Ohio
Department of Agriculture
Department of Natural Resources
Environmental Protection Agency
Lake Erie Commission

Ohio Lake Erie Phosphorus Task Force II Final Report

Final Report
November 2013

Photo caption: Marblehead Lighthouse, Gary Kunze, Kettering Ohio, 2010 *Life on Lake Erie* photo contest entry

Acknowledgements

The Ohio Lake Erie Phosphorus Task Force was comprised of the following members:

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In addition to Task Force Members, several individuals were invited to share their expertise with the group. Presenters included:

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All agendas, presentations, minutes, handouts and other information pertaining to the task force can be found at http://www.epa.ohio.gov/dsw/lakeerie/index.aspx.

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Acronyms

ARS	Agricultural Research Service
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
CAP	Conservation Action Project
CCA	Certified Crop Advisor
CNMP	Comprehensive Nutrient Management Plan
CPPE	Conservation Physical Practice Effects
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
CSO	Combined Sewer Overflow
CSP	Conservation Stewardship Program
DAP	Diammonium Phosphate
DRP	Dissolved Reactive Phosphorus
DSWR	Ohio Department of Natural Resources Division of Soil & Water Resources
EMC	Event Mean Concentration
EQIP	Environmental Quality Incentives Program
FOTG	Field Office Technical Guide of the USDA NRCS
FWMC	Flow-Weighted Mean Concentration
FSA	Farm Service Agency
GLNPO	Great Lakes National Program Office
GLRI	Great Lakes Restoration Initiative
GLWQA	Great Lakes Water Quality Agreement
GPD	Gallons per Day
GPS	Global Positioning System
HABs	Harmful Algal Blooms
HSTS	Home Sewage Treatment System
HUC	Hydrologic Unit Code
IJC	International Joint Commission
IPM	Integrated Pest Management
LEB	Lake Erie Basin
MGD	Million Gallons per Day
MMP	Manure Management Plan or Manure Management Planner
MOU	Memorandum of Understanding
MT	Metric Tons
MTA	Metric Tons per Year
NASS	National Agricultural Statistics Service
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
ODA	Ohio Department of Agriculture
ODNR	Ohio Department of Natural Resources
OEPA	Ohio Environmental Protection Agency
OSU	The Ohio State University
P	Phosphorus
PPB	Parts per Billion

PPM	Parts per Million
PWS	Public Water Supply
RTK	Real Time Kinetic
SRP	Soluble Reactive Phosphorus (same as DRP)
STP	Soil Test Phosphorus
STRAP	Soil Test Risk Assessment Procedure
SWAT	Soil and Water Assessment Tool (Model)
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSP	Technical Service Provider
USDA	United States Department of Agriculture
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WQ	Water Quality
WWTP	Wastewater Treatment Plant

Glossary

Agronomic Range	The maintenance range as defined in the Tri-State Fertility Guide (Vitosh et al., 1996) for individual, specific crops.
Agricultural Nonpoint Source Model (AGNPS)	A distributed event-based model that simulates surface runoff and sediment and nutrient transport, primarily used for agricultural watersheds.
Algae	This term referenced in this document refers to blue-green algae (cyanobacteria).
Buffer Strip	An area that is seeded to grass that can be used for filtering pollutants and provide wildlife habitat. They are also called filter strips, filtered areas, field borders, conservation cover and herbaceous riparian cover (shady habitat).
Bulk Density	The weight of soil for a given volume. Bulk density is used to measure level of compaction; the more compact the soil, the less ability to move water through the soil. Very compact soils have a "platy" or massive structure.
Concentration	The mass or weight of a constituent (e.g., phosphorus, etc.) relative to the volume of transporting fluid, or fluid-constituent mixture. Typically reported in units like mg/L, ug/L, ppm, etc.
Conservation Tillage/Mulch Tillage	Tillage that breaks up the soil but leaves at least 30% of crop residue from the previous year on the soil surface.
Drainage Management	Regulation of the water table by means of pumps, control dams, check drains, or a combination of these, for maintaining the water table at a depth favorable to crop growth.
Controlled Traffic	Repeatedly using the same wheel track for field operations to limit soil compaction.
Conventional Tillage	Uses moldboard plowing or other intensive tillage that buries all previous year's residue and destroys the natural soil structure.
Cover Crops	Used between crop cycles to reduce compaction, recycle nutrients, reduce erosion, improve soil tilth and structure, and fix nitrogen.
Dealer	A commercial agricultural sales operation.
Diagenesis	The physical and chemical changes occurring in sediments during and after the period of deposition up until the time of consolidation.
Discharge	The rate of transport of water. Typically reported in units of m^3/s, ft^3/s, etc.
DRP	Dissolved reactive phosphorus (also called SRP).
Eutrophic	A eutrophic lake has high nutrient concentrations and high productivity.

Flow-weighted Mean Concentration	The sample concentration weighted by both the time and the flow that accompanied it. The FWMC represents the total load for the time period divided by the total discharge for the time period.
GLWQA	Great Lakes Water Quality Agreement
GPS	Global Positioning System
Hypolimnion	Dense, colder water below the thermocline.
Hypereutrophic	An extremely eutrophic lake.
Infiltration	The ease with which water moves into the soil profile from the surface. Good infiltration is better and is most important for soil health.
Interstadial	A warmer subdivision within a glacial stage marking a temporary retreat of the ice.
LaMP	Lake Erie Management Plan
Lateral splitting	The practice of laying additional drainage tiles parallel to existing tiles to create closer spacing and better drainage. Lateral tiles drain into mains.
Load	The total mass or weight of a constituent delivered to some location in a specific period of time. Typically reported in units like tons, kilograms, pounds, cubic feet, etc.
Macropores	Cavities in the soil created by such agents as decayed plant roots, soil cracks and fissures or soil fauna such as earthworms. Macropores increase the hydraulic conductivity of the soil, allowing water to infiltrate faster or for shallow groundwater to flow faster.
Manure brokering	Practice of buying/selling excess manure from livestock operations. In the context of this report, it may lead to manure being removed from the watershed where it was created or imported to a watershed where it was not created.
No-Till/Strip-Till/Direct Seed	Planting in the crop residue of the previous year with no soil disturbance.
P Index	Modeling tool to assess the risk for transport of phosphorus from the landscape to a water body.
Producer	Farmer

RTK auto steer	Real Time Kinematic (RTK) satellite navigation is a technique used to enhance the precision of position data derived from satellite-based positioning systems, being usable in conjunction with GPS, GLONASS and/or Galileo. It uses measurements of the phase of the signal's carrier wave, rather than the information content of the signal, and relies on a single reference station to provide real-time corrections, providing up to centimeter-level accuracy. With reference to GPS in particular, the system is commonly referred to as Carrier-Phase Enhancement, or CPGPS. It has application in land and hydrographic surveys. Agricultural producers use it to steer farm equipment in a particular traffic pattern across fields.
Soil and Water Assessment Tool (SWAT)	A river basin scale model developed to quantify the impact of land management practices in large, complex watersheds.
SRP	Soluble reactive phosphorus (also called DRP)
Stratification	The process of forming or depositing in layers or strata. Used in reference to higher levels phosphorus in the upper tier (top 2 inches) of the soil profile. Stratification of phosphorus can result from natural processes and/or certain types of fertilizer application.
Sub-irrigation	Application of irrigation water below the ground surface through the introduction or pumping of water into the tile drainage network or by raising the outlet elevation through the placement of boards or stops within a drainage water management structure.
Sub-Surface Drainage	Removal of excess water from the land through a network of underground pipes or open ditches.
Sub-surface mains	The collector tile of sub-surface drainage systems that may consist of a number of connected underground pipes (tiles).
Surface Drainage	The natural or diverted removal of excess water from the surface of land by means of improved natural or constructed channels, supplemented when necessary by shaping and grading of land surfaces to such channels.
Tile Drainage	Series of underground tiles that are installed on poorly drained soils to improve soil quality and water infiltration, reduce compaction, improve crop yields, and potentially provide a system to control the amount of surface runoff.
Total P	Total phosphorus including dissolved (SRP or DRP) and particulate phosphorus.
Tri-State	This refers to the partnership of the university agricultural research departments that set agricultural standards in the tri-state area of Michigan, Ohio and Indiana. The three schools are Michigan State University, the Ohio State University and Purdue University.
Water Year	Covers the period from October 1 to September 30.

Section 1 Introduction

In 2012, Ohio EPA, in partnership with the Ohio Lake Erie Commission, the Ohio Department of Agriculture, and the Ohio Department of Natural Resources reconvened the Ohio Lake Erie Phosphorus Task Force as a Phase II effort. Shortly after the 2010 publication of the *Ohio Lake Erie Phosphorus Task Force Final Report*, (Phase I) new information was becoming available and the conversation about nutrient management was broadening to include more stakeholders with additional areas of expertise. A wide range of participants in a variety of disciplines, including members of the original Ohio Lake Erie Phosphorus Task Force, agri-business representatives and crop consultants came together to build upon the findings of the 2010 Phosphorus Task Force report and assess new information.

The purpose of Phosphorus Task Force Phase II is to 1) develop reduction targets for total and dissolved reactive phosphorus that can be used to track future progress, and 2) develop policy and management recommendations based upon new and emerging data and information. The science of phosphorus movement and the factors affecting that movement is evolving. With increased attention to nutrient impacts to water bodies recent research and programmatic developments have been focused on addressing these issues. Phase II of the Ohio Lake Erie Phosphorus Task Force incorporates findings of current research results, develops a broader consensus on the management actions necessary to decrease algae blooms in the Lake Erie and proposes new recommendations. The recommendations in this report reflect the Task Force members' mutual agreement on key issues based on the science and data currently available. As additional research data and results from program implementation become available, the Task Force expects that recommendations for action will evolve over time.

Nutrient impairment continues to plague Lake Erie impacting an $11.5 billion tourism industry and causing increased treatment costs to public water supplies. The Phase I Phosphorus Task Force took a broad-based approach in identifying the potential contributing factors to the increases in algal blooms in Lake Erie. The Task Force concluded that there are multiple contributors to phosphorus into Lake Erie but agriculture is the leading source due to the majority of the land use in agriculture in the Maumee River (~80%) and is key to achieving substantive reductions.

The publication of the Ohio Lake Erie Phosphorus Task Force Phase I report in 2010 served as an important catalyst in bringing awareness and commitment to addressing nutrient loading to Lake Erie. The recommendations in the 2010 report addressed point and nonpoint sources of phosphorus by framing the key issues for each source and providing recommendations for action and identifying research priorities to address the remaining questions about phosphorus and its movement through the landscape. While much remains to be done, substantial progress has been made in addressing nutrient runoff to abate nutrient impairment in stream and algal blooms in Lake Erie. Many of the recommendations in the 2010 report are in varying stages of implementation. For a summary of the status of recommendations from the 2010 report, please see Appendix A of this report. The first task force report is at
http://epa.ohio.gov/portals/35/lakeerie/ptaskforce/Task_Force_Final_Report_April_2010.pdf

Harmful algal blooms (HABs) are actually cyanobacteria and are commonly referred to as "blue-green algae." HABs are considered harmful because they can produce poisons (or toxins) that can cause illness affecting the liver, nervous system and/or skin. The focus on nutrients and algal blooms continues to build in Ohio. Many agencies, organizations, constituencies, researchers and individual agricultural producers are working every day to seek optimal approaches to land management that effectively protect our water resources. This report provides additional data, information and recommendations for refining the decisions we make on nutrient management.

With the implementation of the recommendations in this report, we should see a reduction in the algal blooms in Lake Erie. We also need to acknowledge that we may need to refine or evolve our approaches as more data and information are brought to bear on nutrient practices and transport pathways of those nutrients. Land managers and policy makers want to avoid any unintended consequences from our actions as we work to achieve reductions in algal blooms. An adaptive management process will be critical for continued improvement. Managing adaptively means we need to carefully monitor and observe the situation as our recommendations are implemented and use those observations and new information to refine and improve our recommendations and inform future courses of action to achieve the desired outcomes. While rainfall patterns and storm events will continue to drive the scope of algal blooms in future years, sustained efforts to reduce nutrient loading will reduce the blooms overall. These efforts need to build upon the success achieved over the last 20-30 years in sediment reductions with conservation tillage practices.

Section 2 What's New?

The summers of 2010 and 2011 brought massive algal blooms to Grand Lake St. Marys in west central Ohio and Lake Erie galvanizing state and national attention. In 2010 there were numerous algal blooms across the state leading to 20 inland lakes with public health advisories. While both Grand Lake St. Marys and Lake Erie experienced large blooms in previous years, Grand Lake St. Marys in 2010 and Lake Erie in 2011 far exceeded what had come before. Widespread algal blooms extended far into the central basin of Lake Erie, prompting reactions from many new voices demanding action. And while the land characteristics and land practices vary considerably between Grand Lake St. Marys and Lake Erie, the bloom events served to mobilize action.

In contrast, the drought conditions of 2012 also brought dramatic change to Lake Erie in the substantial reduction of algal blooms. While these conditions were challenging for many agricultural producers, the season did illustrate how quickly Lake Erie will respond when nutrient loading is reduced. See Section 3 for a more detailed comparison of the 2011 and 2012 loadings and resulting conditions.

The Task Force believes it is critical to capture the scope of the momentum of the last few years in addressing nutrient loading. A multitude of stakeholders involved in these issues are working to overcome the complexity of the technical, social and implementation challenges in landscape change. The following narrative provides a brief overview of these efforts and provides an important platform for the additional recommendations developed by the Phosphorus Task Force Phase II.

2.1 Awareness of Phosphorus as a Water Quality Issue

Since 2010, awareness of nutrient issues has grown dramatically among stakeholder groups. Two surveys conducted in winter 2013 provide the first quantification of nutrient application practices and attitudes toward phosphorus as a water quality issue among the agricultural community. The Ohio State University Extension recently summarized results from a survey conducted at the March 2013 Conservation Tillage Conference (CTC), and a survey conducted by mail by the Ohio Agricultural Retailers.

The CTC participants (136 farmers and 157 agricultural industry participants) were given the statement, "Farm Phosphorus loss is a significant problem to Ohio's waters" and a five-option scale ranging from strongly agree to strongly disagree. Farmer response was 71 percent in agreement with the statement with 20 percent neutral and 8 percent in disagreement. Similar responses were related by the agriculture industry participants.

The Ohio Ag Retailers Survey included 54 members representing 4,040,500 acres of nutrient application in both the Lake Erie and Ohio River watersheds. Survey responses to questions on soil sampling practices on Ohio farms indicated that sampling was being conducted on 82% of the acres according to Ohio State University Extension recommended methods. Eleven percent of the acres were sampled but with sample areas of greater than 25 acres. A total of seven percent of the acres were not sampled or the sample was older than 5 years. The CTC survey result showed a similar trend.

A question on application timing in relation to calendar months on the retailer mail survey revealed that fall applications (defined as September through October) accounted for 44%, winter (December – February) are 16%, spring (March-May) are 33% and summer accounted for 7% of the applications. The CTC survey followed a similar trend with slightly higher fall and spring application timings.

The Ohio Agriculture Retailer Survey included a question about application placement and incorporation. Responses indicated application of broadcast P followed by tillage after seven days happened on 15% of applications, broadcast followed by tillage within seven days on 18% of the applications, broadcast with no tillage on 31% of the applications, incorporated using strip tillage on 4% of the applications and incorporated with the planter for 33% of the applications.

2.2 New Programs and Initiatives

State and federal governments have launched a number of voluntary and regulatory programs to address nutrient management. Various industries have also developed and implemented initiatives to help.

Great Lakes Restoration Initiative

In 2010, the U.S. Environmental Protection Agency announced funding for the Great Lakes Restoration Initiative (GLRI). The Initiative had been under development for several years beginning with the release of the *Great Lakes Collaboration Strategy* which was developed with input from more than 1500 stakeholders in the Great Lakes region. That *Strategy* provided the basis for a task force of 11 federal agencies to develop the *Great Lakes Action Plan FY 2010 to 2014*. The Action Plan describes how the GLRI was to be executed.

The GLRI has funded more than 74 projects in Ohio totaling nearly $85 million. These projects span the Ohio Lake Erie basin and focus on a variety of activities including (but not limited to) pollutant reduction, habitat restoration and invasive species control.

Several projects focus particularly on phosphorus and algal blooms including an Ohio EPA funded project to support the work of the Phosphorus Task Force Phase II. Another project funds development of satellite imagery analysis of the algal blooms across the Great Lakes.

One project in particular emerged from the Lake Erie Phosphorus Task Force Phase I, *Phosphorus Reduction Using Variable Rate Technology.* The Conservation Action Project, an agricultural education and outreach organization in northwest Ohio, worked with fertilizer dealers to enroll clients in a program that provided an intense soil sampling regimen and fertilizer applications using variable rate technology. The purpose of the project was to demonstrate how fertilizer dealerships can provide nutrient management services to their clients while implementing nutrient management practices that reduce and incorporate fertilizer applications. The project recently concluded and reported an estimated reduction of 181,510 pounds of phosphorus on 8,653 acres. This results in an average reduction of 20.98 pounds per acre of P_2O_5. Depending on the price paid for phosphorus fertilizer this results in a savings of between $13.00 to $16.00 per acre to the producer, as well as lowering the total pounds of phosphorus at risk of moving off target.

NRCS Great Lakes Conservation Effects Assessment Project (CEAP) Report

In October 2011, NRCS released the USDA CEAP Study "Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Great Lakes Region." (http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/nra/ceap/pub/?&cid=stelprdb1045403) The study by NRCS and ARS applied farmer-sampled actual field data to the APEX model (Agricultural Policy and Environmental Extender, a field-level cropland model)and quantified the effects of applied best management practices on sediment and nutrient delivery to each of the Great Lakes (U.S. drainage basin only). The study showed that the existing conservation practices applied are effective in reducing sediment and nutrient losses, but that many more additional practices will be needed to achieve desired water quality conditions. For the Lake Erie Basin the study reported:

- Eighty-four% of the phosphorus applied to agricultural land in the basin was from commercial fertilizer, and 16% came from animal manure.
- The Lake Erie Basin received the most phosphorus of all the Great Lakes and 44 percent of the total for the Great Lakes.
- Phosphorus delivered to rivers and streams in the Lake Erie Basin from cultivated cropland represented 61% of the total phosphorus load from all sources.
- In the Lake Erie Basin, the average annual phosphorus load delivered from cultivated cropland to edge of fields was 2.05 pounds per acre. The average load delivered from cultivated cropland to the outlets of the HUC 8 watersheds was 1.43 pounds per acre.
- The existing conservation practices (BMPs) applied to cropland in the Lake Erie Basin are reducing edge of field phosphorus losses by 32%, compared to what would be lost if the practices were not in place.

The study also modeled scenarios of the additional phosphorus reductions that could occur with additional cropland treatment and application of additional BMPs. For the Lake Erie Basin, the modeling predicted:

- Treatment of the critical under treated areas (high priority areas as defined in the CEAP report) would reduce phosphorus loading to edge of fields by 6%. Treatment of all the under treated areas in the basin would reduce the phosphorus loading to edge of fields by 35%.
- Treatment of the critical under treated areas (high priority areas as defined in the CEAP report) would reduce phosphorus loading to the HUC 8 outlets by 4%. Treatment of all the under treated areas in the basin would reduce the phosphorus loading to the HUC 8 outlets by 32%.
- Treatment of all under treated areas would reduce loadings to Lake Erie by 20% for the practices modeled.

The study clearly documents the benefits of conservation practices and potential for further phosphorus reductions with increased practice application. At the same time, the results also show that in order to achieve the loading reductions called for in this report, treatment and application of additional BMPs will need to be widespread, beyond just treating the high priority acres.

NRCS Western Lake Erie Basin CEAP

As a result of the Great Lakes CEAP findings and the emergence of the Lake Erie algal issues, in the fall of 2012 NRCS committed $1.5 million to a second much more extensive CEAP Study in the Western Basin of Lake Erie. The special study will include a National Agriculture Statistics Service (NASS) survey of more than 1,000 farmers, which will collect real field crop management data including fertilizer application methods of form, rates, timing and application methods. The CEAP model will be modified to better account for dissolved reactive phosphorus losses through tile drainage. The goal is to generate loading information and BMP effectiveness information, similar to the Great Lakes study, but accurate at the 8-digit HUC levels. When concluded this study will provide much more detailed information than is currently available for the basin. The field surveys are completed and NRCS is beginning work on the APEX modeling. A draft report should be available late in 2013 or in 2014.

NRCS Revised Ohio 590 Standard

In 2012 the NRCS made substantive changes to the Ohio 590 Nutrient Management Standard. These changes were designed to more closely align with current research on nutrient management practices.

Major changes in the new 590 standard include:

- Combines 590 (Nutrient Management) and 633 (Waste Utilization) into one state standard.
- Encourages the application of nutrients as close to the time of uptake as possible.
- Eliminates nutrient application on frozen/snow covered soil.
- Addresses the 4 Rs ("Right timing," "Right placement," "Right amount," and "Right sources") of nutrients like phosphorus and nitrogen. Each "R" considers all nutrients sources, organic (manure) and inorganic (chemical fertilizer).
- Increases emphasis on the risk indices (nitrogen and phosphorus index). Nutrient application rates apply to ALL nutrients, not just fertilizers. Nutrient application rates that exceed the recommendations in the Tri State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa (Extension Bulletin E2567), better known as the Tri-State Fertility Guide will trigger a risk assessment. Excess nutrients are to be considered a temporary situation (Tri- State Fertility Guide 1995, http://www.extension.purdue.edu/extmedia/AY/AY-9-32.pdf).
- Lists additional conservation practices that should be considered in combination with 590 Nutrient Management to further reduce nutrient losses (see p. 11 of new standard).

NRCS Program Initiatives

NRCS has significantly increased its efforts and cost-share programs in the Lake Erie Watershed since the re-emergence of the algal problems. Since federal fiscal year 2010 (October 2009) NRCS has invested more than $24.5 million in conservation cost-share funding in the Western Lake Erie watershed. This includes more than $8.2 million in GLRI funds received by NRCS, nearly $850,000 in GLRI phosphorus funding specifically for the Blanchard Watershed, and more than $15.5 million in regular and special NRCS Environmental Quality Incentive Program (EQIP) cost-share funding in Ohio. GLRI has provided 37% of the cost-share funding to farmers and ongoing NRCS Farm Bill funding has provided 63%.

NRCS has targeted numerous sub-watersheds in the basin for special initiatives, including the Blanchard Watershed. NRCS has also modified its ranking system to give more priority and higher rankings to cost-share applications with nutrient management resource concerns and nutrient management practices.

NRCS has also developed a bundle of conservation practices for EQIP in Ohio which combines precision nutrient management, cover crops, controlled traffic, and conservation tillage or strip tillage into one system. This bundle improves soil health. When the system is used properly, only the nutrients needed are applied where they are needed, when they are needed. The combination of all the practices improves infiltration and reduces surface runoff. NRCS gives priority to these bundled practices in the ranking and provides higher cost share payments when the complete system is applied.

NRCS Revised Nutrient Management Plan (NMP)

The Ohio NRCS is working with state partners to streamline the elements in Nutrient Management Plans (NMPs) and Comprehensive Nutrient Management Plans (CNMPs). The main emphasis is on fertilizer only plans. Custom applicators are a vital component to this. The goal to have one plan the state and NRCS can offer together. Revised templates are currently available.

Ohio Nutrient Reduction Strategy for Ohio Waters

On June 28, 2013, the State of Ohio submitted to U.S. EPA a statewide nutrient reduction strategy (http://epa.ohio.gov/Portals/35/wqs/ONRS_final_jun13.pdf). This framework was prepared by Ohio EPA in collaboration with the Ohio Department of Agriculture (ODA) and the Ohio Department of Natural Resources (ODNR). The strategy reflects input from the various workgroups and the public and includes content specifically requested by U.S. EPA from all states in a March 2011 memo.

The strategy provides an overview of current state program efforts to reduce nutrient impairments and recommends voluntary practices and regulatory-based initiatives designed to reduce nutrient losses in runoff and subsurface drainage and to remove nutrients through point source treatment technologies. The strategy also references the work of several task forces and workgroups, including the Lake Erie Phosphorus Task Force Phase I, the Directors' Agricultural Nutrients and Water Quality Working Group, the Point Source and Urban Runoff Work Group, and the Lake Erie Phosphorus Task Force Phase II.

In addition, the Ohio Nutrient Forum Visioning Workshop, held in November 2012, provided the opportunity for stakeholders to hear about Ohio's nutrient reduction efforts and strategy development, ask questions and offer input. More than 200 people attended. Information and a complete summary of the workshop are available on line (http://www.tetratech-ffx.com/ohio_nutrient/index.html).

Ohio Nutrient Criteria

Ohio EPA is developing water quality standards for streams and rivers to protect beneficial uses of water from adverse impacts due to excess amounts of nutrients entering rivers and lakes (not including Lake Erie).

Ohio EPA has studied more than 100 stream locations since 2002 to develop empirical relationships between nutrient concentrations (total phosphorus (TP) and dissolved inorganic nitrogen (DIN)), chlorophyll a produced by benthic algae, dissolved oxygen and overall biological community health (Ohio's existing biological criteria). A scoring system has been developed that aggregates results from separate evaluations of primary productivity, biological health and in-stream nutrient concentrations. The resulting output is a multi-metric scoring system referred to as the Trophic Index Criterion (TIC). The TIC provides an integration of "stressor" variables (nitrogen and phosphorus concentrations) that potentially cause stream degradation with "response" data collected through measurements of biologically important stream attributes. More information can be obtained at http://www.epa.state.oh.us/dsw/dswrules.aspx.

While not specific to Lake Erie or the Lake Erie basin, this framework for streams will ultimately provide important data in understanding which stream segments in any area of the state are experiencing impacts from nutrient enrichment.

Directors' Agricultural Nutrients and Water Quality Working Group

In 2011, Ohio's Governor charged the Directors of Natural Resources, Agriculture and the Ohio Environmental Protection Agency to develop recommendations for improving Ohio's water resources while maintaining the integrity of the region's agricultural industry. The Directors' Agricultural Nutrients and Water Quality Working Group involved 125 stakeholders from agriculture, agribusiness, environmental advocacy, academia and local government. A final report in March 2012 compiled all of the recommendations brought forward and can be found at: (http://www.dnr.state.oh.us/portals/12/docs/waterqualityreport.pdf). The three directors utilized this input to develop the following recommendations:

- Implement the"4R Nutrient Stewardship," which encourages farmers to use the right fertilizer source, at the right rate, at the right time and with the right placement.
- Continue research into nutrient management with a focus on dissolved reactive phosphorus (DRP).
- Continue communications and education efforts with farmers and other interested parties on agricultural nutrient management.
- Create a program to train farmers about commercial fertilizer application and gain the ability to better understand where fertilizer sales are being made.
- Develop a voluntary, statewide "Certified Nutrient Stewardship Program" for farmers.

The recommendations are being implemented through various actions, including the Healthy Lake Erie Fund (see below). Initiatives to educate Ohioans in the Western Basin area of Lake Erie about the efforts underway to improve Ohio's waterways are being implemented, including working with the media to publish stories on the issue, providing educational materials at fairs and other events and holding field days for farmers, producers and other key stakeholders to demonstrate nutrient stewardship practices and production techniques.

Clean Lakes Ohio Initiative / Healthy Lake Erie Fund

The Ohio Clean Lakes Initiative was created by the directors of Ohio EPA, ODNR and ODA to address the major environmental and economic challenges facing Lake Erie from increased incidences of nuisance algae. The Healthy Lake Erie Fund, created in June 2012 by the Ohio General Assembly, provided $3 million for projects in the Western Lake Erie Basin to help address the agricultural nutrient issues and implement recommendations outlined in the Directors' Agricultural Nutrients and Water Quality Working Group Report, which focuses on reducing excess nutrients entering the Western Basin of Lake Erie. ODNR administers the fund, with assistance from ODA and the Ohio EPA.

As of April 2013, the Healthy Lake Erie Fund has enabled farmers to put to use agricultural nutrient reduction practices on more than 35,000 acres of farmland in the Western Lake Erie Basin watershed. Local soil and water conservation districts assist ODNR in identifying and helping eligible farmers implement the practices. The fund focuses on several agronomic practices such as cover crops, variable rate fertilizer applications, nutrient incorporation and controlled drainage structures. Farmers participating in the Ohio Clean Lakes Initiative conduct soil tests to determine the nutrient levels compared with the requirements for their next crop. They also follow Tri-State Fertilizer Recommendations to determine the appropriate amount of fertilizer to apply to their fields.

More than 290 farmers in Henry, Wood, Putnam, Defiance, and Hancock counties are currently using these new conservation practices, with more expected to participate. In addition, some funds were allocated to soil and water conservation districts to provide technical assistance to farmers. The ODNR Division of Soil and Water Resources plans to designate some of these farmers as "ambassadors" to share their experiences and help expand the adoption of additional practices throughout the Western Lake Erie Basin and the rest of Ohio.

One of the components of the Healthy Lake Erie Fund is to provide for monitoring of water quality in the basin. In June of 2013, the ODNR signed an agreement with USGS to install seven additional water quality monitoring stations in the Maumee River basin mostly near the mouths of the major tributaries to the Maumee River. The sites are designed to capture the loadings for the major watersheds in the upper watershed and that coming in from Indiana. To allow calculations of loads, four new streamflow gages will also have to be installed. The new stations are: Maumee River at Antwerp, Blanchard River near Dupont, Ottawa River near Kalida, and Tiffin River near Evansport. Three water quality monitoring stations will be located at or near existing streamflow gages: Auglaize River near Ft. Jennings (04186500), Auglaize River near Defiance (04191500), and Maumee River near Defiance (04192500). Plans are for samples to be analyzed for TP, DRP, several nitrogen analytes, and sediment. Starting October 1, 2013, the USGS expects to begin the nutrient and sediment sampling and analyses.

Point Source & Urban Runoff Nutrient Workgroup

Ohio EPA convened a work group to look at sources of pollutants from point sources and the urban environment. The group consisted of 25 invited members, including large and small WWTPs, consultants, electric utilities, food industry, environmental, and lawn care industries. The group's charge was to identify actions to take in the short term to reduce nutrients and to identify roadblocks to progress. The group distilled their work into six recommendations:

- Ohio EPA should develop a state-wide nutrient mass balance sheet that accounts for point and non-point sources of nutrients.
- Ohio EPA should encourage and promote operational experimentation at wastewater treatment facilities aimed at achieving low cost nutrient removal.
- Wastewater treatment plant owners should be prepared to determine cost effective means to achieve lower effluent limits wherever facilities are shown to be significant contributors to nutrient enrichment.
- State government should appoint a panel of economic, financial, and policy experts to consider options for funding the implementation of Ohio's nutrient reduction strategy.
- Ohio EPA should publish an annual report on nutrient loadings and resulting water quality conditions in our lakes and rivers.
- Ohio EPA should integrate watershed management and green infrastructure planning with Ohio's nutrient reduction strategy.

The group's report is available at
http://www.epa.ohio.gov/portals/35/documents/point_source_workgroup_report.pdf

4R Nutrient Stewardship

Recently, the 4R Nutrient Stewardship program, developed by the International Plant Nutrition Institute, has gained widespread attention as a meaningful approach towards nutrient management. The 4R approach provides a framework to achieve cropping system goals such as increased production, increased farmer profitability, enhanced environmental protection and improved sustainability. To achieve those goals, the 4R's incorporate the "Right fertilizer source at the Right rate, at the Right time and in the Right place." Properly managed fertilizers support cropping systems that provide economic, social and environmental benefits. Many outreach materials about the 4R program have been developed to target agricultural producers and can be found on the nutrientstewardship.com site sponsored by The Fertilizer Institute.

An advisory committee of experts from Indiana, Michigan and Ohio recently developed a draft 4R Certification Standard as a voluntary program for nutrient service providers. The standard is intended to provide guidance and direction for a consistent, recognized program for agricultural retailers, agricultural service providers and certified professionals. The purpose is to ensure that 4R nutrient management goals are adopted that lead to long term positive impacts in the western Lake Erie basin.

The certification program recently pilot tested four projects in July 2013 and results are being reviewed by the advisory committee. Full roll out of the program is expected to begin within calendar year 2013.

The Adapt Network and the On-Farm Network (OFN)

The Adapt Network is a collaborative approach with farmers and their advisors working together to evaluate nutrient management practices and how to improve the efficiency of nitrogen and phosphorus management. The On-Farm Network® is a group of crop producers interested in economics, stewardship, and reducing their environmental footprint. Both of these networks bring together farmers, their advisors, and university experts to fine-tune nutrient management using data from the farmer's own operation. Over 100 producers farming about 200,000 acres in the western Lake Erie basin are currently involved and the program is growing.

The On-Farm Network and Adapt Network are separate efforts but both are active in the Lake Erie watershed. These Networks are a proven method for farmers to analyze the 4Rs for their operations. Utilizing tools like aerial imagery, rate trials, cornstalk tests and yield data, advisors and farmers can work together to discover the best rate, form, timing and placement of nutrients – the 4Rs – and become more efficient and effective managers, relying on the "5^{th} R" (the right data), improving water quality and boosting profit at the same time.

Lawn Care Industry

In 2010, the Task Force concluded that the relative contribution of the Dissolved Reactive Phosphorus load to Lake Erie from turf is likely to be low. In 2011 the Scotts Miracle-Gro Company announced it would eliminate phosphorus from its lawn maintenance line of products by 2013. In a May 2013 press release, Scotts announced they have met that goal. Phosphorus use in lawn care management is now limited to use in establishing new lawns from seed, correcting deficiencies identified through soil testing, or for some organic based products (phosphorus naturally occurs in the organic materials contained in those products). The elimination of phosphorus in lawn maintenance products by The Scotts Company resulted in an annual reduction of 158 tons of phosphorus sold at retail locations throughout Ohio (based on a 2010 baseline).

The Task Force in 2010 also acknowledged the importance of BMP education and recognized the importance of efforts underway by fertilizer manufacturers and lawn service providers to reduce phosphorus use on mature lawns and turf systems. Taking advantage of the direct to consumer education opportunity Scotts Turf Builder product packaging now includes environmental stewardship practices for homeowners and all Scotts consumer packaging bears instruction to avoid application on driveways, sidewalks, and other hard surfaces. Lawn Service providers are utilizing fertilizer spreaders equipped with deflector shields that direct product away from sidewalks, driveways, and other hard surfaces that can transport fertilizer to storm sewers and waterways during rain events. This technology was extended to the retail market in 2008 and is now widely available to do-it-yourself homeowners. The adoption of BMPs and a voluntary commitment to limited use of phosphorus by Ohio's professional lawn care industry represents an additional estimated reduction of more than 300 tons annually.[1]

In 2011, the Ohio Federation of Soil and Water Conservation Districts developed and implemented education and outreach materials to reach the citizenry in urban areas. The outreach program promotes best practices and highlights simple steps homeowners can adopt to help reduce stormwater run-off and protect Ohio's water resources.

2.3 New Research and Monitoring

What happens in Lake Erie is inextricably tied to what's happening on the land that drains to the lake. The reappearance of algal blooms in the lake has energized research and monitoring in both Lake Erie and its watershed.

2.3.1 In-Lake Monitoring

Monitoring the condition of Lake Erie is resulting in an increased investment in sampling and coordination relative to HABs. Federal, state and local partners are working together to generate common data. A unique public/private partnership between Ohio EPA, Ohio State University, and Lake Erie charter boat captains engages a key stakeholder group directly impacted by the harmful algal blooms and declining conditions on the lake.

Ohio EPA is responsible for monitoring and reporting on the status of Ohio's portion of Lake Erie under the Clean Water Act. After a gap of several years caused by budget constraints, the agency recently re-started a monitoring program under a GLRI grant. The 3-year grant is designed to evaluate the variability and applicability of key parameters and other measures, and results will be used to design a sustainable, long-term monitoring program. As part of the GLRI grant, Ohio EPA is working directly with other state agencies, universities and federal partners. Ohio EPA intends to secure funding to maintain this monitoring on an ongoing basis.

The harmful algal blooms (HABs) that have reappeared in western Lake Erie are dominated by the cyanobacteria *Microcystis*. Researchers are focusing on when and how it appears, its density, how its formation and movement can be predicted. The University of Toledo has been collecting samples once every two weeks at six sites in Maumee Bay for several years, which led to the development of a "biovolume" measure of cyanobacteria.

[1] Approximately half of lawn fertilizer tonnage is applied by homeowners and half is applied by lawn service providers. The Scotts Company retail sales account for approximately 50% of retail lawn fertilizer sales in Ohio.

An important development is the availability of harmful algal bloom bulletins and forecasts. The National Oceanic and Atmospheric Administration (NOAA) has been providing weekly bulletins on harmful algal bloom conditions in western Lake Erie since 2008 to provide natural resource managers and citizens advance notice of harmful algal blooms. The bulletin depicts the HAB's current location and likely future movement, as well as categorizes its intensity on a weekly basis. The information is based on a NOAA-developed algorithm for satellite data that effectively detects both areal extent and concentration of *Microcystis* in western Lake Erie. The detection is done using high temporal resolution satellite imagery from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite sensor. The forecasts are issued on a weekly basis from the first week of June to the last week of October; generally they are issued a day after a clear satellite image that does not contain cloudy conditions.

On July 5, 2012, NOAA scientists at the National Centers for Coastal Ocean Science's (NCCOS) Center for Coastal Monitoring and Assessment (CCMA), Ohio State University's Sea Grant and Stone Laboratory, the University of Toledo and Heidelberg University announced the first seasonal forecast of Harmful Algal Blooms (HABs) in Lake Erie, a first for the Great Lakes region and the country. Being able to forecast the HAB's extent allows community officials and tourism managers to prepare for its impacts and adjust seasonal budgets in advance instead of reacting to the event as it happens. NOAA and its partners expect to continue the seasonal forecasts and bulletins.

In 2013, the USGS Great Lakes Science Center in Ann Arbor started a 3-year project to monitor water quality and algae in the open waters of the western basin at six sites. While most of the monitoring will be in Michigan waters, the project is designed to help answer some of the questions about how and why blooms start in the western basin. The sites will be sampled on a bi-weekly basis through the growing season. Additional sampling will be done for storm and other unusual events. Project goals include assessing the roles of sediment resuspension and mixing of the major river plumes in western basin water quality.

2.3.2 Land and Stream Based Monitoring and Research

A major research effort on a key agriculture tool is underway with initial results expected in 2015. The U.S. Department of Agriculture-Natural Resources Conservation Service Ohio Phosphorus (P) Risk Index is used by farmers statewide to develop nutrient management plans for both manure and commercial fertilizer application. A three-year $2 million project to evaluate and, as necessary, revise the Ohio P Risk Index to better predict the risk of phosphorus moving off farm fields is being funded by a $1 million USDA Conservation Innovation Grant and $1 million in matching donations from the following funding partners: the Ohio Corn Marketing Program, Ohio Small Grains Marketing Program, The Andersons, United Soybean Board, Ohio Farm Bureau Federation, Nachurs, Trupointe Cooperative, Luckey Farmers Cooperative, Schlessman Seed and Paulding County Farm Bureau.

The project will use edge-of-field testing, primarily in the Grand Lake St. Marys and western Lake Erie basin areas, to validate the phosphorous risk index and study the effect of BMPs on phosphorous transport. The project will develop an interactive web-based tool so farmers can calculate their P Risk Index scores, evaluate management options and make informed decisions to better manage phosphorus. The work is being directed by Dr. Elizabeth Dayton, a soil science researcher in Ohio State University's School of Environment and Natural Resources.

2.4 *Other Recent Trends*

In the initial report released by the Ohio Phosphorus Task Force in April of 2010, two items were reported: commercial fertilizer use within Ohio and a balance calculation based upon crop productivity (and subsequent phosphorus removal) and phosphorus production (from manure) and consumption (commercial fertilizer sales). Both of those items have been updated to reflect phosphorus fertilizer sales and phosphorus balance through the year 2011.

Phosphorus sales continued to be below the historical average (202 tons (x 1000)) during the crop years 2008-2011 (Figure 2-1). In fact, phosphorus fertilizer sales have been below the running historic average since 2001. The amount of phosphorus fertilizer sold in Ohio in 2011 was the lowest on record.

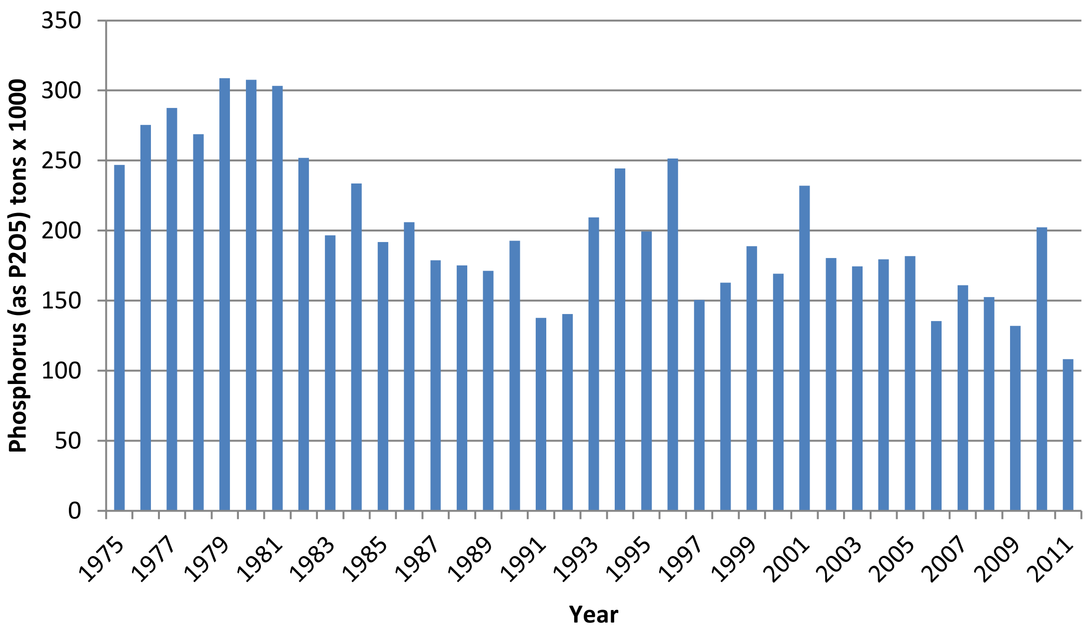


Figure 2-1. Phosphorus commercial fertilizer sales for the state of Ohio from 1975 to 2011.
Source: American Association of Plant Food Control Officials (AAPFCO).

The original balance calculation presented by the Ohio P Task Force had a fundamental flaw in the model. It assumed that manure nutrients were well distributed across the entire state, i.e. manure produced from animal production was distributed for nutrient use without geographic boundaries. This is a poor assumption because manure nutrients are typically distributed fairly close to the source of production. To improve the model, a USDA-ERS report (reference) was used to adjust the distribution of manure nutrients to more closely reflect reality. Both models were evaluated to determine the relative agreement between the two, and while the approach is completely different, the model balance output was quite similar. Therefore only the USDA-ERS approach will be shown in this report (Figure 2-2).

The phosphorus balance in Ohio continued to decline from 2008-2011. This is the result of increased levels of production and decreased fertilizer sales and manure production.

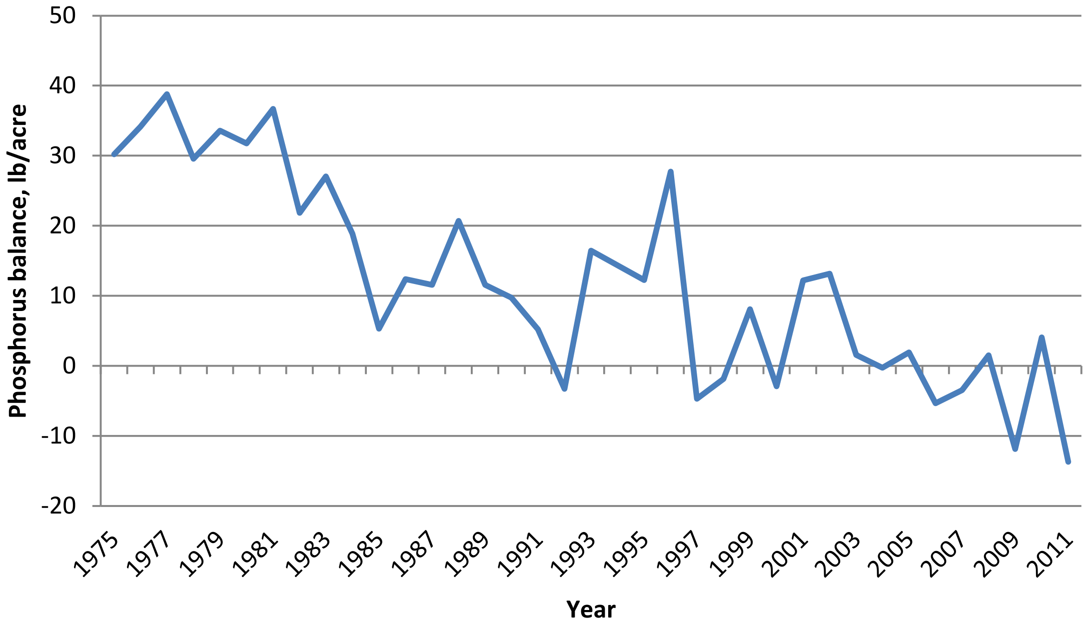


Figure 2-2. Phosphorus balance for the state of Ohio based upon a USDA-ERS adjusted model.
Sources: USDA-NASS, Tri-State Fertilizer Recommendations, AAPFCO, IPNI Nutrient Removal Estimates, and MidWest Plan Service (MWPS-18).

Another piece of information to consider is phosphorus source changes with regard to commercial fertilizer form. There have been some significant shifts in phosphorus source use over the last 26 years (Figure 2-3). Since all fertilizer forms are designed to be highly soluble in water, the possible connection between phosphorus loss and form is not clear. Diammonium phosphate (DAP) use continues to be one of the primary sources of phosphorus fertilizer sold within the state. Monoammonium phosphate (MAP) sales have increased substantially since 2002. Ammonium polyphosphate use has remained relatively stable since 1985. Triple superphosphate use has decreased to almost zero.

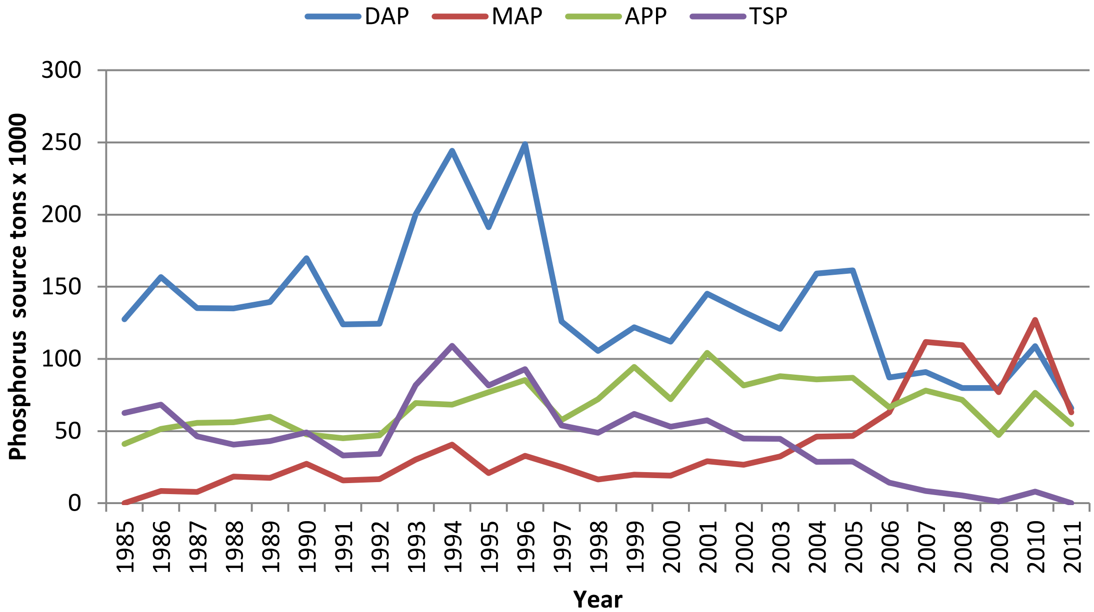


Figure 2-3. Commercial phosphorus fertilizer sales by source since 1985.
Source: American Association of Plant Food Control Officials (AAPFCO).

In 2009 the Lake Erie Protection Fund (administered by the Ohio Lake Erie Commission) funded the following study: Analysis of Soil Testing Laboratories and Data Mining (Mullen & Dayton), to get an overview of soil test P (STP) values in Ohio. The three largest soil test laboratories (A & L, Brookside, and Spectrum analytic) were contacted and graciously agreed to share all their STP data at a zip code resolution. The data are for the Mehlich 3 (M3) soil test P in ppm. The initial data set included STP data from 1992 through 2008, consisting of > 1 million STP data records. Subsequently the labs provided 2009 through spring 2012, bringing the number of data records closer to 2 million.

While this data is a survey of soil test data and not a random sample, it is still a comprehensive overview of the STP status of Ohio and the trending of STP values over time. On a M3 basis the critical STP level, where there could be crop P deficiencies is at approximately 21 ppm, while the level at which no more P fertilizer applications are recommended for any crop is at approximately 71 ppm. Figure 2-4 is a map of the median (50 percentile) STP (Mehlich 3, PPM) values for Ohio sub basins for the STP data for 2000-2012, along with their associated uncertainties.

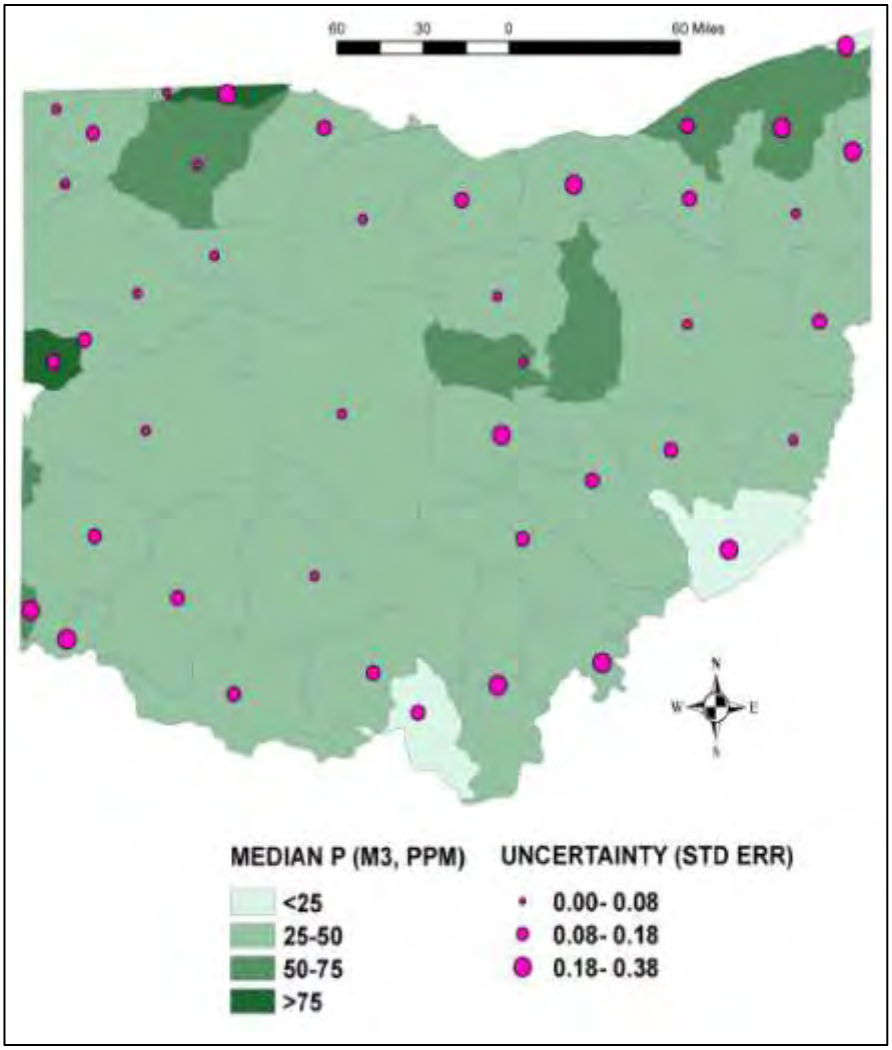


Figure 2-4. Median Mehlich 3 soil test P values (ppm) for Ohio sub basins (hydrologic unit code level 8) including data from 2000-2012 and associated standard errors for measures.

The median STP levels for the majority of the sub basins (39 out of 41) is within the agronomic range with two sub basins being close to the soil P critical level and two with a median above . Those sub basins with median STP values above the agronomic range are often areas with intense agriculture.

Temporal trends in STP were also examined. (Figure 2-5). The 25th, 50th, 75th and 90th percentiles were examined at the sub region level over time increments. The red horizontal reference line at 21 ppm represents the approximate STP critical level below which crop P deficiencies can occur. The upper reference line at 71 ppm represents the approximate STP value where no further P fertilizer is recommended for any crop. For most sub regions 75% of STP values are within the agronomic range. Only sub region 6, which is an area of intense nursery production and sub region 8 which is an area of high animal agriculture had 75th percentiles above the agronomic range, but they appear to be trending down. In many cases there is a downward trend in STP levels. Sub region 9, which affects the Western Lake Erie Basin, shows a downward trend, not just for the 90th percentile, but also for the 75th, 50th and 25th percentiles. Soil test P levels do not change rapidly, even without further fertilizer applications so the downward trend is encouraging.

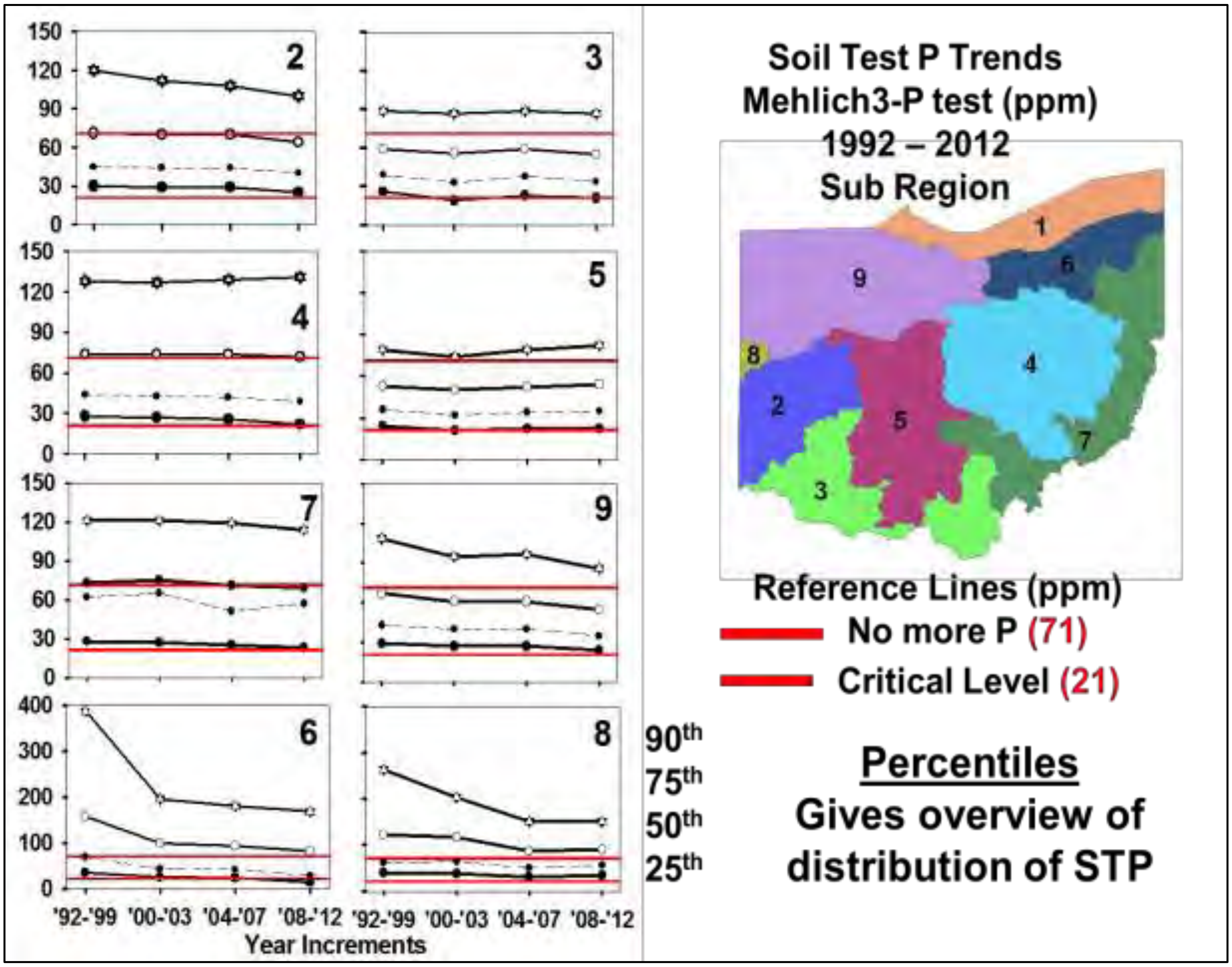


Figure 2-5. Trends in soil test P (Melich3-P, ppm) percentiles over time for aggregated Ohio sub regions.

Section 3 Current Status of Lake Erie

The first Lake Erie Phosphorus Task Force report (Ohio EPA, 2010) reported on conditions in Lake Erie and outlined sources of total and dissolved phosphorus and estimated loading from each type. That information provides good basic information that continues to serve as a useful reference. However, while most of the regulated sources of phosphorus are believed to have remained constant since the first report, more information on costs of point source phosphorus reduction and progress in eliminating or reducing combined sewer overflows (CSOs) is available. Also, information and graphs concerning stream flow and the loadings of total and dissolved phosphorus can be updated. Finally, the weather in 2011 and 2012, and the resulting harmful algal blooms in Lake Erie provide an interesting case study.

3.1 Progress and Costs of Reducing Point Source Loads

Point source total phosphorus load discharged to Lake Erie comes from two main sources, publicly owned sewage treatment plants (POTWs), and overflows of untreated sewage from public sewer systems (combined sewer overflows (CSOs)). Industrial facilities that discharge directly to waters of the state typically do not discharge significant loads of total phosphorus. More information about Ohio point sources is contained in Appendix B.

Cost of Phosphorus Removal at POTWs

The 703 permitted WWTPs in the Ohio Lake Erie watershed discharge approximately 1,076 million gallons per day (MGD). Small package plants discharging less than 50,000 gallons per day account for 66% of these permits. The majority of the flow and phosphorus load comes from the 12 (1.7%) major WWTPs with a discharge greater than 15 MGD each.

Phosphorus limits are assigned to 109 POTW facilities in the Lake Erie Basin. Those with a design flow of 1.0 MGD or more, or designated as a major discharger by the director, must meet a total phosphorus discharge limit of 1.0 milligram per liter (mg/L) as a thirty-day average. POTWs must maintain the treatment works in good working order and operate as efficiently as possible. As a result, many POTWs approach a final outfall concentration of 0.5 mg/L total phosphorus.

POTWs use chemical precipitation and existing equipment to meet the 1 mg/L limit at a reasonably affordable cost. For example, the Northeast Ohio Regional Sewer District (NEORSD), which treats wastewater from the greater Cleveland area and surrounding satellite communities, spends several hundred thousand dollars per year on chemical costs for total phosphorus removal. This is a relatively small cost for such a large utility.

When considering lowering the TP limit to 0.5 mg/L, however, it is important to note that existing POTWs will likely need to install filtration to ensure that they can consistently meet a lower limit. While many POTWs have tertiary filters, the largest POTWs – NEORSD, Toledo, Akron and Sandusky, do not. Installation, operation and maintenance of tertiary filters at these facilities would be expensive. For example, a rough cost estimate to install filters at NEORSD to treat effluent to 0.5 mg/L TP would be $200 million. If the TP limit were lowered to below 0.1 mg/L, membrane filtration would be required which is much more effective than traditional filters and also substantially more expensive. In addition, much larger doses of chemical would be required.

Generally speaking, as nutrient limits are reduced the capital and operating removal costs associated with nutrient removal increase. An example of this is shown in the table, which shows the cost increase associated with reducing phosphorus from 0.5 mg/L to 0.05 mg/L. Operation and maintenance costs at waste water treatment plants must take into account factors such as labor, maintenance, electricity use, chemical use, and sewage sludge management. Costs are difficult to estimate because they fluctuate with market conditions, inflation, geographic location, and the technology employed to facilitate nutrient removal. Capital costs also vary depending on whether the cost is associated with a new treatment plant or with a retrofit of an existing treatment plant. As state and federal cost share assistance for waste water infrastructure diminishes, it is expected that significant rate increases would be passed on to ratepayers for the upgraded technology needed to comply with more stringent nutrient limits.

Phosphorus Limit	Cost ($/lb Phosphorus Removed)
0.5 mg/L	2.60 – 18.00
0.05 mg/L	37.00

Source: Bhattarai, 2010

Progress on Combined Sewer Overflows

The second significant point source load is overflows and bypasses from municipal sewer systems, known as CSOs and SSOs. Ohio has 101 CSO communities, 62 of which are in the Lake Erie drainage basin (Figure 3-1). As with discharges from POTWs, most of the total phosphorus discharged CSO and SSO volume comes from the largest CSO communities – NEORSD, Akron, Toledo, Fremont and Sandusky.

USEPA and Ohio EPA have been working with communities to address combined sewer overflows since the early 2000s. Almost all the CSO communities in the Lake Erie drainage basin have developed comprehensive Long Term Control Plans (LTCPs) to reduce and minimize discharges from CSOs and SSOs. These plans typically recommend a combination of structural controls such as storage basins, tunnels, POTW treatment capacity increases, wet weather physical-chemical treatment facilities and sewer separation projects. Permits and court orders require construction of these structural controls. Many of these communities are currently constructing projects with many communities expected to complete construction of all required projects in the next ten years. For example, by 2020, 40 of the 62 communities in the Lake Erie drainage basin will have completed the projects required by their LTCP, with all projected to be complete by2035.

Year	# of CSO Communities with Complete LTCPs
2013	22
2015	28
2020	40
2025	42
2030	51
2035	62

Ohio EPA estimates approximately 19 billion gallons were discharged in a typical year in the 1990s and that implementation of LTCP projects has already reduced CSO discharges by approximately 7.5 billion gallons since the 1990s. Appendix B contains more information on estimated baseline, current and reduced CSO volumes. Ohio EPA expects continued significant progress in reducing overflows from these larger CSO communities.

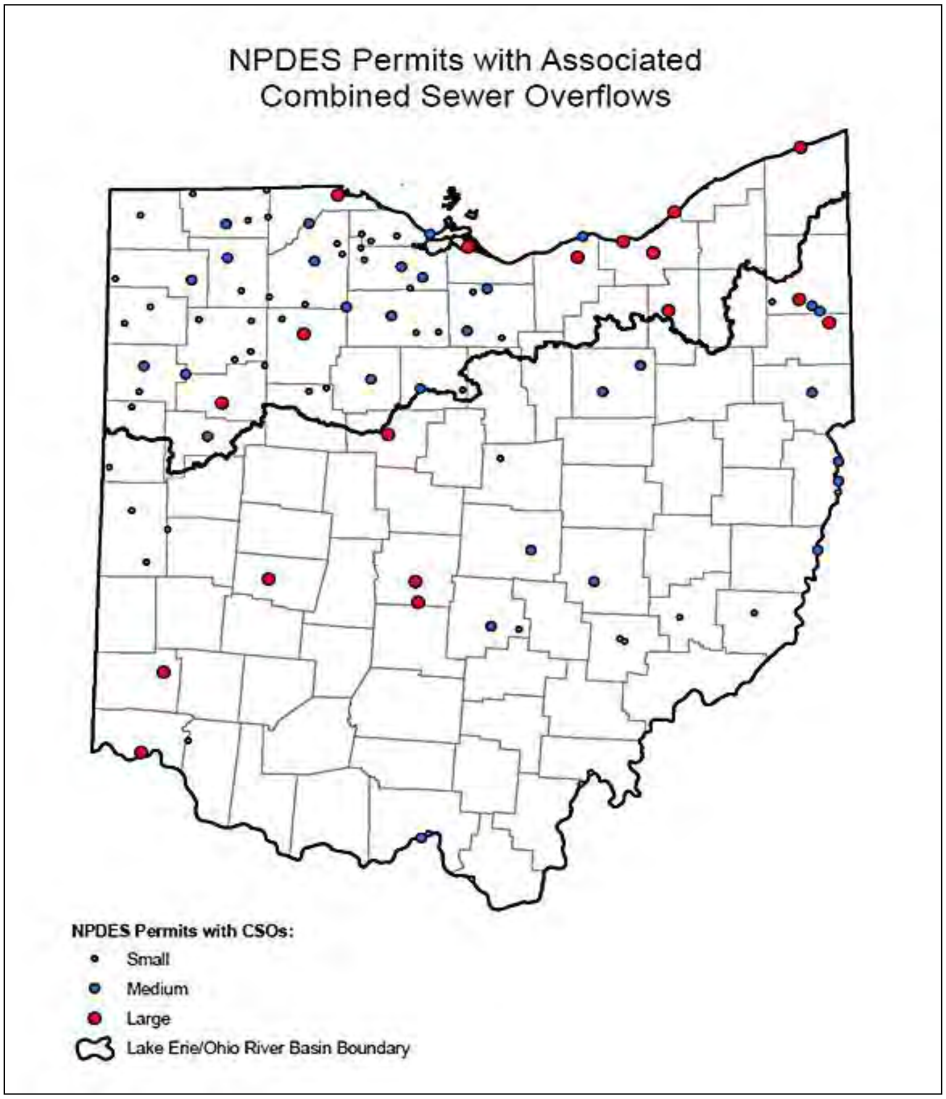


Figure 3-1. CSO communities in Ohio.

NEORSD is investing $3 billion in a LTCP to construct five underground tunnels and to enhance the WWTP, the conveyance system and system storage. NEORSD has reduced their overflow volume to 4.5 billion gallons per year (BG/yr), a 50% decrease from an original baseline overflow estimate of 9 BG/yr. NEORSD continues to make progress and is projected to achieve the goals of the LTCP in 2035. Figure 3-2 shows the projected overflow reductions for NEORSD.

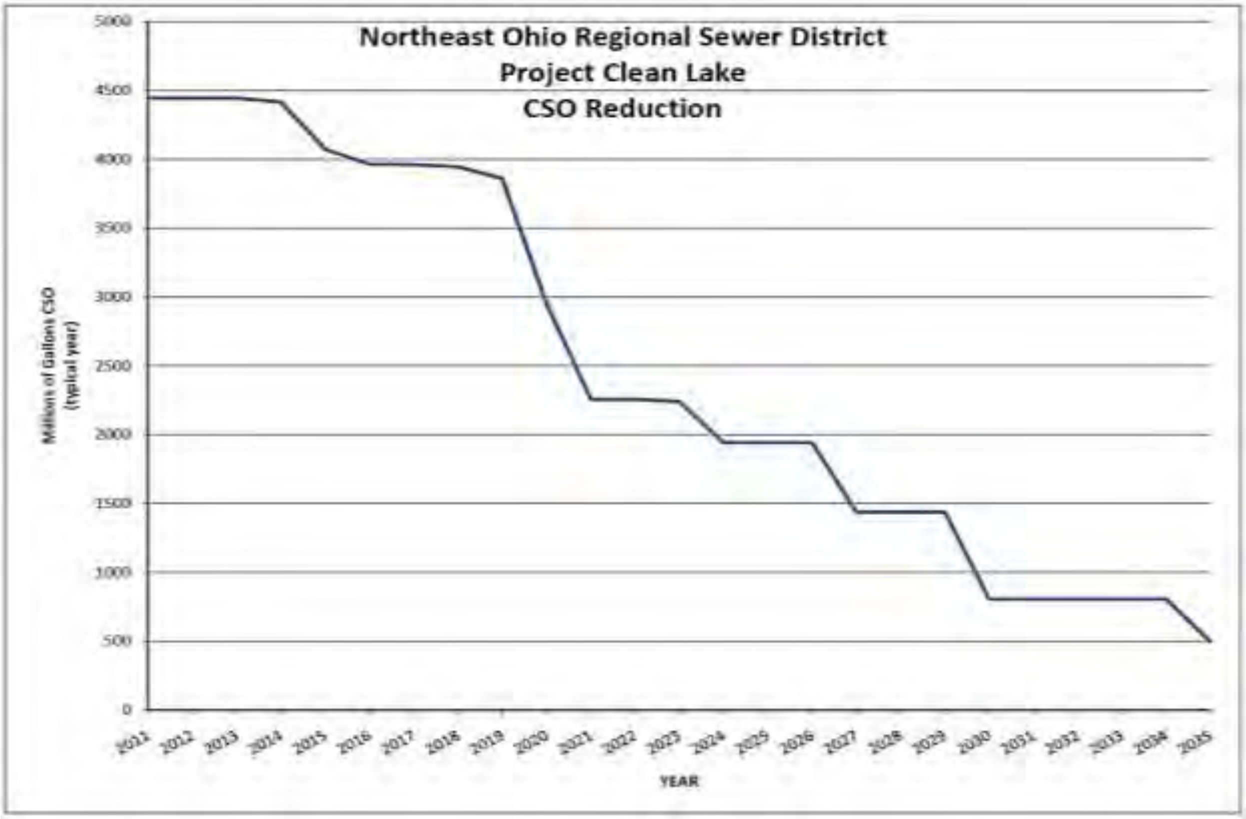


Figure 3-2. CSO Long-Term Control Plan presentation to NEORSD Trustees 11/18/2010.

Akron's LTCP includes the construction of two underground tunnels, upgrades to the WWTP, separation of several combined sewer areas, and storage basin installation. By the end of 2014, Akron has projected to reduce overflow volume by 40% (see Figure 3-3). Akron is investing $900 million in LTCP projects and is scheduled to complete the LTCP in 2028.

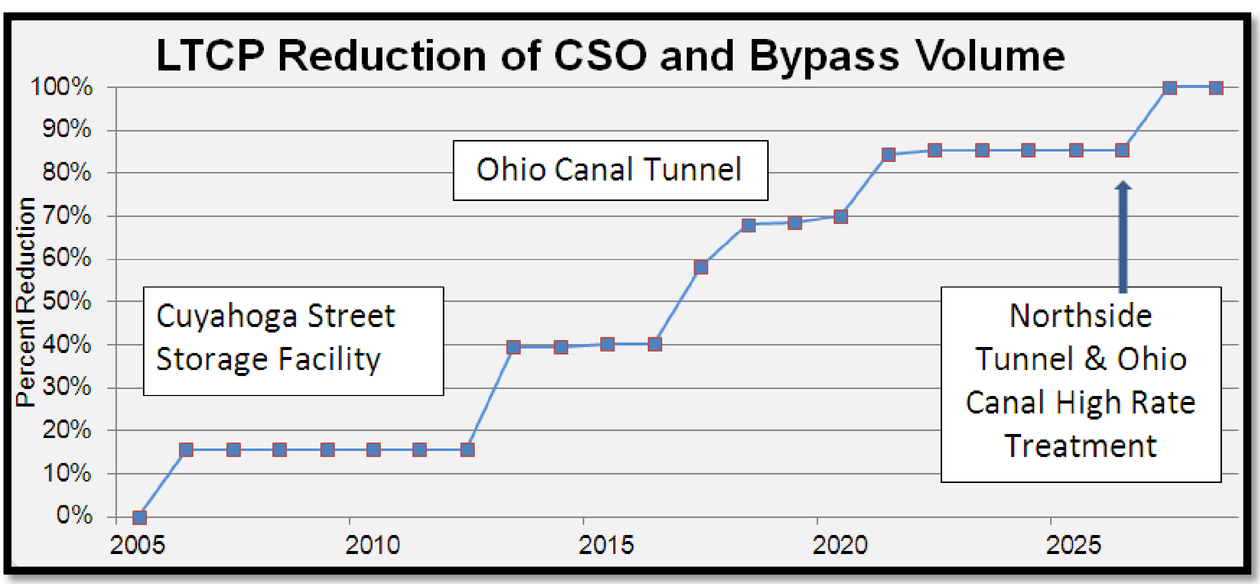


Figure 3-3. Akron projected CSO and bypass volume percent reduction.

Toledo is investing $500 million in a LTCP to be completed in 2020. The LTCP includes projects to expand the WWTP capacity, provide system storage, separate combined sewers and remove inflow and infiltration sources. Toledo also constructed three CSO tunnels between 1988 and 1994.

Sandusky completed a WWTP expansion in 2010 to increase the wet weather capacity from 36 MGD to 42 MGD. Sandusky submitted a revised LTCP in December 2012 and is currently negotiating storage, conveyance and pump upgrades. The Sandusky LTCP will also be completed in 2020.

All these improvements come at a substantial cost to local communities and ratepayers. The total investment among three of the largest communities in the Lake Erie Basin (NEORSD, Akron and Toledo) exceeds $4.4 billion. Almost all these costs are borne by local ratepayers and have resulted in substantial increases in local sewer rates. For example, NEORSD projects average sewer bills for Cleveland residents at $60 per month by year 2019 (Figure 3-4). The City of Akron rates are expected to increase similar to Cleveland projections.

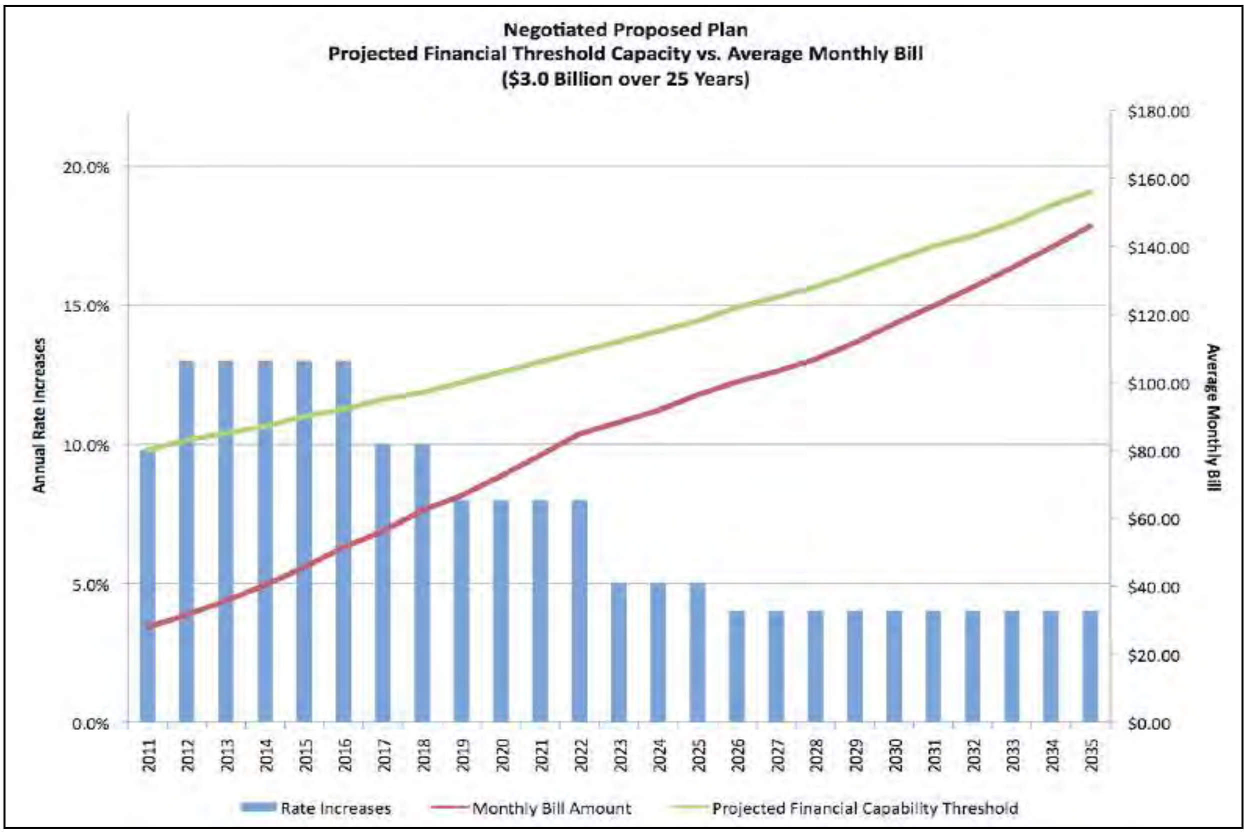


Figure 3-4. CSO Long Term Control Plan presentation to NEORSD Trustees 11/18/2010. (NEORSD, 2010)

The Detroit Wastewater Treatment Plant

There has been much speculation about the impact of the Detroit River and its largest point source discharger, the Detroit wastewater treatment plant, on HABs in Lake Erie. Some of the speculation centers on what happens to the Detroit River water as it flows into Lake Erie.

The Detroit River is approximately 31 miles long, connecting Lake St. Clair and Lake Erie and forming part of the international boundary between Canada and the United States. Nearly 98% of the Detroit River flow enters from Lake Huron via Lake St Clair. The flow in the Detroit River is complicated by the many branches around islands and through navigation channels, particularly in the lower Detroit River near Lake Erie. A study by Charles Herdendorf (ODNR, 1969) documented that the river splits into multiple channels. One of these clings to the western shoreline while the mid-channel water moves toward the Ontario shore. Environment Canada conducted a study in 2007 (Bruxer et al., 2011) to estimate phosphorus loads from the lower Detroit River to Lake Erie. The study results indicated temporal variability of total phosphorus loading, with a significant fraction of the load entering through the westernmost channel. Further, the study showed that the total and dissolved phosphorus loads to Lake Erie can be severely underestimated depending on the method employed.

The Detroit wastewater treatment plant (WWTP) is one of the larger wastewater facilities in the United States, serving the City of Detroit and 76 other communities. The WWTP discharges approximately 650 million gallons per day (MGD) of wastewater on average, about twice as much volume as the combined discharges of the Toledo and Northeast Ohio Regional Sewer District's (Cleveland area) Westerly and Easterly WWTPs. The City of Detroit and some of the surrounding communities have combined sewer systems. As a result, flows to the WWTP are significantly higher than average daily flows when there are storm events. The sustained peak secondary treatment capacity for wet-weather flows is currently 930 MGD; the sustained peak primary treatment (lesser quality than secondary) capacity for wet-weather flows is 1,700 MGD. In the 12 months ending in June 2011, Detroit discharged a total of 1,220,000 pounds (550 metric tons) of total phosphorus. About 93 percent of this was from the wastewater treatment plant, and 7 percent was from combined sewer overflows (Michigan Department of Environmental Quality, 2013).

The State of Michigan recently renewed the discharge permit for the Detroit WWTP. Provisions in the new permit that address the discharge of phosphorus include:

- Outfall 049B – secondary treatment effluent
    - The monthly average total phosphorus limit is decreasing from 1.0 mg/l to 0.7 mg/l beginning January 2015.
    - Beginning in October 2015, a new six-month average "growing season" limit of 0.6 mg/l total phosphorus becomes effective.

- Outfalls 049A and 050A – primary effluent/secondary bypass
    - The monthly average limit is decreasing from 2.5 mg/l to 1.5 mg/l beginning December 2016.

- Outfall 084A – future outfall to the Rouge River (operational April 2019)
    - This is a secondary bypass where discharges will be allowed in accordance with an approved wet weather operational plan, which must be updated annually. A monthly average total phosphorus limit of 1.5 mg/l will apply.

- CSO Control
    - The new permit delays completion of the city's "core" CSO control projects from October 2018 to April 2019. "Core" projects include adding chlorine for disinfection; chemical addition to remove total phosphorus and other pollutants is not required. Completion of "non-core" projects is delayed from 2035 to 2037.

The new permit includes an expanded "green infrastructure" section with benchmarks in terms of dollars spent per year and gallons of storm water removed.

The 2010 Phosphorus Task Force report (Ohio EPA, 2010) found that while the overall loadings from the Detroit River are fairly high, the concentrations needed to feed the algal blooms are low due to the high volume of water in the river. While there have been no changes to these conditions, additional monitoring is needed to better characterize the loading contribution from the Detroit River, particularly in light of the findings of the Environment Canada report. In addition, more data is needed to assess the westernmost flow of the flow pathways described above and its potential influence on algal blooms along the western shore of Lake Erie.

3.2 Phosphorus Loadings

Figures 3-5 through 3-8 provide updated information on loads and discharges from the first Task Force report (Ohio EPA, 2010, Figures 3, 4, 5 and 9). Figure 3-5 shows annual loading contributions from all major sources (both U.S. and Canada) through 2011, compared to the target load (11,000 metric tons/year) for total phosphorus identified by the International Joint Commission (IJC). The data include revisions of previous loading data for total phosphorus inputs to Lake Erie from Lake Huron. The "other" category indicates earlier loading estimates that were not broken down into major categories. The loads for 2009-2011 are provisional and may undergo some revisions.

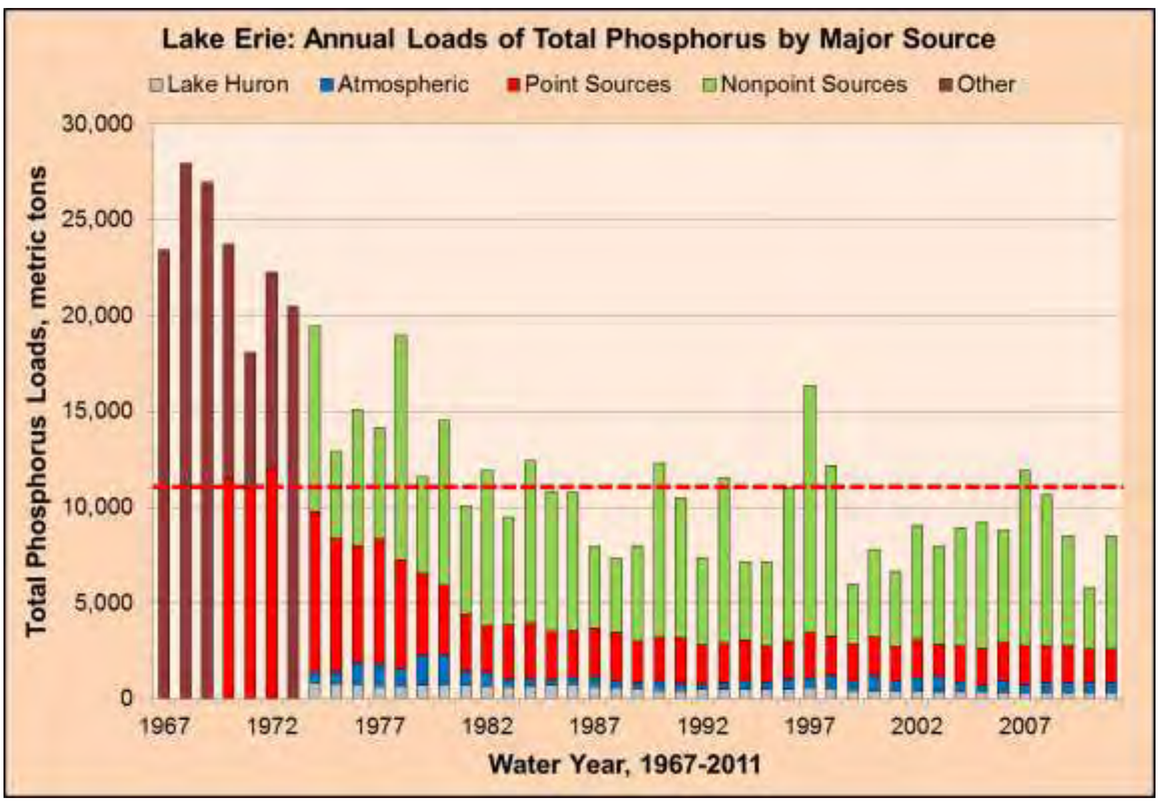


Figure 3-5. Annual loading of total phosphorus to Lake Erie by major sources.
(Data provided by Dr. David Dolan of the University of Wisconsin Green Bay (May 2013). Graph prepared by Heidelberg NCWQR staff.)

Figure 3-6 displays the trend in total phosphorus loading to Lake Erie from point sources in the U.S. and Canada, compared to the IJC target for all sources. While annual loads of total phosphorus are available beginning in 1967, analyses of breakdowns between point and nonpoint sources were not done consistently until 1975. Analyses for point source loading were conducted for 1971, 1972 and 1973 and appear in published reports from that time. Direct point sources include all municipal and industrial sources that discharge into rivers downstream from tributary monitoring stations, into Lake Erie or connecting channels, or into any river system that is not monitored for loading. Indirect point sources include municipal and industrial discharges into rivers upstream from tributary monitoring sites.

Figure 3-7 shows the annual nonpoint source total phosphorus loading to Lake Erie.

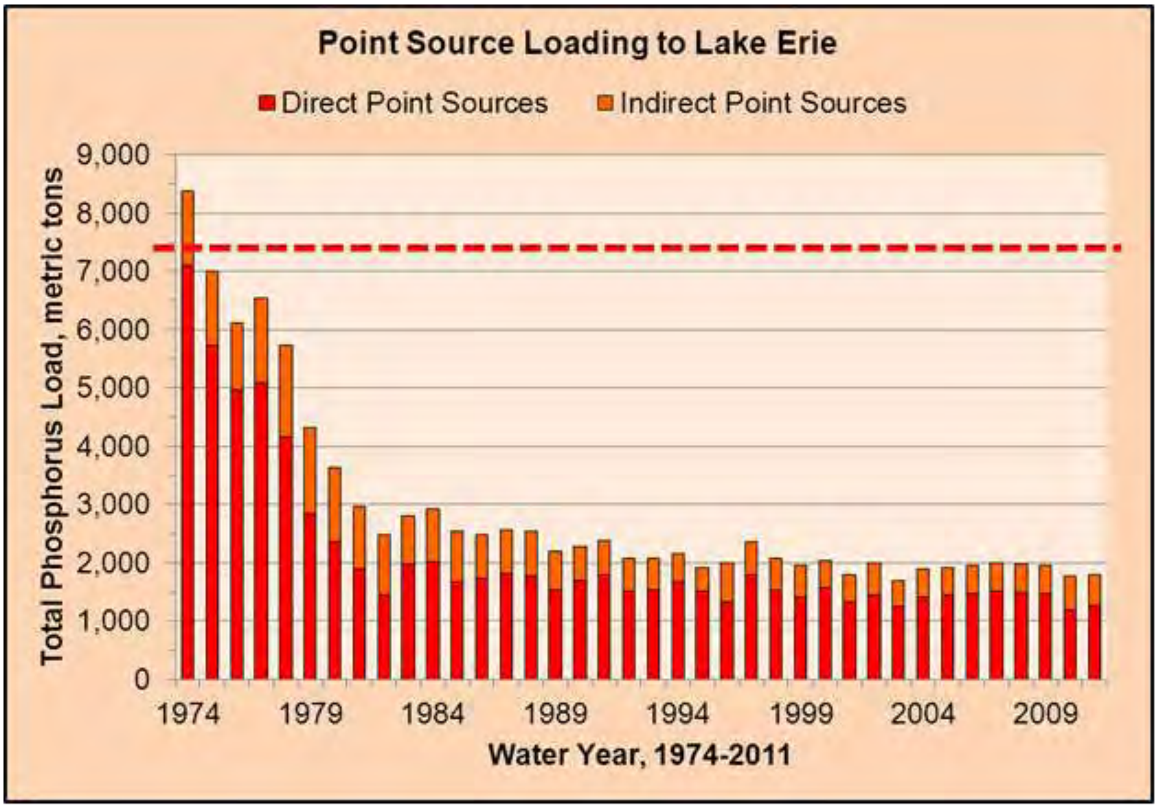


Figure 3-6. Trends in point source total phosphorus loading to Lake Erie from the U.S. and Canada.
(Data sources from Dr. David Dolan, May 2013. Graph prepared by Heidelberg NCWQR staff.)

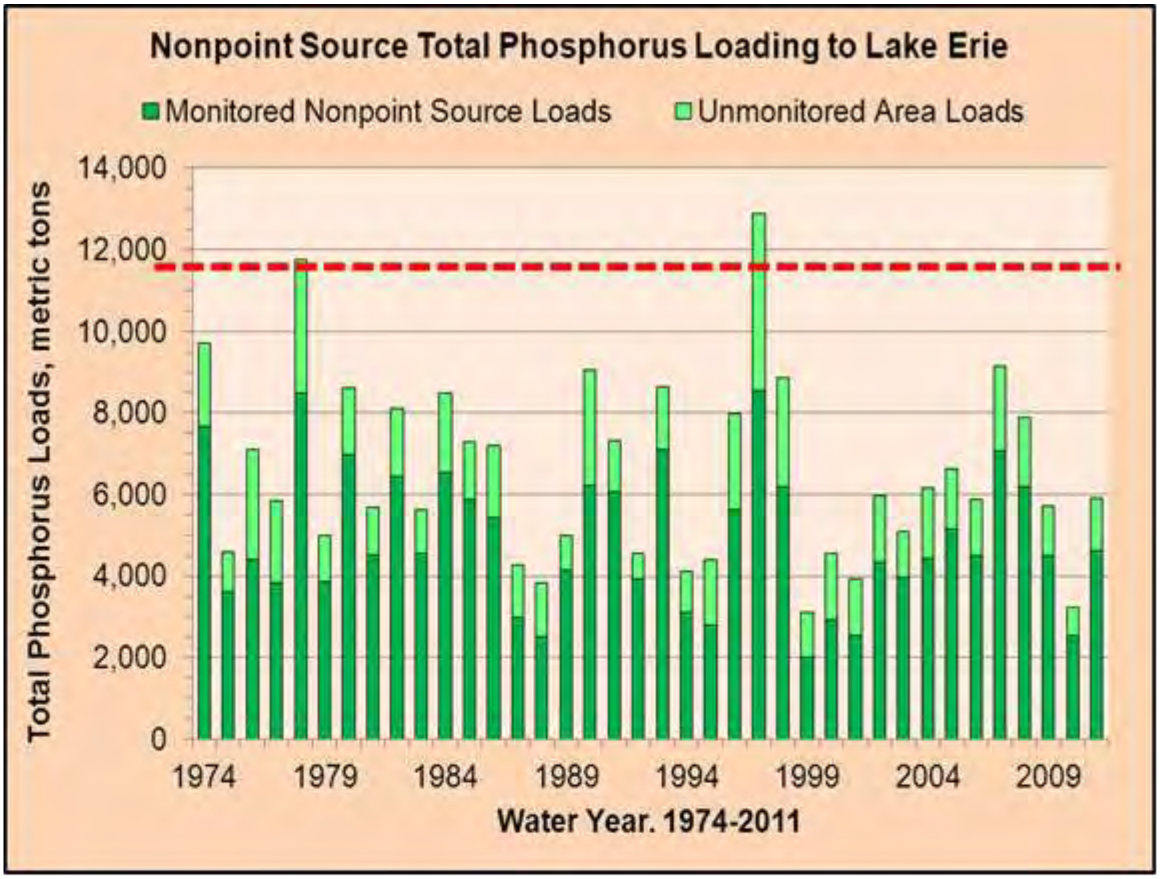


Figure 3-7. Annual variability in nonpoint source total phosphorus loading to Lake Erie.
(Data sources from Dr. David Dolan, May 2013. Graph prepared by Heidelberg NCWQR staff.)

The mean annual discharge and dissolved reactive phosphorus loads from the Maumee River are shown in Figure 3-8. The increasing trend in both annual discharge and flow-weighted mean concentration since the mid-1990s continues.

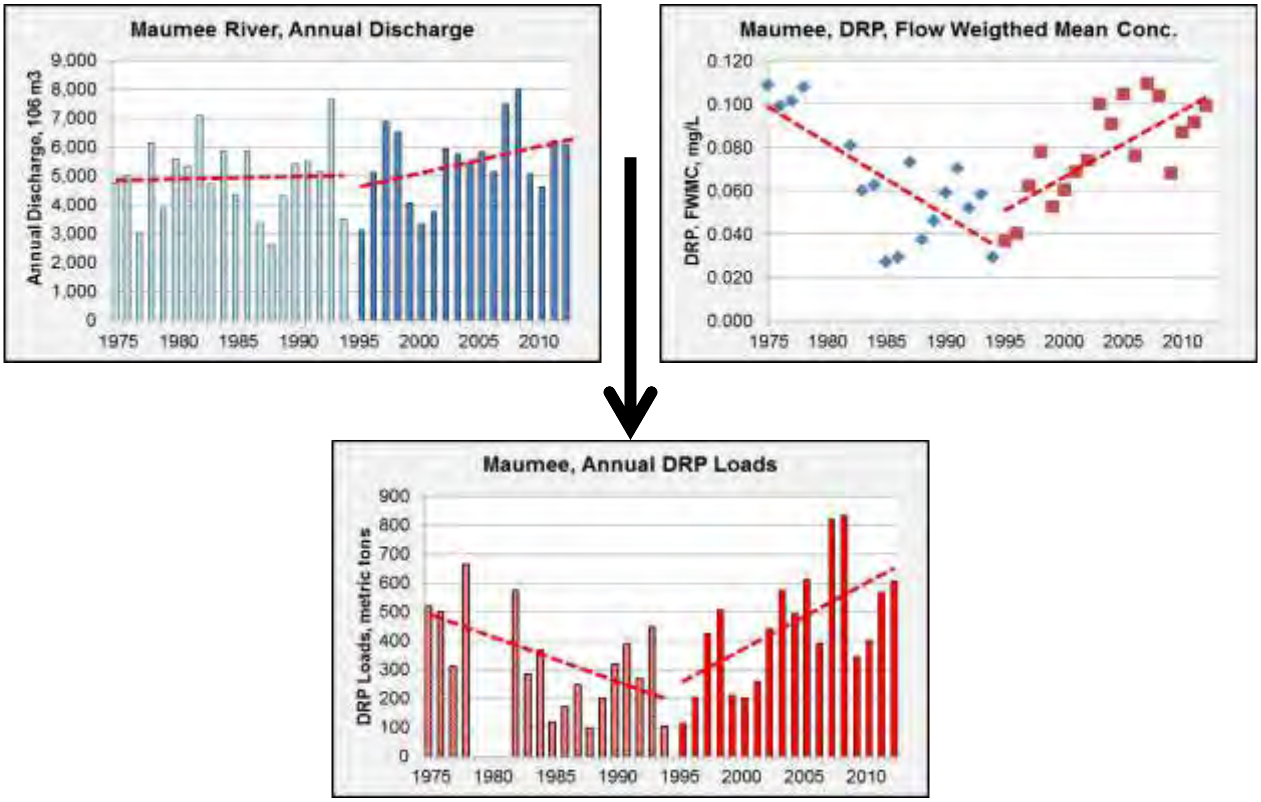


Figure 3-8. Annual discharges and flow-weighted mean concentrations and loads of DRP
(Discharge data from USGS Streamgage Maumee River at Waterville (04193500) and
graphed by Heidelberg University, NCWQR)

3.3 2011 and 2012: A Study in Contrasts

The year 2010 was characterized by a prolonged dry period beginning about the end of June and extending into 2011. This permitted fields to be prepared for 2011, including application of fertilizer, following harvest in the fall. Rain began to fall in mid-February, and runoff in the Maumee started February 17. From then until June 8, a period of 111 days, the river experienced elevated discharge and loading of phosphorus, culminating with a 15-day runoff event (May 25-June 8) that produced a peak flow of nearly 80,000 cfs (Figure 3-9) and a total discharge of 1.17 cubic kilometers as measured at the USGS stream, Maumee River at Waterville. Compared to all other periods of the same length (1975-end of 2011), this time interval produced nearly the largest discharge and phosphorus loads observed in the 35-year history of monitoring (Table 3-1).

Table 3-1. Discharge (km^3) and loads (Mg) for February 7 through June 8, 2011.

	15-day Amount	15-day Percentile	111-day Amount	111-day Percentile	111-day Amount as % of Annual Average
Discharge	1.17	98.8	5.38	99.8	102%
Total Phosphorus	690	98.1	2,665	99.99	123%
Dissolved Reactive Phosphorus	114	98.3	558	99.8	152%

Discharge data from USGS Streamgage Maumee River at Waterville (04193500)

The rest of the summer was characterized by low flow from the tributaries, and weak circulation and other conditions in the Western Basin that were favorable to algal growth (Michalak et al., 2013). These conditions led to the largest cyanobacteria bloom ever measured.

In the fall of 2011, more large storms led to major runoff events. Ironically, this included some 15-day periods that exceeded the May 25 to June 8 event in discharge and phosphorus loading.

The year 2012 was characterized by minimal rain throughout most of the year. Several modest runoff events in March were followed by drought conditions through November. The Western Basin cyanobacteria bloom was only about 15 percent of the 2011 bloom.

Stumpf et al. (2012) have recently shown that Maumee River discharge or phosphorus loads for the 4-month period 1 March through 30 June are good predictors of the severity of the cyanobacteria bloom at the end of the summer, as measured by their Cyanobacteria Index, an integrated measure of duration, intensity, and extent of the bloom based on analysis of satellite imagery. The progress of load accumulation during these months in 2011 and 2012 is shown in Figures 3-10 and 3-11, along with the average for years 2000-2012. The extreme contrast between the spring loads for these two years is also reflected in the ranks of these loads compared to those for the period of record (Table 3-2). Stumpf et al. developed their model using data and satellite images from 2002-2011. The model was used to predict the 2012 bloom intensity, and observed results were quite similar to the prediction.

Table 3-2. Spring discharge (km^3) and loads (Mg) for 2011 and 2012.

	2011		2012		2012 as Percent of 2011
	Amount	**Rank Among 38 years**	**Amount**	**Rank Among 38 years**	
Discharge	5.0	1	1.0	38	20%
Total Phosphorus	2,310	3	391	35	17%
Dissolved Reactive Phosphorus	429	1	63	34	15%

Discharge data from USGS Streamgage Maumee River at Waterville (04193500)

The apparent success of the Stumpf model in predicting the 2012 bloom strongly suggests that tributary loading to the Western Basin is the main determinant of bloom severity.

Internal loading of phosphorus can be very important in lakes. Phosphorus enters Lake Erie dissolved in water, attached to soil particles, and contained in the cells of algae. The components that are attached to particles and in algae often settle to the bottom of the Lake before flowing out at the Niagara River at Buffalo, NY. Phosphorus can remain for many years in the bottom sediment of lakes. We refer to the process of phosphorus re-entering the water column from the bottom sediment as “internal loading.” This can occur when the sediment is lifted or resuspended from the bottom by waves and currents caused by a storm and if the bottom layer of water in the lake becomes devoid of oxygen (anoxic) as frequently occur in the Central Basin during the summer. When water is anoxic, the chemical environment shifts from oxidizing to reducing, and phosphorus in the bottom sediment dissolves back into the water. Internal loading is quite important in the Central Basin of Lake Erie because the cold bottom layer often becomes anoxic during the summer. It is much less important in the Western Basin.

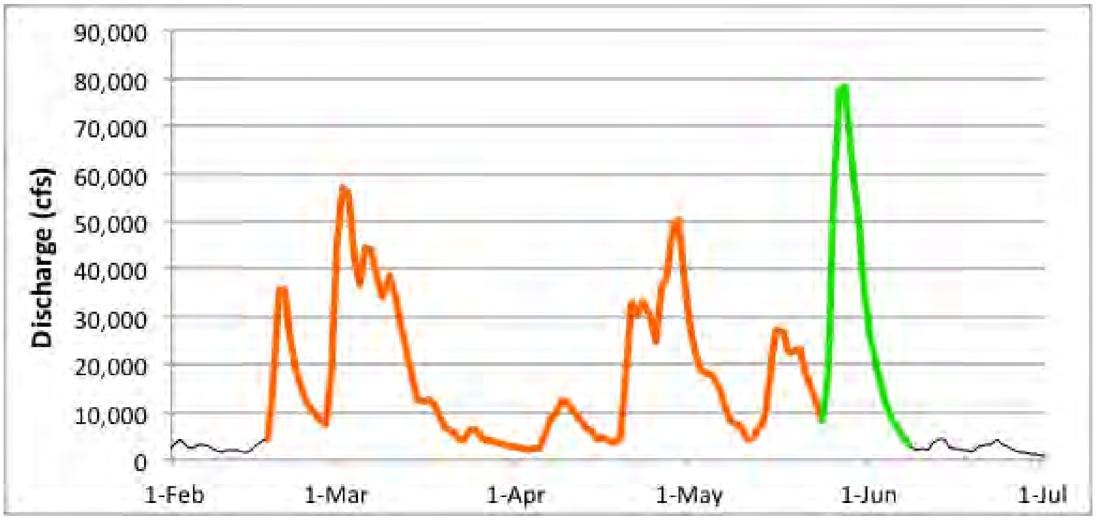


Figure 3-9. Discharge during the spring of 2011 (February 17 – June 8).
The last, largest runoff event is shown in green; the rest of the runoff interval in orange.
Discharge data from USGS Streamgage Maumee River at Waterville (04193500) and graphed by Heidelberg University.

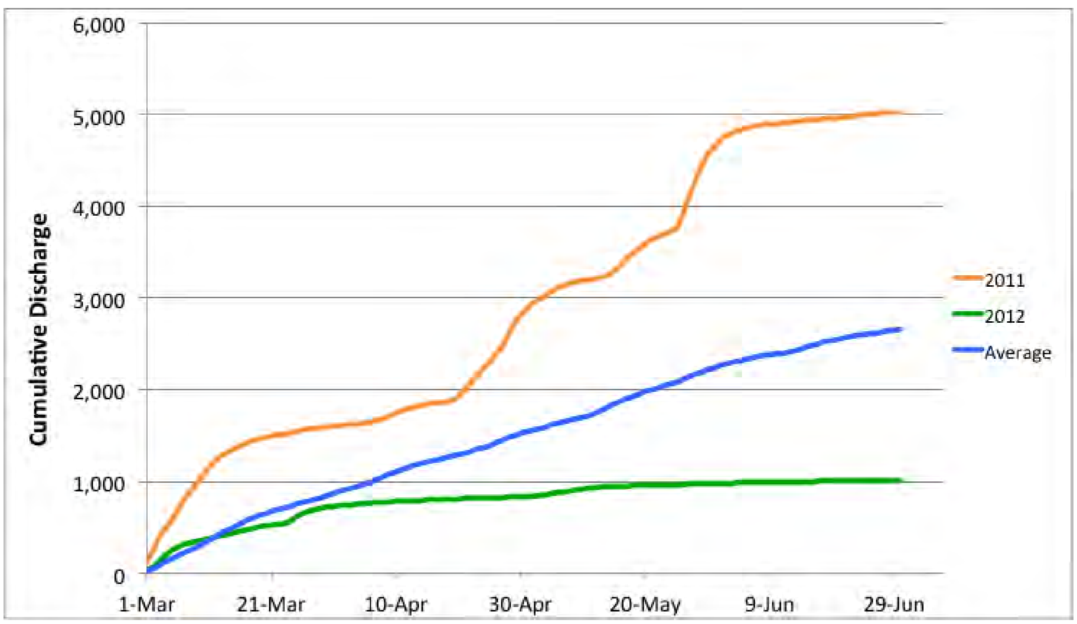
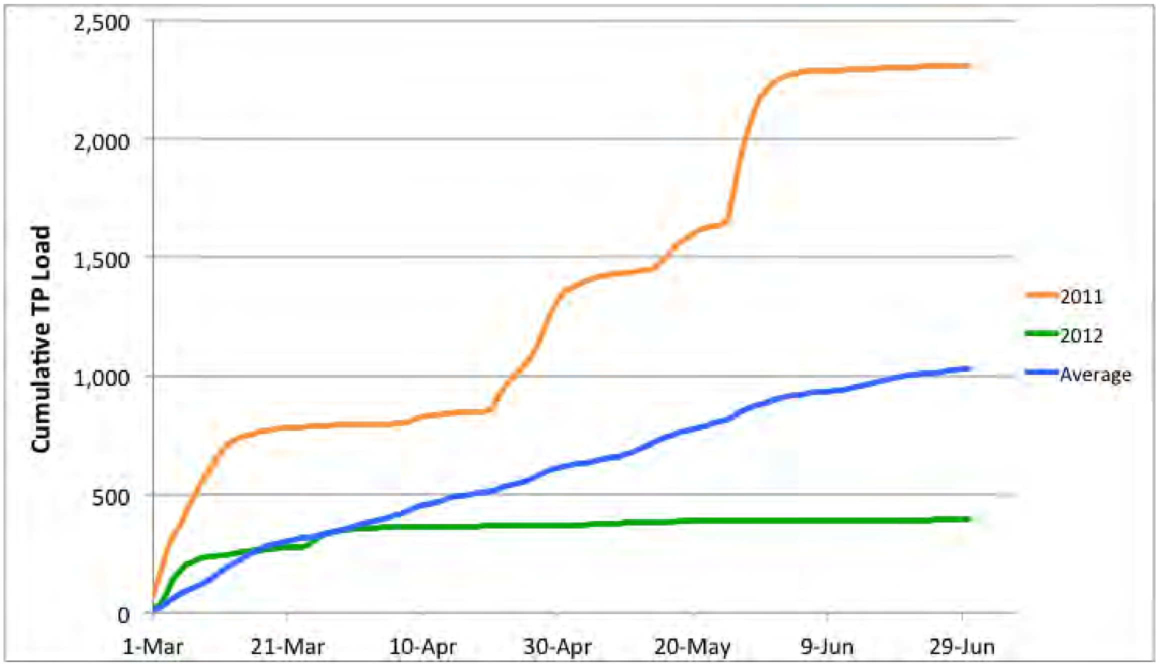


Figure 3-10. Cumulative discharge for 2011 and 2012 and for the 2000-2012 average.
Discharge data from USGS Streamgage Maumee River at Waterville (04193500) and graphed by Heidelberg University.



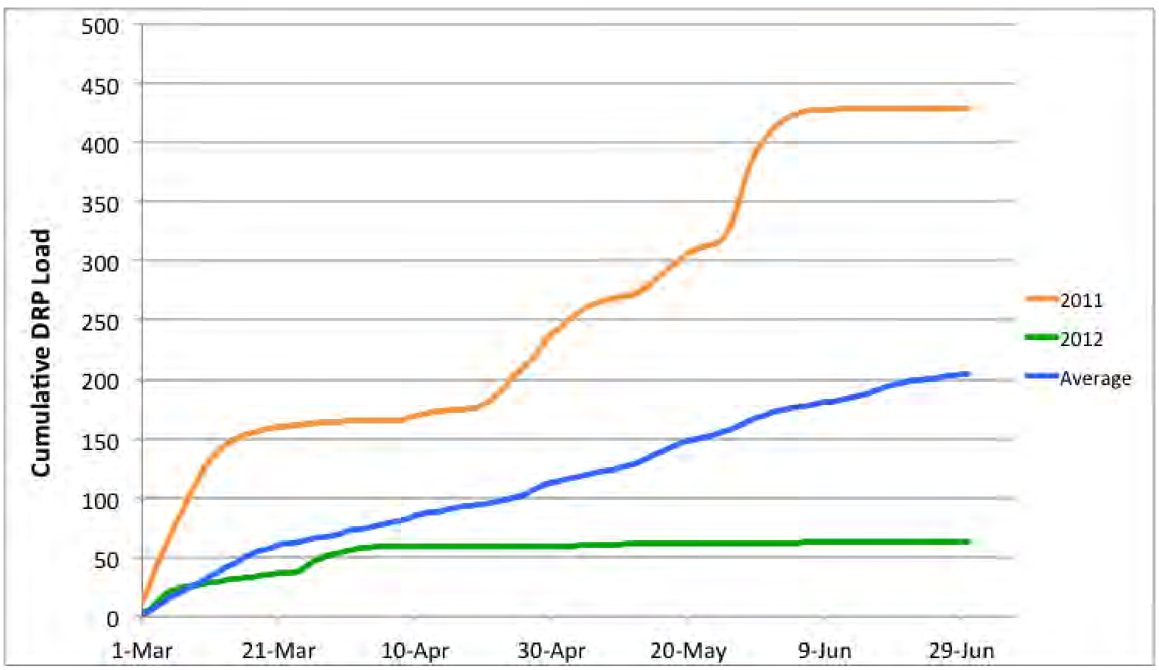


Figure 3-11. Cumulative loads of total phosphorus (top) and dissolved reactive phosphorus (bottom) for 2011, 2012 and the 2000-2012 average.

Section 4 Targets

After hearing from a number of experts at several meetings, the Phosphorus Task Force appointed a subcommittee of Phosphorus Task Force Members and other experts to consider the best way develop a target for Lake Erie's Western Basin. The subcommittee developed proposed targets, which were discussed by the Task Force to arrive at the recommendations presented here.

4.1 Discussion

The members of the subcommittee were

Dr. Jeffrey Reutter, Chair, Ohio Sea Grant and Stone Lab
Dr. David Baker, Heidelberg University
Dr. Tom Bridgeman, University of Toledo
Dr. Justin Chaffin, Ohio Sea Grant and Stone Lab
Dr. David Culver, The Ohio State University
Dan Button, U.S. Geological Survey
Gail Hesse, Lake Erie Commission
Amy Jo Klei, Ohio EPA
Dr. Peter Richards, Heidelberg University
Dr. Richard Stumpf, NOAA

The subcommittee considered the pros and cons of targets based on total and/or dissolved reactive phosphorus, the pros and cons of seasonal versus annual phosphorus loads, the maximum phosphorus load from the Maumee River that will not produce a harmful algal bloom (HAB), and the minimum phosphorus concentration required to produce a HAB or the maximum phosphorus concentration that will not produce a HAB. For example, blue-green algae need a phosphorus concentration of at least "X" to produce a bloom.

The Task Force decided on a goal of developing a loading target for the Western Basin of Lake Erie that will significantly reduce or eliminate HABs. Concentration targets present a challenge because, while a consistent/prolonged total phosphorus concentration of 50 µg/l or higher or a consistent DRP concentration of 10 µg/l or higher in a river or lake will produce a HAB, HABs have been observed at the majority of western basin sampling stations when the DRP concentration was as low as 6 µg/l. In these situations it can be inferred that the DRP concentration had been much higher but had been consumed as the bloom developed. The Lake Erie LaMP has long standing total phosphorus targets of 15 µg/L for the western basin and 10 µg/L for the central and eastern basins and the Task Force supports these goals. However, due to the above challenges dealing with concentrations and the fact that the NOAA model predicts bloom severity based on loads and not concentrations, the Task Force is recommending loading targets rather than concentration targets, but we encourage development of additional concentration targets in the future. Using the NOAA model, the Task Force believes that a loading reduction of approximately 40% will significantly reduce or eliminate HABs in the Western Basin, which is the primary goal of the Task Force. Furthermore, the Task Force is recommending an adaptive management approach that will allow annual reviews of progress and evaluation/modification of loading targets.

Note that total phosphorus concentrations exceeded 50 µg/l in the Maumee River at Waterville 100% of the time between 2004 and 2012, and DRP exceeded 10 µg/l 76% of the time.

By virtue of its location, its high discharges, and its high loads and concentrations of total and dissolved phosphorus, we believe that the Maumee River watershed is the primary driver of algal blooms in the

Western Basin of Lake Erie. The Maumee River watershed is well monitored by Heidelberg University for water quality and for its discharge by USGS, and represents 4.2 million of the 7.1 million acres of agricultural land in the Western Basin watersheds between Monroe, Michigan and Sandusky, Ohio.

The Task Force recommendations are based on loading and discharge data (see Table 4-1), measurements of HABs in Lake Erie (for example, Figure 4-1), and the projection model developed by Dr. Richard Stumpf, NOAA (see Section 2). This model allows us to accurately predict the severity of harmful algal blooms in the western basin of Lake Erie based on the amount of phosphorus that enters the Lake from the Maumee River from 1 March to 30 June. We can then forecast bloom severity in early July, thus providing a 6-week warning prior to the mid-August and September period when blooms are likely to be most severe.

Table 4-1. Comparison of discharge, total phosphorus loads, and dissolved reactive phosphorus (DRP) loads for the Maumee River for water year and spring (March-June) totals for 2000 through 2012.
Loads are in metric tons (tonnes). Bolded observations are the largest observed.

	Water Year Total			**Spring (March-June)**		
	Discharge m^3/year (millions)	**Total Phosphorus** (tonnes/year)	**Dissolved Reactive Phosphorus** (tonnes/year)	**Discharge** m^3/4 mos (millions)	**Total Phosphorus** (tonnes/4 mos)	**Dissolved Reactive Phosphorus** (tonnes/4 mos)
2000	3,352	1,190	202	2,374	965	152
2001	3,770	940	260	1,910	509	108
2002	5,957	2,100	442	2,763	1,044	173
2003	5,764	2,240	576	3,146	1,366	301
2004	5,439	1,810	494	2,687	976	195
2005	5,857	2,750	613	1,254	29	79
2006	5,150	1,790	393	1,857	572	123
2007	7,510	3,500	822	2,356	1,014	253
2008	**8,026**	**3,560**	**835**	3,364	1,293	260
2009	5,075	2,160	346	3,279	1,360	210
2010	4,648	1,530	404	3,494	1,284	317
2011	6,229	2,780	570	**5,022**	**2,310**	**429**
2012	6,106	2,250	607	1,010	391	63
Mean (00-12)	5,606	2,200	505	2,655	1,029	205
Mean (07-12)	6,266	2,630	597	3,087	1,275	256

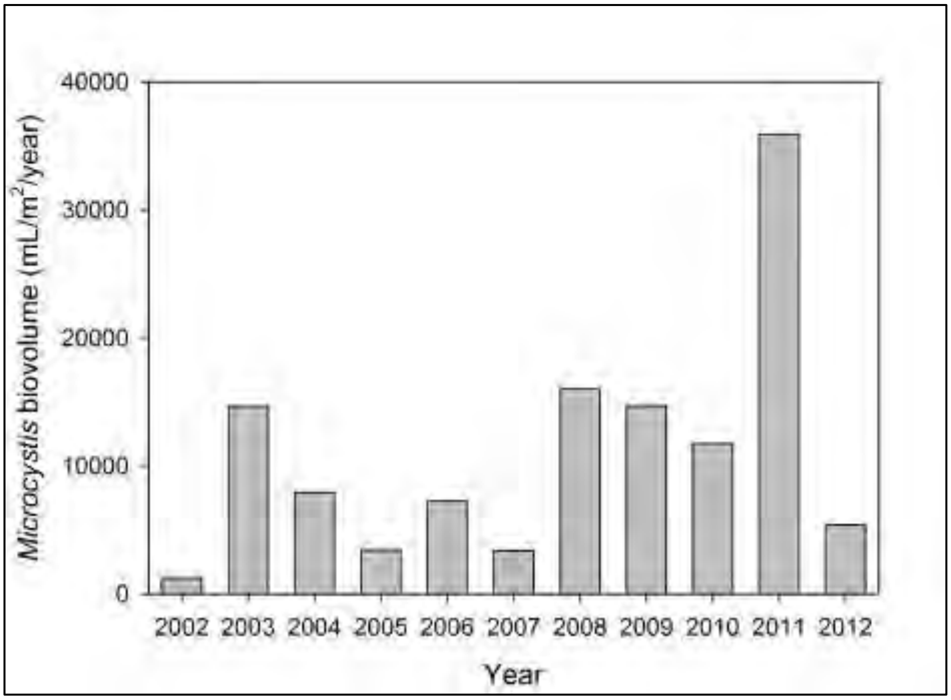


Figure 4-1. Temporal variation in Microcystis biovolume in western Lake Erie, 2002-2012.
(Bridgeman et al., 2013)

Dr. Richard Stumpf, NOAA, has demonstrated that the severity of Western Basin HABs is highly correlated with Maumee River total phosphorus loads from 1 March to 30 June each year. Heidelberg has also shown that unit area loads for all of the tributaries between Monroe and Sandusky are similar (River Raisin is lower). Therefore, it is reasonable to assume that all tributaries between Monroe and Sandusky mirror the loads of the Maumee in proportion to the size of their watersheds.

4.2 Recommendations

The following recommendations represent our scientific judgment based on the best available information.

4.2.1 Robust Monitoring and Adaptive Management

The recommended loading targets represent a conservative first step. Meeting these targets will significantly improve the health of Lake Erie, but may or may not reduce algal blooms to acceptable levels. Therefore, it is important to use an adaptive management approach to address this problem. That is, as we strive for phosphorus reductions to reduce or eliminate harmful algal blooms (HABs), we must continue to review the targets in conjunction with HAB events. This approach requires a robust monitoring program to measure progress toward loading and concentration targets and HAB reduction, and to allow us to annually evaluate and modify those targets in the future, as needed. If an adaptive management approach is not selected, then the target levels recommended in this report would have to be significantly reduced.

4.2.2 Loading Recommendations

For the Maumee River, the Task Force recommends targets for spring loads (defined as 1 March to 30 June) and annual loads (water years, 1 October to 30 September) for both total phosphorus and dissolved reactive phosphorus based on 11 years (2002-12) of observation and models that have proved to be highly accurate. Spring phosphorus loading in particular has been shown to be highly predictive of subsequent HAB size. Because of the large, weather-induced, annual variability in loads, the recommended targets are based on reduction in multi-year average loads rather than acceptable peak loads. We believe that sufficient reductions in average loads will significantly reduce the frequency and severity of HAB-inducing phosphorus loads entering the lake. Future consideration should also include whether to use flow-weighted mean concentrations as targets in place of, or in addition to, loads.

- **Total phosphorus:** The Task Force recommends a 37% reduction in the average spring total phosphorus load of 1,275 metric tons for 2007-12, or a target of 800 metric tons (Table 4-1). The 2007-12 time period was selected to better address predicted increases in the frequency of severe storms due to climate change. For annual total phosphorus loads the Task Force recommends a 39% reduction from the average annual total phosphorus load from 2007-12 of 2,630 metric tons, or a target of 1600 metric tons. Achieving these targets will significantly reduce HABs.
- **Dissolved reactive phosphorus:** The Task Force recommends a spring loading reduction of 41% in the average spring load from 2007-12 of 256 metric tons or a target of 150 metric tons.

The Task Force is confident that restricting loads to this level or lower will significantly reduce or eliminate HABs. As discussed earlier, concentration recommendations for the lake could be developed but will require further discussion and a review of the effectiveness of the proposed targets through adaptive management process.

4.2.3 Applying Loading Recommendations to All Western Basin Tributaries

The actions taken to reduce nutrient loading to reach target loads for the Maumee should be implemented in all watersheds between Monroe, Michigan and Sandusky, Ohio. Attainment of the proposed target loads for the Maumee River, our indicator of progress, and simultaneous implementation of the same actions to reduce the loads in these other watersheds, will significantly reduce HABs in the Western Basin and Lake Erie as a whole.

Section 5 Soil Health

A discussion of water quality and nutrient management would not be complete without a discussion of soil health. The health of the soil will determine how rainwater and dissolved nutrients either infiltrate into the soil or run off the soil surface into ditches and streams. Soil health will also determine if water percolates through the soil profile using matrix flow, which allows for filtration or drops down fissures, cracks or macropores unfiltered to subsurface drains. Soil health emerged as a critical factor as the Ohio Phosphorus Task Force discussed different aspects of nutrient management and nutrient assimilation.

The Phosphorus Task Force appointed a subcommittee of Phosphorus Task Force Members and other experts to consider how soil health is a factor in the delivery of nutrients to Lake Erie. The subcommittee consisted of Mark Scarpitti (Chair, Natural Resources Conservation Service), Todd Hesterman (Conservation Action Project and Henry County SWCD), and Matt Deaton (Ohio Department of Natural Resources).

5.1 Overview of Soils in the Lake Erie Basin

At the end of the last ice age, massive blocks of ice broke off as the glaciers retreated. These dammed the flow of running water and created glacial lakes. The suspended sediments in the running water began to settle out as the velocity of the water diminished. Heavy sand particles fell out first, then silts, and lastly clays. Clay surface soils dominate in northwest Ohio because clay was last to be deposited in the lake. Eventually the ice melted and the lakes drained leaving behind soils with 35-60% clay at the surface. The landscape is very flat with many depressional areas and a seasonal water table near the surface. Even with these flat, ponding soils, the potential for water runoff and soil erosion is high due to the low permeability of these soils.

Deep, somewhat poorly to very poorly drained soils dominate northwest Ohio because of its geologic history. Soils contain heavy lacustrine deposits and dense till. Four soil types make up about 1.4 million acres of northwest Ohio: Hoytville, Paulding, Toledo, and Latty and have similar characteristics. The most common of these is Hoytville. All of these soils are classified as soils with high runoff potential when thoroughly wet.

5.2 Discussion of Soil Quality and Soil Health

Soil Quality

There are many different characteristics that agronomists evaluate when assessing the physical and chemical properties of soil for crop production. Inherent or innate properties cannot be changed very easily. These include characteristics such as soil texture (percent of sand, silt and clay), the type of clay and the depth to bedrock. Other properties of soil are dynamic because they can be changed with management. These include the organic matter content, aggregate stability, infiltration rate, soil fertility and soil reaction (pH). Agronomists can evaluate the quality of the soil using these properties.

Soil Health

The health of the soil is the capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans. It takes into consideration the physical and chemical properties of soil discussed in the soil quality section above but in addition, looks at the biology of the soil and the ability of the soil to sustain life.

5.3 Challenges to a Healthy Soil

Because of the high clay content of these soils, they are very fragile and prone to compaction. Field operations should only be attempted when the soil is dry. One bad management decision can cause a tremendous amount of compaction that can last for years. These soils are relatively high in soil organic matter but have very poor soil structure. Soils in northwest Ohio are also prone to shrink/swell, forming large deep fissures and cracks. There is little if any water filtering capability when soils are compacted and a high percentage of soils in northwest Ohio have compaction problems. Compaction destroys soil structure prohibiting water infiltration and matrix flow through the soil profile. Instead, surface water and dissolved nutrients travel through fissures, cracks and macropores (preferential flow) and out subsurface drains or tiles. A healthy soil with good structure, porosity, and infiltration will promote matrix flow, giving nutrients a chance to bind to the soil.

Any type of field operation completed under wet or damp soil conditions will cause compaction resulting in platy or massive soil structure. Cropping systems using no tillage alone or if poorly managed can cause compaction. Tilling the soil however also causes compaction and creates a tillage pan. Tillage also destroys soil structure, reduces infiltration and porosity, oxidizes (reduces) organic matter, and causes sedimentation. Therefore, neither no-till alone nor tilling is the answer. Producers should utilize a combination of practices to improve soil health. Crop Rotations, Residue and Tillage Management, Cover Crops, Nutrient Management, Controlled Traffic Farming with RTK (satellite navigation in order to minimize wheel traffic and compaction) are all good possibilities. Strip tillage is a good management tool in these soils since nutrients can be banded below the soil surface while leaving the majority of the soil undisturbed.

5.4 Functions of a Healthy Soil

Nutrient Cycling - Soil stores, moderates the release of, and cycles nutrients and other elements. During these biogeochemical processes, analogous to the water cycle, nutrients can be transformed into plant available forms, held in the soil, or even lost to air or water.

Water Relations - Soil can regulate the drainage, flow and storage of water and solutes, which includes nitrogen, phosphorus, pesticides, and other nutrients and compounds dissolved in the water. With proper functioning, soil partitions water for groundwater recharge and for use by plants and soil animals.

Biodiversity and Habitat - Soil supports the growth of a variety of plants, animals, and soil microorganisms, usually by providing a diverse physical, chemical, and biological habitat.

Filtering and Buffering - The minerals and microbes in soil are responsible for filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials. Soil acts as a filter to protect the quality of water, air, and other resources. Toxic compounds can be degraded or otherwise made unavailable to plants and animals.

Physical Stability and Support - Soil has the ability to maintain its porous structure to allow passage of air and water, withstand erosive forces, and provide a medium for plant roots. Soils also provide anchoring support for plants and human structures.

5.5 Principles of Soil Health

Limit Soil Disturbance– Soil disturbance disrupts biotic habitat. Soil disturbance by tillage oxidizes soil organic matter, destroys soil structure, reduces infiltration, reduces porosity, can cause mineralization of nutrients and compaction. Limiting soil disturbance allows the soil structure to develop which improves water movement into and through the soil via matrix flow.

Increase Soil Microbial Diversity–One of the goals of soil health is to create or promote an ecosystem that is conducive to a diverse population of soil microorganisms, arthropods and earthworms. Having a healthy, diverse population of biota promotes a healthy soil by not letting any one type of organism get out of balance. A high population of only soil bacteria is one indicator that the soil is out of balance and in poor health. Having a diverse population of organisms keeps things in balance and helps prevent plant diseases. For example, predatory nematodes in the soil will prey upon nematodes that attack plant roots. Farm Operators should utilize Integrated Pest Management (IPM) to minimize the use of pesticides and foster plant and microbial biodiversity.

Grow Living Roots Year Round– The plant has a symbiotic relationship with soil organism. Through the process of photosynthesis, the leaves of the plant produce glucose and oxygen. The plant captures the energy of the sun and translocates the sugar through the roots into the soil. The microorganisms then feed on the root exudates within the rhizosphere of the plant root. In return, the microorganisms excrete nutrients that are readily available to the plant. Keeping a living plant growing year round (cover crop) will allow the process of photosynthesis to continue uninterrupted and the microorganisms will thrive.

Keep the Soil Covered– Keeping mulch or a layer of residue on the soil surface does a lot to improve soil health. It helps improve water infiltration and reduces surface compaction and crusting by preventing the raindrops from directly impacting the soil surface. Surface mulch reduces water evaporation and soil temperature in the heat of summer creating a more hospitable environment for plants and soil biota. Crop residues also serve as a source of food for soil microorganisms, arthropods and earthworms increasing the number and diversity of the soil biology.

Reduce Compaction – In an otherwise healthy soil, compaction can create a tremendous amount of damage and set the process back very quickly. On soils that are high in clay, one trip over the field with heavy equipment when the soil conditions are wet or moist can undo years of good management. Compaction instantly destroys soil structure, water infiltration, and the pore space within the soil. This directly affects air and water movement within the soil and biota habitat. It also destroys the matrix flow of water through the soil causing water and dissolved nutrients to either run off the surface or down through soil fissures or cracks directly to the tile. Good management, reducing tillage, reducing the number of field operations across the field, and growing cover crops can reduce compaction. On high clay soils, compaction can be further limited by matching the working widths and wheel spacing of tractors, planters, sprayers, combines and setting up a traffic pattern where the same wheel tracts are used for all (or most) operations year after year. This will confine the compaction to the tramlines allowing the rest of the field to heal. Studies show that up to 85% of the field will be tracked over with heavy equipment over a year if there is no traffic pattern followed. The amount of surface area run over by heavy equipment can be reduced to 25%-50% by using Controlled Traffic Farming. Controlled Traffic Farming combined with reduced tillage and the use of cover crops can dramatically reduce compaction and promote soil health.

5.6 Soil Fertility and Nutrient Management

Balanced soil fertility is also a component of a healthy soil. Nutrients are necessary for optimal plant growth and improve the physical, chemical and biological properties of the soil. Evidence seems to indicate that balancing the calcium to magnesium ratio in these high clay lacustrine soils can flocculate clays and improve soil structure and water infiltration.

Phosphorus will be in several different forms in the soil and will tend to seek equilibrium in the soil solution. Therefore, phosphorus that is in the dissolved state one moment might be sorbed and chemically bound to iron and aluminum oxides the next. In order for these reactions to occur however, the nutrients must to be given the opportunity to interact with the soil.

One of the challenges to proper nutrient management is to place nutrients so they can interact with the soil while still improving soil health. This is because as stated above, one of the important principles to promote soil health is to limit soil disturbance. Therefore, using tillage equipment over the entire field (full width tillage) to incorporate surface applied fertilizer can do much damage to an otherwise healthy soil. Full width tillage will also increase soil erosion and likewise increase the loss of particulate phosphorus that is tied to the eroded soil. On the other hand, if surface applied fertilizer is broadcast on an unhealthy soil that suffers from compaction, crusting, poor soil structure, weak aggregate stability or poor infiltration, nutrients will be lost with surface runoff. Nutrients will likely accumulate on the surface of the soil and can cause stratification.

Therefore, the goal must be to apply nutrients in a way they can interact with the soil yet do nothing to reduce the physical or biological health of the soil. Once the soil is healthy and has good water infiltration and water holding capacity it may be possible to surface apply fertilizer knowing that there will be little or no water runoff and that the nutrients will infiltrate and percolate through the soil via matrix flow. This will allow the nutrients to interact and bond with the soil. In addition, fertility requirements will likely be lower in a healthy soil due to better nutrient retention and recycling. The overall retention of nutrients and improved soil biota can affect nutrient cycling may increase efficiency and reduce fertilizer needs.

However, transitioning from an unhealthy soil to a healthy soil means that there needs to be some compromise in nutrient application. There are several options to consider depending on the management and cropping system. These are, in order of the least amount of soil disturbance to the most soil disturbance:

- Broadcast surface application of fertilizer on a growing crop or cover crop
- Banding or injecting nutrients
- Applying nutrients using a Strip Tillage unit and RTK guidance
- Broadcast surface application of fertilizer then using full width tillage for incorporation

The least preferred option, which would actually be a deterrent to improving soil health, would be broadcasting fertilizer on the surface then using full width tillage to incorporate it. The full width tillage will destroy soil structure, oxidize soil organic matter, reduce aggregate stability, and can cause compaction.

The two tables that follow summarize soil health functions and their effect on reducing nutrient transport (Table 5-1) and best management practices that improve soil health (Table 5-2).

5.7 Conclusions

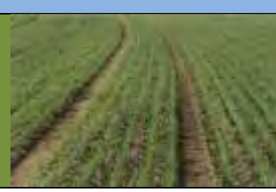
Improving the health of the soil can have a direct impact on improving water quality and reducing nutrient runoff.

- Improving soil structure, aggregate stability and reducing compaction will increase water infiltration while reducing nutrient laden runoff.
- Increasing soil organic matter will improve the water holding capacity of the soil reducing water loss through tile systems.
- Utilize IPM to minimize pesticide use and support soil biodiversity.
- Increasing soil organic matter and microbial activity in the soil will help filter and recycle nutrients.
- Reducing compaction, improving soil structure and aggregate stability will improve matrix flow allowing nutrient filtration and assimilation while reducing fracturing, cracking, and preferential flow.
- Special attention must be given to nutrient application allowing nutrients to interact with the soil without causing soil disturbance that damages soil health.

Table 5-1. Soil health functions and their effect on reducing nutrient transport.

Soil Health Indicator	Soil Health Function	Potential Affect on Reducing Nutrient Transport	Best Management Practices That Promote Soil Health Indicator
Increased Soil Organic Matter (SOM)	Water Relations: Improves infiltration Water Relations: Improves water holding capacity Nutrient Cycling : Increases Cation Exchange Capacity (CEC) Nutrient Cycling : Ties up nutrient in organic form Filtering and Buffering: Promotes matrix flow Biodiversity and Habitat: Improves habitat for soil organisms	-Reduces runoff of nutrients from surface -Increases retention of nutrients -Captures positively charged nutrients -Potentially reduces fertilizer use -Reduces nutrients through tile -Helps recycle nutrients	-Conservation Crop Rotation -Tillage and Residue Mgt -Cover Crops -Nutrient Management
Improved Soil Structure	Water Relations: Reduces crusting of soil surface Water Relations: Increases infiltration Physical Stability and Support : Reduces erosion Biodiversity and Habitat: Improves habitat for soil organisms	-Reduces runoff of nutrients from surface -Reduces runoff of nutrients from surface -Reduces particulate P transport -Helps recycle nutrients	-Conservation Crop Rotation -Tillage and Residue Mgt -Cover Crops -Controlled Traffic Farming
Improved Soil Aggregate Stability	Water Relations: Improves infiltration Biodiversity and Habitat: Improves habitat for soil organisms	-Reduces runoff of nutrients from surface -Helps recycle nutrients	-Conservation Crop Rotation -Tillage and Residue Mgt -Cover Crops
Increased Soil Respiration (CO_2)	Biodiversity and Habitat: Measure of microbial activity	-Repository for nutrients (stored in cells) -Helps recycle nutrients (symbiotic) -Increases percolation / water movement	-Conservation Crop Rotation -Tillage and Residue Mgt -Cover Crops -Integrated Pest Mgt
Reduced Bulk Density (compaction)	Water Relations: Improves infiltration Physical Stability and Support : Increases porosity Biodiversity and Habitat: Improves habitat for soil organisms Filtering and Buffering: Promotes matrix flow	-Reduces runoff of nutrients from surface -Increases percolation / water movement -Helps recycle nutrients -Reduces nutrients through tile	-Conservation Crop Rotation -Tillage and Residue Mgt -Cover Crops -Controlled Traffic Farming
Balanced Soil Fertility	Nutrient Cycling: Promotes healthy ecosystem for crops Nutrient Cycling : Promotes soil organisms	-Reduces excessive nutrient application -Repository for nutrients (stored in cells) -Helps recycle nutrients	-Nutrient Management
Balanced Soil Reaction (pH)	Nutrient Cycling : Balances nutrient availability to crops Nutrient Cycling : Promotes healthy ecosystem for crops Filtering and Buffering: Promotes soil organisms	-More efficient use of nutrients in soil -Reduces excessive nutrient application -Repository for nutrients (stored in cells) -Helps recycle nutrients	-Nutrient Management

Table 5-2. Best management practices that improve soil health.

Best Management Practice:		What does it do?	How does it help?
Conservation Crop Rotation		-Promotes the rotation of different crops -Breaks pest cycles -Reduces erosion (high residue crops) -Adds crop diversity	-Decreases use of pesticides -Improves plant production -Increases the number of soil organisms -Increases the diversity of soil organisms
Cover Crop		-Adds diversity to crop rotation -Fixes nitrogen from the atmosphere (legumes) -Provides a mulch (high carbon - left undisturbed) -Suppresses weeds -Reduces compaction -Increases soil porosity	-Increases soil organic matter -Improves water quality -Improves nutrient use efficiency -Decreases use of pesticides -Improves water efficiency to crops -Reduces soil erosion -Increases the number of soil organisms -Increases the diversity of soil organisms -Promotes matrix flow in the soil profile
Residue and Tillage Management			
No Till / Strip Till		-Leaves crop residues on soil surface as mulch -Increases soil organic matter -Eliminates tillage and minimizes soil disturbance -Reduces trips across the field	-Increases infiltration -Improves water efficiency -Saves renewable resources -Reduces soil erosion -Reduces oxidation of soil organic matter -Reduces compaction (if done properly) -Promotes matrix flow in the soil profile
Mulch Tillage		-Minimizes tillage -Increases soil organic matter	-Improves water quality -Reduces soil erosion (over conventional)
Nutrient Management		-Balances proper management of nutrients -Flocculates clays (Ca:Mg balancing) -Adjusts pH of the soil	-Increases plant nutrient uptake -Improves water quality -Improves plant production -Improves physical, chemical, biological properties
Integrated Pest Management		-Reduces pesticide usage -Decreases pesticide risk to pollinators	-Reduces pesticide risks to water quality -Increases plant pollination and production -Reduces the destruction of soil organisms
Controlled Traffic Farming		-Consolidates the traffic pattern across the field -Confines heavy load wheel traffic to tramlines	-Reduces compaction in non-trafficked areas -Increases water infiltration -Improves biological habitat -Increases soil porosity -Promotes matrix flow in the soil profile

Section 6 Drainage Management

6.1 Background

For purposes of this report, drainage management encompasses those practices designed to improve the soil environment for vegetative growth by managing water for irrigation and drainage. Drainage management encompasses both surface and subsurface practices. Some practices function to move water quickly off fields (e.g., subsurface tile) while others function to provide water retention (e.g., wetlands and drainage water management structures), runoff dispersal and infiltration (e.g., grassed buffers). These practices are intended to improve productivity of poorly drained soils by providing greater soil aeration and enabling faster soil drying and warming in the spring.

The Task Force acknowledges the critical role drainage management practices play in northwest Ohio. Indeed, agriculture in northwest Ohio depends on tiling for crop production. There has been much speculation about the role of the drainage infrastructure in contributing to the delivery of soluble phosphorus to streams and ultimately to Lake Erie. The 2010 report of the Ohio Lake Erie Phosphorus Task Force concluded that diminished stream assimilative capacity and current drainage practices are contributing factors to the transport of DRP but a lack of data and information prevented a more thorough analysis of the relative contribution of delivery of DRP through these transport pathways. In recent years, certain drainage management structures and practices have gained attention as being beneficial to reducing phosphorus transport.

Subsurface Drainage

Subsurface drainage is the removal of excess water below the land surface, usually through perforated pipe at a grade below the soil surface, often referred to as tiling. In the Lake Plain area, tile drainage is installed systematically with spacing usually ranging from 25 to 60 feet. Elsewhere in the glaciated region and in addition to systematic tile drainage, tile risers are often used to remove excess surface water from depressions or 'potholes' in the landscape. They may be found in roadside ditches or in the middle of fields. These risers are connected to the tile but are representative of surface runoff rather than tile flow. Through 'windshield' surveys it was estimated that approximately 75,000 tile risers are present in the Western Basin. Phosphorus movement through tile systems varies widely and is dependent on a number of variables including soil type, slope and management practices for individual fields.

Anecdotal information indicates that tile density has increased over the last 10 to 15 years although no data has been collected to provide more specific information. Increased tile density may accelerate subsurface discharge volume and associated dissolved phosphorus load. It is important to note that not every acre is contributing equally, and that source areas are variable and are not necessarily the same acres from year to year. Management and structural practices designed to reduce or minimize the drainage water volume from the outlet will likewise reduce the DRP load in tile flow proportionally. The edge-of-field studies that are currently underway will provide critical data input necessary to identify best management practices that address both surface and subsurface drainage and update the Ohio Phosphorus Index which will provide an improved tool to better evaluate the potential of nutrient losses from individual fields.

Surface Drainage

Surface drainage refers to the diversion or orderly removal of excess water by means of channels, natural or constructed. The conservation practice known as surface drainage is often used in conjunction with subsurface drainage practices. Surface runoff occurs either in man-made drains, via concentrated flow pathways or through surface riser connected to tile. All move water off the field during high runoff events. There are also related practices in the drainage and riparian corridor that can serve to slow down, store, disperse and infiltrate runoff. These practices also assimilate nutrients from runoff. For example, vegetative barriers (herbaceous and forest cover) and wetland areas are not typically considered as part of the suite of practices for drainage management. They can however, function in similar ways to reduce the rate and volume of runoff discharge and, likewise reduce nutrient and DRP loading proportionate to the percentage of runoff volume reduction.

6.2 Discussion

The first Task Force focused on the role of drainage management as a transport mechanism for dissolved phosphorus acknowledging a lack of data to assess the relative contribution of drainage practices to DRP increases. The Task Force focused on drainage management structures which have emerged in recent years as potentially beneficial to reducing nutrient loss. While drainage management structures are installed to reduce discharge volume, they are also beneficial for reducing both nitrogen and phosphorus. A key consideration that emerged in Task Force discussions about these structures addressed the role of soil health and its impact on water and nutrient movement. Poor soil health, particularly with the high clay content soils in northwest Ohio, can result in water rapidly moving offsite via preferential flow (cracks and macropores). See Section 5 for a more complete discussion on the importance of soil health in nutrient management.

The Task Force explored what research is available on phosphorus removal from drainage management structures. Kevin King, ARS, Task Force member, provided an overview of published and ongoing research compiled from studies conducted worldwide on a variety of different drainage-related practices. Selected studies have shown:

- 50-99% reductions in DRP concentrations using in-stream gypsum beds (Pennsylvania)
- 50- 70% reduction in DRP concentrations using end of tile filters with media rich in aluminum, iron, or calcium (Ohio and New Zealand)
- 20-85% reductions in DRP concentrations and loading through use of drainage water management structures (Ohio, Minnesota, and Sweden)
- 50-70% reduction in DRP load when comparing blind inlets to surface risers (Indiana)
- Approximately 60% reduction in growing season DRP through use of vegetated drainage ditches and linear wetlands (Mississippi)
- An approximate 40% reduction in mean annual DRP concentration when comparing water samples from streams with no buffers to those with grassed buffers (Ohio)

While there is variability in results, there is evidence of reduction in soluble phosphorus. These approaches are designed to work in concert with other drainage management practices. The biggest contributing factor to the effectiveness of structures is the flow rate. Understanding that nutrient loading has been demonstrated to be delivered in high flow events; the key to effective drainage management structures is to design them for variable hydrologic loads. More studies are needed to better understand these practices for nutrient reduction under varying flow regimes. There are also some remaining questions about whether certain practices create anaerobic conditions and therefore increase solubility of applied phosphorus although this situation would be specific to certain field conditions.

The Task Force discussed the efficacy of blind inlets over tile risers for removing DRP. A blind inlet (or French drain) is used to filter sediment from the water that is drained from the field. Additional filters can be installed in the blind inlet to remove additional contaminants (i.e. phosphorus or pesticides). Often, the tile risers are direct conduits for surface runoff to agricultural drainage ditches or streams and can result in excessive loading of sediment and other contaminants to surface water from fields that are often several miles from the ditch or stream. This means that the runoff water quality from these fields that are relatively far from the stream can greatly impact the water quality, because there is no filtering or other type of processing that occurs during drainage of the excess water. The Ohio NRCS practice standard for Underground Outlets (Field Office Technical Guide 620) has been revised to include blind inlets and design criteria for water quality blind inlets has been established in Ohio as of July 2013.

There is a lack of data on the number of acres drained by tile. As an alternative, the Task Force looked at the number of acres of cropland in the Maumee and Sandusky River basins and then identified a subset of those acres characterized by the USDA as “Very Poorly” and “Poorly” drained. This is the soil acreage most likely to benefit from drainage management structures.

Number of Acres	Maumee (Ohio only)	Sandusky
Cropland	2,677,187	1,201,765
Very Poorly/Poorly Drained	1,072,491	248,466

These acreage figures (a combined total of 1,320,957 acres) provide a universe to consider as likely being managed with subsurface drainage (tiling). The Task Force then calculated a maximum number of structures for this area based upon an average of one structure for every 30 acres. A total of 1,320,957 Very Poorly/Poorly Drained combined acres in the Maumee and Sandusky basins and an estimate of one structure for every 30 acres, results in a projected total of 44,032 structures (not accounting for structures currently installed).

However, not all Very Poorly/Poorly Drained acres are well suited for drainage management structures. We also do not know the total number of structures currently installed although we do not expect the number to be high as these are relatively new innovations and only recently offered as part of state and federal cost share programs. The Task Force then considered 25% of 44,032 resulting in 11,008 structures. An estimated capital cost of $2,000 per structure and 1 structure for every 30 acres results in an overall capital investment cost of $22 million.

The Task Force then considered what amount of phosphorus reduction might we expect based upon the estimate of 11,000 structures and an average of 30 acres drained per structure for a total of 330,000 acres. The limited research data provides an estimate of 0.3 pounds loss of phosphorus per acre out of drainage tile. Water control structures (a subset of drainage management) capture approximately 50% of the water and extrapolating that to a 50% reduction of phosphorus from 0.3 pounds results in 0.15 pounds per acre. We then calculated a 0.15 pound reduction for 330,000 acres resulting in the estimate of 49,500 pounds per year of phosphorus reduction, or approximately 25 tons annually for an initial investment of $22 million in addition to annual maintenance costs. In addition, yield benefits are being realized by crop farmers where DWM structures have been installed because more water can be stored in the soil and used by the crops. While these are rough calculations and more thorough analysis is warranted, it appears that this may not be the most cost effective way to significantly reduce nutrient loading.

6.3 Conclusion

The Task Force acknowledges that tiling (subsurface drainage) and surface drainage pathways can allow for expedited delivery of drainage and runoff but little more is known about the extent or density of tile drainage since the 2010 Task Force report. Nonetheless, yield benefits through improved and more densely spaced tiling system are well-established and the trend of improving tiling systems and increasing tile drainage density on agricultural lands in the Western Lake Erie Basin is expected to continue. However, more and more research is being conducted on drainage management structures and much of the research shows promising results in nutrient reductions. Designing these structures to accommodate varying flow rates is the most critical factor for their effectiveness as a nutrient management tool. Recent Task Force discussions concluded that drainage management structures and other edge-of-field runoff reduction and storage practices need to be a part of overall management practices across the northwest Ohio landscape while acknowledging that they may not be well suited for some agricultural fields. All practices that serve to trap, slow, store, infiltrate and filter runoff need to be encouraged and must be designed to suit the unique transport pathways from individual agricultural fields.

Section 7 Nutrient Management and Mitigating Practices

7.1 Background

There have been many successes over the years in reducing sediment and nutrient loading to Lake Erie through the implementation of many conservation practices. Agriculture and other nonpoint source reductions contributed to meeting the 11,000 metric ton goal for Lake Erie by the mid-1980s.

A major factor in the reduction of sediment and particulate phosphorus has been the dramatic increase in the use of conservation tillage from the 1970s to present day. During this time there has been an evolution of several different tillage systems from full tillage (burying the residue of the former crop i.e., plowing), to strip till or controlled tillage (tilling only at the point where the seed will be planted) to no-till/never till- (the only disturbance of the soil is when the seed is planted). For a more complete description of these and other tillage systems and their attributes, see Appendix C - Farming Systems).

The implementation of different tillage systems has been critically important in achieving improved environmental outcomes. We need to continue (and improve) these efforts to not lose the reductions that have been achieved.

Understanding different tillage systems provides important insight to the complexity of farming operations. The same tillage system is not used on all crops in the rotation in a single farming operation. For example, rotations away from small grains and forages into more row crops often result in changes/frequency of tillage. Tillage systems work in concert with the broader farming operations of crop rotations, cover crops, planting methods and fertilizer application. Integrating nutrient management means finding the right point of intervention for different tillage systems while avoiding unintended consequences.

An unintended consequence that could result from the reduction of mold board plowing (deep tilling, full plowing) and the need to replace the nutrients harvested with crops could be the application of nutrients and return of nutrients in the residue. This would cause an increase in the level of nutrients on the surface due to the lack of total mixing of the nutrients in the soil. This stratification can significantly increase the potential for nutrient transport in surface runoff and tile drainage when fissures, cracks, and macropores are present (see Figures 7-1 and 7-2). This illustrates the value of field research: to identify best practices for reducing offsite soluble phosphorus transport.

New and evolving methods are gaining more attention to effectively integrate nutrient management with different tillage systems. Results from the edge-of-field research currently underway and discussed at the end of this section will provide critical data and information to enable a more prescriptive approach for finding the right points of intervention for managing nutrients for individual fields and tillage systems. In the interim, best management practices for nutrient management need to continue to be aggressively pursued.

7.2 Higher Risk Conditions and Risk Reductions

There are several factors that influence the potential for field-specific phosphorus transport. The recently revised USDA-NRCS Conservation Practice Standard Code 590, Nutrient Management (NRCS,

2012) discussed in Section 2 considers not only agronomic crop needs but the associated environmental risk of offsite transport to surface waters as well. The Practice Standard 590 also promotes nutrient applications in accordance with the 4R Nutrient Stewardship Program, which focuses on 1) Right fertilizer source, applied at the 2) Right rate, at the 3) Right time, and using the 4) Right placement (IPNI, 2012; NRCS, 2012), to maximize crop yield while minimizing offsite transport. An increased emphasis is also placed on the use of USDA-NRCS approved nutrient and soil erosion risk assessment tools intended to evaluate field-scale nutrient/soil transport losses (NRCS, 2012). Currently, there are two options available to assess agricultural offsite phosphorus transport risk in Ohio, the USDA-NRCS Phosphorus Index Assessment Procedure (Ohio P Index), and the Soil Test Risk Assessment Procedure (STRAP) within the Nitrogen and Phosphorus Risk Assessment Procedures (NRCS, 2001).

The Ohio P Index combines established phosphorus source and transport factors evaluated at the field-scale. Each factor is weighted according to its presumed contribution to phosphorus transport risk, and weighted sub-values for each factor are added together to provide a score ranging from low to very high risk of offsite phosphorus transport (NRCS, 2001). The Ohio P Index includes soil test phosphorus level, planned amount, and method of fertilizer/manure application. In addition, the P Index includes the following transport factors: a field's soil erosion potential, connectivity to water, runoff class, and whether or not there is a designed filter strip. The Soil Test Risk Assessment Procedure (STRAP) estimates phosphorus transport risk based solely on soil test P levels, a phosphorus source factor. The presumption being that as soil test P levels increases, transport of P in surface or subsurface runoff will increase. The STRAP advocates increasing levels of phosphorus application management as P levels increase in the soil. Once soil test P reaches 150 mg/kg Bray-P no additional P application is recommended (NRCS, 2001).

Risks Based on Soil Test Levels One important factor in future reductions is identification of higher risk fields that should be targeted for additional practices. Many fields that are at or near the critical agronomic soil level of 15 to 30 ppm with our current understanding, have a lower contribution to phosphorus loss (from soil P leaving the soil matrix) compared to fields with higher soil test levels. Figures 7-1 and 7-2 illustrate soluble phosphorus losses based on soil test. At recommended agronomic levels, losses tend to be minimized, where with increasing soil test levels, dissolved phosphorus concentrations and DRP losses increase.

As soil phosphorus load increases the risk of offsite phosphorus transport increases due to increases in phosphorus solubility. Numerous researchers have demonstrated that when soil test P builds up beyond a critical point (Fig. 7-4), as a result of animal manure or fertilizer application, the risk of phosphorus transport increases at an increasing rate (Andraski and Bundy, 2003; Heckrath et al., 1995; Maguire and Sims, 2002b; Pote et al., 1996; Schroeder et al., 2004; Sharpley, 1995; Sharpley, 2001).

A critical soil test P limit, beyond which phosphorus solubility increases rapidly, is based on the assumption of an inflection point associated with soil P solubility/transport risk and not with agronomic sufficiency (McDowell and Sharpley, 2001; McDowell et al., 2002; Sharpley et al., 2012). The simplicity of using a single measure to assess field-scale risk has made the concept of a threshold soil test P level (such as the Ohio STRAP) attractive. Often the inflection or threshold level is associated with the degree of phosphorus saturation of soil phosphorus sorption (binding) sites, which is strongly related to sorption sites on soil non-crystalline iron (Fe) and aluminum (Al) hydrous oxide minerals (McBride, 1994; Sparks, 2003; Sposito, 2008). The observation of an inflection point in surface runoff may be dependent upon the range of STP plotted against runoff and soil type. In addition, most studies are limited to the use of simulated rainfall, using small plots or box plots, to evaluate phosphorus runoff and where there were no recent applications of phosphorus amendments. While not all studies identify an inflection point, they all indicate increasing P solubility/risk of transport with increasing phosphorus loading (STP).

Fields above Tri-State Guide agronomic ranges should be identified as very high risk areas, and managed and treated to draw down soil test levels. Other factors beyond the soil test, such as surface water flows and preferential subsurface flows, are additional criteria that may make a field a high risk area. In addition to drawing down soil phosphorus levels, all high risk areas will also require more extensive hydrologic treatment, including substantial buffering, edge-of-field trapping, and other runoff control factors, to avoid phosphorus export. The higher the soil test P, the more runoff control measures are needed. The current Ohio P Risk Index tools contained within Nutrient Management Plan development tools or NRCS spreadsheets can provide guidance on higher loss potential fields.

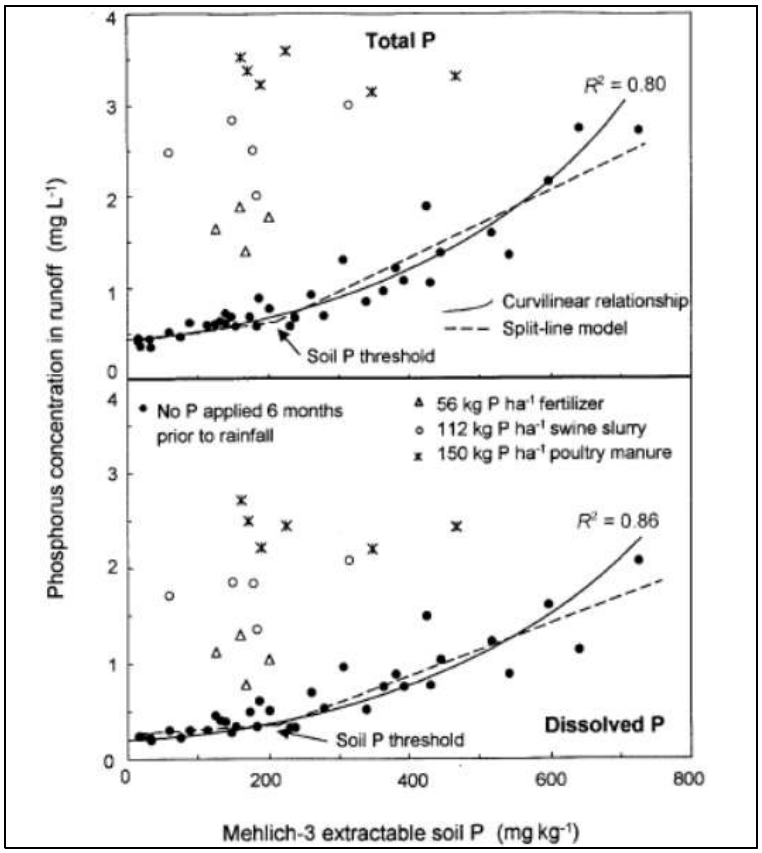


Figure 7-1. Relationship between offsite phosphorus transport and soil test phosphorus for sites where broadcast applications of phosphorus amendments were applied within 3 weeks and where no phosphorus amendments were applied for at least 6 months.

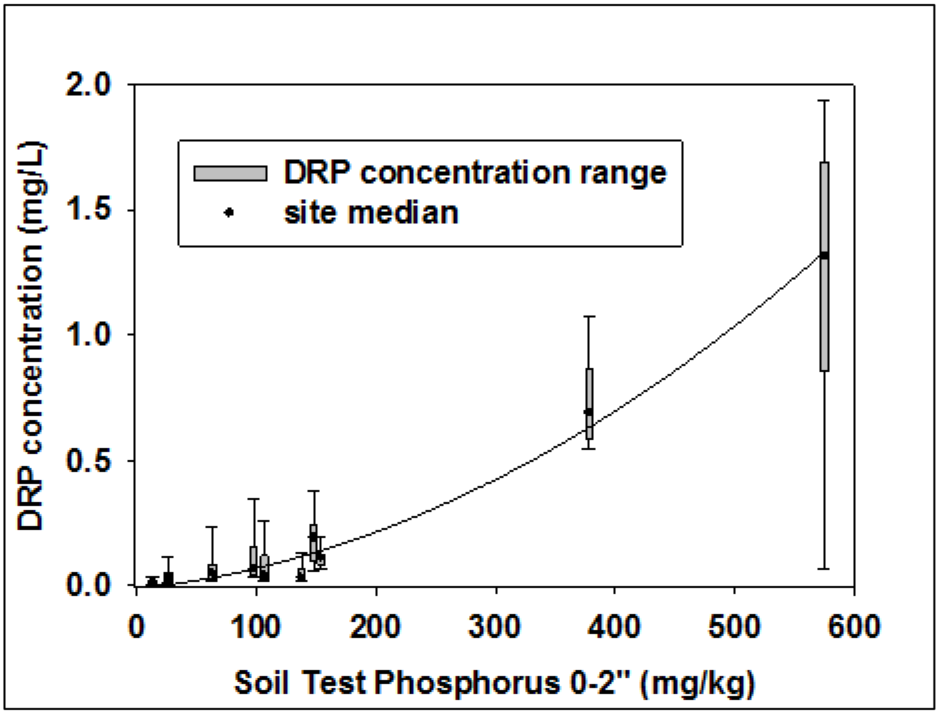


Figure 7-2. Relationship between soil test phosphorus and dissolved phosphorus concentration in tile discharge (upper Big walnut and upper Wabash watersheds).
Source: Kevin King, USDA-ARS, Columbus, OH

Risks Based on Hydrology – There are numerous other factors beyond soil test levels that can result in fields being considered high risk. These factors are associated with field hydrologic conditions, and the 4R factors of Time and Place. Such factors can include methods of application (surface application on frozen ground), time of application (before a large rain) soil compaction (higher runoff rates), soil stratification, soil macropores/preferential flow, presence of tiled drain surface inlets, or proximity to a water course, to name a few.

Work by Sharpley et al. (2001) illustrated that for soils where no fertilizer/manure had been applied for at least six months there was a strong relationship between STP and both total and dissolved runoff phosphorus. However, where a broadcast application of a phosphorus amendment was applied within three weeks of the runoff event both total and dissolved runoff phosphorus were considerably higher than predicted by STP and not well related to STP. Similarly, work by Allen and Mallarino (2008) illustrates striking differences in both dissolved and total runoff phosphorus based manure application amount and placement method over time (Figure 7-3). Varying amounts of phosphorus were surface applied or incorporated (tandem disk-harrow to 10-15cm) to low STP (<15mg/kg, Mehlich-3 P) soils and total and dissolved runoff P were evaluated over time (1, 15 and 180 days) after application. Simulated rainfall applied one day after phosphorus application showed increased phosphorus application amounts resulted in increased runoff phosphorus for both placement methods. However incorporation resulted in much lower runoff phosphorus as compared to surface applied. At 15 days there was, generally, a substantial reduction in runoff for the non-incorporated manure placement method, while there was not a big change in runoff phosphorus for the incorporated manure placement method. After 180 days there was little difference in dissolved or total runoff phosphorus across application amounts or placement method which is consistent with findings (Figure 7-4) by Sharpley et al. (2001). The flipping of the trend, where total P runoff was slightly higher for the incorporated versus non-incorporated placement method at day 15 and 180 was attributed to the slight increase in sediment caused by incorporation.

All fields are subject to losses at and shortly after application that make timing and placement critical factors to consider. Figure 7-3 illustrates a rainfall simulator study which accounts for event timing. After manure nutrient application, rainfall simulator events occurred within 24 hours, 15 days and six months. Rainfall events nearest the time of application and without incorporation led to the highest levels of runoff phosphorus. These graphs show the tendency of phosphorus to bind (attach) to the soil over time. The risk is higher in the first few days after P application; the longer without runoff the less chance there is of movement offsite. Likewise, less surface application means less movement.

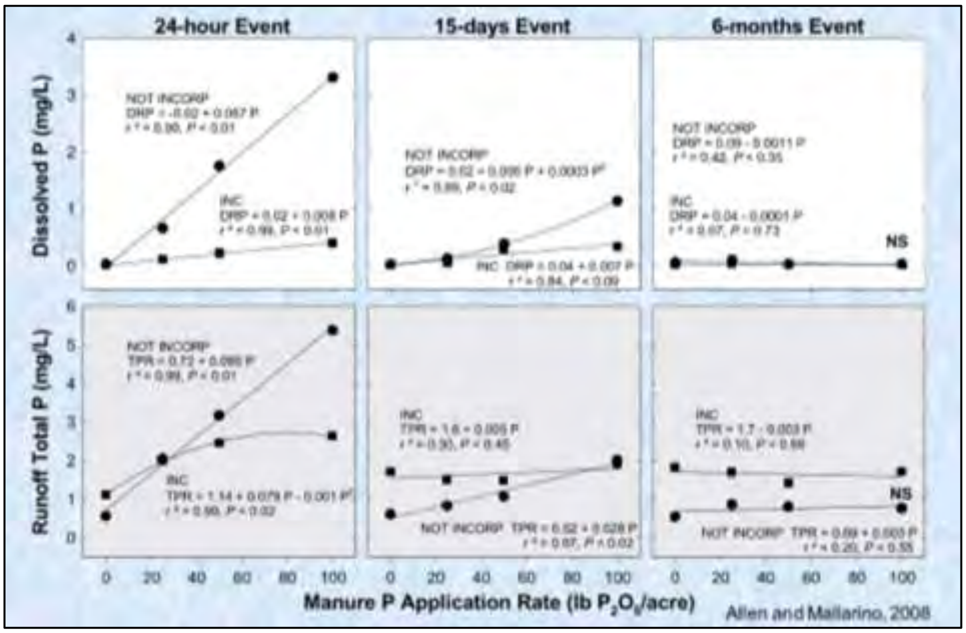


Figure 7-3. Rainfall simulator study, following manure nutrient application.
Source: Allen and Mallarino, 2008.

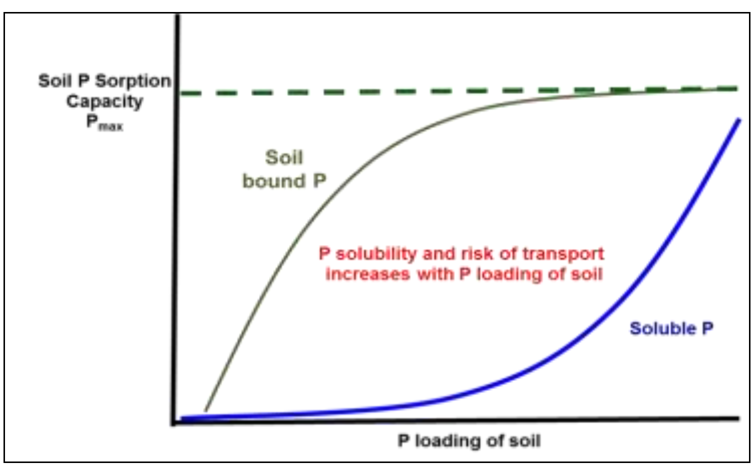


Figure 7-4. Relationship of P solubility and soil assimilative capacity with P loading (STP).
Source: Sharpley et al., 2001.

Beyond soil test level risks and fertilizer application timing risks, risk also increases as runoff increases. As previously noted in sections 5 and 6, factors that may increase runoff from a field include soil compaction and poor soil health, proximity to surface water, connectivity to surface water, presence of soil macropores, surface connection to tile drains, and lack of field buffers/filters, as well as other factors. Hence, even though a field may be low risk based on soil tests in the recommended agronomic range, presence of one or more of the above other hydrologic factors may move it into a higher risk category. Whether STP is high or low, risk of offsite phosphorus transport can be mitigated or exacerbated by field-specific transport factors. As evidenced previously in Figure 2-4, many fields in Ohio are not in the high risk range based on agronomic soil test levels. However, in the aggregate, these fields may still be significant contributors to the cumulative impact of P losses, especially for those fields where the other fertilizer application or hydrologic risk factors exist.

Accordingly, the Task Force is recommending the ACT – Avoid, Control, and Trap, Program for Ohio – as a recommended program for all fields within the Lake Erie Basin, as described in Section 7.3. Application of that program will be field specific, and extent/need will vary from field to field, depending on the current level of risk in each field, existing conservation systems, and other current nutrient management/hydraulic buffer practices.

7.3 Getting Into the ACT

To link key practices and their priority functions, the Task Force encourages the use of a concept borrowed and expanded from USDA-NRCS's Mississippi River Basin Healthy Watersheds Initiative: "ACT" highlights practices for Avoiding, Controlling and Trapping sediment and nutrients. It is important to note that there will be no single practice or solution to reducing sediments and nutrients. There are an infinite number of soils, drainage scenarios, slopes, crops, rotations, yields, cropping practices and farmer decisions that will determine the correct site specific solution. Confounding the best practice identification is seasonality and weather conditions. The following are the priority practices which need to be emphasized in the Western Lake Erie Watershed.

7.3.1 Avoiding Practices

Avoiding practices are practices that manage nutrient handling, improve soil health and optimize nutrient use for crop production and are the first line of defense in preventing nutrient runoff. These practices are implemented to best avoid scenarios that pose risk for nutrient and sediment movement.

- **Nutrient Management** (NRCS Std. 590 & 4 R Nutrient Management) – the goal should be that every acre in the watershed has soil tests meeting the minimum university criteria of at least one test representing no more than 25 acres every three years. More intensive precision technologies utilizing GPS should be encouraged on as many acres as possible. Recommendations for nutrient application should be appropriate to the crop rotation and soil testing results. Excessive nutrient application will reduce profitability and increase chances of movement. Timing and Method of Application should be considered as much as amount of nutrients required. No nutrients should be surface applied on snow covered and/or frozen ground. Nutrients should be incorporated, banded and injected wherever possible. Weather predictions and soil conditions should be taken into consideration to minimize potential runoff of nutrients. To achieve this goal will be dependent on individual farmers, fertilizer dealers and certified crop advisors to create the majority of these plans with assistance from OSU Extension, USDA-NRCS and local SWCDs.

- **Cover Crops** (NRCS Std. 340) (See Section 4 on more detailed information on Soil Health) Cover crops are grasses, small grains, or legumes planted after harvest to protect the soil and hold nutrients until the next crop is planted. Cover crops prevent nutrients from leaching or leaving in runoff waters, improve soil tilth and quality, and reduce erosion. Cover crops work in union with conservation cropping systems and conservation tillage. Including cover crops in more cropping systems is critical to improving soil health, increasing infiltration and reducing critical peak runoff that is transporting sediment and dissolved nutrients.

- **Conservation Cropping Systems (Crop Rotations) –** (NRCS Std. 328) Conservation crop rotations improve soil structure and soil tilth by incorporating more high residue producing crops in the rotation, use of cover crops, and by minimizing oxidation of crop residue through tillage. Improved crop rotations decrease surface runoff volumes through better infiltration and water holding capacities of the soil resulting in decreased runoff amounts and reduced soil erosion losses.

7.3.2 Controlling Practices

In situations where avoiding practices are not well developed, or where unforeseen, excessive, or even normal weather-related precipitation causes nutrient laden transport of runoff and drainage water to occur, *Controlling* practices can be implemented to reduce effects (e.g., erosion, and runoff rate and volume) in which transport pathways have a role.

- **Residue and Tillage Management** – (NRCS Std. 329) The goal for this practice should be every cropland acre. Residue management/conservation tillage is the use of crop production methods that maintain protective crop residue on the soil surface. The two important methods are mulch till and no-till. ***These two practices are critical conservation practices to control soil erosion in the Western Lake Erie Basin.*** Research and modeling conducted in the basin shows that these methods reduce surface runoff volumes and intensities as compared to traditional moldboard plow methods. These practices are also important to climate change mitigation as they sequester carbon in the soil profile. In the winter months, undisturbed cornstalks also provide wildlife food and cover. More recent information indicates that combinations of no-till, strip fertilization and cover crops dramatically reduce runoff and nutrient movement especially on the heavy clay soils that compact easily and seal off, even under no-till or rotational no-till situations.

- **Grade Stabilization Structures** – (NRCS Std. 410) Grade stabilization structures control bank and gully erosion to improve water quality and allow drainage water management.

- **Drainage Water Management** - (NRCS Std. 554) (See Section 5 for more detailed information) Drainage water management utilizes special water control structures in tile drainage systems to raise the potential water table in crop fields during the non-crop period when improved drainage is not needed. The elevated water table reduces volumes of runoff water leaving crop fields under certain conditions thus reducing nitrate and dissolved phosphorus loss to receiving waters.

- **Grassed Waterway** – (NRCS Std. 412) Grassed waterways control ephemeral gully erosion. They reduce sediment delivery to receiving waters and eventually to the harbor and Lake Erie. This practice should be used on critical eroding areas in the watershed.

7.3.3 Trapping Practices

Trapping practices represent “the last line of defense” in agricultural water quality conservation practice selection. Given that the bulk of agricultural nutrient loading usually occurs during only a handful of runoff and drainage events annually, it is vitally important that well considered and designed trapping practices are installed to trap, infiltrate and retain as much of the runoff and nutrients during these events as possible. Slowing down and retaining runoff waters also reduces stressors on stream channels (e.g., bank erosion) and can provide more sustained base flow to the tributary system. This allows for more opportunity for natural assimilation and processing of nutrients in the aquatic system throughout the year. We recommend a concerted effort by state water quality and agricultural agencies to work with FSA, NRCS and SWCDs to improve CRP and CREP program delivery in Ohio so that water quality is given highest priority resulting in more effective edge-of-field trapping practices being promoted, designed and installed.

- **Filter Strips/Filter Areas -** Filter strips/filter areas are plantings of perennial grasses, legumes, and forbs adjacent to watercourses. These areas reduce erosion, trap pollutants and nutrients, improve water quality, and provide habitat. There are several different design standards for filter strips and filter areas and they are all not equally effective at the trapping functions for nutrients as described above. Any design of edge-of-field buffers needs to take into consideration the acres of cropland draining through them, the slope of the land and the ability to disperse concentrated flow and maintain sheet flow to function effectively. Filter Strips/Areas are not meant to replace any conservation practice needed on the cropland field, but to be applied in addition to those practices.

- **Constructed Wetlands** – (NRCS Std. 656) An artificial ecosystem with hydrophytic vegetation for water treatment. For treatment of wastewater and contaminated runoff from agricultural processing, livestock, and aquaculture facilities, or for improving the quality improvement of storm water runoff or other water flows lacking specific water quality discharge criteria. Similar edge-of-field detention basins could also be introduced whereby stored runoff water can be used as a source of irrigation water, or in conjunction with drainage water management systems by reintroducing runoff waters back into tile system when crops could benefit from more water.

- **Blind Inlets** – (Part of NRCS Std. 620) A blind inlet is a structure that is placed in the lowest point of farmed depressions, usually used to replace tile inlet risers. It allows sediment and other potential nutrients to be filtered and retained which would otherwise be transported to ditches or streams.

- **Phosphorus Bioreactor** – (Standard being developed) These are being developed to capture nutrients leaving the field, either in tile flow or sheet flows. They currently are utilizing several types of materials including steel slag and water treatment plant materials that adsorb the dissolved phosphorus and remove it from water.

- **Denitrifying Bioreactor** – (NRCS Std. 747) A structure containing a carbon source installed to intercept subsurface drain (tile) flow or ground water, and reduce the concentration of nitrate-nitrogen. To improve water quality by reducing the nitrate-nitrogen content of subsurface drain flow and ground water.

- **Water and Sediment Control Basin** - (NRCS Std. 638) An earth embankment or a combination ridge and channel generally constructed across the slope and minor water courses to form a sediment trap and a water detention basin. To improve the ability to farm sloping land, reduce watercourse and gully erosion, trap sediment, reduce and manage onsite and downstream runoff and improve downstream water quality.

- **Riparian Forest Buffer -** (NRCS Std. 391) An area of trees and/or shrubs located adjacent to and up-gradient from water bodies. Riparian Forest Buffers reduce excess amounts of sediment, organic material, nutrients and pesticides in surface runoff; reduce excess nutrients and other chemicals in shallow ground water flow; create shade to lower water temperatures to improve habitat for fish and other aquatic organisms; provide a source of detritus and large woody debris for fish and other aquatic organisms and riparian habitat and corridors for wildlife. The forest riparian buffer will be most effective when used as a component of a total management system including nutrient management; pest management, erosion, runoff and sediment control practices as well as non-riparian wildlife habitat management.

7.4 Potential for Success of Proposed Practices

The Iowa Nutrient Reduction Strategy (IDALS, 2013) provides a summary page of practices controlling P transport. This literature search and summary of Iowa research should be critically reviewed by The Ohio State University and others for application to Ohio conditions. Until this review is conducted, the Iowa work provides a starting point. Kevin King and Jon Witter have started this literature review process.

Table 7-1 shows how the same practice can have very different impacts on nutrient movement or crop production. For instance, the practice of using a rye cover crop could vary from a 39% increase in nutrient movement off-site to a 68% decrease in nutrient movement depending on several factors. There is no “one” practice that can be recommended as best in all cases.

7.5 Current Edge-of-Field and P-Index Research

Understanding the sources and transport pathways of nutrients is critical to the development and implementation of effective management practices to address nutrient loss. Edge-of-field (EOF) research has been initiated in Ohio with the objective of elucidating and quantifying the surface and subsurface hydrology and water quality (dissolved and total phosphorus) impacts of different farming system (4R) and conservation management practices. A before/after control impact (BACI) paired research design was selected to quantify the impacts of the different practices. Distinct paired fields consisting of like soils, cropping, and management practices are identified and instrumented for collection of either surface runoff, subsurface drainage or the combination of surface and subsurface discharge. During the control period (one crop rotation), hydrology and water quality data will be collected from each site and a relationship will be established between the pair. During the treatment period (one or two crop rotations), some change in management will be made and the same hydrologic and water quality data will be collected. Differences in the relationships during the two periods will be used to determine the effectiveness of the practice(s).

A partial list of edge-of-field treatment practices for data collection include: incorporation, surface application, fall application, spring application, banding, broadcast application, split application, organic and inorganic formulations, rotation tillage, strip tillage, no-till, cover crops, drainage water management, surface amendments such as gypsum, variable rate application, and controlled traffic.

To date, 30 fields (15 pair) have been identified. Twenty-two fields have been instrumented, eight of those fields (four pair) are located in the Upper Scioto Watershed, eight (four pair) in the Upper Wabash/Grand Lake St. Mary Watershed, and 14 (seven pair) in Western Lake Erie Basin watershed. The fields are representative of the major soils and cropping practices in the eastern corn belt portion of Ohio, including the western basin.

This project will provide event-based, long-term, monitoring data, at the field-scale, for all instrumented field. The purpose of this effort is to quantify best management practices and develop a suite of best practice recommendations to agricultural produces. Additionally the field results will be integrated into the Ohio P Index.

Table 7-1. Table showing potential impact of practices on phosphorus load reduction.
Corn yield impacts associated with each practice also are shown, since some practices may increase or decrease corn production. (Source: Iowa Nutrient Reduction Strategy (IDALS et al., 2013, Section 2.3, Table 1)

	Practice	Comments	% P Load Reduction[a]			% Corn Yield Change[b]		
			Min	Average (SD[c])	Max	Min	Average (SD[c])	Max
Phosphorus Management Practices	Phosphorus Application	Applying P based on crop removal – Assuming optimal STP level and P incorporation	0[d] [0[e]]	0.6[d] [70[e]]	1.3[d] [83[e]]		0[f]	
		Soil-Test P – No P applied until STP drops to optimum	0[g] [35[h]]	17[g] [40[h]]	52[g] [50[h]]		0[f]	
		Site-specific P management	0[h]		14[h]		0[f]	
	Source of Phosphorus	Liquid swine, dairy, and poultry manure compared to commercial fertilizer – Runoff shortly after application	-64	46 (45)	90	-33	-1 (13)	73
		Beef manure compared to commercial fertilizer – Runoff shortly after application	-133	46 (96)	98			
	Placement of Phosphorus	Broadcast incorporated within 1 week compared to no incorporation, same tillage	4	36 (27)	86		0[f]	
		With seed or knifed bands compared to surface application, no incorporation	-50 [-20[i]]	24 (46) [35[i]]	95 [70[i]]		0[f]	
	Cover Crops	Winter rye	-39	29 (37)	68	-28	-6 (7)	5
	Tillage	Conservation till – chisel plowing compared to moldboard plowing	-47	33 (49)	100	-6	0 (6)	16
		No till compared to chisel plowing	27	90 (17)	100	-21	-6 (8)	11
Land Use Change	Crop Choice	Extended rotation		[j]		-27	7 (7) [k]	15
	Perennial Vegetation	Energy crops	-13	34 (34)	79		-100[l]	
		Land retirement (CRP)		75			-100[l]	
		Grazed pastures	2	59 (42)	85		-100[l]	
Erosion Control & Edge-of-Field Practices	Terraces		51	77 (19)	98			
	Wetlands	Targeted water quality		[m]				
	Buffers		-10	58 (32)	98			
	Control	Sedimentation basins or ponds	75	85	95			

a A positive number is P load reduction and a negative number is increased P load.
b A positive corn yield change is increased yield and a negative number is decreased yield. Practices are not expected to affect soybean yield.
c SD = standard deviation.
d Maximum and average estimated by comparing application of 200 and 125 kg P_2O_5/ha, respectively, to 58 kg P_2O_5/ha (corn-soybean rotation requirements) (Mallarino et al., 2002).
e This represents the worst case scenario as data are based on runoff events 24 hours after P application. Maximum and average were estimated as application of 200 and 125 kg P_2O_5/ha, respectively, compared to 58 kg P_2O_5/ha (corn-soybean rotation requirements), considering results of two Iowa P rate studies (Allen and Mallarino, 2008; Tabbara, 2003).
f Indicates no impact on yield should be observed.

g Maximum and average estimates based on reducing the average STP (Bray-1) of the two highest counties in Iowa and the statewide average STP (Mallarino et al., 2011a), respectively, to an optimum level of 20 ppm (Mallarino et al., 2002). Minimum value assumes soil is at the optimum level.
h Estimates made from unpublished work by Mallarino (2011) in conjunction with the Iowa P Index and Mallarino and Prater (2007). These studies were conducted at several locations and over several years and may, or may not, represent conditions in all Iowa fields.
i Numbers are from a report by (Dinnes, 2004) and are the author's professional judgment.
j Water quality data for P loss on extended rotations in Iowa are scarce compared to data for a corn- soybean rotation.
k This increase is only seen in the corn year of the rotation – one of five years.
l The number is -100, indicating a complete cropping change and therefore a corn yield of zero.
m P retention in wetlands is highly variable and dependent upon such factors as hydrologic loading and P mass input.

In Ohio, the risk of agricultural phosphorus P transport to surface water is assessed by the Ohio USDA-NRCS Phosphorus Index Assessment Procedure (Ohio P Index) within the Nitrogen and Phosphorus Risk Assessment Procedures. The Ohio P Index is used for every nutrient management plan (NMP) for manure or commercial fertilizer issued in Ohio. These plans are required for participation in USDA conservation programs and for concentrated animal feeding operations (CAFOs). The ability to quantify reductions in P loss will allow producers to prioritize time and resources when making management decisions. An online, web-based, interactive GIS tool (web-based tool) will also be developed so farmers can calculate their Ohio P Index scores. This streamlined tool will increase the utility of the Ohio P Index beyond a tool used to assess risk of P transport, into a tool producers can use to make management decisions to reduce their risk of P transport.

The P-Index research effort is part of a three- year USDA-NRCS Conservation Innovation Grant (NRCS-CIG) with an additional $1million support in matching contributions from Ohio agri-businesses. Edge-of-field research and assessment is funded through a combination of the NRCS-CIG as well as funding from NRCS-Mississippi River Basin Initiative, USDA-ARS, and other granting institutions.

As part of GLRI and USEPA's Priority Watersheds, the USGS installed an edge of field monitoring site in the Eagle Creek watershed in 2012. As described above, samples will be taken from surface flow and from tile outlets at regular intervals and during storm events. A water quality monitoring station was also established downstream of the edge-of-field site to assess changes in downstream water quality. The results from these sites will be compared to other Priority Watershed sites on the Fox River in Wisconsin and the Saginaw River in Michigan as well as potentially the USDA- NRCS sites above. The purpose is to assess the changes in water quality from the implementation of BMPs.

7.6 Recommendations

1. The Task Force recommends an Avoid, Control and Trap (ACT) approach to nutrient management practices. In particular, the Task Force identified the top seven approaches to addressing nutrient management, aka *Super 7 Strategies*:
    i. Soil test
    ii. Follow Tri-State recommendations
    iii. No application on snow covered/frozen ground and do not apply before a rain event
    iv. Fertilizer placement to ensure contact with soil and avoid surface application

  v. Develop soil health to increase infiltration and reduce runoff
  vi. Manage tile drainage to minimize phosphorus transport
  vii. Utilize trapping practices to slow down and retain water runoff

2. The Task Force recommends shifting the language from 'incorporation' to 'fertilizer placement' to avoid the impression that we are looking to revert back to conventional/inversion tillage. Proper Fertilizer Placement is applying phosphorous in a manner that maximizes contact, binding, and/or retention of P with and in the soil profile to minimize offsite movement. It is part of an overall cropping system and other BMPs that collectively form a conservation system that achieves this goal. Proper Fertilizer Placement is very site/field/system specific but minimizes loss of P via surface or tile runoff through banding, injection, light incorporation, vertical tillage, use of cover crops, strategic timing of applications, and/or other means. Proper Placement also considers need for residue management to maintain surface cover and control erosion, to avoid increasing erosion and sediment P runoff.
3. The Task Force acknowledges that there are likely hotspots and danger times for fertilizer application. We do not have good information on what areas are losing more to runoff than others. These hotspots shift from season to season due to crop rotations and other field management decisions.

Section 8 Additional Considerations

Several topics emerged throughout the deliberations of the Task Force resulting in additional recommendations. These topics are discussed below.

8.1 Field Equipment for Fertilizer Placement

Current equipment availability and design may not exist which meets the dual goal of fertilizer placement below the surface with minimal soil disturbance. Surface application of nutrients is practiced due to the speed of covering acres and the relative ease of coordinating logistics by the fertilizer applicator. To switch application to a below the surface placement will be a slower application process altering the logistics for producers. Adoption of new field equipment will require a change in the inventory of applicators and associated capital costs in the industry.

Additionally a concern exist in balancing placement with soil conservation concerns to assure that soil erosion losses are not increased at the expense of obtaining soil placement below the surface. Current equipment maybe repurposed such as an air seeder repurposed for fertilizer application. Another outcome is innovation with redesigned fertilizer application equipment to meet both placement and soil conservation needs.

The Task Force acknowledges that there are potentially increased capital equipment costs for changes in equipment inventory, redesign of equipment and logistics with fertilizer delivery.

8.2 Soil Test Methodologies

Soil tests are designed to help producers predict available nutrient status in soils. Once existing nutrient levels are established, producers can use the data to determine what nutrients need to be applied for the crops, rotations and yield goals being targeted.

The most commonly known soil test methodologies in Ohio are the Mehlich-3 test (M3) and Bray-Kurtz P1 (Bray-P1 test). The majority of private laboratories in Ohio are using a soil test (Mehlich 3) because it can be utilized to give several different nutrient needs analysis at the same time and is quicker and more efficient than the Bray-P1 methodology. However only the Bray-Kurtz P1 was used to establish soil critical values and response curves for the various agronomic crops (Watson and Mullen). Fertilizer recommendations for crops grown in Ohio soils (Tri-State Fertility Guide) are based on the Bray-Kurtz P1-colorimetric method.

Due to high research expense, field calibration with the Mehlich-3-ICP method for Ohio soils has not been performed to date. The Task Force discussed that the Mehlich-3-ICP test method is cheaper and quicker to perform and that soil test laboratories are unlikely to switch to the Bray-P1 test.

To ensure better consistency and reliability at a time when soil tests have become a critical tool in nutrient management, the Task Force recommends that the Tri-State fertility recommendations be recalibrated to the Mehlich-3-ICP test methodology. The Task Force further recommends that state, federal and private agricultural stakeholders confer with representatives from soil test laboratories used in Ohio to develop mutually acceptable approaches to testing methodologies and alignment with fertility recommendations while also looking at the feasibility of newer testing methods and evaluating both crop response and the potential for use for environmental risk evaluations.

8.3 Federal Farm Policies

The Task Force considered the implications of the federal farm programs and policies to fertilizer application. Federal subsidy, crop insurance and other farm bill provisions are highly complex and further education and analysis on these issues would be needed to make any detailed recommendations. However, the Task Force did agree that federal policies and programs such as crop insurance and cost share practices, while beneficial for the reasons they were created, should not be detrimental to the goal of effective nutrient management and reduction of off-the- field water quality impairments. The Task Force recommended that experts in various farm policy and programs be convened and that farm programs and provisions be examined for any unintended environmental consequences along with recommendations to address those shortcomings.

Section 9 Tracking Progress

The attention generated by the first Phosphorus Task Force report and the severe Lake Erie bloom of 2011 prompted a lot of interest and movement to address the situation, as well as sizable public and private investments. However, there is no easy measure of progress in solving the problem. The Task Force examined a number of possibilities and suggests that the metrics described here will be useful in gauging the payoff on investments being made and guiding next steps in an adaptive management framework.

9.1 Lake Measures

Two measures of algal extent in Lake Erie have emerged from research, a remote sensing method by NOAA and a direct measure method by the University of Toledo. Both methods allow researchers to compare one year to the next and explore the connections between bloom development and environmental factors such as tributary loading and water temperature. The Cyanobacteria Index (CI) and the biovolume measure are very different, but the results from each are highly correlated.

Cyanobacteria Index (CI)

The National Oceanic and Atmospheric Administration (NOAA) has developed a method that uses satellite imagery to estimate the areal extent of cyanobacteria blooms, the Cyanobacteria Index (CI)**.** The medium-spectral resolution imaging spectrometer (MERIS), carried aboard a European Space Agency (ESA) satellite, permits quantification of blooms even in water with suspended sediments, including Lake Erie. The ESA satellite crosses the Lake Erie area every two days, capturing data from an 1150-km-wide area. MERIS data is available since 2002, allowing a comparison of the bloom intensity with Maumee River loads for each of the last 12 years. The CI is the basis for the NOAA harmful algal bloom bulletin and forecasts described in Section 2.2.1. The information was also a key component of the targets presented in Section 4. The images in Figure 9-1 show the peak of blooms in the western basin of Lake Erie for the four worst years on record, 2008 through 2011.

Biovolume

Biovolume is a direct measurement of cyanobacteria in the water. Researchers strain the cyanobacteria out of the water using plankton nets, concentrate it and then measure to how much is there per square meter of lake surface. The result can be expressed either as a biovolume or a biomass of algae per square meter of lake at a given site on a given date. The results from six established sites in the western basin are averaged to track the annual bloom "crop" from beginning to end. Figure 4-1 shows the results of the biovolume measurement in the western basin from 2002 through 2011. The method is described in the *Journal of Great Lakes Research* (Bridgeman et al., 2012).

The method captures cyanobacteria from essentially the whole water column so algae below the surface are included. Also, actual biovolume or biomass is measured so the data can be used for other calculations (Bridgeman et al., 2011). Efforts are underway to increase the number of sites and increase coverage to the whole lake.

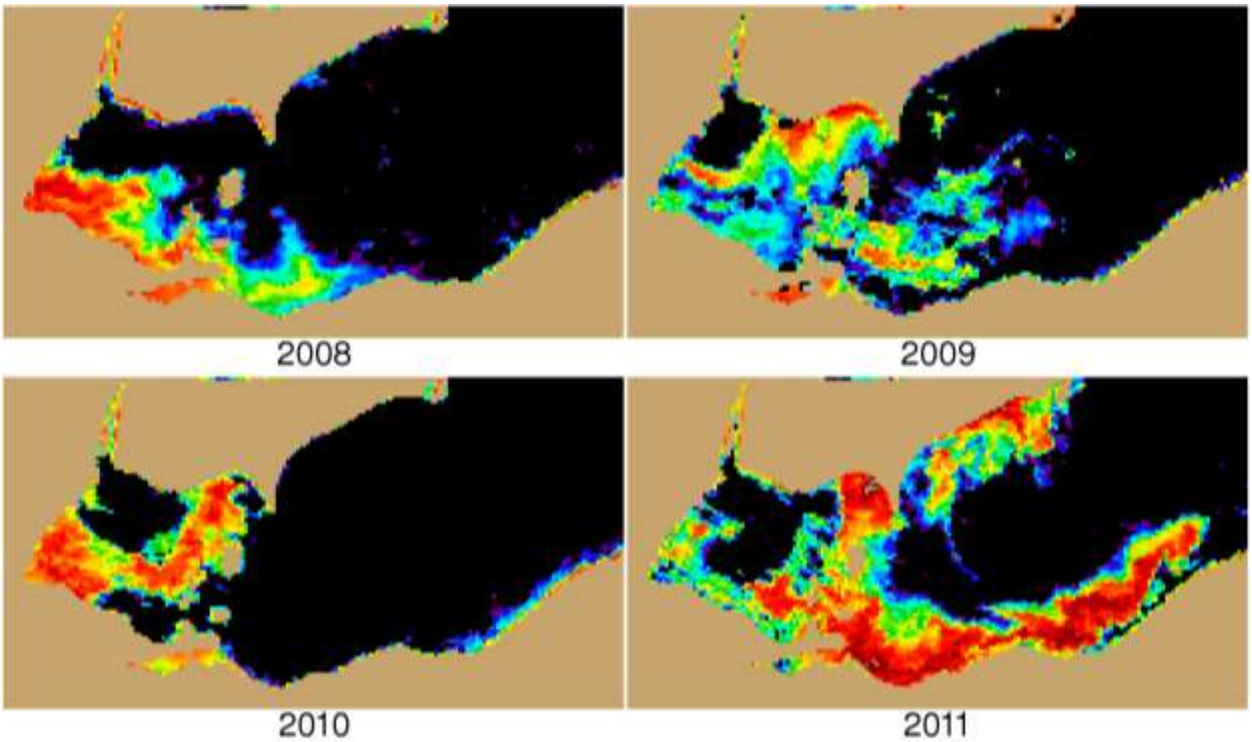


Figure 9-1. Cyanobacteria Index applied to satellite imagery to illustrate the peak of blooms in the western basin.

9.2 Land Measures

Calculating loads on a seasonal and annual basis for comparison to the targets recommended in Section 4 will be an important tracking mechanism. Being able to compare expected load reductions to the rate at which management practices are adopted will inform the adaptive management process.

9.2.1 Phosphorus Targets (Maumee River Load)

The Maumee River at Waterville is a long-term, detailed monitoring station for nutrient and sediment export studies operated by the National Center for Water Quality Research at Heidelberg University (NCWQR) and for discharges from the USGS Maumee River gage at Waterville. This station is located about 20.2 miles upstream from the river mouth and provides detailed information on nutrient, sediment and related chemicals that enter the lower Maumee River and Maumee Bay. A refrigerated autosampler is used to collect samples. Samples are returned to the NCWQR at weekly intervals, where three samples per day are analyzed during high flow periods and one per day during low flows. Details of the sample collection and analytical methods are presented at the tributary loading section of the NCWQR's website. The information is a key component of the targets presented in Section 4.

9.2.2 Tracking Progress of Land Management and Conservation Practice Installation

The adaptive management process will necessitate tracking of conservation practice installation and land cover/land management changes in the watershed, in order to understand the actions land managers are applying in the watershed, and the resulting effects on nutrient export to Lake Erie. Understanding and quantifying what is happening with land management practices will:

- Help program managers and State and Federal Agencies design/implement more effective incentive programs, and provide a unified summary of progress form the many sources of conservation assistance
- Help scientists explain year-to-year changes in loadings and resulting blooms in Lake Erie
- Provide data useful to scientists developing watershed models and conducting research projects on phosphorous movement, transport, and export to the lake.

Key factors and key data elements to collect include:

- *4R Nutrient Management Activities* - This element will measure progress of basin farmers towards applying the right rate, timing, and placement of phosphorus nutrients (fertilizer and animal manures) in according with the NRCS Nutrient Management Standard 590 and the Tri-State Fertility Guide.
- *Crop Management, Crop Residue Management, and Conservation Tillage Activities* - Type and time of tillage, residue management, and crops grown all influence soil health, erosion losses, and rates and volumes of runoff. These in turn impact export of phosphorus, both particulate P and DRP. This element will track those activities.
- *Permanent Grass And Tree Cover* – Permanent vegetation has a beneficial impact on erosion, runoff, and nutrient export from the watershed, as well as impacting processing of nutrients via the stream system. There is a need to monitor increases and decreases in CRP/CREP acres, as well as the practices of filter strips, grass waterways, wetland restorations and riparian tree plantings/protection.
- *Drainage Water Management Practices* – Research shows a substantial amount of DRP can move through tile drainage systems. Practices which can mitigate this movement include drainage water management as well as some means of trapping P in tile drainage mains (currently being researched). There is a need to monitor progress in applying these practices to the land.

Some of the data needed already exists or is annually collected, but is scattered in different places. Other parts of the data are not being collected, or needs funding to insure continued collection. For example, NRCS has been funding SWCDs to collect the conservation tillage transect data with Western Lake Erie Basin Partnership Funds. Those funds are now depleted and the NRCS contract with the SWCDs will be expiring. In addition to collecting the data, the data needs to be compiled in one location, and published annually so that it is accessible by partners and State and Federal Agencies working in the basin. There is a primary and significant need for one entity to take the lead to insure all collected data is reported, compiled, and published for use by all partners. This coordination is currently lacking.

Additionally, while this report deals with Ohio’s actions, 36% of the land area of the Western Basin of Lake Erie lies in Indiana and Michigan. Similar data is needed from all three states to get a complete picture across the watershed.

Table 9-1 depicts the items to track, specific metrics, suggested lead entities, contributing partners, and funding or technical assistance needed to make happen.

Data is available for nutrient management plans prepared with NRCS/SWCD financial or technical assistance. However, these are a small percentage of the land users in the watershed. No readily available information exists for private plans prepared by certified crop consultants or private individual decisions made my landowners doing their own nutrient management planning. Several options were discussed by the task force including:

- Using the NRCS CEAP Process - The special Maumee Conservation Effects Study used the National Agriculture Statistics Service (NASS) to field interview more than 1,000 farmers for the Western Basin Special CEAP study. The date collected will provide a statically accurate 2012 4R snapshot at approximately the eight digit HUC level. However, this process is too expensive and the survey form too burdensome on the producer to conduct every year. The cost of the NRCS CEAP study will exceed $1.5 million, with the bulk of the cost needed for the NASS field interviews. One suggestion is to meet with NASS and see they could design a simper 4R study, which would be less expensive and could be used on a two-three year interview.

- Collecting Farmer Self-Certified Data during FSA Programs Signup - One suggestion is to ask farmers to voluntary self-certify nutrient management practice during FSA program sign-up. This idea offers some advantages but raises many questions. 1) Federal agencies are limited in the surveys they can conduct and information they may ask/require without going through a formal approval process. 2) Would all farmers participate voluntarily, and if not, how valuable would the data be? 3) Fertility management information is in CCA plans or Fertilizer Dealer records and recommendations. Consideration should be given to identify how readily accessible and accurate this information would be to collect/produce during FSA signup. 4) How/who would summarize data?

- A third option would be to use the private CCA network and/or the proposed voluntary 4R Dealer Certification to collect trend data. Either of these would obviously require much work, planning, and implementation funding.

- Ag Stats as part of the federal agricultural census.

It was beyond the ability of the Task Force to resolve this issue prior to this report. *It is recommended that a special team or task force be tasked with following up on this item, and developing a plan that identifies the information that will be most useful to track, the minimum information needed, and the most efficient and feasible means to obtain/track the information with the least amount of imposition.* The task force should include representation from the fertilizer and commodity industry, farm groups, NASS, Ohio State Extension, and the other appropriate state and federal agencies.

Further, the Task Force recommends continuing tillage transect surveys. This information is valuable to track as the linkages between nutrient transport and different tillage systems are becoming better understood.

Table 9-1. Conservation practice and land management tracking items and metrics.

Item To Track	Benefit	Lead	Data Source/actions	Outputs	Funding/TA Needs
Rates of Adoption of 4R Nutrient Management Practices	Will provide information on rate of progress towards adopting the 4R activities on Basin farms.	NRCS for Federal Programs	Compile data from NRCS reporting system and report to ODNR	Number of new nutrient management plans developed meeting standard 590	Already captured in NRCS Reporting System
		ODNR for State Programs	Compile data from SWCD reporting system (SWIMS)	Number of new nutrient management plans developed meeting standard 590	Already captured in SWCD Reporting System
		CCAs/ Agribusiness	*** (See Text for Discussion)	*** How to capture info on private sector plans developed that meet the 590 standard?	*** What are funding needs to accomplish?
		ODNR	Compile and publish all data	Annual report of 4R adoption	Staff Time/ Resources - Need is for someone to compile, summarize and publish
Trends In Crop Management and Residue Cover on Cropland	Will quantify year by year changes in crop management, residue cover on cropland, which affects erosion losses, soil health, and rates of water runoff	ODNR/SWCD's to collect and summarize.	Continue the Geo-referenced Conservation Tillage Transect Surveys in the Western Basin	Acres of Residue Management Acres and Types of Tillage Acres of Fall Tillage Acres of 3 Primary Crops – Corn, Soybeans, and Wheat (Data will be geo-referenced at 8 Digit HUC Level)	Via Contract/ Funding to SWCD's to continue transects (NRCS format already developed)
Acres of Winter Cover Crops on Cropland	Will quantify trends and amounts of cover crops used on cropland in the basin, which affects erosion losses, soil health, rates of water runoff, and nutrient export	ODNR/SWCDs to collect and summarize.	Collect Cover Crop Use date as part of the Conservation Tillage Transects	Acres of Winter Cover Crops (Data will be geo-referenced at 8 Digit HUC Level)	Via Contract/ Funding to SWCD's to continue transects

Item To Track	Benefit	Lead	Data Source/actions	Outputs	Funding/TA Needs
Trends in Permanent Vegetative Cover in the Watershed	Quantify yearly changes in permanent grass or natural cover in the watershed, which affects erosion losses, soil health, rates of water runoff, and nutrient export	ODNR to collect and summarize	FSA CRP/CREP Reporting Data Base & NRCS Reporting Data Base	Net change in CRP acres (Whole Field and Continuous) Acres of Filter Strips Acres of Wetland Restorations Acres of Riparian Tree Plantings	Captured in existing databases. Need is for someone to compile, summarize and publish
Drainage Water Management Activities	Quantify yearly accomplishments in improved drainage water management. Capture of practices that slow water runoff and nutrient export.	ODNR to collect and summarize	SWCD Reporting Database & NRCS Reporting Database	Number of Drainage Water Management Structures installed Feet of Two-stage or Over-wide Drainage Channels Installed Tile Risers or Blind Inlets Converted to Catch Basins Innovative Treatment Systems Installed on Tile Outlets	Captured in existing databases. Need is for someone to compile, summarize and publish
Compiled Annual Report	Compiled annual trends into format easily understood by public and popular audience	ODNR/OEPA	Above Reported Items	Popular type Summary Report targeted to general audiences	Cost to compile and publish.

Section 10 Recommendations

The Task Force considered many recommendations as critical steps to be taken to address phosphorus runoff to Lake Erie. The Task Force recommends that efforts continue to be made to reduce all sources of dissolved phosphorus, urban and rural, point and nonpoint sources. Items 1 – 12 listed below are brought forward from earlier sections of this report while Items 13 - 20 reflect priority actions that emerged in Task Force deliberations.

Rainfall patterns, weather extremes and storm events will continue to drive the scope of algal blooms in future years. The Task Force believes that sustained efforts to reduce nutrient loading from all sources are critical for long term results so that even in years with high rainfall events and high loads of phosphorus delivery, we will see significant reduction of the algal blooms.

1. The Task Force recommends adopting phosphorus loading targets for tributaries draining to the western basin of Lake Erie. For the Maumee River, the Task Force recommends the following targets for spring loads (defined as 1 March to 30 June) for both total phosphorus and dissolved reactive phosphorus and annual loads (water years, 1 October to 30 September) for total phosphorus:
   - Total phosphorus
     - Spring: 800 metric tons
     - Annual: 1,600 metric tons
   - Dissolved reactive phosphorus
     - Spring: 150 metric tons.

   See Section 4 “Targets”.

2. The Task Force recommends applying target loading recommendations to all Western Basin tributaries. The targets are for the tributaries and are intended to encompass all phosphorus loading sources. The Maumee River watershed represents 4.2 million of the 7.1 million acres draining to the western basin. NOAA has demonstrated that the severity of HABs in the western basin is highly correlated with Maumee River loads. Heidelberg University has also shown that unit area loads for all of the tributaries between Monroe Michigan and Sandusky, Ohio are similar. The actions taken to reduce nutrient loading to reach target loads for the Maumee should be implemented in all watersheds between Monroe, Michigan and Sandusky, Ohio. Attainment of the proposed target loads for the Maumee River, our indicator of progress, and simultaneous implementation of the same actions to reduce the loads in these other watersheds, would significantly reduce HABs in the Western Basin and Lake Erie as a whole.
   See Section 4 “Targets”.

3. The Task Force recommends continuation and expansion of a thorough monitoring and adaptive management program. Monitoring in the tributaries and in the Lake is necessary to measure progress toward loading and concentration targets and HAB reduction will allow us to annually evaluate and modify those targets in the future, as needed.
   See Section 4 “Targets”.

4. The Task Force recommends emphasizing the role of soil health for crop production and minimization of nutrient transport off-field. Encourage and adopt the following practices that maintain soil health:
   - Limit soil disturbance
   - Increase soil microbial diversity
   - Grow living roots year round
   - Keep the soil covered
   - Reduce compaction

   These practices will improve soil structure, aggregate stability and reduce compaction to increase water infiltration while reducing nutrient laden runoff. Additionally, increasing soil organic matter will improve the water holding capacity of the soil reducing water loss through tile systems and increasing soil organic matter and microbial activity in the soil. These processes will help filter and recycle nutrients. Reducing compaction will improve soil structure and aggregate stability to improve matrix flow allowing nutrient filtration and assimilation while reducing fracturing, cracking, and preferential flow.
   See Section 5 “Soil Health”.

5. The Task Force recognizes the importance of drainage tile to production agriculture and recommends that drainage management structures and enhancements to these systems be evaluated for water quality effects and costs in varying Ohio field conditions and flow regimes. Recent research indicates promising results for nutrient reductions for several different structures. In addition, blind inlets are now eligible for funding as part of the NRCS Underground Outlet practice. Engineering technicians at the local level should be trained on design and installation of blind inlets and blind inlets should be prioritized and promoted as a means to reduce nutrient losses that occur through existing surface inlet infrastructure.
   See Section 6 “Drainage Management”.

6. In addition to continuing promotion of the 4R Nutrient Stewardship Program, the Task Force recommends an Avoid, Control and Trap (ACT) approach to nutrient management practices. In particular, the Task Force identified the top 7 approaches to addressing nutrient management, i.e., the *Super 7 Strategies*:
   - Soil test
   - Follow Tri-State recommendations
   - No application on snow covered/frozen ground or before a rain event
   - Fertilizer placement to ensure contact with soil and avoid surface application
   - Develop soil health to increase infiltration and reduce runoff
   - Manage tile drainage to minimize phosphorus transport
   - Utilize trapping practices to slow down and retain water runoff

   See Section 7 “Nutrient Management and Mitigating Practices”.

7. The Task Force recommends shifting the language from ‘incorporation’ to ‘fertilizer placement’ to avoid the impression that we are looking to revert back to conventional/inversion tillage. Proper Fertilizer Placement is applying phosphorous in a manner that maximizes contact, binding, and/or retention of P with and in the soil profile to minimize offsite movement. It is part of an overall cropping system and other BMP's that collectively form a conservation system that achieves this goal. Proper Fertilizer Placement is very site/field/system specific but

minimizes loss of P via surface or tile runoff through banding, injection, light incorporation, vertical tillage, use of cover crops, strategic timing of applications, and/or other means. Proper Placement also considers need for residue management to maintain surface cover and control erosion, to avoid increasing erosion and sediment P runoff.
See Section 7 “Nutrient Management and Mitigating Practices”.

8. The Task Force recommends continued focus and priority be placed on updating the Ohio Phosphorus Index. The Index is a critical tool to identify areas within a farm field that may require different management approaches to minimize risk for off-site phosphorus movement. The results from the edge-of-field research currently underway will be an important component to understanding what management measures will be best to help lower the risk of off-site phosphorus movement. Once updated, an educational effort will be needed to inform producers about the Index and assist with its application in the field.
See Section 7 “Nutrient Management and Mitigating Practices”.

9. The Task Force recommends that soil test laboratories be encouraged to clarify results by including methods and sources of recommendations.

   Due to the various options that can be used in reporting on soil test reports by laboratories, the Task Force recommends that soil test labs clearly note methods for reporting available nutrient on soil test reports and reference the source for nutrient recommendations associated with their reports. This will help the end user in utilizing the results and interpreting recommendations. At a minimum the soil test report should clearly:
   - Identify whether reporting units for available P or K are stated in Parts per Million (PPM) or pounds per acre.
   - Reference the soil testing method used to report available P or K nutrient concentration on the soil test report form (commonly used methods are Bray P1, Bray P2, Mehlich 3 (colorimetric), or Mehlich 3-ICP).
   - Reference the source of recommendations provided where recommendations are given. To report as Tri-State Recommendations, nutrient recommendations need to match the formulas provided for phosphorus and potassium buildup, maintenance and drawdown as stated in Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa E-2567 or equivalent.

See Section 8 “Additional Considerations”.

10. The Task Force recommends that the Tri-State Fertility Recommendations be recalibrated to the Mehlich-3-ICP test methodology. The Task Force further recommends that state, federal and private agricultural stakeholders confer with representatives from soil test laboratories used in Ohio to develop mutually acceptable approaches to testing methodologies and alignment with fertility recommendations while also looking at the feasibility of newer testing methods and evaluating both crop response and the potential for use for environmental risk evaluations.
See Section 8 “Additional Considerations”.

11. The Task Force recommends a special working group or team be formed to investigate options for land based tracking of conservation practices as discussed in Section 9. Tracking of conservation practice installation and land cover/land management changes in the watershed will be critical to understand the actions land managers are applying in the watershed and the resulting effects on nutrient export to Lake Erie. The Task Force recommends development of

one or more tracking mechanisms of conservation practice installation and land cover/land management changes in the watershed in order to understand the actions land managers are applying in the watershed, and the resulting effects on nutrient export to Lake Erie. The Task Force recommends the group be tasked with developing a plan that identifies the information that will be most useful to track, the minimum information needed, and the most efficient and feasible means to obtain/track the information with the least amount of imposition. The team should include representation from the fertilizer and commodity industry, farm groups, NASS, Ohio State Extension, and the other appropriate state and federal agencies.
See Section 9 “Tracking Progress”.

12. The Task Force recommends tillage transect surveys continue to be funded. Tillage transect surveys will continue to be an important tool in evaluating field management measures. Task Force discussions reflected concerns that recent messaging on the need for placement of fertilizer into the soil (see Recommendation #7 above) may lead some agricultural producers to revert back to conventional tillage methods. Placement of fertilizer in direct contact with the soil is possible while maintaining conservation tillage. Conservation tillage methods are important for managing sediment runoff potential.
See Section 9 “Tracking Progress”.

13. The Task Force recommends a concerted effort by state water quality and agricultural agencies to work with FSA, NRCS and SWCDs to improve CRP and CREP program delivery in Ohio so that water quality is given highest priority and results in increased promotion, design, and installation of more effective edge-of-field runoff and drainage trapping practices. The Ohio NRCS State Technical Committee has a pivotal role in advising the USDA-NRCS on natural resource conservation provisions of Farm Bill legislation representing the largest assistance program to producers. Further, federal, state and local agencies need to collaborate to ensure the most efficient use of program funding.

14. The Task Force recommends continued pursuit of the recommendations made by the Point Source and Urban Runoff Nutrient Workgroup (as discussed in Section 2). The role of point sources in nutrient reduction is an important contribution in effective nutrient management.

15. The Task Force recommends continued implementation of Long Term Control Plans for Combined Sewer Overflows (as discussed in Section 3). The Task Force acknowledges the progress (and costs) municipalities have made to date but want to emphasize the need for continued vigilance towards meeting the milestones and objectives called for in the Long Term Control Plans for individual municipalities.

16. The Task Force recommends building upon the gains made within the lawn care industry for reducing phosphorus with education and outreach efforts for BMPs for lawn care.

17. The Task Force recommends that the Phosphorus Task Force continue to meet on a periodic but regular basis (two to four times annually). The primary functions could include:
    - Track annual and spring loads against targets
    - Share and track research results related to nutrient management
    - Develop programmatic recommendations based on research results
    - Share information on emerging policies and programs
    - Provide recommendations to the State of Ohio

18. The Task Force recommends developing a dedicated source of funding that is non-federal and non-state to support the following activities as they relate to nutrient management:
    - Practices
    - Monitoring
    - Research
    - Evaluation
    - Education

19. The Task Force recommends the following items be high priorities for future research so that we may better manage our land and water resources in a constantly changing environment:
    - Tile drainage information for Ohio
    - New equipment to accommodate fertilizer placement that facilitates BMPs in all types of tillage.
    - Creation of an Ohio-based research watershed in the Maumee River watershed similar to the Discovery Farms approach in Wisconsin. A research watershed would facilitate an adaptive management approach at a faster pace.
    - Better understanding of loading contribution from the Detroit River as a whole, plus if and how its various channels influence algal blooms along the western shore of Lake Erie.

20. The Task Force requests that the recommendations contained in this report be considered in Indiana and Michigan (similar to the way we are asking the targets be applied to the watersheds from Monroe, MI to Sandusky, OH). The Task Force recommends that the State of Ohio take the lead to convene one or a series of meetings with state and federal counterparts in Indiana, Michigan and Ontario.

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Appendix A – Progress on Recommendations of First Phosphorus Task Force

The first Phosphorus Task Force developed several recommendations, primarily focusing on upland measures that will better manage phosphorus inputs into the system. Progress on these recommendations is presented in the following action matrix.

Progress on Recommendations of First Phosphorus Task Force

	TOPIC	ISSUE	RECOMMENDATION	PROGRESS
Point Sources				
1	Point Source Dischargers	Point source dischargers are required to meet discharge limits under the provisions listed in NPDES permits. Ohio EPA issues the NPDES permits by Water Quality Standards, reviewing discharge data, reviewing records, doing inspections, considering the targets set in the GLWQA (0.5 to 1 mg/l TP), and the recommendations in TMDL reports.	A. Maintain effective permit compliance and enforcement program for NPDES permitted facilities. B. Continue to pursue progress with regard to Long Term Control Plans (LTCP) for Combined Sewer Overflows (CSOs) and Sanitary Sewer Overflows (SSOs). C. Maintain timely issuance of discharge permits. D. Evaluate need to reduce Phosphorus concentration limits in individual NPDES permits based on findings in TMDL reports or other action plans (WAP, RAP, LaMP).	Ohio EPA maintains NPDES program, inspects facilities and issues timely permits. Since 2009, seven Lake Erie basin communities completed implementation of a LTCP: 5 sewer separation, 2 a combination of partial separation, conveyance, storage, and treatment to reduce overflows to 4 or less during a typical year. Ohio TMDLs include allocations for point and nonpoint sources that lead to attainment of beneficial uses in tributaries to Lake Erie.

Progress on Recommendations of First Phosphorus Task Force

	TOPIC	ISSUE	RECOMMENDATION	PROGRESS
2	Home Sewage Treatment Systems	Data collected by the Ohio Department of Health in 2008 indicate that 23% of the household sewage treatment systems are failing with an additional 13% projected to fail within the next 5 years. Soil limitations, substandard or poor designs, space limitations, system age, shallow seasonal water tables and poor operation and maintenance were reported as most common reasons for system failure.	A. A successful household sewage treatment system program for Ohio should be based on the establishment of statewide minimum standards/rules to provide program continuity across all 88 counties in Ohio. B. To protect public health and the environment, household sewage treatment systems must be designed to ensure the proper treatment (not disposal) of household sewage. C. Proper household sewage treatment system siting, design (based on the soil and site characteristics) and installation combined with an inspection and maintenance program will ensure system long-term sustainability and protect public health and the environment. D. The use of off-lot discharge for household sewage treatment systems should be minimized. E. A training and continuing education program for household sewage treatment system designers, installers, inspectors, regulators, maintainers and operators must be established.	Changes to Ohio Revised Code (ORC) Chapter 3718 (Home Sewage and Small Flow Systems), effective 9/17/2010 reflected the recommendations of the 2009 Household Sewage and Small Flows On-Site Sewage Treatment System Study Commission. The Ohio Department of Health (ODH) is proposing to replace Ohio Administrative Code Chapter 3701-29 with new proposed sewage treatment systems rules, anticipating final adoption of the rules by Fall 2013, with a proposed effective date of 1/1/2014.
Nonpoint Sources: Agriculture				
3	Current agronomic recommendations (Vitosh et al. 1996).	The current agronomic recommendations for rates of P usage are considered to be valid; however, it is apparent that some fraction of the farming community is either over-applying or applying P without proper consideration to timing or methods of application, contrary to Tri-state fertilizer recommendations for corn, soybeans, wheat, and alfalfa (Vitosh et al., 1996).	A. Agricultural agencies and crop consultants need to emphasize (and producers need to follow) the prescriptions called for in the Tri-State recommendations (Vitosh et al. 1996). B. Reinforce through increased training of agency staff, producers, crop consultants, etc. C. Update recommendations as needed, with special emphasis on timing and method application.	

Progress on Recommendations of First Phosphorus Task Force

	TOPIC	ISSUE	RECOMMENDATION	PROGRESS
4	Soil Tests – increase usage	There is limited usage of soil tests for environmental purposes. Insufficient use of soil tests for agronomic purposes results in uncertainty as to how much cropland in Ohio is regularly soil tested.	A. Develop incentives to encourage more soil testing. B. Promote wider adoption of soil testing with a goal of getting a higher % of cropland tested C. Expand soil test procedures to include water extractable solubility, P-saturation and stratification in order to expand the base of knowledge and gain additional data sets to understand risks of P transport.	Evidence indicates that soil labs in Ohio are seeing a significant increase in the number of soil tests, presumably reflecting an increase in the number of fields tested and frequency of testing for individual fields.
5	Linkage of soil test results to fertilizer recommendations and actual application.	Basis for recommendations from soil labs and crop consultants to guide decisions by producers with respect to P application rates and methods are currently unknown.	Conduct needs assessment of the soil labs, CCAs and others (Extension, landowners, unaffiliated consultants) to learn the basis of P recommendations given with soil test results	The Ohio Lake Erie Commission funded a project to analyze soil labs in Ohio. Results found that with the exception of 1 lab, the accuracy of soil test results are reliable. Further work is needed to evaluate and ensure recommendations to clients are consistent with Tri-State recommendations.

Progress on Recommendations of First Phosphorus Task Force

	TOPIC	ISSUE	RECOMMENDATION	PROGRESS
6	Reliability, availability and comparative usefulness of soil test laboratory results	Reliability of some soil test results remains questionable in the absence of sampling technique standardization • In order to validate program effectiveness, we need more access to soil test data from laboratories • We also need access to collection methods data to analyze them as one factor in soil test reliability	Encourage and support development and implementation of a soil P analytical lab certification program A. Establish a central clearinghouse of soil test results to: • analyze trends and levels • identify number and location by watershed of tests taken utilizing GIS capabilities • identify problem areas and targeted watersheds B. Standardize collection methods C. Standardize analytical methods D. In the absence of a state-sponsored certification program, the agencies should consider requiring data come from certified labs allowing the industry (laboratories) the flexibility of implementing their own certification requirements. E. Review the Wisconsin "discovery farm" experience (www.uwdiscoveryfarms.org) and the Ontario example.	See above, no further progress to report.
7	P-runoff risk screening tool for farmers (expansion of Soil Test Risk Assessment Procedure in the NRCS *Section 1, Field Office Technical Guide*)	There is a need for development of a simple tool to be used in the field for a rapid determination of risk of P transport to surface water. A screening tool would serve as a precursor to the more detailed analysis of the P Index.	Develop and implement a P-Risk Screening Tool that includes: • potential for off-site P transport; • seasonality/weather conditions; • runoff and erosion potential to surface waters; • distance/connectivity to surface inlets and subsurface drainage systems to surface waters; • P solubility; and • soil test data (including stratified data where available).	Research on Phosphorus Risk Index underway; results expected within 3 years

Progress on Recommendations of First Phosphorus Task Force

	TOPIC	ISSUE	RECOMMENDATION	PROGRESS
8	Phosphorus Index (as defined in the NRCS *Section 1, Field Office Technical Guide*	The current phosphorus index in use by the NRCS is a comprehensive tool that is in need of updating.	A. Recommend revisions as needed to the P Index to NRCS if warranted based upon: • data from last 10 years • the need to make the P-Index more quantitative to risk of P runoff from site • include a dissolved P component B. Validate as specific to Ohio	Research on Phosphorus Risk Index underway.; results expected within 3 years
9	Promotion of phosphorus management using improved assessment tools	How to get P runoff assessment tools used more often and to be more useful.	A. Emphasize incorporation of fertilizer and manure B. Discourage application of manure and P-containing fertilizer unless P-Index/Soil Test Risk Assessment Procedure score is below a value that is determined to be acceptable. C. Promote the use of the P runoff risk assessment tools in nutrient management plans D. Promote potential economic benefit of Phosphorus management E. Develop incentives in State and Federal programs to increase usage of updated assessment tools such as: • Tax/rebates associated with P sales • Incentives directed at crop consultants	NRCS 590 standards revised. Research on Phosphorus Risk Index underway. Phosphorus Task Force Phase II report contains additional information on the 4R and other approaches to nutrient management.
10	Promotion of Recommended BMPs (see Appendix B)	Priority practices for nutrient management are currently available with existing cost share programs. However, these BMPs are not fully optimized by producers. Recommended BMPs for nutrient management need to be more strongly advocated with alternative approaches.	Recommend that cost-share agencies develop innovative approaches to agricultural programs such as: • linking the use of the P Index and/or a screening tool to allocating funds for adoption of BMP practices • explore on farm challenge projects (e.g., American Farmland Trust BMP Challenge Program) • identify options to more fully support Recommended BMPs that address nutrient management	The NRCS EQIP program adopted changes to encourage “bundling” of practices for more effective nutrient management.

Progress on Recommendations of First Phosphorus Task Force

	TOPIC	ISSUE	RECOMMENDATION	PROGRESS
Nonpoint Sources: Urban and Residential				
11	Contributions of P from dishwasher detergent	SB 214 has been introduced to the Ohio legislature. If adopted, SB 214 would ban phosphorus from dishwasher detergents.	The P Task Force recommends passage of this legislation.	Legislation passed in 2009, effective as of July 1, 2010
12	Lawn care fertilizers	The Task Force considers P contributions to increasing algal blooms in Lake Erie from lawn care fertilizers to be low, but contributions could be locally significant as a result of the misapplication of lawn care products.	Identify opportunities to support low-P lawn care products and proper stewardship of product recommendations. A. Develop an MOU between the State of Ohio and lawn care manufacturers and service providers to achieve a reduction in pounds of phosphorus applied in lawn care products for all 88 Ohio counties. B. Support education and outreach targeted to homeowners to implement appropriate stewardship practices in the use of lawn care fertilizers.	In 2013, Scotts reached its goal of eliminating phosphorus from its lawn maintenance products. (The original report included a list of best management practices for homeowners.) SWCD's implemented an education program for homeowners in 2011.
13	Transport Mechanisms	Subsurface drainage, surface drainage and channelized streams and ditches -are contributing factors to the transport of DRP. Lack of available data prevents a thorough analysis of the relative contribution.	A. Support the recommendations of the Ohio Rural Drainage Committee. B. Promote/encourage complementary practices to surface and subsurface drainage practices to address potential delivery of DRP to streams. C. Conduct data collection on drainage intensity via the ag census and/or survey. D. Conduct research on sampling discharges from tile drain systems. E. Further develop BMP effectiveness analysis to guide BMP selection.	No new data in Ohio; see Items 6 and 7 for recommendations.
Other				

Progress on Recommendations of First Phosphorus Task Force

	TOPIC	ISSUE	RECOMMENDATION	PROGRESS
14	Public Education and Involvement	Education of residents about harmful algal blooms and local actions needed to address this problem on a long term basis.	A. Ohio EPA should work with sister agencies to coordinate the delivery of Phosphorus Task Force recommendations for public outreach and education utilizing current programs to the extent possible. Where gaps exist, funding should be sought to fulfill identified needs. B. Ohio EPA and ODNR should seek funding that will result in the development and implementation of new Watershed Action Plans and updates to existing plans to fully address Phosphorus Task Force recommendations in the Lake Erie basin.	Much progress has been accomplished since 2010 on the awareness of the linkage between nutrient management and harmful algal blooms. See Section 2 for a description of recent survey results conducted with agricultural representatives. Section 2 also provides descriptions of the Directors Agricultural and water Quality Working Group and other efforts, including the Healthy Lake Erie Fund.

Progress on Recommendations of First Phosphorus Task Force

	TOPIC	ISSUE	RECOMMENDATION	PROGRESS
15	Research agenda for Ohio	Current research projects underway will yield valuable results in understanding the science and mechanisms in the movement of phosphorus and its impact to Lake Erie. The Task Force recommends an integrated, interdisciplinary approach to current and future projects to maximize the application of results to an adaptive management approach in addressing phosphorus delivery to Lake Erie.	A. Develop a research agenda designed to: • identify specific P reduction targets for the western basin; • identify nearshore targets; • identify potential linkages of DRP levels with rainfall intensity; • identify (any) direct linkages of DRP and harmful algal blooms; • determine extent of contributions of P from internal cycling; and • impacts of P stratification in soil. B. Develop a Discovery Farm and/or Watershed in Ohio (based upon the Wisconsin model) to demonstrate results from research (both agricultural and environmental) and linkages between land and water. C. Expand soil test procedures to include water extractable solubility, P-saturation and stratification in the soil to expand base of knowledge and data set to estimate the risk of P transport from a given site. D. Develop and implement a P-Risk Screening Tool (as described in #6). E. Validate the P-Index (as developed in #7). F. Develop new BMPs to minimize Phosphorus movement from the landscape where risk of P transport is known to be high.	This report recommends an adaptive management approach and phosphorus reduction targets for the western basin tributaries. P-Index work is underway. Phase II research recommendations…

Progress on Recommendations of First Phosphorus Task Force

	TOPIC	ISSUE	RECOMMENDATION	PROGRESS
16	Phosphorus Water Quality Standards for streams	Need WQ standards for TP and DRP; Need to consider loading standards vs. concentration standards.	A. Ohio EPA should monitor or require monitoring for dissolved phosphorus. B. Adopt and update nutrient standards for water quality. C. Develop standard operating procedures for dissolved phosphorus samples in runoff.	Ohio EPA routinely measures orthophosphate-P (the reactive component of dissolved phosphorus) in ambient samples in streams and in Lake Erie. Dissolved phosphorus has not been adopted as a requirement for discharger effluent monitoring. Ohio EPA is developing nutrient standards for discussion with interested parties. Ohio EPA also is working with ODNR and ODA to develop an Ohio nutrient strategy.
17	Create an Ohio Research Advisory Committee	The State of Ohio would benefit from a coordinated effort among researchers and program managers to assess research needs in Ohio	Form a committee of applied interdisciplinary researchers (including managers, users, academia).	The Phosphorus Task Force Phase II recommends that the Task Force be reconvened on a periodic but regular basis.

Appendix B – Point Sources of Total Phosphorus

Ohio EPA requires a permit for all facilities discharging pollutants from a point source to a surface water of the state. This permit is called a National Pollutant Discharge Elimination System (NPDES) permit and regulates wastewater discharges by limiting the quantities of pollutants in the discharge and establishes monitoring requirements and other conditions.

This appendix will discuss the current and future load contribution of total phosphorus from point sources in the Lake Erie watershed. In addition, it will overview possible control measures and expected costs to reduce that load.

The majority of point source total phosphorus load discharged to Lake Erie comes from two main sources, publicly owned sewage treatment plants (POTWs) and overflows of untreated sewage from public sewer systems. Industrial facilities that discharge directly to waters of the state typically do not discharge significant loads of total phosphorus.

POTWs are the wastewater treatment plants (WWTPs) that treat the domestic, commercial and industrial wastewater generated in villages and cities. Wastewater is conveyed to the WWTP through a network of sewers known as a collection system. During wet weather events, the sewer capacity may become overloaded by infiltration and inflow (I/I) of clean water into the collection system and untreated/partially treated sewer overflows and treatment plant bypasses may occur. These are known as Sanitary Sewer Overflows (SSOs) and Combined Sewer Overflows (CSOs). SSOs are overflows from sewer systems that are designed to separately convey sewage directly to the POTW and storm water to a receiving stream. CSOs occur from sewer systems designed to convey both storm water and sewage to the POTW with overflows of combined sewage and storm water during storm events. The vast majority of these sewer overflows, both by volume and by pollutant load, is from CSOs.

POTWs

As discussed in the April 2010 Ohio Lake Erie Phosphorus Task Force Report, "There are 703 Ohio National Pollutant Discharge Elimination System (NPDES) permitted WWTPs discharging to the Ohio Lake Erie watershed. They account for a total discharge volume of approximately 1,076 million gallons per day (MGD). About 464 (66%) of these permits are issued to small package plants discharging less than 50,000 gallons per day. However, the majority of the flow comes from the 12 (1.7%) major WWTPs with a discharge greater than 15 MGD. These are also the plants that contribute the majority of the phosphorus load. Based on U.S. EPA PCS data, Dolan estimates an average load of 585 metric tonnes per annum (MTA) of total phosphorus from Ohio WWTPs."

There are currently 109 POTW facilities in the Lake Erie Basin with phosphorus limits. Any POTW in the Lake Erie basin with a design flow of 1.0 million gallons per day (MGD) or more, or designated as a major discharger by the director, must meet a total phosphorus discharge limit of 1.0 milligram per liter (mg/L) as a thirty-day average.

Any POTW with a design flow of 0.2 MGD or more that discharges to a publicly owned lake or reservoir must also meet a total phosphorus discharge limit of 1.0 mg/L (thirty-day average). This limit also applies to discharges of this magnitude to a tributary of such lake or reservoir if the discharge would contribute significant loadings of phosphorus to the reservoir. This does not apply to discharges to upground reservoirs or privately owned lakes, or to point source discharges to Lake Erie.

POTWs with a design flow less than 1 MGD in the Lake Erie Basin may also have limits for phosphorus incorporated into NPDES permit in accordance with TMDL recommendations. Section 303(d) of the Clean Water Act links the water-quality based goals to the NPDES permit limits to achieve the desired uses of a water body.

Language is also included in POTW NPDES permits to maintain the treatment works in good working order and operate as efficiently as possible. As a result, many POTWs approach a final outfall concentration of 0.5 mg/L total phosphorus.

There are also currently 291 Ohio POTW facilities in the Lake Erie Basin with phosphorus monitoring requirements; limits for total phosphorus are not included in these permits. Many of the POTWs that monitor only are likely to receive a future phosphorus limit due to requirements from TMDLs and the local stream impacts from nutrients

Table B-1. Ohio publicly owned treatment works facilities in the Lake Erie basin.

Nutrient	Facilities with Monitoring	Facilities with Limits
Phosphorus	291	109

Looking ahead to future trends in total phosphorus loading from Ohio POTWs, the population of Ohio is relatively stable and therefore the volume of sewage from POTWs is expected to remain fairly stable. Absent any required regulatory reduction in total phosphorus, the discharge load of total phosphorus is also expected to remain stable. The stability of the total phosphorus load would also be true when considering the expected imposition of total phosphorus limits on an increasing number of POTWs due to TMDLs and localized nutrient impacts (see above discussion). Implementation of those TMDL recommendations would affect POTWs less than 1 MGD which contribute only a minor portion of the total phosphorus load.

The above discussion raises the question as to whether further regulatory reduction should be required for POTWs. The majority of total phosphorus load is from the larger POTWs. These POTWs in the Lake Erie basin already have a total phosphorus limit of 1 mg/L. POTWs use chemical precipitation and existing equipment to meet the 1 mg/L limit at a reasonably affordable cost. For example, the Northeast Ohio Regional Sewer District (NEORSD), which treats wastewater from the greater Cleveland area and surrounding satellite communities, spends several hundred thousand dollars per year on chemical costs for total phosphorus removal. This is a relatively small cost for such a large utility.

When considering lowering the total phosphorus limit to 0.5 mg/L, however, it is important to note that existing POTWs will likely need to install filtration to assure that they can consistently meet a lower limit. While many POTWs have tertiary filters, the largest POTWs – NEORSD, Toledo, Akron and Sandusky, do not. Installation, operation and maintenance of tertiary filters at these facilities would be expensive. For example, a rough cost estimate to install filters at NEORSD to treat effluent to 0.5 mg/L total phosphorus would be approximately $200 million.

If the total phosphorus limit were lowered to below 0.1 mg/L, membrane filtration would be required which is much more effective than traditional filters and also substantially more expensive. In addition, much larger doses of chemical would be required.

Generally speaking, as nutrient limits are reduced the capital and operating removal costs associated with nutrient removal increase. An example of this is shown in Table B-2 which demonstrates the cost increase associated with reducing phosphorus from 0.5 mg/L to 0.05 mg/L. Operation and maintenance costs at waste water treatment plants must take into account factors such as labor, maintenance, electricity use, chemical use, and sewage sludge management. Costs are difficult to estimate because they fluctuate with market conditions, inflation, geographic location, and the technology employed to facilitate nutrient removal. Capital costs also vary depending on whether the cost is associated with a new treatment plant or with a retrofit of an existing treatment plant. As state and federal cost share assistance for waste water infrastructure diminishes, it is expected that significant rate increases would be passed on to ratepayers for the upgraded technology needed to comply with more stringent nutrient limits.

Table B-2. Limit comparison of cost per pound removal of phosphorus.

Phosphorus Limit	Cost ($/lb Phosphorus removed)
0.5 mg/L	2.60 – 18.00
0.05 mg/L	37.00

Source: Bhattarai, 2010.

Sewer Overflows

As discussed previously, a second significant point source load is overflows and bypasses from municipal sewer systems known as CSOs and SSOs. Ohio has 101 CSO communities, 62 of which are in the Lake Erie drainage basin (Figure B-1).

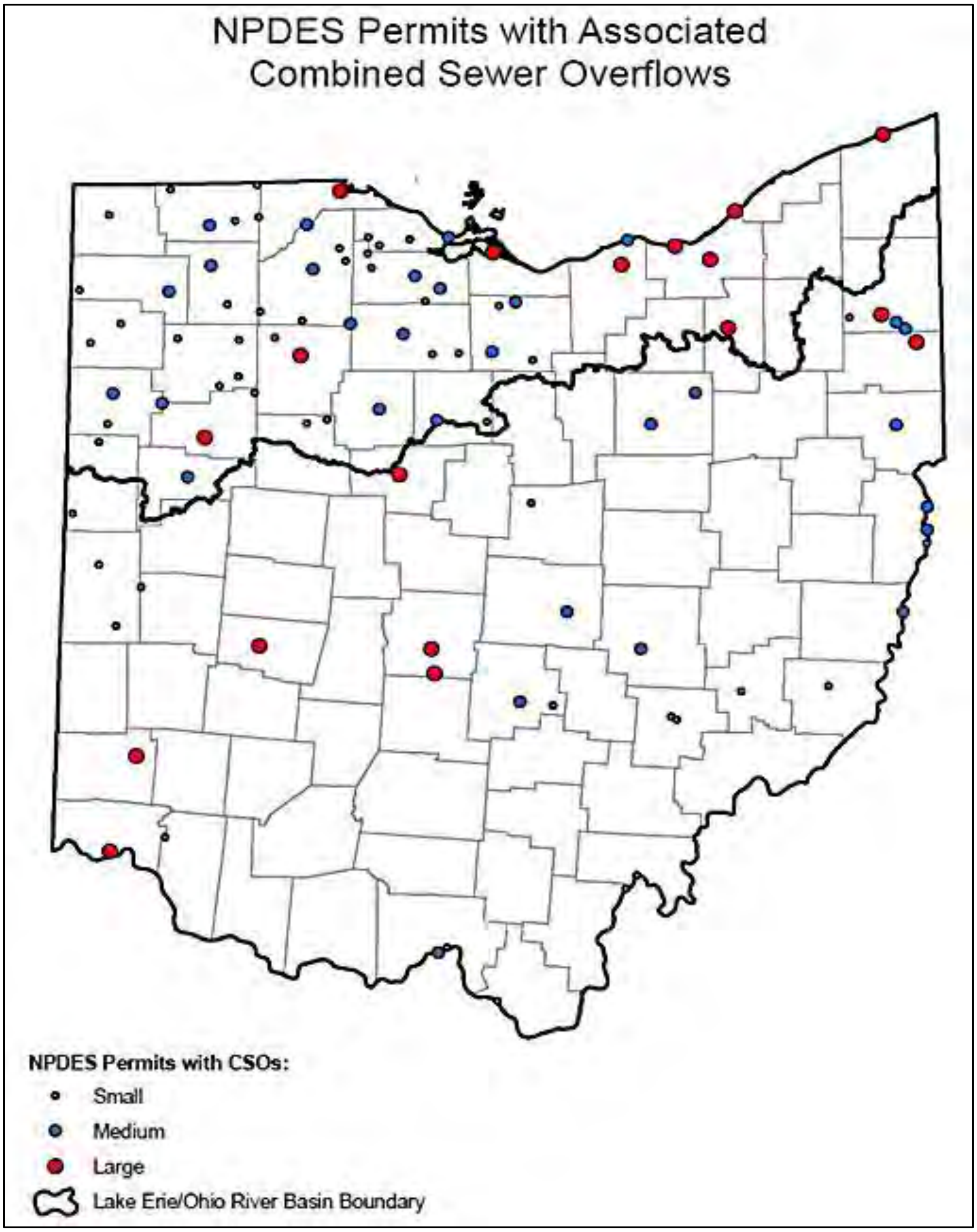

Figure B-1. NPDES permitted CSO communities in Ohio.

The issue of total phosphorus Loading from sewer overflows was discussed in the April 2010 Ohio Lake Erie Phosphorus Task Force Report, "combined sewer overflows (CSOs) may discharge sewage directly into the Lake and its tributaries when storm water overloads the capacity of storm drains designed to discharge through WWTPs. Unfortunately, there are few direct measurements of total phosphorus or DRP contributions from CSOs. For the purposes of this exercise, therefore, using total phosphorus measurements from some of the Northeast Ohio Regional Sewer District (NEORSD) CSOs and an estimated total CSO annual flow of 10.9 billion gallons as presented in a 2007 report on sewage overflows to Lake Erie (Environment Ohio, 2007), the Task Force estimates an annual CSO total phosphorus load to Lake Erie of 90.4 MTA."

This 90.4 MTA total phosphorus attributed to CSOs is significantly lower than the 585 MTA TP estimate for POTWs from Dolan (previously discussed). This trend was also observed in a study of *Nutrients from Urban Point Sources* conducted by Dale White of Ohio EPA.

Progress in Reducing CSO Discharges

USEPA and Ohio EPA have been working with communities to address combined sewer overflows since the early 2000s. Almost all the CSO communities in the Lake Erie drainage basin have developed comprehensive Long Term Control Plans (LTCPs) to reduce and minimize discharges from CSOs and SSOs. These plans typically recommend a combination of structural controls such as storage basins, tunnels, POTW treatment capacity increases, wet weather physical-chemical treatment facilities and sewer separation projects. NPDES permits and court orders require construction of these structural controls. Many of these communities are currently constructing projects with many communities expected to complete construction of all required projects in the next ten years. For example, by year 2020, 40 communities of the 62 communities in the Lake Erie drainage basin will have completed all the projects required by their LTCP. Table B-3 below shows the progression of the number of communities with completion of all of the projects required by their LTCP.

Table B-3. Projected long term control completion progression of Ohio CSO communities.

Projection Year	Projected # of CSO Communities That Will Have Completed All Projects Required by LTCP
2013	22
2015	28
2020	40
2025	42
2030	51
2035	62

As with total phosphorus discharges from POTWs, most of the total phosphorus discharged CSO and SSO volume comes from the largest CSO communities – NEORSD, Akron, Toledo, Fremont, Lima and Sandusky.

Ohio EPA estimates that Ohio's six largest POTWs discharged a baseline CSO volume of approximately 15.3 BG per year. Table B-4 shows the communities in the Lake Erie basin that discharge the highest volume of CSO, the respective estimated baseline and current CSO volumes and the volume reduction achieved. Ohio EPA estimates that implementation of LTCP projects in these six communities, which discharge the majority of CSO volume in the Lake Erie basin, has already reduced CSO discharges by approximately 6.3 Billion Gallons to date. Further reductions in CSOs are projected through 2035.

Table B-4. Lake Erie basin significant CSO discharge.
Baseline – Volume at time of LTCP submittal (based on LTCPs – most LTCPs submitted early 2000s) and current CSO volumes (annual average of reported volumes 2010 through 2012)

CSO Community	Baseline CSO Volume (MG/yr)	Current CSO Volume (MG/yr)	CSO Volume Reduction (MG/yr)	Comments
Akron	2500	1500	1000	Baseline CSO volume and current CSO volume estimates from the Akron Long Term Control Plan
Fremont	1270	1235	35	Baseline CSO volume was calculated using the average annual reported overflow volume from 2005-2008 eDMR data; current CSO volume is based on the average annual reported overflow volume from 2009-2012 eDMR data
Lima	663	663	0	Reliable baseline CSO volume data unavailable; baseline and current CSO volumes are based on the average annual reported overflow volume from 2009-2012 eDMR data
NEORSD	9000	4400	4600	Baseline CSO volume and current CSO volume estimates from NEORSD Long Term Control Plan.
Sandusky	500	241	259	Baseline CSO volume based on values from the Sandusky Long Term Control Plan; current CSO volume is the average annual reported overflow volume from 2009-2012 eDMR data.
Toledo	1323	900	423	Baseline CSO volume was calculated using the average annual reported overflow volume from 2005-2009 eDMR data-the Toledo Consent Decree to address overflows was signed in 2010; current CSO volume is based on the average annual reported overflow volume from 2010-2012 eDMR data.
Total	**15256**	**8939**	**6317**	

Notes: MG/yr – million gallons per year. eDMR is monthly reporting by the facility.

Ohio EPA expects continued significant progress in reducing overflows from these larger CSO communities. A discussion of efforts by NEORSD, Akron, Toledo, Lima and Sandusky is presented below.

NEORSD (Cleveland area) is investing $3 billion in a LTCP to construct 5 underground tunnels, storage basins and additional treatment. As of 2012, NEORSD had reduced their overflow volume to 4.5 billion gallons per year (BG/yr), a fifty percent decrease from an original baseline overflow estimate of 9 BG/yr. NEORSD continues to make progress and is projected to achieve an additional 2.5 BG reduction in overflow volume by 2024 and is expected to meet the goals of the LTCP in 2035. Figure B-2 shows the projected CSO overflow volumes for NEORSD by calendar year.

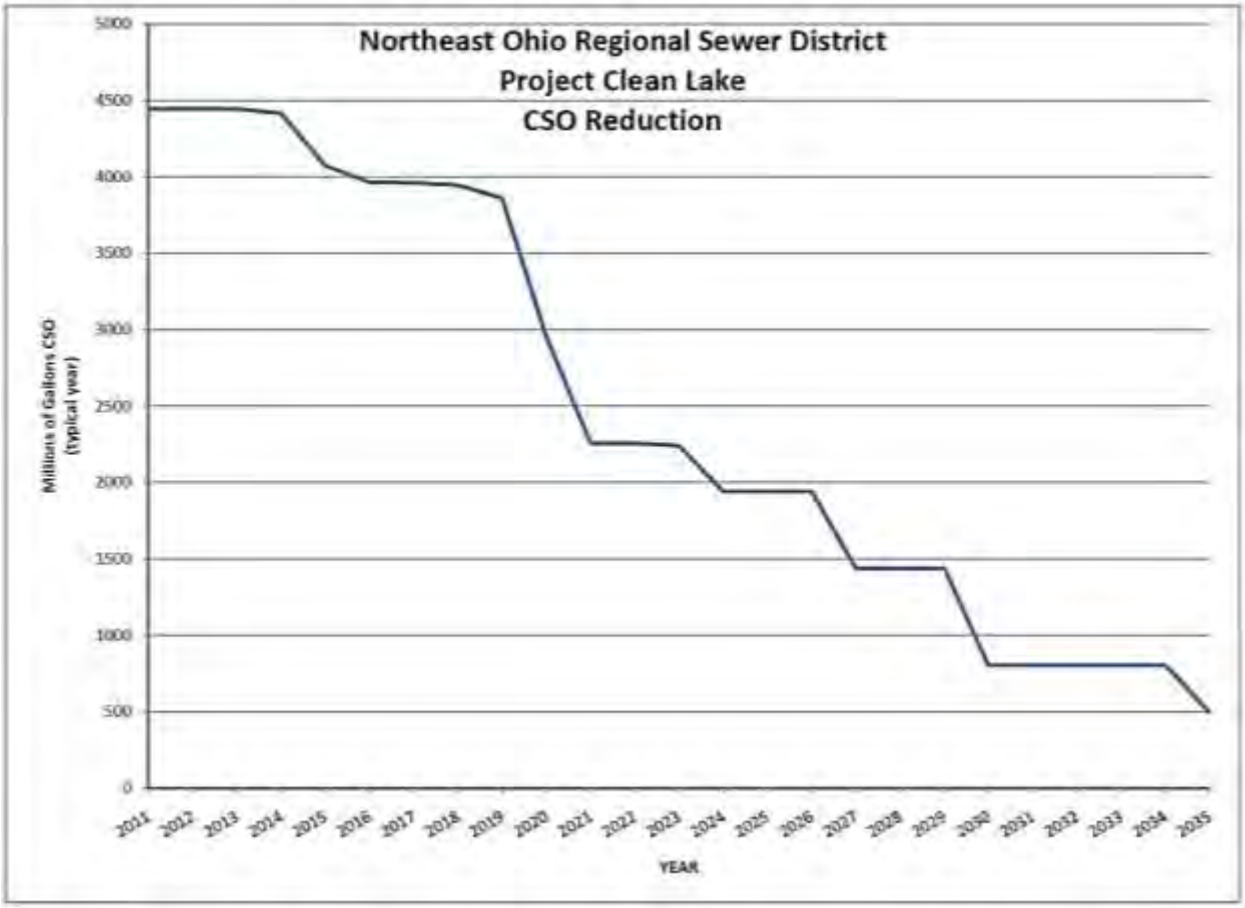

Figure B-2. CSO long-term control plan presentation to NEORSD Trustees 11/18/2010.
(NEORSD, 2010)

Akron's LTCP includes the construction of two underground tunnels, upgrades to the WWTP, construction of physical-chemical wet weather treatment facilities, separation of several combined sewer areas, and seven surface storage basins. By the end of 2013, Akron has projected to reduce overflow volume by 40% (see Figure B-3). Akron is investing $900 million in LTCP projects and is scheduled to complete the LTCP in 2028.

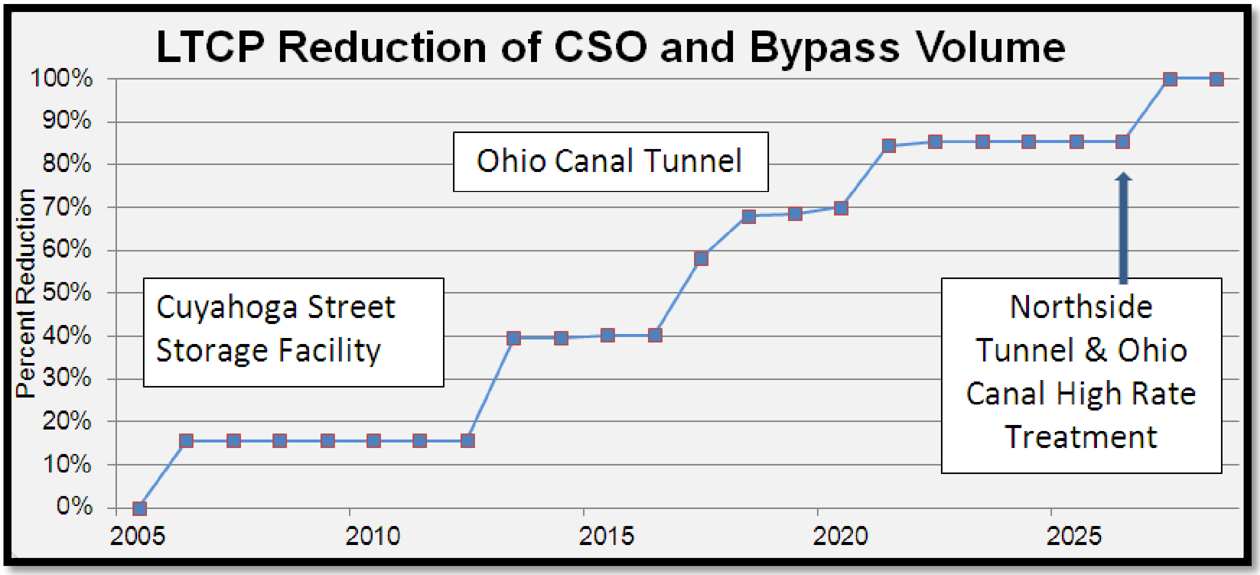

Figure B-3. Akron projected CSO and bypass volume percent reduction.

Toledo is investing $500 million in a LTCP to be completed in 2020. The LTCP includes projects to expand the WWTP capacity, provide system storage, separate combined sewers and remove inflow and infiltration sources. Toledo also constructed three CSO tunnels between 1988 and 1994.

Sandusky completed a WWTP expansion in 2010 to increase the wet weather capacity from 36 MGD to 42 MGD. Sandusky submitted a revised LTCP in December 2012 and is currently negotiating storage, conveyance and pump upgrades. The Sandusky LTCP projects are to be completed in 2020.

Lima and USEPA negotiations on a LTCP have been ongoing for many years and are ongoing.

All these improvements come at a substantial cost to local communities and ratepayers. The total investment among three of the largest communities in the Lake Erie Basin (NEORSD, Akron and Toledo) will be over $4.4 Billion. Almost all these costs are borne by local ratepayers and have resulted in substantial increases in local sewer rates. For example, NEORSD projects average sewer bills for City of Cleveland residents at $60 per month by year 2019 (Figure B-4). The City of Akron rates are expected to increase similar to Cleveland projections.

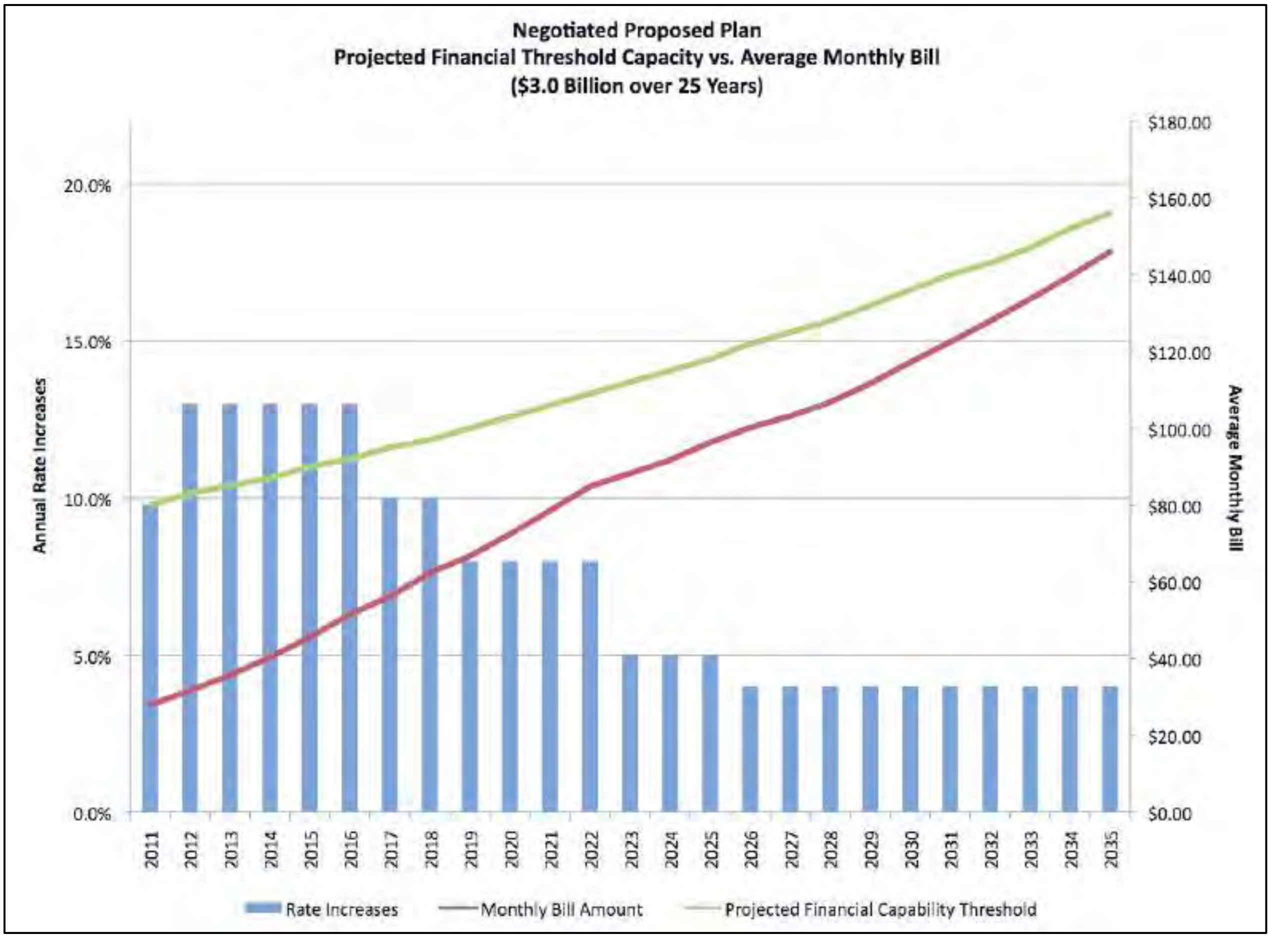

Figure B-4. CSO long term control plan presentation to NEORSD Trustees 11/18/2010. ***(NEORSD, 2010)***

Conclusions

As discussed in the April 2010 Ohio Lake Erie Phosphorus Task Force Report "Combining Dolan's average estimates for WWTP loads (585 MTA), Dolan's average industrial loads (32.5 MTA), and the HSTS load estimate (88 MTA) with the CSO load estimate (90.4 MTA), generates an average annual total point source TP load to Lake Erie from Ohio of 795.9 MTA. Considering the fact that most of the phosphorus in the point source load is bioavailable, this is a significant source of phosphorus to Lake Erie. However, this load has remained fairly consistent since 1981 and is not considered to be a significant contributor to the increases in DRP loads being measured in Ohio's Lake Erie tributaries. "

As presented earlier in this section, loads from WWTPs are expected to remain constant, absent a regulatory requirement to reduce total phosphorus loads. Most of the total phosphorus load is generated at the largest POTWs that already are required to meet a limit of 1 mg/L total phosphorus. Reducing the limit to 0.5 mg/L is expected to cost well over several hundred million dollars for these larger plants. Reducing the total phosphorus limit to 0.1 mg/L would increase this cost by double or more.

Ohio has made and will continue to make significant progress reducing point source loads from sewer overflows. These improvements have come at a considerable cost to local communities. Additional improvements beyond what is currently required are unlikely.

Appendix C – Farming Systems

Farming systems have changed significantly over the last 20-25 years. The evolution of different tillage systems is a big part of that change. Understanding different tillage systems provides important insight to the complexity of farming operations. The same tillage system is not used on all crops in the rotation in a single farming operation. For example, rotations away from small grains and forages into more row crops often result in changes/frequency of tillage. Tillage systems work in concert with the broader farming operations of crop rotations, cover crops, planting methods and fertilizer application. Integrating nutrient management means finding the right point of intervention for different tillage systems while avoiding unintended consequences.
These tillage systems include:

- Full tillage- Burying the residue off the former crop (plowing); clean tilling to prepare for seedbed finishing and seeding in the spring.
    - Pros: Easy to find times to incorporate, thoroughly mixes nutrients in soil profile, plowing initially left soil very rough and restricted surface runoff
    - Cons: can be bad for soil erosion, loss of sediment bound nutrients, organic matter and destroys soil health
- Stale Seedbed- All primary and secondary tillage is done in the fall, leaving the field ready to plant in the spring.
    - Pros: Allows nutrients to be incorporate **IF** they are applied prior to primary tillage, can reduce spring compaction.
    - Cons: same as fall tillage above, plus smooth ready to plant condition allows quicker surface runoff
- Conservation tillage- Using Chisel Plows or Disk rippers in the fall (that leave various amounts of residue) Performing secondary finish tillage in the spring before planting.
    - Pros: reduces soil loss, leaves crop residue on surface and leaves soil surface rough to slow down surface water movement, increased residue improves soil biology/health over complete full tillage
    - Cons: while allowing for incorporation of nutrients, surface applied nutrients are only incorporated in the top 3-4 inches of the soil profile.
- Strip Till-Controlled tillage only at the point of where you plant the seed. Usually 4-6 inches wide out of a 30 inch space. In the spring you plant into the previously tilled spot leaving the balance undisturbed.
    - Pros: Great for erosion control and soil health, use of strip fertilization, RTK guidance, cover crops and controlled traffic provide for even more benefits of improved nutrient use (reduced losses) and reduced compaction.
    - Cons: Takes specialized equipment/more costly, newer technology, May not be practical on steeper slopes unless contoured (water can follow the tilled strips on steeper slopes, washing out seed, nutrients and topsoil)
- Vertical tillage- Somewhat new. Uses equipment that very lightly (1-2 inches deep) works the soil and leaves the crop residue on top. Usually a no till system is used to plant into residue. There is a lot of variability in how much residue can be left. Pros: can be used to warm up cold wet soils in the spring, It can put surface applied nutrients in contact with the soil, but will not address stratification and we do not have data on how much it could reduce nutrient movement, can leave residue on surface for better water infiltration and reduced surface runoff, if used properly

    - Cons: if improperly utilized, can lead to reduced soil health, increased erosion
- No-Till/Never till- the only disturbance of the soil in this system happens when the seed is placed.
    - Pros: If done on a continuous basis, it is best for soil health, increased water infiltration and reduced erosion.
    - Cons: Difficult to incorporate fertilizer in this system, unless using row fertilizer on the planter or adopting some of the new strip fertilization practice technologies. If not continuously no-tilled and some other method of tillage is used on one of the other crops in the rotation, then many of the benefits of soil heath, increased water infiltration may be lost or never obtained.