KIESER & ASSOCIATES
ENVIRONMENTAL SCIENCE & ENGINEERING

TECHNICAL MEMORANDUM

To: Victoria Pebbles, Great Lakes Commission

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cc: Nicole Zacharda, Dan Gold, Great Lakes Commission

RE: **WLEB Supply & Demand Analysis**

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1.0 Overview

This technical memorandum was prepared by Kieser & Associates, LLC (K&A) for the Great Lakes Commission (GLC). It summarizes the findings of a preliminary water quality trading (WQT) credit demand and supply analysis for the Western Lake Erie Basin (WLEB). This analysis is part of an ongoing effort under a USDA Conservation Innovation Grant to assess the applicability of WQT as a potentially viable tool to help achieve WLEB phosphorus load reduction goals. Potential demand and supply are assessed for the portions of the WLEB including Michigan, Indiana and Ohio. No assessment of opportunities was attempted for Ontario which is operating its own system for permitting regulated discharges. Ontario will not use nonpoint source reductions from agricultural operations in the U.S. portions of the WLEB for potential WQT opportunities with Canadian discharges.

WQT offers a cost-effective, flexible compliance option for permitted dischargers to meet nutrient loading limits while simultaneously incentivizing the installation of best management practices (BMPs) in watershed areas impacting the same water resource. In this case, the WLEB is the resource area of concern, though water quality restrictions in smaller tributary drainages to the WLEB may otherwise restrict the geographic extent of water quality trades. Referred to as point source/nonpoint source trades, such exchanges are envisioned for total phosphorus (TP) between wastewater treatment plants (WWTPs) as permitted discharge buyers, and agriculture as the supplier of TP reduction credits. The motivation to trade is based on substantial cost differentials between the price for treatment technology upgrades by WWTPs to meet load limits and costs for conservation practices to meet equivalent load reductions. For the purposes of this demand and supply analysis for point source/nonpoint source trades in the WLEB, the equivalent unit of exchange is based on pounds of total phosphorus (TP) reduced per year with a 3:1 trade ratio applied to buyer reduction needs. This means that agriculture must supply three pounds of TP reduction from conservation practices to offset one pound of WWTP discharge demand. This 3:1 equivalence is the default trade ratio currently being considered for a WLEB water quality trading framework in the CIG-funded project. As such, it is applied in demand and supply comparisons in this memorandum.

2.0 Background for the Analysis

The goal of this memorandum is to identify the potential demand for WQT within the WLEB in the context of potential supply. Credit demand, as quantitatively examined in the context of this memorandum, refers to WWTP load reductions that will be required by state agencies. Credit supply refers to TP load reductions generated by the placement of conservation practices in the agricultural landscape.

As a preliminary starting point for considering potential credit demand in the WLEB, K&A considered the Annex 4 open lake phosphorus reduction target of 40%.[1] Though Ohio, Michigan, Indiana and Ontario are each crafting their own approaches towards achieving this goal, K&A preliminarily considered the 40% reduction in the context of WWTPs. The initial consideration focused on 2008 WWTP discharge levels as the baseline year and the general consideration of where WWTPs are in relation to the 40% reduction goals based on current 2015 discharges.

This notion, when relayed to state agency participants resulted in varying feedback on how this related to current actions or considerations that states were making for permitted dischargers. In the one application where this might apply, K&A used an OEPA-suggested approach for examining potential demand by Ohio WWTPs in the WLEB. This therefore serves as an initial approach used herein for forecasting potential WQT credit demand in the basin but should not be construed as a finalized strategy for Ohio. It is only used to illustrate demand considerations where there yet remains formal action for WWTPs.

National Pollution Discharge Elimination Discharge System (NPDES) permittees may also face more stringent mid- or long-term effluent limit reductions, though these have not yet been specifically identified by state regulatory agencies. This limits considerations for various WWTP demand scenarios in this memorandum to the 40% reduction goal in this analysis. The demand analysis includes quantifying load reduction estimates and estimating potential costs to meet these reductions through WWTP actions (e.g., plant optimization, chemical additions, or technology upgrades).

Total Maximum Daily Loads (TMDLs) commonly serve as a driver for WQT. In the WLEB, there are few circumstances where a phosphorus TMDL is currently driving WWTPs toward more stringent effluents that might otherwise trigger trading considerations. While the Ohio Environmental Protection Agency (OEPA) has identified nutrient impaired waters for several areas in Ohio draining to the WLEB, a 2015 Ohio Supreme Court ruling determined that a TMDL established pursuant to the Clean Water Act is a rule subject to the requirements of R.C. Chapter 119, the Ohio Administrative Procedure Act. This has, in effect, delayed implementation of wasteload allocations in TMDLs being directly applied to individual NPDES permit limits. This in turn, serves to delay TMDLs being a potential WQT driver in Ohio. There are no phosphorus TMDLs, current or pending development for Indiana watersheds draining to the WLEB.[2] One TMDL for phosphorus exists in Michigan's portion of the WLEB. The 2004 TMDL

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[1] Recommended Phosphorus Loading Targets for Lake Erie. 2015. Annex 4 Objectives and Targets Task Team Final Report to the Nutrients Annex Subcommittee.
[2] Indiana Department of Environmental Management-Nonpoint source water pollution. Nd. TMDL Documents. Accessed online at: http://www.in.gov/idem/nps/2652.htm

addresses nutrient loading to run-of-the-river impoundments including Ford and Belleville Lakes. Ford Lake is located in southeast Washtenaw County and Belleville Lake is located immediately east of Ford Lake in Wayne County.[3] Point source limits for one WWTP upstream of these lakes are being contested, so this setting offers no real opportunities for trading consideration in this analysis. Narrative consideration of other potential drivers for phosphorus demand is discussed in Section 3.2.

Following consideration of WWTP demand in this memorandum, the analysis estimates potential TP credit supply and associated costs as generically produced by select conservation practices applied to croplands in the U.S. portion of the WLEB. Demand, supply and comparative costs are then analyzed for a subset of point sources that may have the greatest potential to consider trading under the hypothetical 40% WWTP reduction target used in this analysis. A background summary for these state-by-state demand analyses as well as for the broader multi-state estimation of potential supply is provided as follows to set up more detailed discussions of this assessment in Sections 3 and 4, respectively.

The remainder of Section 2 provides these background considerations used to initially assess WWTP demand opportunities for each state, and those for assessing potential agricultural supply on a broader basin-wide approach.

2.1 Ohio Dischargers

K&A was provided permit information for all Ohio WWTP facilities within the WLEB by OEPA (see Attachment 1). Using permit information (flow, concentration, technology, etc.), the first demand scenario in this analysis calculated potential credit demand and estimated upgrade costs for a subset of these focusing on all major municipal permittees in Ohio's portion of WLEB. In the near-term, it appears that major WWTPs (>1 MGD design flow) will likely be able to readily achieve 40% reductions while minor permittees (<1 MGD design flow) are perhaps more likely to consider WQT. The 2016 "State of Ohio's Western Lake Erie Basin: Collaborative Implementation Plan"[4] identified 12 minor municipal WWTPs in the Maumee River watershed (out of 30 facilities noted in the Collaborative). These have warranted particular attention by OEPA given their relatively high TP load compared to other minor and major facilities. This subset of WWTPs served as the basis for a second demand scenario of potential credit demand within Ohio's portion of WLEB.

[3] Michigan Department of Environmental Quality: Water Division. 2004. Total Maximum Daily Load for Phosphorus in Ford and Belleville Lakes. Accessed online at: http://www.michigan.gov/documents/deq/wrd-swas-tmdl-fordbelleville_451021_7.pdf

[4] Ohio EPA. 2016. State of Ohio's Western Lake Erie Basin Collaborative Implementation Plan. Accessed at http://epa.ohio.gov/Portals/33/documents/WLEBCollaborative.pdf

2.2 Indiana Dischargers

Indiana Administrative Code requires that any facility discharging more than 10 pounds per day in Lake Erie or Lake Michigan watersheds reduce their phosphorus discharge to a maximum of 1 mg/L for POTWs and by at least 90% for industrial facilities (unless it can be demonstrated that removal to 90% is technologically infeasible due to factors unique to that facility). Indiana also requires all major wastewater treatment plants, regardless of location, to meet a 1 mg/L TP limit.

In addition to the above technology-based requirements, all facilities regardless of size or discharged load, will trigger a TP limit if they discharge directly to a stream segment impaired due to nutrients.

There are eighteen WWTPs discharging to the WLEB located in Indiana; eight major and ten minor facilities. The complete list of Indiana point source facilities and their associated TP discharge data are presented in Attachment 2 and is based on information provided by IDEM. NPDES discharge data in Attachment 2 for Indiana WWTPs indicate that all the facilities are well below the current 1 mg/L Lake Erie TP effluent limit with the exception of one minor facility. That facility is required by its NPDES permit to reduce TP to 1 mg/L or less by March 2020.

Existing facility TP discharge levels are considered sufficient to meet 40% point source reduction targets by the Indiana Department of Environmental Management (IDEM). IDEM therefore does not anticipate the need for trading for either major or minor permittees in the near-term.[5] Given the previously noted rule and policy requirements related to TP control, and that the existing point source discharges are all currently at or well below 1 mg/L (see Attachment 2), IDEM also does not believe additional TP point source effluent standards are warranted.

As such, K&A does not believe there is any near-term WQT credit demand for major or minor permittees in the WLEB of Indiana. No further discussion of Indiana WWTP demand is therefore included in this memorandum.

2.3 Michigan Dischargers

The Michigan Department of Environmental Quality (MDEQ) asserts trading will not be utilized by municipal wastewater permittees in the state for the WLEB.[6] The State is currently working with four WWTPs to implement lower TP effluent limits. The agency has issued new permits to Detroit WWTP, Ypsilanti Communities Utility Authority

[5] Personal communications with Paul Novak and Jeff Ewick from August, 2016 to September, 2016; December 21, 2016. Here, any communication with IDEM staff is assumed to be with Paul Novak and Jeff Ewick unless otherwise noted.

[6] Personal communications with Phil Argiroff from April, 2016 to September, 2016. Here, any communication with MDEQ staff is assumed to be with Phil Argiroff unless otherwise noted.

WWTP (YUCA), and Monroe WWTP and has a draft permit for the Wayne County Downriver WWTP. MDEQ indicated these four facilities will be under strict liability limits and will not be allowed to trade in order to meet compliance requirements.[7] Given the new permit language and the MDEQ stance on trading, K&A assumes there to be no credit demand by WWTPs in Michigan in the near-term and therefore, no further considerations are made herein for these or other WWTPs. MDEQ has agreed to provide WWTP discharge information to the project, but these will not likely be available until after the completion of this memorandum but still with the no trading assumption prevailing.

2.4 Multi-state Credit Supply

The credit supply assessment for the WLEB examined readily available but current information on TP losses and runoff reduction opportunities in the agricultural sector. The supply analysis in this memo focuses on TP reductions and subsequent credit generation on agriculture lands identified by USDA-NRCS as being vulnerable for nutrient loss. The supply analysis applied three BMPs (cover crops, residue/tillage management, and nutrient placement) to a portion of acres in the WLEB based on relative vulnerability to soil-attached and soluble phosphorus losses. (Soluble phosphorus may often be referred to as dissolved reactive phosphorus, or DRP from an analytical chemistry definition.) Using average, per acre TP loading estimates for the Basin and published TP removal efficiencies, potential TP reductions were estimated from each BMP. These were monetized as $/lb for deriving costs of credits that can be compared to WWTP costs for similar reductions. Details of this analysis are provided in Section 4 of this memorandum.

3.0 WQT Credit Demand

WWTPs in Ohio are the sole target for this demand analysis based on data and agency positions expressed for WWTPs in Michigan and Indiana. The hypothetical driver for WQT demand for Ohio WWTPs in the WLEB for this analysis stems from the 2015 Annex 4 Report. The Annex discusses reductions over the 2008 baseline WWTP loads. As a demand scenario, a hypothetical 40% reduction serves as an initial consideration for OEPA suggestions on WWTPs. The following subsection describes current demand considerations for trading in Ohio as per conversations with state agency staff and best available information related to WLEB targeted point source reductions.

3.1 Ohio Credit Demand Scenarios

Two primary scenarios were examined by K&A for potential WWTP credit demand from Ohio point sources in the WLEB. Under the first hypothetical demand scenario, OEPA

[7] Personal communication with Phil Argiroff (MDEQ) on October 14, 2016.

would place new effluent limits on major permitted dischargers throughout the WLEB. The second hypothetical scenario utilizes information provided in the 2016 OEPA Collaborative and assumes new effluent limits would be placed on only a subset of minor permittees throughout the Maumee River watershed of WLEB. Figure 1 depicts both major facilities and 12 minor facilities in the WLEB watershed of Ohio. Specific OEPA hypothetical conditions discussed next serve as a backdrop for both of these demand scenarios.

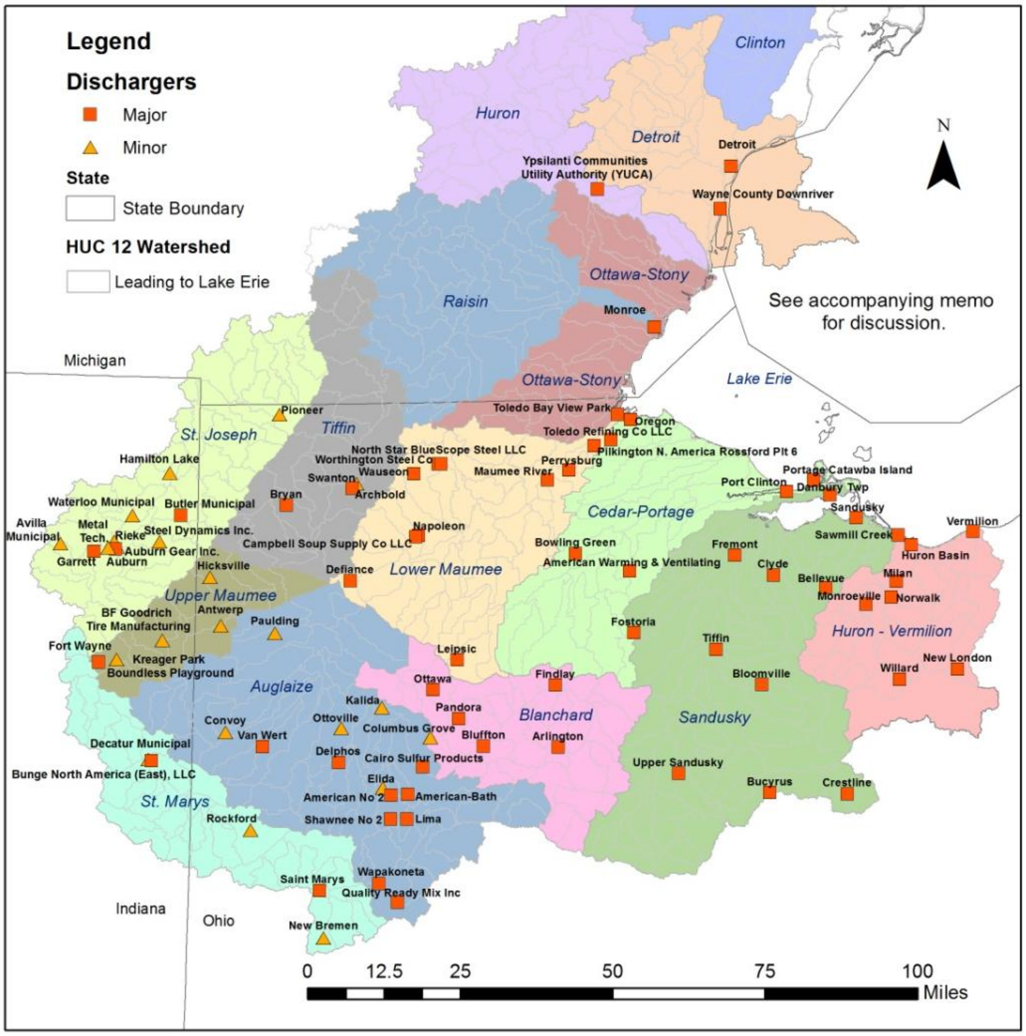

Figure 1: Selected Point Source Permittees in WLEB Considered in the Demand Analysis

OEPA staff provided a variety of data and supporting information used to help K&A develop demand scenarios in relation to current requirements or targets, and potential future effluent limits for point sources.[8] Detailed facility information provided by OEPA

[8] Personal communications with Gary Stuhlfauth (OEPA) from April, 2016 to September, 2016. Mr. Stuhlfauth provided raw data for Ohio point sources and possible scenarios for future limits. Kieser & Associates, LLC interpreted the information provided. Here, any communication with OEPA agency staff is assumed to be with Gary Stuhlfauth unless otherwise noted.

specific to approximately 70 major permittees discharging to the WLEB was used to consider initial WQT demand opportunities for Ohio under the first demand scenario. The complete list of major municipal permittees with relevant discharge information is included as Attachment 1 to this memorandum. (Industrial dischargers included in the original information from OEPA were excluded in the final scenario due to a lack of sufficient information on treatment technology to extrapolate demand, though this does not preclude actual trading opportunities in this sector.) According to OEPA, major facilities typically utilize chemical additions in order to meet the current 1mg/L TP Great Lakes effluent limit. Minor facilities currently do not have specified TP limits in their permits. Of note, several of these facilities, though they may have design flow capacity of >1 MGD, are on average, discharging below 1 MGD.

The Annex 4 reduction goal of 40% serves as a starting point for considerations to envision possible technology-based compliance strategies used here to preliminarily estimate potential WWTP demand. To this end, OEPA suggested a series of hypothetical point source permit reduction scenarios. Such scenarios are not formal policy or are these necessarily being adopted by OEPA. Rather, these represent an initial reflection of potential options for point source reductions that could be instructive for assessing demand in this memorandum.

The second demand scenario for Ohio utilizes information contained in the 2016 OEPA Collaborative document that summarizes the current status of Ohio's portion of the Basin. This report included, in part, a summary of the top 30 TP dischargers in the Maumee watershed to the WLEB. Of the 30 identified facilities, 12 are minor municipal dischargers. As Ohio does not currently place effluent limits on minor dischargers, K&A assessed the hypothetical scenario for these minor facilities would be required to meet a 1 mg/L discharge limit. OEPA staff suggested these minor facilities identified in the Collaborative may be initially targeted for new effluent limits given their relatively higher loads and potentially higher degree of public scrutiny.[9]

3.1.1 Ohio Major Dischargers

The first credit demand scenario assumes that major facilities would face a new TP effluent limit of 0.7 mg/L to achieve the 40% reduction goal. OEPA indicated that under this hypothetical scenario, major dischargers would most likely opt to increase their existing chemical additions to meet such new effluent limitations. OEPA staff noted that: 1) such an approach is cost-effective for major facilities, and; 2) it eliminates the uncertainty associated with contracting with nonpoint source credit sellers in an alternative WQT scenario. Long-term chemical addition costs would remain cost-

[9] OEPA did not provide a hypothetical scenario for minor facilities highlighted in the Collaborative report. Kieser & Associates used personal communications with Gary Stuhlfauth, OEPA and made assumptions on future effluent limits in order to conduct analyses surrounding the 13 facilities.

effective even with what OEPA would envision as upfront feasibility studies by major facilities with one-time costs ranging from $25,000-$50,000 per study.

Towards this end, K&A estimated the cost per pound of additional TP removed through increased chemical addition based on a 2013 technical report prepared for OEPA[10] (Attachment 3). This yielded an estimated additional treatment cost of $0.34/lb. At this level treatment, the average major permittee in Ohio will face an annual treatment cost increase of $1,833 excluding one-time feasibility study costs. The range of annual treatment costs varied from $1 to $29,599 for the smallest to largest WWTPs, respectively for these major facilities. This generally affirms OEPA's position that with this potentially low-cost treatment option, there will be limited interest or need for WQT by major point sources in the Ohio portion of the WLEB.

This analysis did not specifically consider the motivations of major industrial dischargers. These facilities may opt for trading over facility retrofits depending on the type of technology employed in their operations and subsequent costs for upgrading. For instance, industrial facilities (as well as municipal facilities treating an industry's pre-treatment load) may face more expensive treatment options based on the characteristics of influent wastewater. K&A did not, however, attempt to speculate on preferences of these facilities based on a lack of readily available treatment technology information necessary to estimate potential costs to reduce current phosphorus discharges. An in-depth analysis of by each industrial facility would be necessary to complete an upgrade cost estimate.

3.1.2 Ohio Minor Dischargers

The 2016 OEPA Collaborative identified 12 municipal minor facilities in the Maumee with relatively higher loads compared with other minor and major facilities in the drainage area. K&A assumed a 1mg/L effluent limit for minor facilities (which is the current limit for major facilities) for the purposes of forecasting potential WQT demand. This analysis excluded one minor industrial facility identified in the OEPA collaborative as Cooper Farms Cooked Meats in Van Wert, Ohio due to a lack of effluent flow data and information on current treatment technology. As such, it was considered too speculative to include it here, though this by no means suggests trading is not an option for this facility.

Using the hypothetical assumption that minor municipal permittees would face a 1 mg/L TP effluent concentration, K&A calculated reductions necessary for this compliance scenario. Table 1 summarizes these calculations using reported design flows.

[10] Tetra Tech. 2013. Cost Estimate of Phosphorus Removal at Wastewater Treatment Plants: A Technical Support Document prepared for Ohio Environmental Protection Agency by Tetra Tech.

Table 1: Anticipated Reductions of Minor Permittees at a 1 mg/L Effluent Limit for TP

Permit Name	Design Flow (MGD)	TP Concentration (mg/L)	TP Load (lbs/yr)	New Limit (mg/L)	New Load (lbs/yr)	Reductions Needed (lbs/yr)
Antwerp WWTP	0.33	2.62	2,632	1.0	1,005	1,627
Kalida STP	0.20	4.08	2,332	1.0	608	1,724
Convoy WWTP	0.20	2.73	1,912	1.0	608	1,304
Rockford STP	0.25	2.33	4,664	1.0	760	3,904
Ottoville WWTP	0.34	3.02	2,097	1.0	1,030	1,066
Hicksville WWTP	0.40	1.15	2,990	1.0	1,216	1,774
Elida WWTP	0.50	1.77	3,186	1.0	1,520	1,666
Pioneer WWTP	0.50	2.37	1,742	1.0	1,520	223
Paulding WWTP	0.71	1.47	2,935	1.0	2,158	777
Columbus Grove WWTP	0.82	1.10	2,295	1.0	2,493	(198)
New Bremen WWTP	0.90	2.87	6,061	1.0	2,736	3,325
Swanton WWTP	0.92	1.90	3,417	1.0	2,797	620

Unlike major permittees, these facilities may not be able to optimize their plant operations or make simple adjustments to achieve a new effluent limit. Small facilities might therefore have to install more expensive tertiary units, or perhaps entirely upgrade their current facilities to meet a new effluent of 1 mgl/L. Such upgrades can represent potentially enormous costs for smaller communities thus pointing to alternative compliance with WQT. Table 2 summarizes generic upgrade costs for these facilities. Unit costs ($/lb) are based on a 2011 WQT feasibility study for the Wabash River Watershed that include capital and O&M expenditures represented as 2016 dollars.[11]

Table 2: Average Cost for Minor WWTP Upgrade for a 1 mg/L Including O&M

Permit Name	*Reductions Needed (lbs/yr)*	*Reduction Cost-Average ($/lb)*	*Total Cost (Average)*
Antwerp WWTP	1,627	45.52	$ 74,061
Kalida STP	1,724	59.67	$ 102,881
Convoy WWTP	1,304	45.52	$ 59,353
Rockford STP	3,904	59.67	$ 232,971
Ottoville WWTP	1,066	45.52	$ 48,532
Hicksville WWTP	1,774	Not Available	Not Available
Elida WWTP	1,666	59.67	$ 99,402
Pioneer WWTP	223	59.67	$ 13,281
Paulding WWTP	777	6.40	$ 4,974
Columbus Grove WWTP	(198)	Not Applicable	Not Applicable
New Bremen WWTP	3,325	6.40	$ 21,297
Swanton WWTP	620	6.40	$ 3,972

[11] Conservation Technology Information Center, Tetra Tech, Inc, and Kieser & Associates, LLC. 2011. Wabash River Watershed Water Quality Trading Feasibility Study. A U.S. EPA Targeted Watershed Grant (WS-00E71501-0)

While exploratory, the information presented in Table 2 suggests smaller facilities may opt for trading in the near-term (assuming stricter regulatory limits) due to the higher treatment costs compared to major facilities. This notion of minor WWTP demand is explored in more detail later in this report under Section 6 discussing potential pilot trading opportunities.

3.2 Alternative Demand Opportunities

Absent a clear or definitive regulatory driver incentivizing the need for water quality credits for WWTPs, other opportunities may exist for generating demand. As these may arise, a WLEB trading framework should recognize the potential for alternative demand drivers. Though there is no attempt here to quantify what may unfold in the mid- to long-term, K&A provides a narrative describing these potential future opportunities.

3.2.1 Stewardship Credits

The Ohio River Basin pilot trading initiative has recently explored the use of 'stewardship credits' in lieu of demand for regulatory-based credits. Stewardship credits may be used to meet sustainability or supply chain offset goals that a public, private, or NGO entity may desire.[12] Because these credits are born out of trading, the credits are quantified and verified with the same scrutiny as those in a WQT program. These stewardship credits do not, however, receive any discounting with a trade ratio applied to compliance trades. The Ohio River Basin pilot has experienced slow adoption of stewardship credits as of this writing. Members of the Trading Advisory Group for WLEB expressed interest in including these types of credits in the larger WLEB WQT framework. This memorandum will not attempt to quantify potential demand of such credits rather acknowledge here a potential buyer(s) may emerge in the Basin with interest in stewardship credits.

3.2.2 Stormwater Runoff

Alternative credit demand may also arise from needs for controlling municipal stormwater runoff and/or offsetting new growth. Currently, Ohio only includes non-quantitative nutrient related measures in MS4 permits. For instance, an MS4 may choose BMPs that will address known water quality impairments; however, there are no specific load reduction targets.[13] Similarly, Indiana does not include a stormwater provision in their current MS4 permits.[14] Michigan currently allows off-site mitigation for MS4 redevelopment projects that are unable to meet 100 percent of their local stormwater retention performance standards on-site. Off-site mitigation is simply a BMP installed

[12] Electric Power Research Institute. Nd. Invitation to Water Stewardship Credit Auction. Accessed online at: http://wqt.epri.com/pdf/WQT_invite_ver12_updated.pdf
[13] Personal communication with Gary Stuhlfauth (OEPA) on October 13, 2016.
[14] Personal communication with Catherine Hess (IDEM) on October 13, 2016

within the same jurisdiction and drainage area as the redevelopment project.[15] This Michigan MS4 permit provision is analogous to type of trading program described in this memo but rather as nonpoint source/nonpoint source trades. Under this approach a municipality or any individual entity would be required to offset any increased TP load resulting from new and/or redevelopment. This requirement is currently used in the Lake Simcoe Phosphorus Offset Program which requires a net zero TP discharge to Lake Simcoe from any new or redevelopment.[16] Recognition of stormwater offsets under the proposed WLEB WQT program may therefore garner additional future demand. Such opportunities are only speculative until such time there are numeric or load limits placed on stormwater discharges (such as in the Chesapeake Bay[17]), or with required growth offsets.

In addition to state policy, an increasing number of municipalities are passing stormwater fees for impervious surfaces. Detroit for instance pays more than $125 million a year to mitigate stormwater. The City has recently started assessing new stormwater fees to commercial and residential properties to recoup a portion of this cost.[18] Cities such as Detroit are opting to install urban green infrastructure for controlling stormwater runoff volume throughout the City thus mitigating the potential for Combined Sewer Overflow (CSO) events. These volume control projects may also reduce TP loads within the municipal boundary. Under specific conditions, a trading program could consider these efforts as credit-generating projects for possible MS4 demand. Future policies at the state and municipal level might also recognize these TP reductions (accomplished as an ancillary benefit to flood mitigation) for future MS4 regulatory compliance.

3.2.3 Municipal WWTP Growth

The demand analysis in this report did not attempt to quantitatively capture potential credit demand associated with new growth for a municipal footprint or increased flow to a WWTP. The first WWTP demand scenario for major municipal WWTPs in Ohio only examined current WWTP flows, and not design flows. Potential demand might therefore arise with offset requirements for new growth that might lead to increased wastewater treatment plant discharge volumes at hypothetical existing limits under the 40% reduction scenario.

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[15] State of Michigan- Department of Environmental Quality. National Pollutant Discharge Elimination System: Permit Application for Discharge of Stormwater to Surface Waters of the State from a Municipal Separate Storm Sewer System. Page 10-11.
[16] Lake Simcoe Region Conservation Authority. 2014. Lake Simcoe Phosphorus Offset Program: Summary report.
[17] For example, see: https://www.epa.gov/sites/production/files/2014-12/documents/bay_tmdl_executive_summary_final_12.29.10_final_1.pdf
[18] Ferretti, C. (Detroit News). 2016. DWSD to charge new drainage fees beginning Oct. 1. Accessed at http://www.detroitnews.com/story/news/local/detroit-city/2016/08/17/detroit-drainage-fees/88904128/

Take for instance that 13 major Ohio WWTPs experienced an average increase of 31% in flow between 2008 and 2015. Future TMDLs would cap TP loads from WWTPs. As growth continues to occur after a TMDL is approved, any permitted increase in hydraulic capacity will have to be offset by a reduction in phosphorus concentrations. Treatment costs for phosphorus effluent limits increase exponentially with stricter effluent limits. Given the uncertainty surrounding future WWTP growth and facility capacity, the trading framework should consider this as a possible influencing factor on future demand.

3.3 Demand Conclusions

Point source credit demand is limited for the foreseeable future in both Indiana and Michigan given the lack of a regulatory driver, currently achieved WWTP discharge concentrations and stated positions of both state agencies. It could come to pass that a Basin-wide TMDL might eventually prompt permit modifications for both Indiana and Michigan, at which time trading may become a viable, cost-effective option. Indiana has expressed some potential consideration of point source to point source trading.

Ohio is the most likely of the three states to utilize trading in the near-term. Through several assumptions, this memo concluded that major Ohio municipal permittees would likely be able to cost-effectively meet future effluent limits through increasing chemical additions. Major dischargers might also have interest in trading at some point depending on the finalization of Basin-wide standards, or if faced with new growth requiring increased WWTP loads to the WLEB.

Ohio minors in the Maumee watershed, identified in the OEPA Collaborative document, present the greatest potential for near-term trading. These facilities not only discharge at relatively higher rates than other point sources in the watershed, but through the Collaborative document have been identified publically as significant contributors of TP loading.

Industrial WWTPs could also have potential near-term interest in WQT, however, facility-specific data and direct discussions with plant representatives and OEPA would likely be necessary to flush out opportunities.

Other drivers for credit demand are possible. These could include corporate sustainability investments for conservation practices that produce stewardship credits, offsets for urban stormwater discharges and/or offsets for municipal growth and related WWTP discharges may be mid- to long-term drivers for trading. Thus, a WLEB WQT framework should recognize these as tradable opportunities

4.0 WQT Credit Supply

The credit supply analysis for the WLEB is based on current, broad-based assumptions of phosphorus loss pathways and runoff reduction opportunities for agricultural lands throughout the Basin. It does not necessarily reflect more detailed considerations of forms of phosphorus or new research in the WLEB discussing movement and transport of these forms under varying conditions and conservation practices. As will be discussed further in the Erie P Market water quality trading framework, total phosphorus exists in particulate and dissolved forms.[19] Each form has unique characteristics related to bioavailability and methods for control. A recent shift in agricultural nutrient management research highlights the necessity to consider the contribution of both particulate-bound and dissolved reactive phosphorus (DRP) forms in site-specific estimation of phosphorus loads in the Basin. This is especially important for water quality crediting where equivalence in the forms of phosphorus between WWTP buyers and agricultural sellers must be considered. Such calculation tools will be identified in this Erie P Market project to ensure reductions are meaningful and thus, credits are real. For this supply analysis, however, coarse extrapolations from broad-brush application of conservation practices do not necessarily require such specificity.

4.1 Agriculture BMPs for WLEB

Ohio, Indiana, and Michigan provided an RCPP Priority BMP Practice list developed by each state for areas currently targeted by RCPP funding. These practices were reviewed for TP reduction capabilities from which a subset of priority BMPs was selected that the states unanimously identified for implementation in the WLEB. These select BMPs include *cover crops, residue/tillage management*, and *nutrient placement*. These are certainly not the only BMPs applicable to agriculture in WLEB. These selections are used to simply illustrate the potential reductions achieved through well-recognized BMPs in the context that the vast majority of phosphorus loads originate from agriculture in the Basin.

Literature reduction efficiencies for TP were ascribed to these select practices as a coarse means to forecast phosphorus reduction potential across vast expanses of cropped lands in the WLEB. Though the eventual WLEB trading framework will likely employ site-specific calculation tools to estimate site by site crediting opportunities, literature-based BMP performance estimates are sufficient for this limited credit supply analysis. It is likely that site-specific modeling techniques will also be refined over time, but at present, targeted estimation tools such as STEP-L that calculate particulate phosphorus runoff, and other methods to credit DRP (e.g., the Pennsylvania DEP phosphorus calculator

[19] This assumes particulate phosphorus is bound either through adsorption with soils or through absorption related to plant growth.

developed for the Chesapeake Bay WQCT program[20]) may be deployed under the final WQT framework for selected practices. Other much more detailed studies have been and will continue to be used in the WLEB for refining future trading considerations, but for purposes of a supply analysis in the face of limited near-term demand, the current approach was selected.

4.2 Ag Lands Targeted for Credit Supply

With an estimated 5.2 million acres of cultivated land in the WLEB, there is substantial land cover that may be appropriate for BMP implementation to serve as credit supply. A 2016 USDA-NRCS Conservation Effects Assessment Project (CEAP) report estimates proportions of this 5.2 million acres as having low, moderate, moderately-high, and high vulnerability for phosphorus loss through surface and subsurface pathways.[21] Vulnerability was defined in a 2011 CEAP report as 'acres with the least conservation treatment and the highest losses of sediment or nutrients'.[22] The 2016 CEAP report further characterizes agricultural lands as either vulnerable to surface or subsurface runoff. For this supply analysis, selected BMPs are applied only to categories identified as moderately-high and highly vulnerable for nutrient loss.

On an average acre of agriculture land in WLEB, 0.5 pounds of phosphorus is estimated to be lost annually through surface runoff in particulate form. The same acre of land will lose 2.0 pounds of soluble phosphorus. Loading may be much higher on certain lands throughout the Basin. The 2011 CEAP report estimates up to 5.9 pounds of P per acre are lost from manure-applied lands throughout the Great Lakes Region. Furthermore, the 2016 CEAP concludes up to 9 percent of production lands in the WLEB utilize manure applications, which suggests a portion of the Basin has above average loading and may be a viable source for additional reductions/credits. Despite the potential for more pronounced TP reductions from manure-applied lands, the following analyses use a more conservative average per acre loading of 2.5 lbs TP as identified in the 2016 CEAP report to calculate potential TP reductions resulting from each BMP considered here.

4.2.1 Cover Crops

Cover crops primarily mitigate soil erosion and minimize surface runoff containing particulate-bound phosphorus. The 2016 CEAP report estimates for an average field in

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[20] The *DRAFT- Phosphorus and Sediment Credit Calculation Form- Effective January 30, 2008* Excel spreadsheet is available on page 9 of the 2016 Pennsylvania Department of Environmental Protection Phase 2 Watershed Implementation Plan Nutrient Trading Supplement. Accessed at http://files.dep.state.pa.us/Water/BPNPSM/NutrientTrading/NutrientTradingSupplementToPhase2WIP.pdf

[21] United States Department of Agriculture, Natural Resources Conservation Service-Conservation Effects Assessment Project (CEAP). 2016. Effects of conservation practice adoption on cultivated cropland acres in Western Lake Erie Basin, 2003-06 and 2012

[22] United States Department of Agriculture, Natural Resources Conservation Service-Conservation Effects Assessment Project (CEAP). 2011. Assessment of the Effects of conservation practice adoption on cultivated cropland acres in the Great Lakes Region.

WLEB, 0.6 lbs of phosphorus per year is lost through surface runoff, of which only 0.1lb is soluble. Given the high proportion of particulate-bound phosphorus, this analysis applies cover crops to agriculture lands with high or moderately-high vulnerability to surface runoff. Table 3 summarizes the estimated TP removal accomplished through cover crop installation across agricultural lands in the WLEB.

Table 3: Estimated Total Phosphorus Removal using Cover Crops (NRCS Practice Standard 327)

Cover Crops (327)			
High Surface Runoff Vulnerability Acres	Phosphorus Loading (lb/ac)	TP Removal Efficiency (average %)	Total Phosphorus Removal (lbs/yr)
104,600	2.5	50%	130,750
Moderate-High Surface Runoff Vulnerability Acres	Phosphorus Loading (lb/ac)	TP Removal Efficiency (average %)	Total Phosphorus Removal (lbs/yr)
1,202,900	2.5	50%	1,503,625

**Applicable acreage is based on type of phosphorus transport the BMP addresses. As found in: USDA-NRCS-Conservation Effects Assessment Project. 2016. Effects of Conservation Practice Adoption on Cultivated Cropland Acres in Western Lake Erie Basin, 2003-06 and 2012*

***Phosphorus loading per acre is based on 2016 CEAP report*

****TP removal efficiency from: Iowa Department of Agriculture and Land Stewardship, Iowa DNR, and Iowa State University. 2016. Iowa Nutrient Reduction Strategy: A science and technology-based framework to assess and reduce nutrients to Iowa waters and the Gulf of Mexico*

4.2.2 Residue/Tillage Management

Similar to cover crops, residue/tillage management primarily controls soil erosion and particulate-bound phosphorus. This analysis assumed residue/tillage management is only applicable to agriculture land with high and moderately-high vulnerability to surface runoff. Table 4 summarizes the estimated TP removal accomplished through residue/tillage management under this scenario.

TP removal efficiency is reported at 60%-80%. As this is a commonly identified BMP in the WLEB, an average TP removal efficiency of 70% is used to forecast potential supply in Table 4.

Table 4: Estimated Total Phosphorus Removal using Residue/Tillage Management (NRCS Practice Standards 329A and 329B)

Residue/Tillage Management (329A and 329b)			
High Surface Runoff Vulnerability Acres	Phosphorus Loading (lb/ac)	TP Removal Efficiency (average %)	Total Phosphorus Removal (lbs/yr)
104,600	2.5	70%	183,050
Moderate-High Surface Runoff Vulnerability Acres	Phosphorus Loading (lb/ac)	TP Removal Efficiency (average %)	Total Phosphorus Removal (lbs/yr)
1,202,900	2.5	70%	2,105,075

**Applicable acreage is based on type of phosphorus transport the BMP addresses. As found in: USDA-NRCS-Conservation Effects Assessment Project. 2016. Effects of Conservation Practice Adoption on Cultivated Cropland Acres in Western Lake Erie Basin, 2003-06 and 2012*
***Phosphorus loading per acre is based on 2016 CEAP report*
****TP removal efficiency from: Watson, S., D. Carpenter, and IJC Science Advisory Board. 2013. Taking Action on Lake Erie*
*****TP removal efficiency ranges from 60%-80*

4.2.3 Nutrient Placement

Controlling nutrient placement is an important practice for short and long-term management of phosphorus. The advantage of this BMP relates to the effectiveness of controlling soluble phosphorus throughout the WLEB. As reference, DRP may be transported off fields through both surface and subsurface pathways.

Soils throughout the WLEB are highly concentrated in the upper portions (0-5cm) as a result of broadcast fertilizer application, minimal incorporation and no-till management practices over the past several years. As soils become overly concentrated with phosphorus, the bonds holding phosphorus to soil particles grow increasingly weak to the point where phosphorus is released from the upper soil layers. A general acceptance of no-till management practices throughout the Basin has led to the formation of macropores through agricultural fields. These pores serve as preferential pathways for phosphorus and allow for subsurface leaching of soluble phosphorus. As such, the 2016 CEAP report assumes subsurface phosphorus is almost entirely soluble. This soluble phosphorus may freely enter tile lines and be transported off the field to surface waters.

The practice of nutrient placement avoids the broadcast application of phosphorus and instead places the fertilizer below the already enriched 0-5cm enriched layer. This management practice allows phosphorus to bind with soils and minimizes the potential for subsurface leaching. Table 5 summarizes the estimated phosphorus controlled through placement in WLEB as the third BMP crediting scenario.

Table 5: Estimated Total Phosphorus Removal using Nutrient Placement (NRCS Practice Standard 590)

Nutrient Placement (590)			
High Subsurface Runoff Vulnerability Acres	Phosphorus Loading (lb/ac)	TP Removal Efficiency (average %)	Total Phosphorus Removal (lbs/yr)
1,562,900	2.5	29%	1,133,103
Moderate-High Subsurface Runoff Vulnerability Acres	Phosphorus Loading (lb/ac)	TP Removal Efficiency (average %)	Total Phosphorus Removal (lbs/yr)
2,615,000	2.5	29%	1,895,875

**Applicable acreage is based on type of phosphorus transport the BMP addresses. As found in: USDA-NRCS-Conservation Effects Assessment Project. 2016. Effects of Conservation Practice Adoption on Cultivated Cropland Acres in Western Lake Erie Basin, 2003-06 and 2012*
***Phosphorus loading is per acre is based on 2016 CEAP report*
***TP removal efficiency from: Gildow, M., N. Aloysius, S. Gebremariam, J. Martin. 2016. Fertilizer placement and application timing as strategies to reduce phosphorus loading to Lake Erie. Journal of Great Lakes Research*
****TP removal efficiency ranges from 60%-80*

While the percentage of TP removal using placement is lower than that of residue/tillage management and cover crops, nutrient placement is potentially more effective at controlling DRP than either of the other two BMPs considered here. DRP removal through nutrient placement may be as high as 46% according to a recent study[23] and does not appear to have the potential to be an intermittent source of soluble phosphorus as is the case with cover crops and residue/tillage management.

4.3 Agricultural BMP Costs

Using the information presented above, K&A calculated the cost efficiency of each selected BMP. The unit cost for each practice was derived from the NRCS Electronic Field Office Technical Guide.[24] Table 6 summarizes BMP practice costs in WLEB. A practice cost is the same regardless of whether it is applied on high or moderate-high vulnerability lands. Table 7 presents the reductions from BMPs reported in Table 6 as monetized, tradable credits and the cost associated with each credit under trade ratios of 2:1 and 3:1. Consideration of trade ratios here is important for later cost comparisons to WWTP upgrades.

[23] Gildow, M., N. Aloysius, S. Gebremariam, and J. Martin. 2016. Fertilizer placement and application timing as strategies to reduce phosphorus loading to Lake Erie. Journal of Great Lakes Research.
[24] The unit costs presented here are taken from Ohio's eFOTG documentation. Indiana uses the same cost documentation as Ohio and Michigan's costs were within an order of magnitude of both Ohio and Indiana. Unit costs have been adjusted based on a 75% cost share. Recognizing BMP unit costs will vary from region to region within a state in any given year the unit costs presented here give a general estimate of practice costs.

Table 6: Cost per Pound TP Removed for Select BMPs

Best Management Practice (BMP) and Applicable Land	Applicable Acres for BMP Application	Estimated TP Removal (lbs/yr)	BMP Unit Cost ($/ac)	Total Cost of BMP Implementation	Cost per Pound of TP Removed
Cover Crops *High Vulnerability Lands*	104,600	130,750	$ 74.38	$ 7,780,148	$ 59.50
Cover Crops *Moderate-High Vulnerability Lands*	1,202,900	1,503,625	$ 74.38	$ 89,471,702	$ 59.50
Residue/Tillage Management *High Vulnerability Lands*	104,600	183,050	$ 23.79	$ 2,488,434	$ 13.59
Residue/Tillage Management Moderate-*High Vulnerability Lands*	1,202,900	2,105,075	$ 23.79	$ 28,616,991	$ 13.59
Nutrient Placement *High Vulnerability Lands*	1,562,900	1,133,103	$ 71.65	$ 111,981,785	$ 98.83
Nutrient Placement Moderate-*High Vulnerability Lands*	2,615,000	1,895,875	$ 71.65	$ 187,364,750	$ 98.83

Table 7: Credit Cost and Availability

Best Management Practice (BMP) and Applicable Land	Credits Available at 2:1	Cost per Credit at 2:1	Credits Available at 3:1	Cost per Credit at 3:1
Cover Crops *High Vulnerability Lands*	65,375	$ 119.01	43,583	$ 178.51
Moderate-High Vulnerability Lands	751,813	$ 119.01	501,208	$ 178.51
Residue/Tillage Management *High Vulnerability Lands*	91,525	$ 27.19	61,017	$ 40.78
Moderate-*High Vulnerability Lands*	1,052,538	$ 27.19	701,692	$ 40.78
Nutrient Placement *High Vulnerability Lands*	566,551	$ 197.66	377,701	$ 296.48
Moderate-*High Vulnerability Lands*	947,938	$ 197.66	631,958	$ 296.48

The analysis here recognizes the cost per credit will vary as more precise practice costs are applied. However, in this context, K&A also recognizes there is ample supply of potential credits generated from these select practices in WLEB, especially given limited demand. The cost of implementing agriculture BMPs is also highly site-specific. Factors such as weather conditions, mobilization cost of contractors, and available supplies all may raise or lower practice costs. Thus, estimates in Tables 6 and 7 are strictly based on average reductions for an average acre of land in the WLEB and NRCS payments. There will be certain agricultural areas throughout the Basin that have a higher TP loading than the average 2.5lb/acre. Using information contained in the 2016 CEAP report, K&A would project, for example, that 20% of agriculture lands in the WLEB lose up to 4.3lbs annually. Management practices targeted to these acres would result in greater TP reductions and subsequently lower unit costs for BMPs.

4.2 WQT Credit Supply Conclusions

There appear to be few limitations for finding credit supply for potential near-term or even mid- to long-term buyers in the WLEB. Ultimately, all credits will need to be calculated on a site-specific basis for individual trades. BMP options for agriculture may be numerous, but such BMPs should be evaluated on the basis of their phosphorus load reduction benefits with consideration of both particulate and dissolved phosphorus fractions. BMPs considered in this analysis will vary in their potential to address both of these phosphorus fractions. Available credit quantification tools will be well-suited to calculate particulate fractions. Some adaptations of other WQT program calculation tools may be needed to assess load reductions associated with dissolved fractions.

5.0 WWTP Upgrade Cost Comparisons with Supply

To identify potential WQT opportunities based on credit demand and credit supply findings, this section compares WWTP upgrade costs for the 12 minor WWTPs in Ohio (Section 3) with credit supply costs (Section 4). Costing assumptions noted in these previous sections recognize the potential for wide variations on both demand and supply sides of the trading equation. In particular, this section includes supply cost information from other WQT programs examined by K&A for this CIG project. These programs have differing pricing mechanisms and land targeting approaches that focus on low-cost, high return BMP investments. This provides a useful and potentially more realistic comparison of demand and supply costs.

Table 8 provides these comparisons. WWTP upgrade costs for minor facilities in Ohio are derived from Table 2. NRCS practice costs for supply come from Table 7. Alternative credit pricing in Table 8 comes from the Ohio River Basin (ORB) WQT Pilot Project, Great Miami River (GMR) Pilot Program,[25] and Pennsylvania's (PA) WQT program[26] for the Chesapeake Bay.

Potential savings presented in Table 8 illustrate that in some cases, WQT could be beneficial for select minor WWTPs in Ohio. Table 8 uses the lowest unit cost of the three select agriculture BMPs for residue/tillage management as derived from NRCS payment schedules presented in Table 6. A 3:1 trade ratio applied to this unit cost of approximately $14/acre results in a credit cost of approximately $42/credit. Compared to WWTP upgrade costs, there will be some minor facilities that would experience cost-savings with WQT. Table 8 values is red indicate trading would be more expensive than simply upgrading the facility.

[25] Great Miami River costs were obtained from personal communication with Sarah Hippensteel of the Miami Conservancy District, October 12, 2016.

[26] Results of credit auctions in Pennsylvania indicate costs for TP reductions range from less than $1/unit to over $2/unit. For simplicity this memo assumes a cost of $2/lb. Past auctions are accessed online at: http://www.markit.com/Product/Pennvest

Table 8: WWTP Upgrade Costs (Demand) in Comparison to Agricultural Credit Supply Costs Based on NRCS Payment Schedules and Other WQT Programs (incorporating a 3:1 trade ratio)

WWTP Demand				Agricultural Supply											
Potential Upgrade Costs for TP Controls							Potential WQT costs for Ag BMP Reductions of TP								
				eFOTG costs			*Ohio River Basin Pilot Project*			*Great Miami River WQT Pilot Program*			*Pennsylvania WQT Program*		
Minor Ohio Permittee	Estimated Required Reductions (lbs/yr)	Total Cost of Treament	Facility Cost ($/lb TP Removed)	Residue/ Tillage Management Cost ($/lb)	Total Cost at 3:1 Trade Ratio	Potential Savings (Upgrade Cost-Supply Cost)	Cost for Stewardship Credit ($/lb TP)	Total Cost at 3:1 Trade Ratio	Potential Savings *(Upgrade Cost - Supply Cost)*	Cost per TP Reduction ($/lb)	Total Cost at 3:1 Trade Ratio	Potential Savings *(Upgrade Cost - Supply Cost)*	Cost per TP Reduction ($/lb)	Total Cost at 3:1 Trade Ratio	Potential Savings *(Upgrade Cost - Supply Cost)*
Antwerp WWTP	1,627	$ 74,061	$ 46	$ 14	$ 42	$ 5,727	$ 10	$ 30	$ 25,251	$ 0.51	$ 1.53	$ 71,572	$ 2	$ 6	$ 64,299
Kalida STP	1,724	$ 102,881	$ 60	$ 14	$ 42	$ 30,470	$ 10	$ 30	$ 51,159	$ 0.51	$ 1.53	$ 100,243	$ 2	$ 6	$ 92,537
Convoy WWTP	1,304	$ 59,353	$ 46	$ 14	$ 42	$ 4,591	$ 10	$ 30	$ 20,237	$ 0.51	$ 1.53	$ 57,358	$ 2	$ 6	$ 51,530
Rockford STP	3,904	$ 232,971	$ 60	$ 14	$ 42	$ 68,999	$ 10	$ 30	$ 115,848	$ 0.51	$ 1.53	$ 226,997	$ 2	$ 6	$ 209,546
Ottoville WWTP	1,066	$ 48,532	$ 46	$ 14	$ 42	$ 3,754	$ 10	$ 30	$ 16,548	$ 0.51	$ 1.53	$ 46,901	$ 2	$ 6	$ 42,135
Hicksville WWTP	1,774	Not Available	Not Available	$ 14	$ 42	Not Available	$ 10	$ 30	Not Available	$ 0.51	$ 1.53	Not Available	$ 2	$ 6	Not Available
Elida WWTP	1,666	$ 99,402	$ 60	$ 14	$ 42	$ 29,440	$ 10	$ 30	$ 49,429	$ 0.51	$ 1.53	$ 96,853	$ 2	$ 6	$ 89,407
Pioneer WWTP	223	$ 13,281	$ 60	$ 14	$ 42	$ 3,933	$ 10	$ 30	$ 6,604	$ 0.51	$ 1.53	$ 12,941	$ 2	$ 6	$ 11,946
Paulding WWTP	777	$ 4,974	$ 6	$ 14	$ 42	$ (27,644)	$ 10	$ 30	$ (18,325)	$ 0.51	$ 1.53	$ 3,786	$ 2	$ 6	$ 314
Columbus Grove WWTP	(198)	Not Applicable	Not Applicable	$ 14	$ 42	Not Applicable	$ 10	$ 30	Not Applicable	$ 0.51	$ 1.53	Not Applicable	$ 2	$ 6	Not Applicable
New Bremen WWTP	3,325	$ 21,297	$ 6	$ 14	$ 42	$ (118,365)	$ 10	$ 30	$ (78,461)	$ 0.51	$ 1.53	$ 16,210	$ 2	$ 6	$ 1,346
Swanton WWTP	620	$ 3,972	$ 6	$ 14	$ 42	$ (22,073)	$ 10	$ 30	$ (14,631)	$ 0.51	$ 1.53	$ 3,023	$ 2	$ 6	$ 251

Considering NRCS payment schedules yielded much higher agricultural credit costs ($60-$98/lb) than tillage, cost savings shown in Table 8 would be non-existent with a 3:1 trade ratio in most cases. Comparison to other WQT program costs, potential savings are even greater.

6.0 Pilot Trade Options

Based on the demand and supply cost comparisons, K&A illustrates here two hypothetical trading considerations among minor WWTPs in Ohio relating to interstate pilot discussions. Both Antwerp WWTP and Rockford STP are located in western Ohio within the Maumee watershed. Antwerp has the potential for upstream agricultural credits generated in Indiana while Indiana credits for Rockford would be downstream. Figure 2 illustrates Antwerp and Rockford’s location and the surrounding agriculture lands. We outline in this section the basis for a potential trade and its outcomes.

The 2016 OEPA Collaborative document identified these facilities as relatively high contributors to the WLEB load, and conversations with OEPA indicated these facilities (along with the other minor facilities in the Collaborative) may be of initial focus for state regulators. Table 9 provides a brief summary of facility information derived from the Collaborative Report that was also expressed in Table 2 of this memorandum (with updates from OEPA).

Both Antwerp WWTP and Rockford STP as possible pilot sites (or other minor dischargers) may be targets in part because of the projected annual costs for both these facilities. The estimated cost per pound of TP for these facilities is considerably higher than the projected cost of $0.34/lb for major permittees in Ohio. The estimated costs in Table 9 illustrate how minor facilities may be targeted as they serve a relatively fewer number of households compared to major facilities. Fewer households translates to a smaller tax base which exacerbates public cost ramifications.

To further illustrate considerations for pilot opportunities, K&A estimated the serviced population of each facility using guidance and reference data from the 10 State Standards.[27] The 10 State Standards recommend wastewater facilities be designed based on an average per capita daily flow of 100 gallons. The 10 State Standards do not account for I&I and CSO events, and so as a conservative estimate, K&A assumed a per capita flow of 125 gallons per day to account for these uncertainties along with an assumption for an average household of 2.5 individuals. Table 10 shows the application of these assumptions for example illustrations of the Antwerp and Rockford wastewater treatment facilities.

[27] Wastewater Committee of the Great Lakes-Upper Mississippi River. 2014. Recommended standards for wastewater facilities.

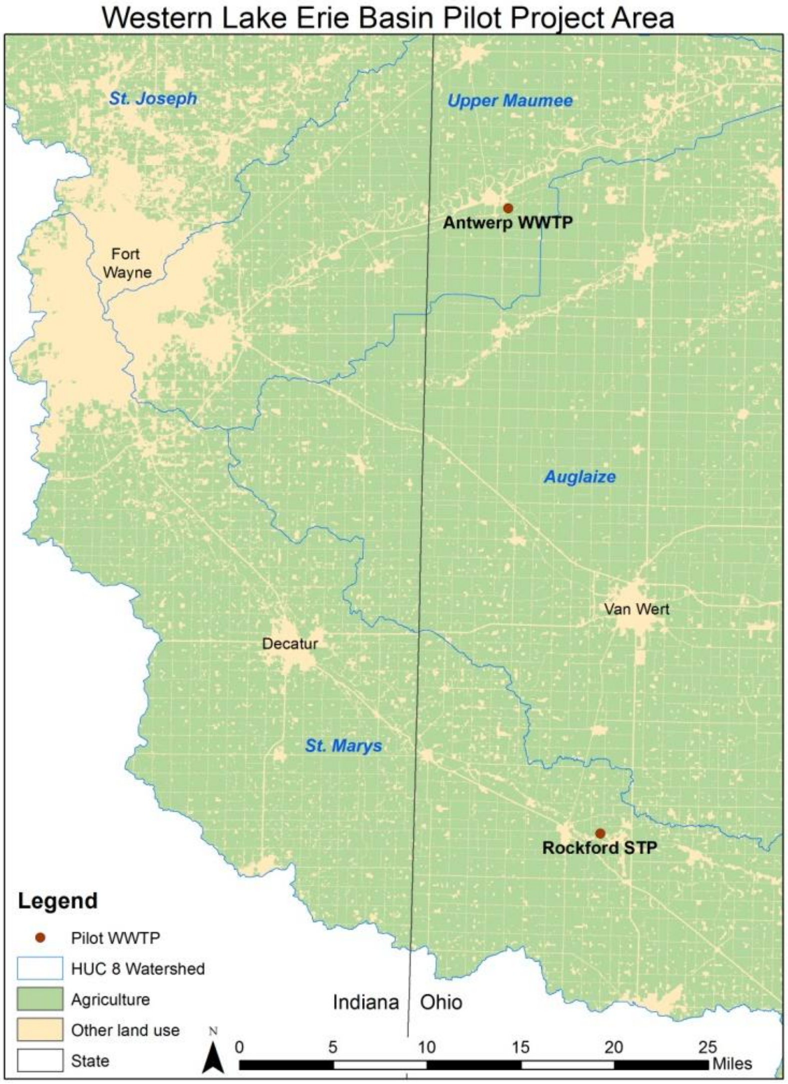

Figure 2: Pilot WWTPs in Maumee Watershed of Ohio

Table 9: Summary of Pilot WWTP Facilities

Facility Name	Anticipated Reductions under a 1mg/L Effluent Limit	Estimated Unit Cost ($/lb TP reduced)	Estimated Annual Cost ($/yr)
Antwerp WWTP	1,627	46	74,061
Rockford STP	3,904	60	232,971

Table 10: Households in Service Area

Facility	WWTP Flow (gpd)	Flow per capita (gpd)	Persons per Household	Total Households Serviced
Antwerp WWTP	330,000	125	2.5	1,736
Rockford STP	250,000	125	2.5	1,119

Tables 9 and 10 illustrate how WQT may be a more desirable tool for compliance at smaller facilities compared to major treatment plants. Trading may therefore serve as an interim compliance option for small communities in the process of financing wastewater treatment plant upgrades/retrofits, or as a long-term compliance alternative to upgrades. While this calculation is speculative, it attempts to illustrate the burden smaller communities face, and justify why these communities may desire trading.

7.0 Summary, Conclusions, and Future Considerations

This memo assessed the near-term potential demand and demand for water quality trading in the WLEB. Demand for WQT credits is currently considered to be very limited among point sources in Ohio, Indiana, and Michigan. Both Indiana and Michigan agency representatives indicated trading was either unlikely to occur or unnecessary given the lack of Basin-wide standards and current compliance with permit effluent limits. Based on conversations with OEPA staff, Ohio presents the most likely opportunity for WQT in the near to mid-term, specifically for select minor facilities representing a significant load to the WLEB. Wide-spread point source demand may materialize for Ohio permittees through the implementation of TMDLs or new, more stringent nutrient standards.[28] Similar changes in Indiana and Michigan may spur point source credit demand in the remaining U.S. jurisdictions of the WLEB. Other drivers for WQT demand may exist through voluntary interests (e.g., stewardship credits) of with regulation of urban stormwater discharges (either driven by MS4 permit limits or local policy), and growth (as both might increase stormwater or WWTP loading). Industrial WWTP dischargers could potentially be interested in WQT, however, facility-specific data would be needed to more fully identify these opportunities.

Credit supply in the WLEB is ample given the vast coverage of agriculture in the landscape coupled with the relatively low demand for trading in the near-term. Supply would be expected to remain sufficient even under new, stricter point source effluent limits and/or application of other drivers.

For long-term considerations, a WLEB trading program must consider the confounding dynamics between particulate and soluble phosphorus as well as associated removal efficiencies of various BMPs that may be applied on the landscape. Nutrient placement, while perhaps not the most cost-effective BMP, may hold the highest potential for widespread adoption in the Basin. This may be important as an estimated 60% of farmers in the WLEB broadcast apply phosphorus[29] leaving a relatively high percentage of

[28] The July 2016 OEPA report, *Ohio 2016 Integrated Water Quality Monitoring and Assessment Report* discusses draft changes to Ohio's 303(d) list of impaired waters. The report is accessed online at: http://wwwapp.epa.state.oh.us/dsw/2016IR.pdf

[29] Fisher, M. 2015. Subsoil phosphorus loss: A complex problem with no easy solution. American Society of Agronomy, Vol. 60 (2): 4-9.

vulnerable lands exposed to subsurface losses of DRP. High DRP removal efficiency relative to other BMPs suggests nutrient placement as a viable BMP in the short and long-term. Cost-savings associated with WQT mechanisms to engage farmers would likely lower the costs of BMP implementation compared to NRCS payment schedules in the basin.

Two potential opportunities from this analysis illustrate the potential for a multi-jurisdictional trade between Ohio minor municipal WWTPs and Indiana farmers. Antwerp WWTP and Rockford STP examples, both in the western portion of the Maumee basin in Ohio, could experience cost-savings with WQT if OEPA were to apply TP limits of 1 mg/L in their current NPDES permits. It is uncertain whether OEPA will move forward with more stringent effluent limits at these facilities. If not, there is the possibility to discuss early crediting with later compliance application. Credits from Indiana agriculture would be upstream of Antwerp and downstream of Rockford in such trades. Local impairment of surface waters, particularly for Rockford might require agricultural credits to be generated upstream of this plant. The same constraint might not apply for Antwerp. Other minor facilities in the WLEB may also be potential candidates for pilot trading, though each such opportunity will need to be examined more closely regarding multi-jurisdictional trading options.

Attachment 1: Ohio Major Permittees[30]

Permit No.	Permit Name	Flow (MGD)				TP Concentration (mg/L)				2015 TP Load (lbs/yr)
		Minimum	Maximum	50th Percentile	Average	Minimum	Maximum	50th Percentile	Average	
2PB00029	Pandora WWTP	0.070	1.400	0.500	0.712	1.410	4.030	2.050	2.385	5,162
2PA00050	Arlington WWTP	0.118	0.250	0.140	0.145	0.710	3.140	1.895	1.990	876
2PC00006	Crestline WWTP	0.368	2.369	0.703	0.890	0.120	2.070	1.130	1.157	3,129
2IH00021	Campbell Soup Supply Co LLC	1.200	5.200	3.700	3.579	0.230	2.470	1.060	1.082	11,771
2PB00053	Bloomville WWTP	0.020	0.960	0.054	0.085	0.720	1.450	1.015	1.067	277
2PB00025	Swanton WWTP	0.179	2.222	0.450	0.578	0.090	2.560	0.790	0.989	1,737
2PD00029	Delphos WWTP	0.000	1.280	0.810	0.784	0.140	5.160	0.740	0.863	2,054
2PD00013	Defiance WWTP	1.257	14.306	2.330	3.290	0.157	3.870	0.540	0.835	8,349
2PD00017	Archbold WWTP	0.471	6.054	1.365	1.408	0.210	2.950	0.570	0.761	3,257
2PD00037	City of Bellevue WWTP	0.598	4.750	0.999	1.138	0.200	2.600	0.550	0.691	2,390
2PD00005	Willard WPCP	0.835	7.716	1.452	2.119	0.390	1.220	0.650	0.682	4,392
2PD00008	Findlay WPCF	5.759	35.550	8.825	11.540	0.220	1.050	0.700	0.680	23,842
2PD00000	Napoleon WWTP	0.821	6.492	1.347	1.763	0.180	1.190	0.640	0.656	3,517
2PK00002	Shawnee No 2 WWTP	0.917	8.133	1.814	2.125	0.100	1.200	0.600	0.641	4,138
2PB00058	New London WWTP	0.216	1.158	0.365	0.444	0.340	1.600	0.525	0.640	865
2PD00009	Bowling Green	2.909	30.803	4.867	6.059	0.200	1.200	0.600	0.640	11,780
2PK00000	Maumee River WWTP	11.085	42.898	15.050	15.850	0.330	1.210	0.610	0.633	30,516
2IH00021	Campbell Soup Supply Co LLC	0.039	3.644	0.531	0.613	0.420	0.780	0.555	0.585	1,091
2IH00021	Campbell Soup Supply Co LLC	0.026	4.253	0.739	0.749	0.130	1.030	0.555	0.561	1,277
2PB00040	Leipsic WWTP	0.384	2.033	0.644	0.721	0.200	1.000	0.500	0.546	1,196
2PH00007	American-Bath WWTP	0.501	5.786	0.921	1.239	0.290	0.730	0.520	0.515	1,940
2PF00001	Sandusky WPC	3.500	43.800	11.400	14.060	0.200	0.900	0.500	0.486	20,758
2PG00053	Danbury Twp WWTP	0.442	3.396	0.875	1.039	0.170	1.880	0.390	0.484	1,529
2PB00037	Milan WWTP	0.074	0.481	0.126	0.144	0.270	0.870	0.430	0.465	203
2PE00000	Lima WWTP	5.000	44.900	11.410	14.820	0.140	2.020	0.405	0.463	20,835
2PD00035	Oregon WWTP	2.930	34.299	4.870	6.318	0.200	1.100	0.400	0.456	8,759
2PD00002	Perrysburg WWTP	3.433	17.114	4.710	5.400	0.190	1.010	0.460	0.451	7,400
2IH00021	Campbell Soup Supply Co LLC	0.026	6.155	1.134	1.336	0.150	0.810	0.420	0.439	1,783
2ID00015	North Star BlueScope Steel LLC	0.020	0.391	0.288	0.281	0.160	0.860	0.410	0.432	369
2PD00026	Saint Marys STP	0.929	8.027	1.722	2.269	0.060	1.160	0.350	0.430	2,964
2PD00025	Tiffin WWTP	1.565	6.630	3.250	3.349	0.150	1.120	0.390	0.428	4,359
2PF00000	Toledo Bay View Park WWTP	36.300	353.300	55.500	67.930	0.140	1.380	0.400	0.421	86,930
2PD00021	Bucyrus WWTP	1.350	7.020	2.710	3.174	0.110	1.000	0.360	0.414	3,990
2PD00039	Upper Sandusky WWTP	0.665	3.589	1.107	1.417	0.110	1.150	0.320	0.411	1,769
2IF00008	Cairo Sulfur Products	0.009	0.138	0.050	0.056	0.047	0.800	0.430	0.407	70
2PJ00004	Portage Catawba Island WWTP	0.133	2.421	0.331	0.394	0.130	1.040	0.325	0.394	471
2PD00031	Fostoria WWTP	2.416	11.250	3.714	4.494	0.140	0.940	0.335	0.383	5,233
2PD00006	Van Wert WWTP	1.441	11.186	2.432	3.243	0.110	0.800	0.350	0.366	3,612
2PD00028	Ottawa WWTP	0.569	8.405	1.096	1.596	0.060	1.220	0.230	0.365	1,772
2PB00056	Sawmill Creek WWTP	0.285	3.438	0.503	0.679	0.110	0.830	0.320	0.345	711
2PD00016	Wauseon WWTP	0.340	3.350	0.800	1.124	0.040	2.720	0.190	0.332	1,134
2PD00024	Norwalk WWTP	1.064	7.290	1.814	2.322	0.070	0.886	0.271	0.299	2,109
2PD00007	Fremont WPCF	2.006	7.280	4.164	4.178	0.080	1.280	0.205	0.295	3,746
2PD00032	Vermilion WPCF	0.144	5.767	0.860	1.087	0.060	0.650	0.265	0.285	942
2PH00006	American No 2 WWTP	0.453	3.432	0.690	0.900	0.100	0.820	0.170	0.239	655
2PD00018	Bryan WWTP	1.040	5.975	1.643	2.059	0.080	0.470	0.220	0.238	1,486
2PB00004	Monroeville WWTP	0.052	1.313	0.180	0.244	0.100	0.670	0.197	0.233	173
2PD00019	Wapakoneta WWTP	1.110	8.135	2.394	2.941	0.050	0.880	0.170	0.228	2,040
2IN00030	Pilkington North America Rossford Plt 6	0.005	0.005	0.005	0.005	0.130	0.310	0.235	0.226	3
2IJ00086	Quality Ready Mix Inc	0.007	0.007	0.007	0.007	0.225	0.225	0.225	0.225	5
2PC00001	Huron Basin WWTP	0.279	6.379	0.743	0.930	0.080	0.390	0.170	0.204	576
2PD00004	Clyde WWTP	0.675	6.098	1.484	1.665	0.070	0.630	0.155	0.188	953
2IN00030	Pilkington North America Rossford Plt 6	0.010	0.100	0.030	0.027	0.140	0.370	0.170	0.188	15
2IN00030	Pilkington North America Rossford Plt 6	0.005	0.050	0.050	0.037	0.050	0.510	0.120	0.186	21
2IN00030	Pilkington North America Rossford Plt 6	0.009	0.068	0.017	0.021	0.090	0.320	0.140	0.154	10
2PD00014	Port Clinton WWTP	0.749	25.398	1.479	2.191	0.010	0.770	0.120	0.143	953
2PC00005	Bluffton WWTP	0.348	7.900	0.609	0.792	0.048	0.330	0.100	0.119	287
2ID00014	Worthington Steel Co	0.042	0.281	0.149	0.151	0.040	0.120	0.060	0.060	28

[30] Data obtained through personal communications with Gary Stuhlfauth (Ohio EPA) in 2016.

Attachment 2: Indiana Major Permittees[31]

NPDES Permit Number	Facility Name	Parameter Description	Average Concentration (mg/L)	Average Daily Flow (MGD)
IN0000507	BF GOODRICH TIRE MANUFACTURING	Phosphorus, total (as P)	0.552	0.698
IN0000566	AUBURN GEAR INC	Phosphorus, total (as P)	0.140	0.436
IN0000591	BUNGE NORTH AMERICA (EAST), LLC	Phosphorus, total (as P)	3.868	0.578
IN0000868	RIEKE PACKAGING SYSTEMS	Phosphorus, total (as P)	0.070	0.466
IN0020664	AVILLA MUNICIPAL WWTP	Phosphorus, total (as P)	0.425	0.277
IN0020672	AUBURN WATER POLLUTION CONTROL FACILITY	Phosphorus, total (as P)	0.492	2.820
IN0020672	AUBURN WATER POLLUTION CONTROL FACILITY	Phosphorus, total (as P)	0.587	0.020
IN0020711	WATERLOO MUNICIPAL WWTP	Phosphorus, total (as P)	0.417	0.227
IN0022462	BUTLER MUNICIPAL WWTP	Phosphorus, total (as P)	0.314	0.381
IN0022462	BUTLER MUNICIPAL WWTP	Phosphorus, total (as P)	0.567	1.041
IN0022969	GARRETT WWTP	Phosphorus, total (as P)	0.483	0.748
IN0032191	WATER POLLUTION CONTROL PLANT	Phosphorus, total (as P)		0.000
IN0032191	WATER POLLUTION CONTROL PLANT	Phosphorus, total (as P)	0.483	49.632
IN0039314	DECATUR MUNICIPAL WWTP	Phosphorus, total (as P)	0.525	2.823
IN0050822	HAMILTON LAKE TREATMENT PLANT	Phosphorus, total (as P)	0.487	0.152
IN0059021	STEEL DYNAMICS INC-FLAT ROLL DIV	Phosphorus, total (as P)		
IN0061263	METAL TECHNOLOGIES AUBURN LLC	Phosphorus, total (as P)	0.032	
IN0063703	KREAGER PARK BOUNDLESS PLAYGROUND	Phosphorus, total (as P)		

[31] Facility information obtained from personal communications with Paul Novack and Jeff Ewick (IDEM) in 2016.

Attachment 3: Annual Costs for Increased Chemical Additions to Major Ohio Facilities *(total costs assume treatment as $0.34/lb TP)*[32]

Permit #	Permit Name	Average Flow (MGD)	Average Concetration (mg/L)	Pounds of P Treated per year	Total Cost for Additional Treatment
2PB00029	Pandora WWTP	0.712	2.385	5,170	$ 1,758
2PA00050	Arlington WWTP	0.145	1.990	877	$ 298
2PC00006	Crestline WWTP	0.890	1.157	3,134	$ 1,065
2IH00021	Campbell Soup Supply Co LLC	3.579	1.082	11,788	$ 4,008
2PB00053	Bloomville WWTP	0.085	1.067	277	$ 94
2PB00025	Swanton WWTP	0.578	0.989	1,739	$ 591
2PD00029	Delphos WWTP	0.784	0.863	2,057	$ 700
2PD00013	Defiance WWTP	3.290	0.835	8,362	$ 2,843
2PD00017	Archbold WWTP	1.408	0.761	3,262	$ 1,109
2PD00037	City of Bellevue WWTP	1.138	0.691	2,394	$ 814
2PD00005	Willard WPCP	2.119	0.682	4,398	$ 1,495
2PD00008	Findlay WPCF	11.540	0.680	23,877	$ 8,118
2PD00000	Napoleon WWTP	1.763	0.656	3,522	$ 1,198
2PK00002	Shawnee No 2 WWTP	2.125	0.641	4,145	$ 1,409
2PB00058	New London WWTP	0.444	0.640	866	$ 294
2PD00009	Bowling Green	6.059	0.640	11,797	$ 4,011
2PK00000	Maumee River WWTP	15.850	0.633	30,561	$ 10,391
2IH00021	Campbell Soup Supply Co LLC	0.613	0.585	1,092	$ 371
2IH00021	Campbell Soup Supply Co LLC	0.749	0.561	1,279	$ 435
2PB00040	Leipsic WWTP	0.721	0.546	1,198	$ 407
2PH00007	American-Bath WWTP	1.239	0.515	1,942	$ 660
2PF00001	Sandusky WPC	14.060	0.486	20,788	$ 7,068
2PG00053	Danbury Twp WWTP	1.039	0.484	1,531	$ 520
2PB00037	Milan WWTP	0.144	0.465	203	$ 69
2PE00000	Lima WWTP	14.820	0.463	20,865	$ 7,094
2PD00035	Oregon WWTP	6.318	0.456	8,772	$ 2,982
2PD00002	Perrysburg WWTP	5.400	0.451	7,410	$ 2,520
2IH00021	Campbell Soup Supply Co LLC	1.336	0.439	1,786	$ 607
2ID00015	North Star BlueScope Steel LLC	0.281	0.432	369	$ 125
2PD00026	Saint Marys STP	2.269	0.430	2,968	$ 1,009
2PD00025	Tiffin WWTP	3.349	0.428	4,365	$ 1,484
2PF00000	Toledo Bay View Park WWTP	67.930	0.421	87,057	$ 29,599
2PD00021	Bucyrus WWTP	3.174	0.414	3,996	$ 1,359
2PD00039	Upper Sandusky WWTP	1.417	0.411	1,771	$ 602
2IF00008	Cairo Sulfur Products	0.056	0.407	70	$ 24
2PJ00004	Portage Catawba Island WWTP	0.394	0.394	472	$ 161
2PD00031	Fostoria WWTP	4.494	0.383	5,241	$ 1,782
2PD00006	Van Wert WWTP	3.243	0.366	3,617	$ 1,230
2PD00028	Ottawa WWTP	1.596	0.365	1,775	$ 603
2PB00056	Sawmill Creek WWTP	0.679	0.345	712	$ 242
2PD00016	Wauseon WWTP	1.124	0.332	1,136	$ 386
2PD00024	Norwalk WWTP	2.322	0.299	2,112	$ 718
2PD00007	Fremont WPCF	4.178	0.295	3,752	$ 1,276
2PD00032	Vermilion WPCF	1.087	0.285	943	$ 321
2PH00006	American No 2 WWTP	0.900	0.239	656	$ 223
2PD00018	Bryan WWTP	2.059	0.238	1,489	$ 506
2PB00004	Monroeville WWTP	0.244	0.233	173	$ 59
2PD00019	Wapakoneta WWTP	2.941	0.228	2,043	$ 695
2IN00030	Pilkington North America Rossford	0.005	0.226	3	$ 1
2IJ00086	Quality Ready Mix Inc	0.007	0.225	5	$ 2
2PC00001	Huron Basin WWTP	0.930	0.204	577	$ 196
2PD00004	Clyde WWTP	1.665	0.188	954	$ 324
2IN00030	Pilkington North America Rossford	0.027	0.188	15	$ 5
2IN00030	Pilkington North America Rossford	0.037	0.186	21	$ 7
2IN00030	Pilkington North America Rossford	0.021	0.154	10	$ 3
2PD00014	Port Clinton WWTP	2.191	0.143	954	$ 325
2PC00005	Bluffton WWTP	0.792	0.119	288	$ 98
2ID00014	Worthington Steel Co	0.151	0.060	28	$ 9

[32] Facility data obtained from Gary Stuhlfauth and cost estimates derived from Tetra Tech. 2013. Cost Estimate of Phosphorus Removal at Wastewater Treatment Plants: A Technical Support Document prepared for Ohio Environmental Protection Agency by Tetra Tech.