Water Data to Answer Urgent Water Policy Questions:

Monitoring design, available data, and filling data gaps for determining the effectiveness of agricultural management practices for reducing tributary nutrient loads to Lake Erie

Addendum
describing new, expanded, and planned monitoring sites

A report published by
The Northeast-Midwest Institute in collaboration with the U.S. Geological Survey

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Citation

Betanzo, E.A., Choquette, A.F., and Hayes, L., 2015, Water data to answer urgent water policy questions: Monitoring design, available data and filling data gaps for determining the effectiveness of agricultural management practices for reducing tributary nutrient loads to Lake Erie, Addendum describing new, expanded, and planned monitoring sites, Northeast-Midwest Institute Report, 27 p., http://www.nemw.org/.

Funding

This work was made possible by a grant from the U. S. Geological Survey.

ISBN: 978-0-9864448-1-4

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Acknowledgements

We thank the following individuals for providing information on existing, new, and planned water-quality and agricultural management programs and activities in the Lake Erie drainage basin, and(or) for reviewing the manuscript:

Cathy Alexander, Ohio Environmental Protection Agency
Dick Bartz, U.S. Geological Survey
Maitreyee Bera, U.S. Geological Survey
Elaine Brown, Michigan Department of Agriculture and Rural Development
Paul Buszka, U.S. Geological Survey
Allegra Cangelosi, The Northeast-Midwest Institute
Jeffrey Frey, U.S. Geological Survey
Ralph Haefner, U.S. Geological Survey
Kirk Hines, Ohio Department of Natural Resources
Chi-Hua Huang, U.S. Department of Agriculture
Laura Johnson, Heidelberg University
Matt Komiskey, U.S. Geological Survey
Katie Merriman-Hoehne, U.S. Geological Survey
Jim Morris, U.S. Geological Survey
Gary Rowe, U.S. Geological Survey
Stephen Shine, Michigan Department of Agriculture and Rural Development
Michael Woodside, U.S. Geological Survey
Paul Youngstrum, U.S. Department of Agriculture

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1.1 Introduction

This Addendum describes new, expanded, and planned water monitoring sites in the Lake Erie drainage basin that were initiated subsequent to the preparation of Betanzo et al. (2015), the primary report with which this Addendum is associated. In addition to the new water monitoring sites, new programs have been initiated that focus on expansion of agricultural management practices to reduce nutrient transport to Lake Erie and facilitate data sharing between researchers involved with agricultural management and water-quality monitoring. This Addendum evaluates the applicability of these new monitoring sites and programs for answering the case-study policy question explored in Betanzo et al. (2015), "How effective are agricultural management practices at reducing nutrients from nonpoint sources at the watershed scale in the Lake Erie drainage basin?" The water monitoring data needs for answering the case-study policy question identified in Table 18 of Betanzo et al. (2015) were used to identify relevant monitoring sites in this Addendum, specifically focusing on total phosphorus (TP), dissolved reactive phosphorus (DRP)[1], and streamflow data (the complete list of parameters needed appears in Table 3 of Betanzo et al. (2015)). The new information summarized in this Addendum consists of water monitoring and agricultural management activities conducted by agencies and organizations whose data were compiled in the nutrient data set described in Betanzo et al. (2015), and programs identified in public news releases. Although this information is considered to be comprehensive and complete as of February 2015, there may be other new or planned water monitoring programs, of which we are not aware, that are not included here.

1.2 New, expanded, and planned small watershed monitoring

The monitoring sites shown in Figure 1, an update of Figure 21 from Betanzo et al. (2015), include existing, new, expanded, and planned small watershed monitoring sites that meet, or nearly meet the monitoring criteria identified in Table 18 of Betanzo et al. (2015). Chapter 5 of Betanzo et al. (2015) describes the rationale for each of these criteria. A minimum of 6 small watershed monitoring sites that provide spatial coverage of the Lake Erie drainage basin and represent a variety of watershed characteristics are needed to answer the case-study policy question. Table 1 summarizes the existing, new, expanded, and planned small watershed monitoring sites.

Increased sampling frequency is planned at site H (Old Woman Creek at Berlin Road); Heidelberg University, which monitored this site during 1987-1990, will re-initiate daily plus storm sampling for TP and DRP at this site in 2015, in addition to the long-term DRP monitoring conducted by the National Oceanic and Atmospheric Administration (NOAA) National Estuarine Research Reserve System (NERRS) at this site (Laura Johnson, Heidelberg University, written commun., 2015; National Oceanic and Atmospheric Administration, 2015). The U.S. Geological Survey (USGS) will continue to maintain the streamgage at site H. Heidelberg University also will re-initiate daily and storm monitoring of TP and DRP at site Y (Old Woman Creek at US Highway 6, monitored previously during 1987-1990), which is also monitored for DRP by NOAA NERRS (National Oceanic and Atmospheric Administration, 2015). Site Y, which is downstream of site H, is not co-located at an existing streamgage. Bidirectional flows occur at this site due to its close proximity to Lake Erie.

Sites I-M are a group of 5 monitoring sites that are part of the U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS) Upper Cedar Creek Conservation Effects Assessment Project (CEAP) in the St. Joseph watershed; this monitoring program also includes 8 additional edge-of-field monitoring sites

[1] DRP is the dissolved, reactive portion of TP that most directly stimulates algal growth, also referred to as bioavailable phosphorus or soluble reactive phosphorus, and is frequently measured in stream samples as dissolved orthophosphate.

nearby (U.S. Department of Agriculture, 2015). The data reviewed for these sites in Betanzo et al. (2015) included inconsistent sampling during the winter months over the years of record, so these monitoring sites did not meet the minimum sampling frequency criteria in that report (12 monthly plus 12 supplemental samples per year). New information indicates that the USDA ARS initiated weekly grab samples during winter months at sites I-M in 2007 (Chi-Hua Huang, U.S. Department of Agriculture-Agricultural Research Service, written commun., 2015). Data through 2009 are available for these monitoring sites through the Water Quality Portal.

Sites N through V are new monitoring sites maintained by the Ohio Environmental Protection Agency (OH EPA) with streamgages maintained by the USGS. These sites will be sampled monthly and two automatic samplers will be rotated among sites O (Little Flatrock Creek), P (West Creek), and two larger watershed monitoring sites to monitor high-flow events during the spring, starting in April of 2015 (Ohio Environmental Protection Agency, 2015; Cathy Alexander, Ohio Environmental Protection Agency, written commun., 2015). These sampling strategies, without dedicated, fixed-location auto-samplers at each site, lack sufficient supplemental high-flow monitoring to meet the minimum sampling frequency identified in Table 18 of Betanzo et al. (2015) (12 monthly plus 12 supplemental samples per year). Water monitoring is funded at these sites for 3 years and the collected water data will be entered in the U.S. Environmental Protection Agency's (USEPA) STOrage and RETreival (STORET) data system (Cathy Alexander, Ohio Environmental Protection Agency, oral commun., 2015).

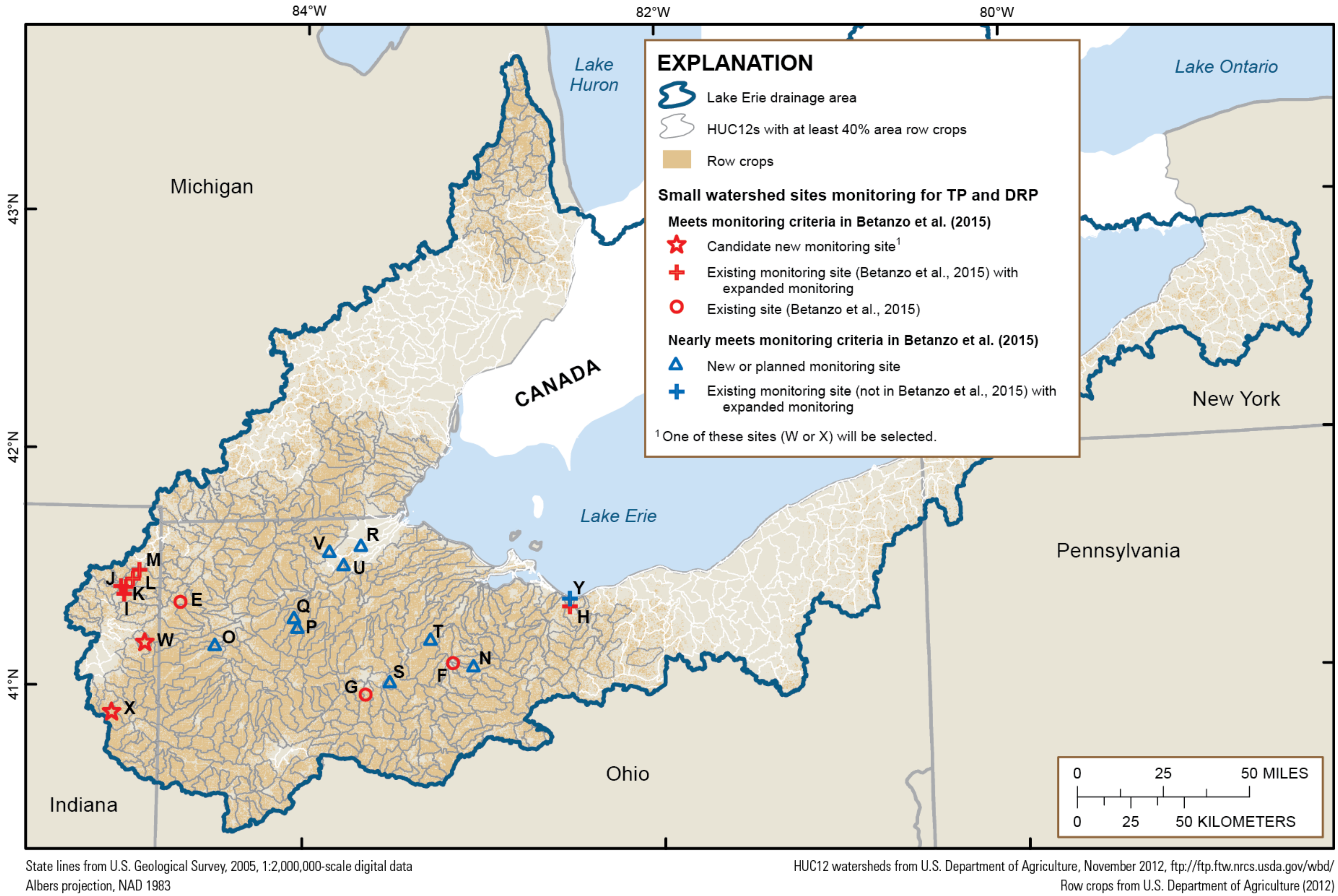


Figure 1. Locations of existing, new, expanded and planned water-monitoring sites with monthly or more frequent monitoring for total phosphorus (TP) and dissolved reactive phosphorus (DRP) in watersheds smaller than approximately 50 square miles in areas of row-crop land use, as of February 2015. Site labels are defined in Table 1.
[Abbreviations: HUC, hydrologic unit code; %, percent]

Table 1. Existing, new, expanded, or planned water-monitoring sites with monthly or more frequent monitoring for total phosphorus and dissolved reactive phosphorus in watersheds smaller than approximately 50 square miles in areas of row-crop land use that meet, or nearly meet, all monitoring criteria for detecting water-quality change resulting from agricultural management practices, as of February 2015. This table includes additions or updates to the sites summarized in Table 19 in Betanzo et al. (2015). The map reference letters correspond to the sites shown in Figures 1, 2, 4, and 5.

[**Abbreviations:** mi^2, square miles; %, percent; TP, total phosphorus; DRP, dissolved reactive phosphorus; HUC, Hydrologic Unit Code; NERRS, National Estuarine Research Reserve System; OH, Ohio; Ohio EPA, Ohio Environmental Protection Agency; USGS, U.S. Geological Survey; USDA, U.S. Department of Agriculture; ARS, Agricultural Research Service; n/a, not applicable]

Map reference letter	Monitoring site identification number	Monitoring organization	Site name	Basin area (mi^2)	Row crop area (% of basin)	Water-quality parameter	Years of record (TP and DRP)	Sampling frequency
Meets all monitoring criteria identified in Table 18 of Betanzo et al., 2015								
E (existing)	ohUSGS:04185440 04185440[1]	Heidelberg University [Flow: USGS]	Unnamed Tributary to Lost Creek near Farmer, OH	4.23	78%	TP, DRP, streamgage	5-10	Daily plus storm
F (existing)	ohUSGS:04197170 04197170[1]	Heidelberg University [Flow: USGS]	Rock Creek at Tiffin, OH	34.6	73%	TP, DRP, streamgage	>20	Daily plus storm
G (existing)	04188496	USGS	Eagle Creek above Findlay, OH	51.0	79%	TP, DRP, streamgage	<5	Monthly plus supplemental; continuous turbidity
H (expanded)	ohBR, owcbr; 04199155[1]	Heidelberg University [NERRS, Ohio EPA] [Flow: USGS]	Old Woman Creek at Berlin Road near Huron, OH	22.1	70%	TP, DRP, streamgage	(5-10+, historical)[2]	Daily plus storm
I (expanded)	inINSJ-INSJBLG	USDA-ARS	Tile-fed drainage ditch 2.5 mi SSE of Waterloo, IN	5.47	83%	TP and DRP, streamflow	5-10[3]	Daily plus storm Apr-Nov Weekly Dec-Mar[4]
J (expanded)	inINSJ-INSJCLG	USDA-ARS	Tile-fed drainage ditch 1.4 mi SE of Waterloo, IN	5.33	73%	TP and DRP, streamflow	5-10[3]	Daily plus storm Apr-Nov Weekly Dec-Mar[4]
K (expanded)	inINSJ-INSJAXL	USDA-ARS	Tile-fed drainage ditch 1.4 mi SE of Waterloo, IN	16.6	78%	TP and DRP, streamflow	5-10[3]	Daily plus storm Apr-Nov Weekly Dec-Mar[4]
L (expanded)	inINSJ-INSJALG	USDA-ARS	Tile-fed drainage ditch 3.5 mi ENE of Waterloo, IN	7.47	77%	TP and DRP, streamflow	5-10[3]	Daily plus storm Apr-Nov Weekly Dec-Mar[4]
M (expanded)	inINSJ-INSJAME	USDA-ARS	Tile-fed drainage ditch 6.3 mi ENE of Waterloo, IN	1.15	79%	TP and DRP, streamflow	5-10[3]	Daily plus storm Apr-Nov Weekly Dec-Mar[4]
W[5] (candidate)	HUC12: 041000050104[6]	USGS	Black Creek, IN	19.2	52%	TP, DRP, streamgage	n/a	Monthly plus supplemental
X[5] (candidate)	HUC12: 041000040503[6]	USGS	Nickelsen Creek, IN	25.8	80%	TP, DRP, streamgage	n/a	Monthly plus supplemental

Map reference letter	Monitoring site identification number	Monitoring organization	Site name	Basin area (mi^2)	Row crop area (% of basin)	Water-quality parameter	Years of record (TP and DRP)	Sampling frequency
Nearly meets all monitoring criteria identified in Table 18 of Betanzo et al., 2015								
N (new)	oepa_U04G18 04197152[1]	Ohio EPA [Flow: USGS]	Rock Creek near Republic, OH	15.2	69%	TP, DRP, streamgage	n/a	Monthly
O (new)	oepa_302837 04191444[1]	Ohio EPA [Flow: USGS]	Little Flatrock Creek near Junction, OH	15.3	88%	TP, DRP, streamgage	n/a	Monthly plus periodic supplemental[7]
P (new)	oepa_P10K07 04192574[1]	Ohio EPA [Flow: USGS]	West Creek near Hamler, OH	15.5	89%	TP, DRP, streamgage	n/a	Monthly plus periodic supplemental[7]
Q (new)	oepa_P09S09 04192583[1]	Ohio EPA [Flow: USGS]	Lost Creek near Elery, OH	20.6	88%	TP, DRP, streamgage	n/a	Monthly
R (new)	oepa_P11P18 04193999[1]	Ohio EPA [Flow: USGS]	Wolf Creek at Holland, OH (near Toledo)	24.8	37%	TP, DRP, streamgage	n/a	Monthly
S (new)	oepa_302838 04188399[1]	Ohio EPA [Flow: USGS]	The Outlet above Findlay, OH	36.5	79%	TP, DRP, streamgage	n/a	Monthly
T (new)	oepa_302839 04197277[1]	Ohio EPA [Flow: USGS]	Wolf Creek near Kansas, OH	42.7	78%	TP, DRP, streamgage	n/a	Monthly
U (new)	oepa_P11W13 04193997[1]	Ohio EPA [Flow: USGS]	Blue Creek near Whitehouse, OH	44.6	49%	TP, DRP, streamgage	n/a	Monthly
V (new)	oepa_P11W15 04193994[1]	Ohio EPA [Flow: USGS]	Ai Creek near Swanton, OH	44.7	64%	TP, DRP, streamgage	n/a	Monthly
Y (expanded)	ohWM, owcwm: ohUSGS:04199165	Heidelberg Univ. [NERRS, Ohio EPA] [no flow gage]	Old Woman Creek at US Highway 6 at Huron, OH (near estuary)	26.5	51%	TP, DRP	(2-10+, historical)	Daily plus storm

[1] USGS streamgage identification number.
[2] TP sampling by Ohio EPA and Heidelberg University has started and stopped multiple times over the data record at this site.
[3] 2009 was the most recent year of water-quality data available at the time of publication.
[4] Weekly grab samples were initiated in 2007 for December through March (Chi-Hua Huang, U.S. Department of Agriculture Agricultural Research Service, written commun., 2015).
[5] One of the watersheds, W or X, will be selected for monitoring as part of the Great Lakes Restoration Initiative-USGS cooperative program (Matthew Komiskey, U.S. Geological Survey, written commun., 2015).
[6] Specific site location has not yet been identified; information for this site refers to the watershed defined by the HUC12 boundaries.
[7] Two automatic samplers for collecting supplemental samples will be rotated between sites O, P, and two additional monitoring sites in larger watersheds (Ohio Environmental Protection Agency, 2015).

The USGS is planning to start new edge-of-field and watershed-scale monitoring in May 2015 at either site W (Black Creek) or X (Nickelsen Creek) in Indiana as part of the Great Lakes Restoration Initiative (GLRI) Priority Watersheds (U.S. Environmental Protection Agency, 2015); the final site will be selected in April, 2015 (Jeffrey Frey, U.S. Geological Survey, written commun., 2015). Monitoring involves the establishment of edge-of-field and subsurface tile monitoring sites on fields that will receive conservation practices that could beneficially affect concentrations of nonpoint-source water-quality constituents; a complimentary tributary monitoring site will measure watershed-scale changes that result from new application of management practices at the field scale (Paul Buszka, U.S. Geological Survey, written commun., 2015). The sampling plan for this monitoring project meets the criteria identified in Table 18 of Betanzo et al. (2015), and monitoring at the selected site is planned for 5 to 10 years (Matthew Komiskey, U.S. Geological Survey, written commun., 2015); streamflow and water-quality data will be available online in the National Water Information System (U.S. Geological Survey, 2015).

The USDA ARS Soil Drainage Research Unit (Columbus, Ohio) has established, as of August 2014, some edge-of-field research sites in the western Lake Erie drainage basin to quantify the hydrologic and water-quality impacts of various conservation and crop-management practices. These sites are located in Crawford, Defiance, Henry, Paulding, Seneca, and Wood Counties in northwestern Ohio (Norman R. Fausey, U.S. Department of Agriculture, written commun., 2014); the locations and sampling records for these edge-of-field monitoring sites and any related watershed-scale monitoring sites were unavailable at the time of publication.

Figure 2 superimposes the highest contributing areas for each of the 6 priority watershed characteristics, as described and defined in section 4.5 of Betanzo et al. (2015) on one map with the locations of all the small-watershed monitoring sites from Figure 1. The 6 priority characteristics are:

- Soil-runoff vulnerability,
- Soil-leaching vulnerability,
- High TP yield from fertilizer, estimated using the SPAtially Referenced Regressions On Watershed attributes model (SPARROW),
- High TP yield from manure, estimated using SPARROW,
- High TP yield, estimated using the Soil and Water Assessment Tool (SWAT), and
- High DRP yield, estimated using SWAT.

Table 2 lists the priority characteristics in each watershed. As shown in Figure 2, site X is located in an area with multiple priority watershed characteristics. In comparison, sites N-V and site W monitor watersheds with fewer priority characteristics. Of the sites described in Table 1 and Table 2, sites E, F, H-M and X meet the sampling frequency criteria and are located in watersheds exhibiting one or more priority watershed characteristics. As described in Betanzo et al. (2015), water monitoring at site E (Unnamed tributary to Lost Creek) and site F (Rock Creek) meets the monitoring criteria presented in Table 18 of Betanzo et al. (2015). Site G (Eagle Creek) meets the sampling frequency criteria, but it is located in a watershed that does not include any of the priority watershed characteristics related to phosphorus sources and transport to streams. Site G is part of the same GLRI Priority Watersheds program as sites W and X described above.

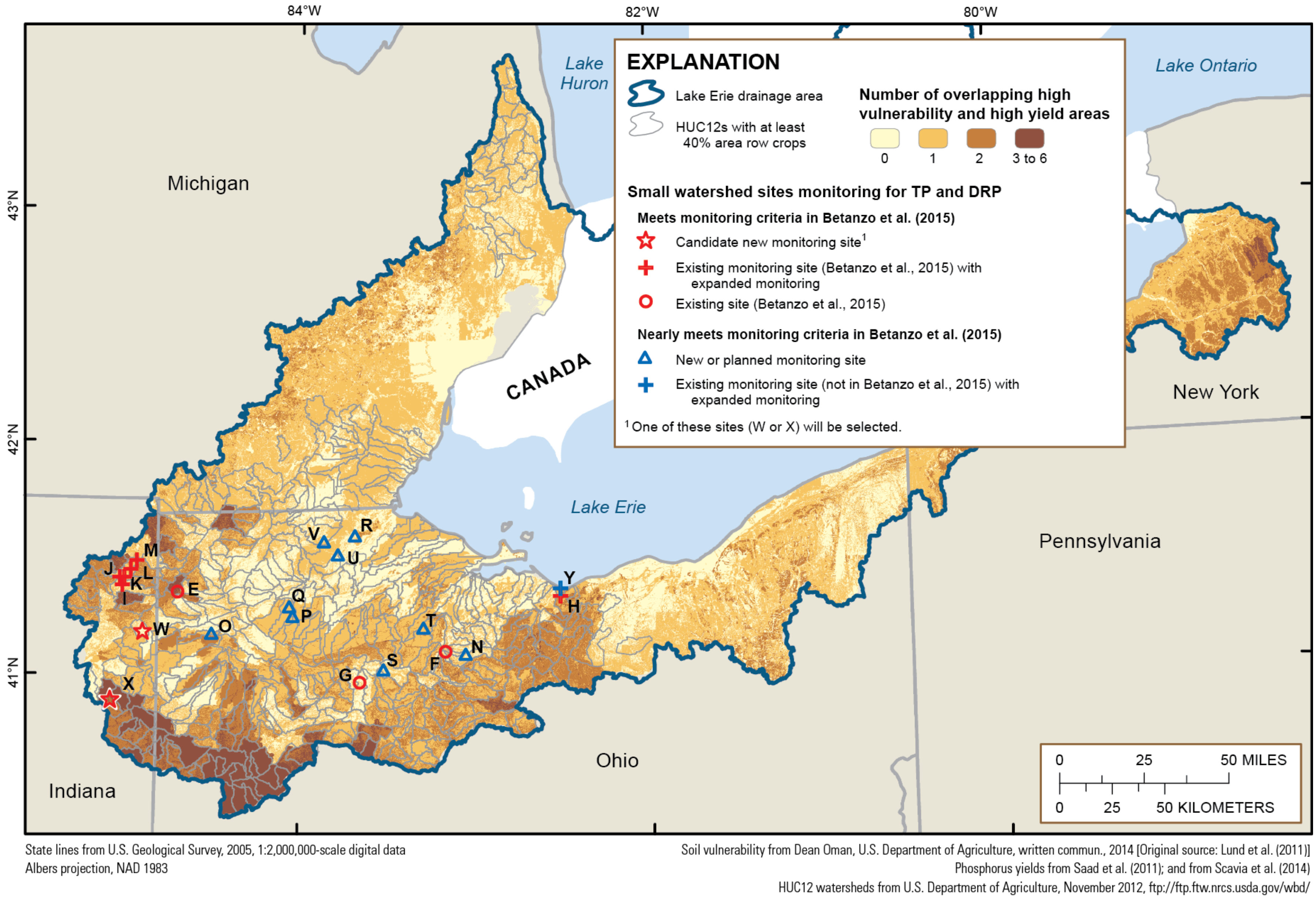


Figure 2. Spatial distribution of watershed characteristics related to phosphorus sources and transport to streams (Betanzo et al., 2015), showing existing, new, expanded and planned total phosphorus (TP) and dissolved reactive phosphorus (DRP) monitoring sites in watersheds smaller than approximately 50 square miles, as of February 2015. Site labels are defined in Table 1.

Table 2. Summary of total phosphorus and dissolved reactive phosphorus monitoring and priority watershed characteristics for small watershed monitoring sites. Map reference labels refer to sites shown in Figures 1, 2, 4, and 5.
[Abbreviations: SWAT, Soil and Water Assessment Tool; SPARROW, SPAtially Referenced Regressions On Watershed attributes]

Map reference label	Short site name	Monitoring criteria	Priority watershed characteristics
E (existing)	Unnamed Tributary to Lost Creek, OH	Meets all monitoring criteria	• High TP yield as modeled by SWAT • High DRP yield as modeled by SWAT • High vulnerability to soil runoff
F (existing)	Rock Creek, OH	Meets all monitoring criteria	• High vulnerability to soil runoff
G (existing)	Eagle Creek, OH	Meets all monitoring criteria	• Watershed does not have substantial priority characteristics
H (expanded)	Old Woman Creek at Berlin Road, OH	Meets all monitoring criteria	• High TP fertilizer yield as modeled by SPARROW • High vulnerability to soil leaching or soil runoff
I-K (expanded)	Drainage ditches in Waterloo, IN	Meets all monitoring criteria	• High vulnerability to soil runoff
L-M (expanded)	Drainage ditches in Waterloo, IN	Meets all monitoring criteria	• High vulnerability to soil runoff • High vulnerability to soil leaching
N (new)	Rock Creek near Republic, OH	Lacks consistent supplemental monitoring	• High vulnerability to soil runoff
O (new)	Little Flatrock Creek, OH	Lacks consistent supplemental monitoring	• High TP fertilizer yield as modeled by SPARROW • High DRP yield as modeled by SWAT
P (new)	West Creek, OH	Lacks consistent supplemental monitoring	• High TP fertilizer yield as modeled by SPARROW
Q (new)	Lost Creek near Elery, OH	Lacks consistent supplemental monitoring	• High TP fertilizer yield as modeled by SPARROW
R (new)	Wolf Creek, OH	Lacks consistent supplemental monitoring	• High vulnerability to soil leaching
S (new)	The Outlet, OH	Lacks consistent supplemental monitoring	• High vulnerability to soil runoff
T (new)	Wolf Creek, OH	Lacks consistent supplemental monitoring	• High TP fertilizer yield as modeled by SPARROW
U (new)	Blue Creek, OH	Lacks consistent supplemental monitoring	• High vulnerability to soil leaching
V (new)	Ai Creek, OH	Lacks consistent supplemental monitoring	• High vulnerability to soil leaching
W[1] (candidate)	Black Creek, IN	Meets all monitoring criteria	• Watershed does not have substantial priority characteristics
X[1] (candidate)	Nickelsen Creek, IN	Meets all monitoring criteria	• High TP manure yield as modeled by SPARROW • High TP fertilizer yield as modeled by SPARROW
Y (expanded)	Old Woman Creek at US Highway 6, OH	Does not meet streamflow monitoring requirements	• High TP fertilizer yield as modeled by SPARROW • High vulnerability to soil leaching or soil runoff

[1] One of these two sites (W or X) will be selected for monitoring in 2015 as part of the Great Lakes Restoration Initiative-USGS program.

1.3 New, expanded, and planned medium and large watershed monitoring

New and expanded monitoring sites in medium and large watersheds (exceeding 50 square miles) in the Lake Erie drainage basin, shown in Figure 3, have the potential to support nested-scale monitoring designs and inform nutrient transport mechanisms from small upstream watersheds to Lake Erie. These monitoring sites are described in Table 3. The planned duration of monitoring varies at these sites. For example, sites 8-10 in Table 3 are currently funded for only 1 year of monitoring; sites with short monitoring duration will be of limited value for informing the case-study policy question.

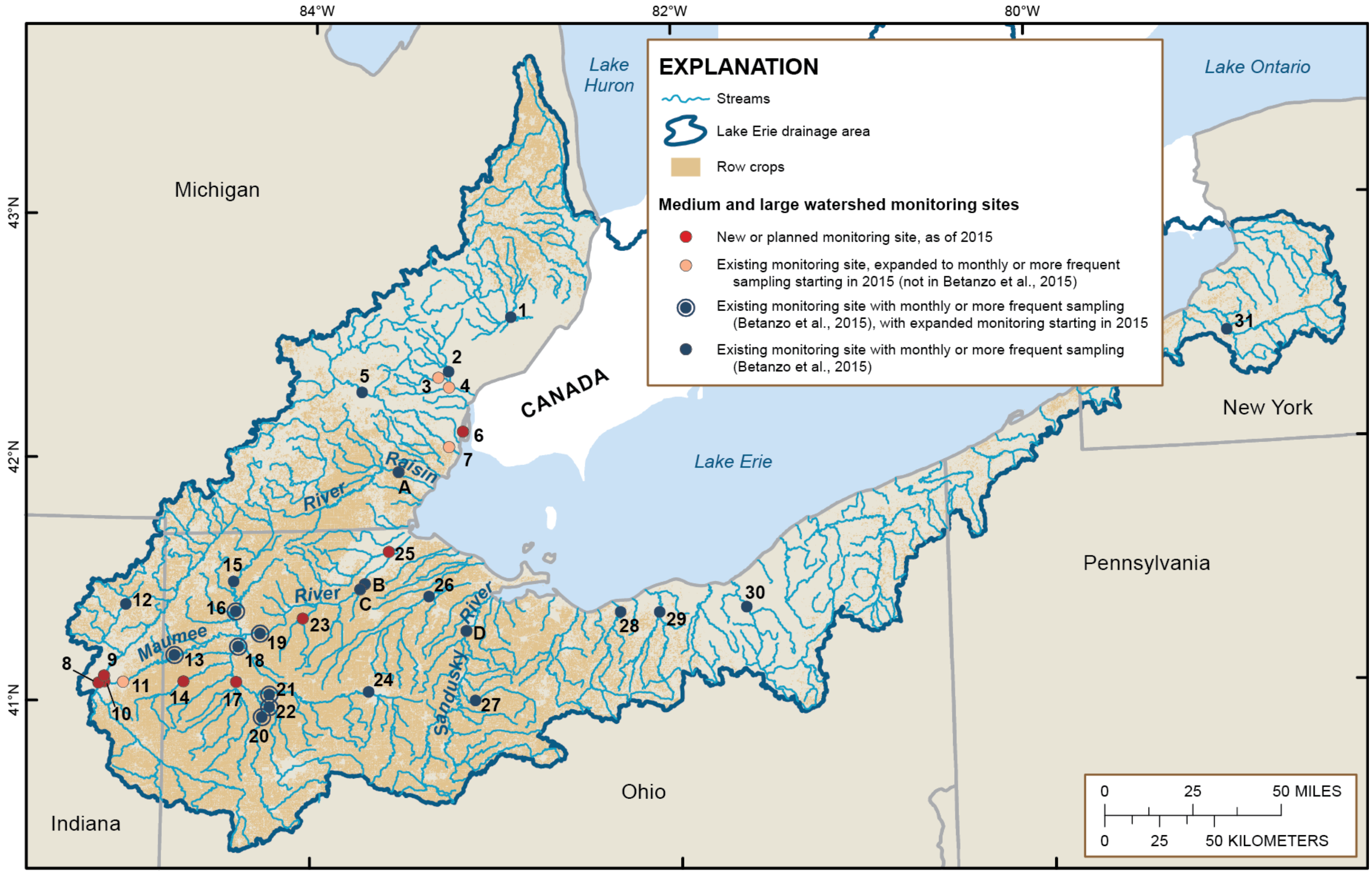
Table 3. Summary of existing, new, expanded, and planned water-monitoring sites with streamflow and monthly or more frequent monitoring for total phosphorus and dissolved reactive phosphorus in watersheds larger than 50 square miles, as of February 2015.

[**Abbreviations:** mi^2, square miles; USDA, U.S. Department of Agriculture; ARS, Agricultural Research Service; USGS, US Geological Survey; IDEM, Indiana Department of Environmental Management]

Map reference label	Site number	Site name	Basin area (mi^2)	Water-quality monitoring organization	Streamflow monitoring organization
A (existing)	miUSGS:04176500	River Raisin near Monroe, MI	1,043	Heidelberg University; USGS	USGS
B (existing)	ohUSGS:04193500	Maumee River at Waterville, OH	6,330	USGS	USGS
C (existing)	ohUSGS:04193490 [streamgage:04193500]	Maumee River near Waterville, OH	6,313	Heidelberg University	USGS
D (existing)	ohUSGS:04198000	Sandusky River near Fremont, OH	1,252	Heidelberg University	USGS
1 (existing)	04165500	Clinton River at Moravian Drive at Mt. Clemens, MI	734	USGS	USGS
2 (existing)	04166500	River Rouge at Detroit, MI	187	USGS	USGS
3 (expanded)	04167000[1]	Middle River Rouge near Garden City, MI	99.9	USGS	USGS
4 (expanded)	04168400[1]	Lower River Rouge at Dearborn, MI	91.0	USGS	USGS
5 (existing)	04174500	Huron River at Ann Arbor, MI	729	USGS	USGS
6 (new)	04168640[1]	Detroit River at Trenton, MI	>220,400	Environment Canada; USGS[2]	USGS
7 (expanded)	04175120[1]	Huron River at Rockwood, MI	851	USGS	USGS
8 (new)	04182769[1]	St. Marys River at Main St. at Fort Wayne, IN	823	USGS	USGS
9 (new)	04180610[1] [streamgage: 04180500]	St. Joseph River at Parnell Ave. at Fort Wayne, IN	1,094	USGS	USGS
10 (new)	04182867[1] [streamgage: 04182900]	Maumee River at Tecumseh Street at Fort Wayne, IN	1,926	USGS	USGS
11 (existing)	04183000[1]	Maumee River at New Haven, IN	1,967	IDEM	USGS
12 (existing)	INSJF34	Cedar Cr., 3.1 km S of Waterloo, IN	74.7	USDA-Agricultural Research Service	USDA
13 (expanded)	04183500	Maumee River at Antwerp, OH	2,129	USGS	USGS

Map reference label	Site number	Site name	Basin area (mi^2)	Water-quality monitoring organization	Streamflow monitoring organization
14 (new)	oepa_P06S35[1] [streamgage: 04191378]	Flatrock Creek near Payne, OH	144	Ohio EPA	USGS
15 (existing)	ohUSGS:04185000	Tiffin River at Stryker, OH	410	Heidelberg University	USGS
16 (expanded)	04185318	Tiffin River nr Evansport, OH	563	USGS	USGS
17 (new)	04191058[1]	Little Auglaize River at Melrose, OH	401	USGS	USGS
18 (expanded)	04191500	Auglaize River at Defiance, OH	2,318	USGS	USGS
19 (expanded)	04192500	Maumee River nr Defiance, OH	5,545	USGS	USGS
20 (expanded)	04186500	Auglaize River near Ft Jennings, OH	332	USGS	USGS
21 (expanded)	04190000	Blanchard River nr Dupont, OH	756	USGS	USGS
22 (expanded)	04188100	Ottawa River nr Kalida, OH	350	USGS	USGS
23 (new)	oepa_302836[1] [streamgage:04192599]	S. Turkeyfoot Creek near Shunk, OH	116	Ohio EPA	USGS
24 (existing)	ohUSGS:04189000	Blanchard River near Findlay, OH	346	Heidelberg University	USGS
25 (new)	04194002[1]	Swan Creek at Champion Street at Toledo, OH	201	USGS	USGS
26 (existing)	ohUSGS:04195500	Portage R. near Woodville, OH	428	Heidelberg University	USGS
27 (existing)	ohUSGS:04197100	Honey Creek at Melmore OH	119[3]	Heidelberg University	USGS
28 (existing)	04199500	Vermilion River near Vermilion, OH	262	USGS	USGS
29 (existing)	04200500	Black River at Elyria OH	396	USGS	USGS
30 (existing)	ohUSGS:04208000	Cuyahoga River at Independence OH	707	Heidelberg University	USGS
31 (existing)	04213500	Cattaraugus Creek at Gowanda, NY	436	USGS	USGS

[1] Site previously did not qualify as monthly or greater in Betanzo et al. (2015); new or expanded monitoring has increased the sampling frequency to monthly or greater.
[2] Environment Canada operates an automatic sampler (at fixed point in the river channel); USGS collects periodic, cross-sectional samples (width and depth integrated across channel) for comparability at this large river site.
[3] Water-quality site is located upstream from the streamgage which has a drainage area of 149 mi^2.



State lines from U.S. Geological Survey, 2005, 1:2,000,000-scale digital data
Streams from U.S. Geological Survey, 2012, 1:1,000,000-scale digital data
Albers projection, NAD 1983

HUC12 watersheds from U.S. Department of Agriculture, November 2012, ftp://ftp.ftw.nrcs.usda.gov/wbd/
Row crops from U.S. Department of Agriculture (2012)

Figure 3. Locations of existing, new, expanded, and planned water-monitoring sites with streamflow and monthly or more frequent monitoring for total phosphorus and dissolved reactive phosphorus in watersheds larger than 50 square miles, as of February 2015. Site labels are defined in Table 3.

1.4 Additional small watershed data needed to answer the case-study policy question

Section 9.1 of Betanzo et al. (2015) identified the study design and water data needed to answer the case-study policy question, and section 9.2 concluded that additional small watershed data are needed for answering the case-study policy question. A minimum of 6 small watershed monitoring sites with the described study design are needed in the Lake Erie drainage basin to answer the case-study policy question. Betanzo et al. (2015) found that this need could be met through continued monitoring at sites E and F, increased sampling frequency at site H and one of sites I-M, and at least two additional monitoring sites. Monitoring to answer the case-study policy question should continue for a minimum of 10 years during implementation of new agricultural management practices, and the use of agricultural management practices for reducing nutrient transport should be maximized in monitored watersheds. This section reviews these small watershed monitoring recommendations in consideration of the new and expanded monitoring and suggests a path forward using these sites to acquire the information needed to answer the case-study policy question.

As shown in Table 2, expanded monitoring at sites H-M will fill the need for increased sampling frequency at two monitoring sites. The close proximity of sites I-M do not provide sufficient spatial representation for these sites to account for more than one of the six needed monitoring sites. Planned monitoring at site W or X will fill the need for one additional monitoring site. Planned monitoring at sites N-V does not include enough supplemental sampling and would need to be modified to use these sites to answer the case-study policy question. Planned monitoring at site Y is subject to limitations. This site does not have a streamgage, bidirectional flow occurs at this site due to its proximity to Lake Erie, and the area between site H and site Y is primarily a wetland preserve. For these reasons, site Y is not a priority site for monitoring the effectiveness of agricultural management practices and was excluded from the rest of the tables in this Addendum.

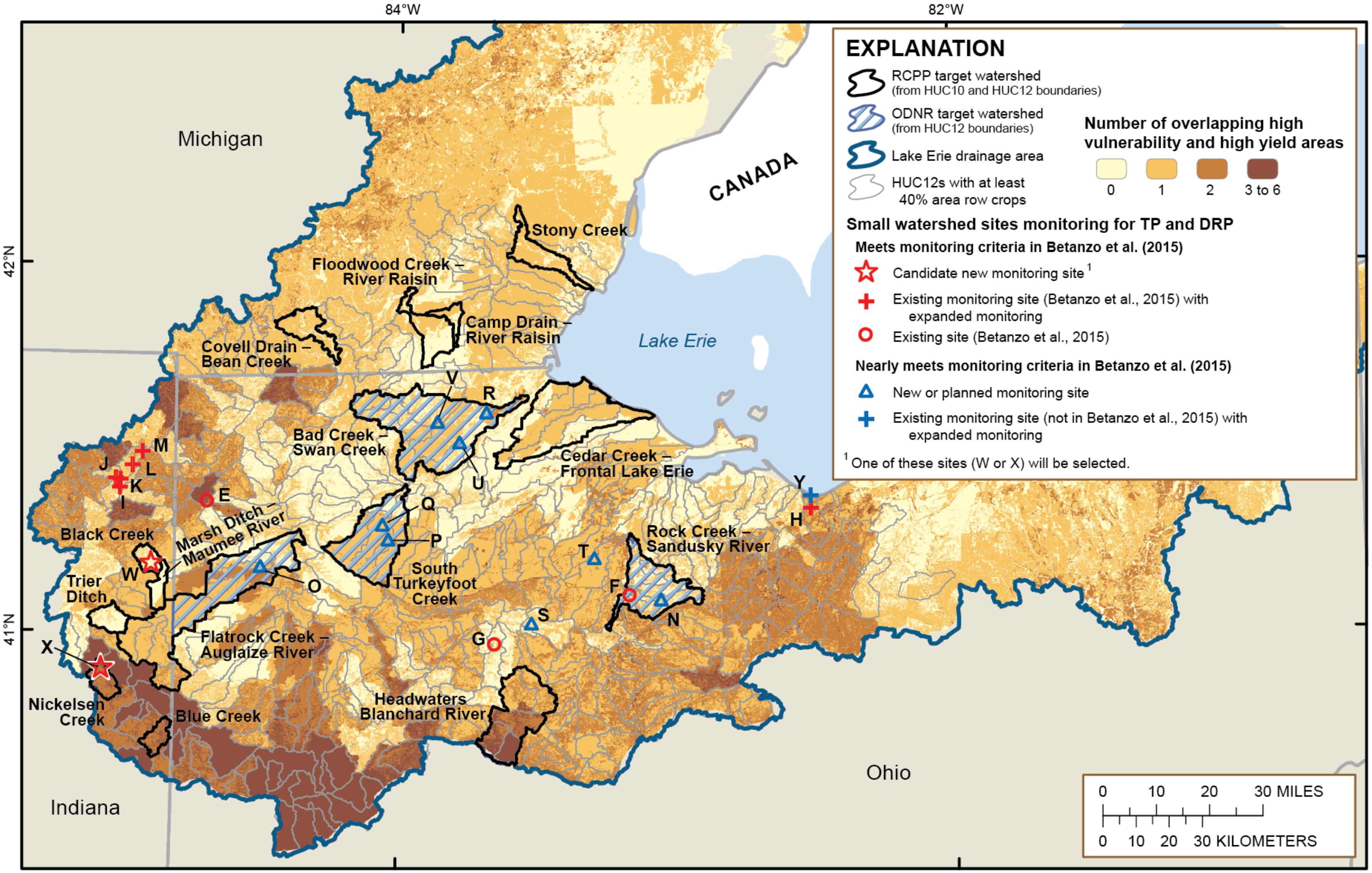
In addition to new monitoring sites, new conservation practice incentive programs are planned in the Lake Erie drainage basin and several of these areas align with new monitoring sites. The GLRI Priority Watershed monitoring program includes agricultural management practice incentives within the watersheds that are monitored for this program (site G, and candidate sites W and X). The USDA-ARS Cedar Creek CEAP project also includes incentives as part of the monitoring program at sites I-M. Figure 4 shows areas targeted for incentive programs by the Ohio Department of Natural Resources (ODNR) (Kirk Hines, Ohio Department of Natural Resources, written commun., 2015) and the USDA Natural Resources Conservation Services Regional Conservation Partnership Plan (NRCS RCPP) (Shine, 2015) and the small watershed monitoring sites discussed in this Addendum. While there is overlap between many of these new incentive areas and existing and planned water monitoring sites (sites F, N-R, U-X), there are some incentive areas without any planned monitoring (Stony Creek, Floodwood Creek-River Raisin, Covell Drain-Bean Creek, Camp Drain-River Raisin, Cedar Creek-Frontal Lake Erie, Trier Ditch, Blue Creek, Marsh Ditch-Maumee River, and Headwaters- Blanchard River) and some monitoring sites that are not located in incentive areas (sites E, H, S, and T).

In another new development, the USGS has recently developed a Memorandum of Understanding (MOU) with NRCS to share conservation practice implementation data with the USGS to support water-quality data analysis (Katherine Merriman-Hoehne, U.S. Geological Survey and Paul Youngstrum, U.S. Department of Agriculture Natural Resources Conservation Service, written commun., 2015). Figure 5 shows the portion of the western Lake Erie drainage basin that is included in the MOU and the locations of existing, expanded, new, and planned small watershed monitoring sites. This MOU is limited to sharing NRCS data with USGS and focuses on conservation practice implementation data from 2004 to 2014. Updates to this agreement would be needed to share data collected through the new NRCS RCPP program. The specific implementation details of these incentive programs and the MOU are still under development.

Table 21 in Betanzo et al. (2015) presented a process for identifying new monitoring sites to answer the case-study policy question. This process includes identifying sites located in watersheds with priority characteristics and sites with existing data, identifying opportunities for nested-scale monitoring designs, and then reviewing each site case-by-case looking at local information regarding tile drainage, the potential for implementing new management practices, and participation of the local agricultural community. The sites presented here were evaluated using regionally available datasets; further evaluation considering local information, including availability of agricultural management practice implementation information, would be needed to identify the most effective monitoring sites for answering the case-study policy question. Table 4 summarizes whether each monitoring site meets the sampling frequency criteria, the number of priority characteristics within the watershed of each monitoring site, years of existing data at the monitoring site, location relative to new conservation incentive programs, and whether the monitored watershed is part of the USGS-NRCS data-sharing MOU. Table 4 shows that few sites have each of these factors in place and consequently there are advantages and disadvantages to most of the monitoring sites described in this Addendum.

Table 5 shows the representation of the six priority watershed characteristics within the small watersheds monitored by existing, new, and planned monitoring sites within the Lake Erie drainage basin. Table 5 indicates that high TP yield from manure estimated using SPARROW (Robertson and Saad, 2011; U.S. Geological Survey, 2013) and high TP yield estimated using SWAT (Scavia et al., 2014) are not well represented among the available monitoring sites. Further, as shown in Figure 4, important areas in the southwest portion of the drainage basin in Ohio where spatial overlaps of three or more priority watershed characteristics occur, including high TP yields from fertilizer and manure estimated using both SPARROW and SWAT, and high vulnerability to soil runoff, do not have any existing or planned monitoring sites. These high priority areas may respond to agricultural management practices sooner than other less vulnerable areas of the western Lake Erie drainage basin, and produce detectable reductions in nutrient loads in a shorter amount of time. Consequently, these areas are good candidates for additional monitoring sites.

Table 6 summarizes the water monitoring data needs, agricultural management practices and ancillary data needs for each small watershed monitoring site described in this Addendum for any individual site to achieve the study design to answer the question “How effective are agricultural management practices at reducing nutrients from nonpoint sources at the watershed scale in the Lake Erie drainage basin?” based on the criteria presented in Betanzo et al. (2015). This table summarizes conservation practice incentive programs and implementation data sharing needs based on the information obtained at the time this Addendum was prepared (Shine, 2015; Kirk Hines, Ohio Department of Natural Resources, written commun., 2015; Paul Youngstrum, U.S. Department of Agriculture, written commun., 2015); there may be additional incentive programs and data sharing mechanisms in place that are not included here.



State lines from U.S. Geological Survey, 2005, 1:2,000,000-scale digital data
Albers projection, NAD 1983

Soil vulnerability from Dean Oman, U.S. Department of Agriculture, written commun., 2014 [Original source: Lund et al. (2011)]
Phosphorus yields from Saad et al. (2011); and from Scavia et al. (2014)
HUC10 and HUC12 watersheds from U.S. Department of Agriculture, November 2012, ftp://ftp.ftw.nrcs.usda.gov/wbd/

Figure 4. Locations of areas planned to be targeted by new conservation incentive programs, showing existing, new, expanded, and planned total phosphorus (TP) and dissolved reactive phosphorus (DRP) monitoring sites in watersheds smaller than approximately 50 square miles, as of February 2015. Site labels are defined in Table 1. [Abbreviations: RCPP, Tri-state Western Lake Erie Basin Regional Conservation Partnership Project (Shine, 2015); ODNR, Ohio Department of Natural Resources Ohio Clean Lake Initiative-Impaired Watershed Restoration project (Kirk Hines, Ohio Department of Natural Resources, written commun., 2015); HUC, hydrologic unit code]

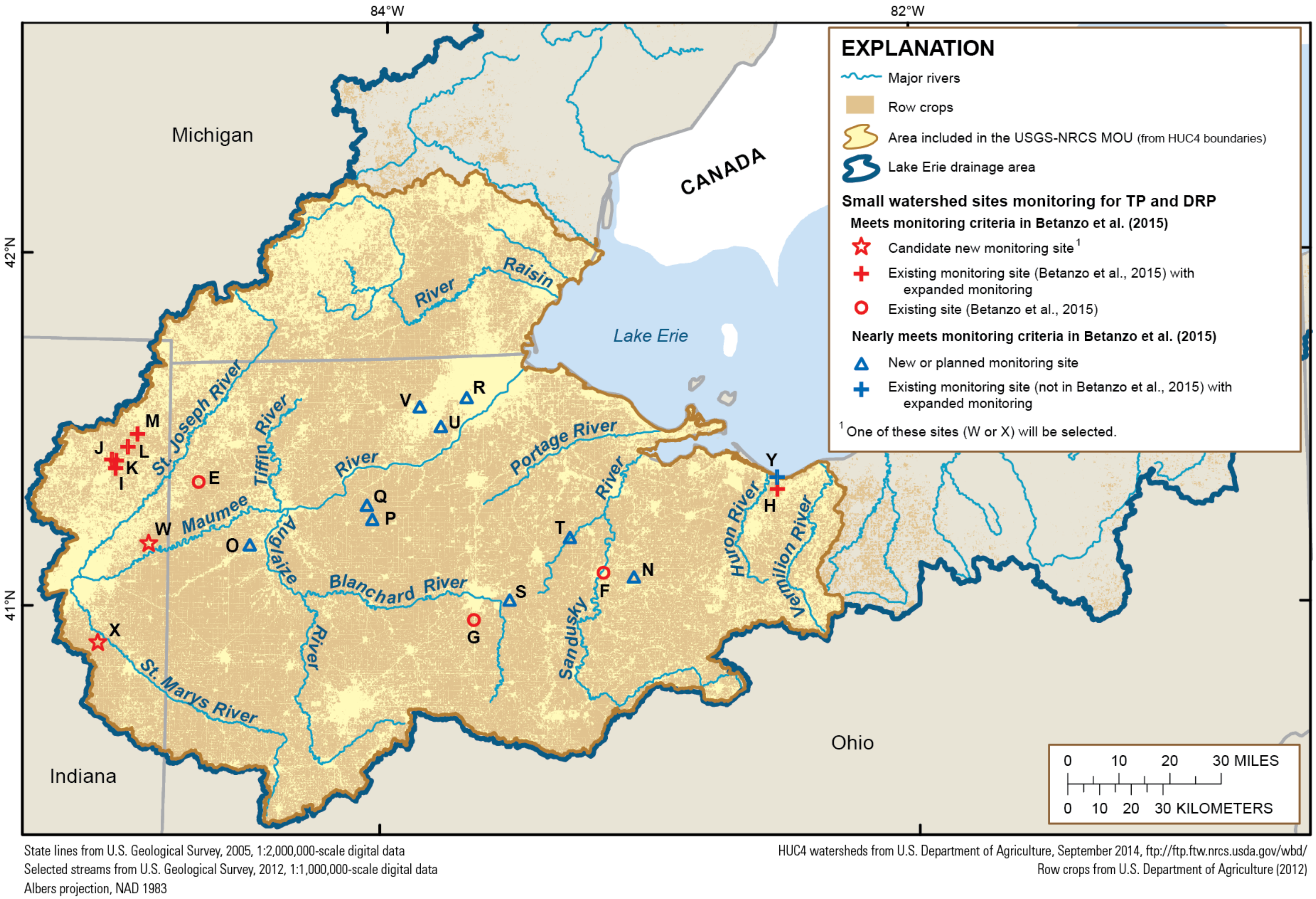


Figure 5. Location of the area covered by the U.S. Geological Survey-Natural Resources Conservation Service (USGS-NRCS) memorandum of understanding (MOU) for sharing conservation practice implementation data showing existing, new, expanded, and planned total phosphorus (TP) and dissolved reactive phosphorus (DRP) monitoring sites in watersheds smaller than approximately 50 square miles, as of February 2015 (Paul Youngstrum, U.S. Department of Agriculture, written commun., 2015). Site labels are defined in Table 1.

[Abbreviations: HUC, Hydrologic unit code]

Table 4. Summary of existing, new, expanded, and planned small watershed monitoring sites and factors related to measuring the effectiveness of agricultural management practices. Site labels are defined in Table 1.
[**Abbreviations:** TP, total phosphorus; DRP, dissolved reactive phosphorus; USGS, U.S. Geological Survey; NRCS, Natural Resources Conservation Services; MOU, Memorandum of understanding; RCPP, Regional Conservation Partnership Plan; Ohio DNR, Ohio Department of Natural Resources; GLRI, Great Lakes Restoration Initiative; USDA-ARS, U.S. Department of Agriculture-Agricultural Research Service; n/a, not applicable]

Map reference label	Short site name	Meets sampling frequency criteria[1]	Priority characteristics (number of characteristics in the watershed)[2]	TP and DRP monitoring record (years)[3]	Agricultural management practice incentive program[4]	Watershed included in USGS-NRCS MOU[5]
E (existing)	Unnamed Tributary to Lost Creek, OH	Yes	3	5-10	No	Yes
F (existing)	Rock Creek, OH	Yes	1	>20	RCPP, Ohio DNR	Yes
G (existing)	Eagle Creek, OH	Yes	0	<5	GLRI	Yes
H (expanded)	Old Woman Creek at Berlin Road, OH	Yes	2	>10	No	Yes
I-K (existing)	Drainage ditches in Waterloo, IN	Yes	1	5-10	USDA-ARS	No[6]
L-M (existing)	Drainage ditches in Waterloo, IN	Yes	2	5-10	USDA-ARS	No[6]
N (new)	Rock Creek near Republic, OH	No	1	n/a	RCPP, Ohio DNR	Yes
O (new)	Little Flatrock Creek, OH	No	2	n/a	RCPP, Ohio DNR	Yes
P (new)	West Creek, OH	No	1	n/a	RCPP, Ohio DNR	Yes
Q (new)	Lost Creek near Elery, OH	No	1	n/a	RCPP, Ohio DNR	Yes
R (new)	Wolf Creek, OH	No	1	n/a	RCPP, Ohio DNR	Yes
S (new)	The Outlet, OH	No	1	n/a	No	Yes
T (new)	Wolf Creek, OH	No	1	n/a	No	Yes
U (new)	Blue Creek, OH	No	1	n/a	RCPP, Ohio DNR	Yes
V (new)	Ai Creek, OH	No	1	n/a	RCPP, Ohio DNR	Yes
W (candidate[7])	Black Creek, IN	Yes	0	n/a	RCPP, GLRI	Yes
X (candidate[7])	Nickelsen Creek, IN	Yes	2	n/a	RCPP, GLRI	Yes

[1] As identified in Table 18 of Betanzo et al. (2015).
[2] As identified in Table 2 of this Addendum.
[3] As identified in Table 1 of this Addendum.
[4] On the basis of information provided by Shine (2015), Kirk Hines (Ohio Department of Natural Resources, written commun., 2015), or research studies (U.S. Department of Agriculture, 2015; Matthew Komiskey, U.S. Geological Survey, written commun., 2015).
[5] Watersheds identified in Paul Youngstrum (U.S. Department of Agriculture, written commun., 2015).
[6] USDA-ARS research is not included in the scope of the USGS-NRCS MOU (Paul Youngstrum, U.S. Department of Agriculture, written commun., 2015).
[7] One of the watersheds, W or X, will be selected for monitoring as part of the Great Lakes Restoration Initiative-USGS cooperative program (Matthew Komiskey, U.S. Geological Survey, written commun., 2015).

Table 5. Representation of priority watershed characteristics within watersheds monitored by existing, new, expanded, and planned monitoring sites in the Lake Erie drainage basin. The priority watershed characteristics are described and defined in Betanzo et al. (2015) section 4.5. Site labels are defined in Table 1. Solid cells indicate the characteristic covers 40-percent or more of the entire watershed; diagonal-hatched cells indicate that two characteristics combined cover 40-percent or more of the entire watershed but do not overlap with each other.

[**Abbreviations**: TP, total phosphorus; SPARROW, SPAtially Referenced Regressions On Watershed attributes; SWAT, Soil and Water Assessment Tool; DRP, dissolved reactive phosphorus]

Priority watershed characteristics	Existing, new, and planned monitoring sites (site reference label)																
	E	F	G	H	I-K	L-M	N	O	P	Q	R	S	T	U	V	W	X
High TP Yield fertilizer; SPARROW				■				■	■	■			■				■
High TP Yield manure; SPARROW																	■
High TP Yield; SWAT	■																
High DRP Yield; SWAT	■							■									
High vulnerability to soil runoff	■	■		▨	■	■	■					■					
High vulnerability to soil leaching				▨		■					■			■	■		

Table 6. Summary of water monitoring data, agricultural management practices, and ancillary data needed for each existing, new, expanded, or planned small-watershed monitoring site to answer the case-study policy question "How effective are agricultural management practices at reducing nutrients from nonpoint sources at the watershed scale in the Lake Erie drainage basin?" based on criteria presented in Betanzo et al. (2015) and information summarized in Table 4. Site labels are defined in Table 1.

[Abbreviations: MOU, Memorandum of understanding between the U.S. Geological Survey and the U.S. Department of Agriculture Natural Resources Conservation Service]

Map reference label	Short site name	Water monitoring data	Agricultural management practices	Ancillary data[1]
E	Unnamed Tributary to Lost Creek, OH	Continue monitoring for minimum of 10 years	Identify and implement mechanisms to increase agricultural management practices in this watershed	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection
F	Rock Creek, OH	Continue monitoring for minimum of 10 years	Prioritize incentive program implementation in this watershed	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection
G	Eagle Creek, OH	Continue monitoring for minimum of 10 years	Continue as planned and increase implementation as feasible	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection
H	Old Woman Creek at Berlin Road, OH	Maintain increased sampling frequency and continue monitoring for minimum of 10 years	Identify and implement mechanisms to increase agricultural management practices in this watershed	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection
I-M	Drainage ditches in Waterloo, IN	Maintain increased sampling frequency and continue monitoring for minimum of 10 years	Continue as planned and increase implementation as feasible	Secure an agreement for sharing agricultural management practice implementation data
N	Rock Creek near Republic, OH	Increase sampling frequency and plan for a minimum of 10 years of monitoring	Prioritize incentive program implementation in this watershed	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection
O	Little Flatrock Creek, OH	Increase sampling frequency and plan for a minimum of 10 years of monitoring	Prioritize incentive program implementation in this watershed	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection
P	West Creek, OH	Increase sampling frequency and plan for a minimum of 10 years of monitoring	Prioritize incentive program implementation in this watershed	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection

Map reference label	Short site name	Water monitoring data	Agricultural management practices	Ancillary data[1]
Q	Lost Creek near Elery, OH	Increase sampling frequency and plan for a minimum of 10 years of monitoring	Prioritize incentive program implementation in this watershed	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection
R	Wolf Creek, OH	Increase sampling frequency and plan for a minimum of 10 years of monitoring	Prioritize incentive program implementation in this watershed	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection
S	The Outlet, OH	Increase sampling frequency and plan for a minimum of 10 years of monitoring	Identify and implement mechanisms to increase agricultural management practices in this watershed	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection
T	Wolf Creek, OH	Increase sampling frequency and plan for a minimum of 10 years of monitoring	Identify and implement mechanisms to increase agricultural management practices in this watershed	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection
U	Blue Creek, OH	Increase sampling frequency and plan for a minimum of 10 years of monitoring	Prioritize incentive program implementation in this watershed	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection
V	Ai Creek, OH	Increase sampling frequency and plan for a minimum of 10 years of monitoring	Prioritize incentive program implementation in this watershed	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection
W	Black Creek, IN	Monitor as planned for minimum of 10 years	Prioritize incentive program implementation in this watershed	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection
X	Nickelsen Creek, IN	Monitor as planned for minimum of 10 years	Prioritize incentive program implementation in this watershed	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection
Additional Site	Add one additional monitoring site in southwest area of Lake Erie drainage basin in Ohio	Implement sampling plan identified in Table 18 of Betanzo et al. (2015)	Identify and implement mechanisms to increase agricultural management practices in this watershed	Use the existing MOU to share implementation data for water-quality data analysis and extend it to cover future data collection

[1]Ancillary data needs include (1) detailed agricultural management practice implementation and maintenance data and (2) detailed data on other nutrient sources, other changes on the land, and climate data within the monitored watershed. This column only addresses item (1); site by site investigation of item (2) was beyond the scope of this study.

Water-quality sampling frequencies, locations of conservation practice incentive programs, and data sharing agreements can be modified for an individual watershed, but the presence of watershed characteristics that contribute to nutrient transport and the availability of a multi-year monitoring record are essentially fixed in the short-term. Priority watershed characteristics and data record should be the primary considerations when selecting sites to implement the study design for answering the case-study policy question. The monitoring site descriptions presented in Table 4 and the study design needs for each monitoring site in Table 6 should be evaluated by water monitoring, agriculture, and conservation agencies to identify the most suitable and cost-effective sites for increased investment. Six monitoring sites should be considered the minimum number of small watershed sites; additional monitoring sites that implement the study design elements described in Table 6 will add to the understanding of agricultural management practice effectiveness in a variety of agricultural, soil, and land-use conditions.

1.5 Conclusions

The overall information needs for answering the case-study policy question identified in Betanzo et al. (2015) do not change significantly in light of new and planned water monitoring in the Lake Erie drainage basin. Of the new, planned, and existing monitoring sites, only sites F (Rock Creek, OH) and X (Nickelsen Creek, IN) have the monitoring design, conservation practice incentive program, and data sharing agreement in place to answer the case-study policy question. Sites G (Eagle Creek, OH) and W (Black Creek, IN) have the needed sampling frequency, incentive program, and data sharing agreement in place, but are located in watersheds without priority characteristics; these sites are valuable because they have the appropriate study design in place or planned. However, priority areas identified in Figure 4 that lack monitoring sites may offer even more effective locations to implement this study design.

The following recommendations, which build on the recommendations outlined in Chapter 9 of Betanzo et al. (2015), summarize the next steps to collect the information needed to answer "How effective are management practices at reducing nutrients from nonpoint sources at the watershed scale?"

Additional water data needed to answer the case-study policy question:

- Select a minimum of 6 monitoring sites for implementing and maintaining the study design needed to answer the case-study policy question (minimum monitoring period of 10 years during implementation and maintenance of new agricultural management practices and sharing of agricultural management practice implementation and ancillary data).
    - Maintain existing and enhanced water-quality and streamflow monitoring at sites E, F, H, and I-M as recommended in Betanzo et al. (2015). Identify and implement mechanisms to increase agricultural management practices and share agricultural management practice implementation data in these watersheds.
    - Select one or both of sites W and X.
    - Initiate additional small watershed monitoring sites with the needed study design in the southwest portion of the drainage basin in northwest Ohio.
    - To further increase spatial coverage across the Lake Erie drainage basin and monitor a variety of watershed characteristics, select a subset of additional small watershed monitoring sites for increased sampling frequency that includes sampling during high flows and winter months. When selecting these sites, practitioners should consider watershed characteristics and the monitoring and agricultural management factors in place (Table 4) and the modifications

needed (Table 6) for each monitoring site, as well as local information regarding tile drainage, untreated areas, and the ability to engage local agricultural communities.

- Maintain large watershed long-term water-quality and streamflow monitoring at the Raisin, Maumee, and Sandusky River sites monitored by Heidelberg University and the USGS as recommended in Betanzo et al. (2015).
- Establish a coordinating entity to ensure that existing and new water monitoring plans, water-quality data and agricultural-management-practice data sharing, and ongoing water-quality data analysis activities across the Lake Erie drainage basin are compatible, publicly available, and provide the most efficient use of available monitoring and agricultural management practice implementation resources.
    - As sites are selected for increased monitoring, water monitoring agencies should agree upon the specific forms of nutrients analyzed (phosphorus and nitrogen), including sampling and analytical methods, to support basin-wide analyses and comparison of trends between monitoring sites.

Implement agricultural management practices

- Implement conservation practice incentive programs and maximize management practice impact in monitored watersheds.

Collect ancillary data

- Implement and extend MOUs for sharing detailed agricultural management practice implementation and maintenance data between agricultural practitioners and water-quality analysts.
- Collect other ancillary data on nutrient sources, changes in land use, and climate data in both large and small monitored watersheds.

Decision-makers have an urgent need to understand the effectiveness of agricultural management practices for reducing nutrient concentrations and loads delivered to Lake Erie to inform strategies and realistic goals for reducing algal blooms and hypoxia in Lake Erie. Implementing the recommendations in this Addendum and in Betanzo et al. (2015) will provide the information needed to answer the question, "How effective are management practices at reducing nutrients from nonpoint sources at the watershed scale in the Lake Erie drainage basin?" It is vital that the agencies involved in water monitoring and agricultural management practices throughout the Lake Erie drainage basin work together to coordinate their activities and facilitate information exchange, efficiently use available funding, and share lessons learned. Data collection, data sharing, and interpretive study with adequate planning and support will provide answers to the case-study policy question and will supply information needed to guide adaptive management decisions. The new information presented in this Addendum provides an opportunity for the water monitoring and agriculture organizations to analyze current and planned programs to identify the most effective monitoring sites and supporting programs to answer this long-standing policy question of critical importance to the long-term health and vitality of Lake Erie.

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