the list of uncertainties on p. 36 of the AMP:
    a. Which of these uncertainties will affect each adaptive management project?
    b. Are there additional uncertainties not currently being accounted for in the AMP?
    c. Identify strategies to reduce them over time if possible (e.g., effectiveness, costs, and relationships).

Questions within Thematic Areas

The questions below have arisen during the review of the current DAP and AMP, including progress that has been made or not, and barriers that have been identified. These questions include and extend beyond the seven Adaptive Management Plan projects.

Watershed Practices

1. What are cost effective methods for detecting changes in water quality (i.e., TP and SRP) resulting from the implementation of agricultural best management practices (BMPs)[38] and landscape infrastructure.

[38] Best management practices are defined here in an agricultural context and include filter strips and cover crops.

2. How will warmer winter temperatures and changing precipitation patterns impact:
    a. The efficacy of agricultural BMPs and landscape infrastructure across the watershed?
    b. The implementation of agricultural BMPs?
3. Do you predict shifts in agricultural nutrient management practices as climate conditions change and as population size and density grows in Michigan? Have these shifts occurred in other states? If so, what can be learned from them?

Agricultural Practices

1. What is the suite of in-field and edge-of-field BMPs that are effective at addressing TP and SRP combined that could be implemented as sets of stacked practices?
    a. Can these practices be ranked from least to most effective?
2. How do we overcome barriers to adoption of BMPs in the agricultural community?
    a. What examples can we draw on from other states that have already overcome these barriers?
3. What level of implementation is required to detect the impact of agricultural land management changes in Lake Erie water quality?

Other Land Management Practices

1. Would additional wetlands assist in the reduction of P delivery to Lake Erie?
    a. What types of wetlands would be appropriate?
    b. What are the siting considerations for these types of BMPs?
    c. Are there existing examples of effective approval approaches that can expedite implementation in other states?
    d. What effective approaches could be used to engage landowners and agricultural producers in wetland restoration or creation on agricultural lands?
2. Is there existing work [in Michigan or other states] related to drains or other riparian areas that would be beneficial for P reduction? How much of that work would need to occur to see a measurable reduction?
3. Are there actions that other land managers, private landowners, or municipalities could be doing to also help achieve the NPS P reduction?
4. What should drain commissioners consider when implementing two-stage drainage ditches, including infrastructure limitations, assessment, and long-term operations and maintenance?

Research

1. What are the next steps for the current edge-of-field research evaluating drain tile flow management?
2. What other areas of research regarding management practices need to be conducted to inform decision making?
3. How should legacy P in soils be addressed, measured, or managed as a matter of reducing P loading in the WLEB?

For all of the above, which activities should be led by the State of Michigan or the Annex 4 team [US, Canada, State, and Provincial governments] or an external partner?

Appendix B: Responses to overarching questions broken down by Priority Objective Subtasks

***Priority Sub-tasks 3f, 3h, 6e:* MAEAP - track progress and set goals in Bean Creek, St. Joseph River, and River Raisin Watersheds to increase enrollment**

Working Hypothesis: Using the MAEAP model in a more targeted effort will improve the adoption rate that results in improved water quality.

1) *What metrics or monitoring are needed to adequately monitor progress on meeting the Priority Objectives?*

Science Panel Response:

MAEAP should track outreach efforts including landowner/producer engagement, such as individual contacts between producers and staff, information sharing, expressed concerns or barriers from producers; and focus on the most effective promotion efforts such as field days or winter meetings.
In addition to internal tracking and monitoring, the State of Michigan should invest in ongoing external (to avoid conflict of interest) evaluation of MAEAP. This evaluation should focus on:

1) Who participates;
2) Additionality of the program (does MAEAP participation either directly or indirectly result in changes in management that can reduce nutrient losses, or is it just verifying in-place practices?);
3) Changes in farm production practices, such as nutrient management and tillage practices, following verification; and
4) Impacts on water quality outcomes. External evaluation should test if current verification standards are sufficient to positively impact water quality.

2) *Which of these uncertainties will affect each adaptive management project? Are there additional uncertainties not currently being accounted for in the AMP? Identify strategies to reduce them over time if possible (e.g., effectiveness, costs, and relationships).*

Science Panel Response:

Uncertainties:

The impact of MAEAP verification on nutrient management in the WLEB is unknown:

- Nutrient management planning and verification procedures are vague within the MAEAP structure with no standard process for implementation.

Reduce uncertainties by:

- Add specific nutrient management practices including subsurface application of phosphorus fertilizer to MAEAP.
- Update nutrient management recommendations beyond current State of Michigan standards for phosphorus.

***Priority Sub-tasks 3i and 6g:* Conduct Agricultural Inventories in priority HUC-12 sub-watersheds in the Bean Creek and River Raisin Watersheds**

Working Hypothesis: *Agricultural inventories will make it possible to more effectively place and fund BMPs, as well as increase the potential to improve water quality.*

1) *What metrics or monitoring are needed to adequately monitor progress on meeting the Priority Objectives?*

Science Panel Response:
EGLE's ongoing GIS analysis of priority fields, based on slope and proximity to water courses, is important. Current research by outside parties to improve spatially explicit modeling of water and P movement through the watersheds should also be helpful. It is not clear how well tile drainage is represented in the spatial data, even though that could be a major route of P export to streams. Michigan staff should gain access to FSA data on the distribution and kinds of BMPs currently in practice.

2) *How could projects better address their associated working hypotheses; or how could these hypotheses be adjusted to address existing projects?*

Science Panel Response:
- Update the agricultural inventory at a frequency that captures BMP adoption changes over time (will vary by BMP) to support efforts that direct the focus of strategic engagement with producers.
- Identifying areas with existing management practices is only the first step of increasing adoption of BMPs. The state should also consider that:
    - Inventories need to be accessible and actionable by organizations supporting conservation practice adoption at farm and field scales, such as NRCS, Conservation Districts, watershed councils, farmer-led groups, and other NGOs.
    - Conservation organizations may need support for strategic planning of outreach programs that leverage inventory data and focus conservation outreach and program delivery with the appropriate producers.
    - Producer/landowner willingness is also an important aspect of this focus work; even with existing cost-share, some farmers will not willingly adopt practices.
- Identifying nutrient management is beyond the scope of the agriculture inventory. This is a limitation that must be overcome through other means, such as remotely sensed data or through one-on-one meetings with producers to collect nutrient management data.
- Next steps:
    - Coordinate with NRCS
    - Expand research to understand stacked practices
    - Utilize private sector tools offered by organizations such as IndigoAg, CIBO, and HabiTerre

3) *Which of these uncertainties will affect each adaptive management project? Are there additional uncertainties not currently being accounted for in the AMP? Identify strategies to reduce them over time if possible (e.g., effectiveness, costs, and relationship*s).

Science Panel Response:

Uncertainties:

Annual variation in BMP success (e.g., cover crop growth); weather patterns; and missing data. Missing data produces more uncertainty in watershed models.

Reduce uncertainties by:

Developing alternatives to capture information that cannot be assessed from windshield monitoring, specifically:

- 15-20% of fields that are not along roads
- Nutrient management practices

Understanding the net effect of conservation vs. conventional tillage on P export from fields:

- Conservation tillage may reduce soil erosion but may increase SRP losses via macropore flow

Evaluating early research to predict hotspots of current loads within subwatersheds (sources and sinks).

***Priority Sub-task 4f:* Point Source Loading Reductions - EGLE and GLWA evaluate soluble reactive phosphorus discharge quality as a function of the level of municipal treatment**

Working Hypothesis: *Improving understanding of phosphorus (P) speciation in effluent may make it possible to optimize treatment operations and seasonal approaches to reduce soluble reactive phosphorus (SRP) vs. total phosphorus (TP) across all wastewater treatment plants.*

1) *What metrics or monitoring are needed to adequately monitor progress on meeting the Priority Objectives?*

Science Panel Response:

The state still needs to conduct the following:

- Measure P (including SRP) and N forms in wastewater treatment plant effluent under various treatments;
- Monitoring and experiments to understand nutrient cycling within the river; and
- Modeling to assess impacts of wastewater treatment plant-derived nutrient sources on HABs and hypoxia.

2) *How could projects better address their associated working hypotheses; or how could these hypotheses be adjusted to address existing projects?*

Science Panel Response:

- Although all P matters, SRP may have the most immediate impact due to its higher bioavailability, and this is especially true where it is discharged directly into water bodies.
- National Pollution Discharge Elimination System (NPDES) permit limits on wastewater treatment plant effluent only apply from April to September. Also consider P amounts and concentrations discharged during the rest of the year because Lake Erie has a water residence time of ~2–3 years.
- P loading from the Detroit River, including GLWA effluent as well as outflow from Lake Huron and Ontario rivers, may be significant for spring diatom blooms in western and central basins and consequent Central Basin hypoxia (LimnoTech nutrient synthesis report to the IJC, p. 14), but this link is not well established.
- The Panel suggests that the State of Michigan roughly estimate the costs of optimizing treatment operations to reduce SRP and TP, then weigh the benefits of both optimizations by modeling the impacts on WLEB HABs and Central Basin hypoxia.

3) *Which of these uncertainties will affect each adaptive management project? Are there additional uncertainties not currently being accounted for in the AMP? Identify strategies to reduce them over time if possible (e.g., effectiveness, costs, and relationships).*

Science Panel Response:

Uncertainties: Scientific understanding of nutrient cycling, specifically the following aspects:

- Importance of TP:SRP ratio to HABs;
- Timescale:
  - On a short time scale, evidence is stronger for SRP, over TP, in causing spring load/summer bloom;
  - TP load may be a longer term concern due to internal loading and cycling;
- All P is potentially bioavailable and its storage in soils and sediments is not necessarily permanent; large legacy stores may "leak" P for decades. Land use changes, including drainage water retention and wetland creation, can mobilize stored (legacy) P by flooding previously unsaturated soils;
- Importance of total ammonia nitrogen and total Kjeldahl nitrogen in stimulating toxic blooms; and
- All models, whether physical or numerical, have uncertainties.

Reduce uncertainties by:

- For numeric models it is critical that the relationships across state variables and drivers are well understood.
- If not, conduct a sensitivity analysis to prioritize the most "sensitive" parameters, which can then lead to the development of a physical model for testing and documenting the response surfaces (i.e., the hypothesis) associated with a particular driver (i.e., forcing function).

<u>Priority Sub-task 5e:</u>* *Field BMPs: Tile line discharge control study

The working hypotheses for the Priority Objective 5 Sub-tasks are lumped together with a set of research projects. The Science Panel suggests specific hypotheses for individual projects. MAEAP, CREP, and FarmBill are useful but are tactics more than objectives in and of themselves.

<u>Science Panel's Suggested Hypothesis:</u> Manipulation of tile drainage, using water level control structures and diversion of water into buffer zones, can substantially reduce nutrient export to recipient water bodies by increasing water residence time and contact with soils and plants.

1) *What metrics or monitoring are needed to adequately monitor progress on meeting the Priority Objectives?*

<u>Science Panel Response:</u>
The Panel finds this research to be interesting and important, but wondered about the cost of deployment at scale compared to other measures.

2) *How could projects better address their associated working hypotheses; or how could these hypotheses be adjusted to address existing projects?*

<u>Science Panel Response:</u>
- For nutrient loading to streams in the Michigan portion of the WLEB, tile drainage should be of particular interest.
- Southeast Michigan, especially Lenawee County, has the highest density of drainage structures - tile line storage and wetland interception of draining waters here offer promising potential measures to reduce P loads.
- The pilot study on drainage water management control structures has been a priority through the nonpoint source implementation grant.
  - We know that tile drain control structures can control N.
  - How effective are control structures at capturing P? Ehsan Ghane's research at MSU is pertinent for proof of concept.

3) *Which of these uncertainties will affect each adaptive management project? Are there additional uncertainties not currently being accounted for in the AMP? Identify strategies to reduce them over time if possible (e.g., effectiveness, costs, and relationships).*

<u>Science Panel Response:</u>
Even if demonstration projects show BMPs are effective at reducing P, *uncertainties remain:*
- BMPs may not be implemented or maintained, e.g., water control gates are often not managed years after installation.
- Gates may hold back too much water, raising the water table in farm fields may mobilize P.

Reduce uncertainties by:

- Implementing smart gate structures, e.g., automated controlled gates.
- Outsource long-term maintenance.

***Priority Sub-task 5g:** Field BMPs: Reinstate Conservation Reserve Enhancement Program*

Science Panel's Suggested Hypothesis: The observed correlation between CREP enrollment and River Raisin P loads suggests that CREP is an effective measure to reduce nutrient export from croplands and that the program should be continued and expanded.

1) *What metrics or monitoring are needed to adequately monitor progress on meeting the Priority Objectives?*

Science Panel Response:

- The Panel recommends that conservation district staff focus outreach efforts for enrolling Conservation Reserve Enhancement Program (CREP) acres on land with highest P loss potential as identified through the Agricultural Inventory.
- P loss via tile drainage should be considered in addition to loss via overland flow.

2) *How could projects better address their associated working hypotheses; or how could these hypotheses be adjusted to address existing projects?*

Science Panel Response:

- CREP needs numerical acreage targets in the WLEB to determine if it will move the needle.
- The panel understands that Michigan will be adding more BMPs to the CREP practices list.
- Past incentive programs have not generated sufficient interest among Michigan landowners. Ongoing assessment is needed for social/cognitive factors driving or limiting conservation behavior. The state should invest in social science research regarding adoption. Similar research has been conducted in Ohio,[39] but contextualized research in Southeast Michigan is also needed. Research should explore both factors motivating or limiting adoption of conservation practices, as well as perceptions and participation in state and federal programs.

3) *Which of these uncertainties will affect each adaptive management project? Are there additional uncertainties not currently being accounted for in the AMP? Identify strategies to reduce them over time if possible (e.g., effectiveness, costs, and relationships).*

Science Panel Response:

Uncertainties:

Reliability of CREP funding which may change over time due to political factors and may not be sufficient to reach enrollment acreage goals in the WLEB.

[39] See articles listed in the "Farmer/Landowner Willingness to Adopt Practices" section in the bibliography.

Reduce uncertainties by:

- Estimating impact of conservation practices at specific locations - no one size fits all due to soil, slope - impact effectiveness of practices.
- Prioritizing cost effectiveness per unit P export reduction (pay-for-performance): Targeted approach was 7x more cost effective than randomly selected fields in a recent MSU IWR study.[40]

***Priority Sub-task 6k:* Saline River Watershed buffer easement pilot project – Phase 1**

Working Hypothesis: Buffer establishment of sufficient size to achieve substantial sediment reductions and other benefits (habitat, carbon storage) can be identified, appropriate land can be acquired, and sufficient funds for construction, maintenance, monitoring will be available, and sites will consistently capture and retain sediment, and consequently P, as expected.

1) *What metrics or monitoring are needed to adequately monitor progress on meeting the Priority Objectives?*
2) *How could projects better address their associated working hypotheses; or how could these hypotheses be adjusted to address existing projects?*

Science Panel Response:

- The Panel agrees that this is an innovative approach that is worthy of continued implementation and evaluation.

3) *Which of these uncertainties will affect each adaptive management project? Are there additional uncertainties not currently being accounted for in the AMP? Identify strategies to reduce them over time if possible (e.g., effectiveness, costs, and relationships).*

Science Panel Response:

Uncertainties:

- Finding appropriate locations without a prioritization tool.
- Cost effectiveness of buying farmland and converting it to permanent buffers?
- Will allowing harvestable perennial crops make buffers strips more profitable or increase adoption rates?
- Effectiveness of buffer strips may be greatest where overland flow is important, but could be minimal where tile drains bypass them.
- Model sensitivity to dairy vs. other land uses.

Reduce uncertainty by:

- Using tools (LIDAR, slope, soil types) with SWAT model to determine reductions at specific locations and conduct cost analysis.

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[40] Publication not yet available. Please see abstract here: Asher et al. 2022. Performance-Based Payments for Conservation Adoption. Conservation Models, Tools, and Technologies.

<u>Priority Sub-task 10e:</u> Implement an agricultural wetland restoration pilot project in the WLEB

<u>Working Hypothesis</u>: Wetland and buffer restoration sites of sufficient size to achieve substantial phosphorus reductions and other benefits (habitat, carbon storage) can be identified, appropriate land can be acquired, and sufficient funds for construction, maintenance, and monitoring will be available, and restored sites will consistently capture and retain phosphorus as expected.

1) *What metrics or monitoring are needed to adequately monitor progress on meeting the Priority Objectives?*

<u>Science Panel Response:</u>

- The Panel noted that wetland restoration would have to entail large acreage in numerous locations to lead to measurable P reductions. Research is needed to determine where, within each watershed, wetland restoration or creation would be most efficacious and cost effective, and that may be in more downstream reaches as opposed to along or above headwater streams.
- DNR staff explained that 200 priority sites have been identified but few landowners have expressed interest. DNR must offer more enticing incentives and invest in engaging with landowners. Based on experience in South Florida, participatory modeling that involves landowners and other citizens may be a good approach to engaging landowners throughout the stages of adaptive management from planning to monitoring and assessment.

2) *How could projects better address their associated working hypotheses; or how could these hypotheses be adjusted to address existing projects?*

<u>Science Panel Response:</u>

- Look to Ohio for information on their wetland monitoring projects
- See discussion of Objective 10 regarding wetlands

3) *Which of these uncertainties will affect each adaptive management project? Are there additional uncertainties not currently being accounted for in the AMP? Identify strategies to reduce them over time if possible (e.g., effectiveness, costs, and relationships).*

<u>Science Panel Response:</u>

Uncertainties:

- Cost effectiveness per acre of farmland removed from production?
- Can enough water be directed through wetlands for enough time to make a difference?

Reduce uncertainty by:

- Identifying where in the river network a given acreage of restored or created wetlands would contact the most flow - headwaters vs. larger channels vs. near river mouth.

Appendix C: Key Elements of a Realistic and Effective Adaptive Management Framework

1) Comprehensive and Integrated Monitoring Networks:

- Comprehensive and integrated monitoring networks must be sustained over decades to achieve successful adaptive management.
- In other watersheds, successful monitoring networks have been sustained over decades by accessing funding from multiple sources. These shared networks are managed collaboratively through shared decision making across individual monitoring programs.
- Successful monitoring networks directly engage management agencies, ensuring their buy-in through clearly stated objectives and by addressing key management questions. Management questions are addressed through data collection, analysis, interpretation, and public sharing of findings.
- These management-relevant monitoring networks adapt to address new policy and other management needs as they arise, as well as new scientific insights into how ecosystems are responding to different stressors.

2) Management-oriented Linked Models Directed towards Scenario Simulation and Interpretation:

- Management-oriented environmental models support the interpretation of monitoring data. These models require extensive and comprehensive environmental data to develop, calibrate and validate them.
- Once developed, these models can support management decision making through scenario analysis. In this process, managers identify various management scenarios for which the models can provide simulated outcomes for comparison with observations from monitoring networks and data analysis.

3) Tracking, Reporting, and Verification of Implemented BMPs:

- A detailed understanding of both history, geospatial location, and current status of various BMPs is crucial to understanding the reason for observed trends in monitoring data.
- When managers are able to connect the verified presence and function of BMPs on the ground with trends in monitoring data, they are able to make important connections between practice and ecosystem responses, enabling them to adapt policies, regulations, and programs.

4) Monitoring, Reporting, and Loading Trend Analysis of Permitted Municipal and Industrial Dischargers:

- In parallel to efforts to track and verify BMPs to manage nonpoint sources, management agencies must track point source discharge loads at permitted facilities across jurisdictions and through time, ensuring routine collection, sharing, and interpretation of data.

5) Assessment of Land Use and Land Cover Trends Over Time:

- Trends, including direction and magnitude, in monitoring data should be interpreted in parallel with land use/land cover changes over the same time period.

- Management-oriented linked models support adaptive management by helping to assess how changes in land use and land cover over time affect land-based sources and loads of pollutants of interest, e.g., P.

6) Collaborative Data Analysis and Interpretation System:

- A commonly accepted approach to the analysis and interpretation of monitoring data is key to an effective adaptive management framework. Therefore, it is important to bring together data analysis experts with a range of backgrounds and expertise who can develop shared analytical objectives and a way to interpret a common data set.
- The application of consistent and common trend analysis techniques shared across multiple agencies, organizations and institutions yields not only collective savings in personnel and financial resources, but greatly increases the credibility of the interpreted trends and their management implications.

7) Elements for Explaining Trends:

- To fully explain trends, the first six elements above must be functioning and integrated into the adaptive management framework.
- Successful adaptive management frameworks depend on analysis of trends, such as direction and magnitude, and the driving factors or mechanism behind those trends.

8) Numerical Goals and Targets Against Which to Assess Progress:

- Adaptive management frameworks require definitive targets, or measures, in order to judge whether or not an intervention has been successful.
- Management agencies must clearly define quantitative measures to fully understand both the direction of, and the degree to which, existing policies, programs, and financial investment are having the desired effect.

9) System for Regular Public Reporting of Progress:

- Public opinion shapes policies and programs, therefore, the public should routinely be informed about return on public investments -- to themselves, regional and local communities, and economies.
- Agencies and partnerships which are successful at causing real and visible positive environmental change depend upon established systems for regular public reporting of the good, the bad, and the ugly.

10) Recognized Triggers which will Prompt Adapting Public Policies and Management Actions:

- Successful collaborative decision-making processes among multiple agencies and partners identify specific triggers that allow for, or require changes to previous agreements, such as to policies, programs, regulations, and funding priorities.
- The true end goal: the successful implementation of an adaptive management framework supports a process of iterative change when past actions have not led to the desired outcomes. This process leads to enhanced understanding of system responses to different interventions.