ILLINOIS NUTRIENT LOSS REDUCTION STRATEGY

Illinois Department of Agriculture

Acknowledgements

Steering Committee
Marcia Wilhite, Illinois EPA
Amy Walkenbach, Illinois EPA
Warren Goetsch, Illinois Department of Agriculture
Dr. Brian Miller, Illinois Water Resources Center

Communication and Coordination Team
C. Eliana Brown, Illinois Water Resources Center
Corrie Layfield, Illinios Water Resources Center
Simon Daniels, Illinois EPA
Lisa Merrifield, Illinois Water Resources Center
Anjanette Riley, Illinois-Indiana Sea Grant
Carla Blue, Illinois Water Resources Center

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The contest recognizes Illinois photographers who have captured what water means to them, their communities, and the state. Photos included throughout the strategy are contest entries. They feature waterbodies in urban and rural areas from geographically diverse parts of Illinois. To see all of the entries, please visit: http://go.illinois.edu/IWRCphotocontest.

Policy Working Group
Kay Anderson, American Bottoms Regional Wastewater Treatment
Tim Bachman, Urbana-Champaign Sanitary District
Howard Brown, Illinois Council on Best Management Practices
Dr. George Czapar, University of Illinois Extension
Dr. Mark David, University of Illinois at Urbana-Champaign, Dept. of Natural Resources & Environmental Sciences
Warren Goetsch, Illinois Department of Agriculture
Kerry Goodrich, USDA-Natural Resources Conservation Service
Albert Ettinger, Attorney
Liz Hobart, Illinois Council on Best Management Practices
Dr. Stacy James, Prairie Rivers Network
Jim Kaitschuk, Illinois Pork Producers Association
Bradley Klein, Environmental Law and Policy Center
Lauren Lurkins, Illinois Farm Bureau
Rick Manner, Urbana-Champaign Sanitary District
Dr. Greg McIsaac, University of Illinois at Urbana-Champaign, Dept. of Natural Resources & Environmental Sciences
Nick Menninga, Downers Grove Sanitary District
Alec Messina, Illinois Environmental Regulatory Group
Emerson Nafziger, University of Illinois at Urbana-Champaign, Dept. of Crop Sciences
Rich Nichols, Association of Illinois Soil and Water Conservation Districts
Jean Payne, Illinois Fertilizer and Chemical Association
Dr. Gary Schnitkey, University of Illinois at Urbana-Champaign, Dept. of Agricultural and Consumer Economics
Dr. Cindy Skrukrud, Sierra Club
David St. Pierre, Metropolitan Water Reclamation District of Greater Chicago
Rod Weinzierl, Illinois Corn Growers Association
Marcia Willhite, Illinois EPA

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ILLINOIS NUTRIENT LOSS REDUCTION STRATEGY

Improving our water resources with collaboration and innovation

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Photo by Jeremy Tiemann, photo contest Honorable Mention

Executive Summary

The Illinois Nutrient Loss Reduction Strategy (Illinois NLRS or the strategy) is a framework for using science, technology, and industry experience to assess and reduce nutrient loss to Illinois waters and the Gulf of Mexico. The strategy will direct efforts to reduce nutrients from point and non-point sources in a coordinated, primarily voluntary, and cost-effective manner.

Nutrient loss and runoff is a major threat to water quality in Illinois. State and local efforts over the decades to control nutrients have yielded positive results, but new and expanded strategies are needed to secure the future health of our water throughout Illinois and the Mississippi River Basin.

The Illinois NLRS builds upon existing programs to optimize nutrient loss reduction while promoting increased collaboration, research, and innovation among the private sector, academia, non-profits, wastewater agencies, and state and local government. It does not call for new regulations for either point or non-point sources.

The plan will be introduced and implemented throughout the state with leadership from the Illinois Environmental Protection Agency, the Illinois Department of Agriculture, the Illinois NLRS Policy Working Group, and newly formed committees. Emerging science, new technology, and practical experience will continue to identify the financial benefits and costs of the strategy's recommendations and inform future policy. Success will require that stakeholders closely collaborate and acknowledge their evolving and increasing mutual dependency.

Development of the Illinois Nutrient Loss Reduction Strategy

The strategy was developed in response to the U.S. Environmental Protection Agency (U.S. EPA) 2008 Gulf Hypoxia Action Plan, which calls for each of the 12 states in the Mississippi River Basin to produce a plan to reduce the amount of phosphorus and nitrogen carried in rivers throughout the states and to the Gulf of Mexico. In 2011, U.S. EPA provided a recommended framework for state plans. Illinois' strategy follows this framework.

The Illinois NLRS was developed by a Policy Working Group that includes representatives from local, state, and federal agencies, the agricultural industry, and non-profit organizations as well as scientists, academics, and wastewater treatment professionals.

Key Strategy Components

- Extends ongoing regulatory and voluntary efforts. The strategy describes a comprehensive suite of best management practices for reducing loads from wastewater treatment plants and urban and agriculture runoff. These practices will help the state reduce its phosphorus load by 25 percent and its nitrate-nitrogen load by 15 percent by 2025. The eventual target is a 45 percent reduction in the loss of these nutrients to the Mississippi River. These actions will also assist in addressing water quality problems in Illinois rivers, lakes, and streams for the benefit of Illinois citizens.

- Identifies priority watersheds for nutrient loss reduction efforts. Recommended practices target the state's most critical watersheds and are based on the latest science and best-available technology.

- Establishes the Nutrient Monitoring Council to coordinate water quality monitoring efforts by government agencies, universities, non-profits, and industry.

- Creates the Nutrient Science Advisory Committee to develop numeric nutrient criteria for Illinois waters. This committee will evaluate all available research, data, and methodologies and recommend a credible approach.

- Identifies strategies for improving collaboration among government, non-profits, and industry. This includes formation of an Agriculture Water Quality Partnership Forum to steer outreach and education efforts to help farmers address nutrient loss and an Urban Stormwater Working Group to coordinate and improve stormwater programs and education.

- Defines a process for regular review and revision by the Policy Working Group, as well as for measuring progress and reporting to the public.

The Illinois NLRS outlines strategies that meet community and industry needs while reducing the negative impacts of nutrient loss on the environment, industry, and public health. Although many are cost-effective, some, particularly those related to point source reductions, will require significant investment.

Chapter 1
Introduction

The Illinois Nutrient Loss Reduction Strategy (Illinois NLRS or the strategy) was developed by the Illinois Environmental Protection Agency (Illinois EPA), the Illinois Department of Agriculture (IDOA), and a multi-stakeholder Policy Working Group that included federal and state agencies, industry, agriculture, wastewater treatment agencies, and non-governmental organizations. The goal of the strategy is twofold: reduce the load of nutrient pollution leaving the state by way of the Mississippi River and improve water quality for the benefit of Illinois residents.

This document mentions existing nutrient loss reduction efforts occurring across Illinois and lays out a roadmap for improving these efforts through increased watershed targeting, improved collaboration, and new initiatives. While the strategy is not a regulatory document, it does identify existing and proposed regulations that may contribute to nutrient load reductions.

The Illinois NLRS is divided into separate chapters addressing point sources, agricultural non-point sources, and urban non-point sources. The entire strategy is driven by a science assessment (chapter 3) that identifies the volume of nutrients by source and predicts source-specific reductions needed to achieve target levels. This assessment was written by scientists, economists, and natural resource experts from the University of Illinois and peer reviewed by academics in the Upper Mississippi region. The strategy also describes methods for prioritizing specific, high-nutrient load watersheds, verification measures that will be used to assess success, and plans for reporting progress and challenges to the public.

Background

Nutrient pollution is generally caused by excess nitrate-nitrogen and total phosphorus from sources ranging from wastewater treatment effluent to agricultural runoff to urban stormwater. Illinois waterways contribute a significant percentage of the nitrate-nitrogen and total phosphorus that reach the Gulf of Mexico hypoxic zone through the Mississippi River. Closer to home, these excess nutrients can also impair drinking water quality, harm aquatic life, and limit recreational opportunities by fertilizing harmful algal blooms.

The Illinois NLRS is an effort to improve water quality in Illinois and comes in response to two federal initiatives to address the Gulf of Mexico hypoxic zone: the Gulf Hypoxia Action Plan 2008 created by the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force and the U.S. Environmental Protection Agency (U.S. EPA) memorandum Recommended Elements of a State Nutrients Framework.

Strategy recommendations are based closely on the guidelines laid out in both the plan and memo, but the input of stakeholders who participated in the Policy Working Group (described below) was the shaping force of each strategy element. Many proposed solutions are both innovative and promising but will require extensive research and evaluation beyond the scope of this plan. The Illinois NLRS remains a living document with the potential to be updated and expanded as needs arise.

Gulf Hypoxia Action Plan 2008

The Gulf Hypoxia Action Plan describes a national strategy for reducing, mitigating, and controlling hypoxia in the Gulf of Mexico and improving water quality in the Mississippi River Basin. It calls for states to "complete and implement comprehensive nitrogen and phosphorus reduction strategies." The plan reaffirms goals first adopted by Mississippi River/Gulf of Mexico Watershed Nutrient Task Force in 2001.

The plan also outlines six overarching principles as guidance for reaching these goals:

- Encourage actions that are voluntary, incentive-based, practical, and cost-effective.
- Use existing programs, including state and federal regulatory mechanisms.
- Follow adaptive management strategies.
- Identify additional funding needs and sources during the annual agency budget processes.
- Identify opportunities for and potential barriers to innovative and market-based solutions.
- Provide measurable outcomes.

To achieve the three major goals of the plan, the U.S. EPA Science Advisory Board estimated that "significant reductions in nitrate-nitrogen and total phosphorus are needed. To achieve the Coastal Goal for the size of the hypoxic zone and improve water quality in the Basin, a dual nutrient strategy targeting at least a 45% reduction in riverine total nitrate-nitrogen load and in riverine total phosphorus load, measured against the average load over the 1980-1996 time period, may be necessary" (U.S. EPA, 2007). For more information on the 2008 action plan, visit water.epa.gov/type/watersheds/named/msbasin/.

Coastal Goal: Subject to the availability of additional resources, we strive to reduce or make significant progress toward reducing the five-year running average areal extent of the Gulf of Mexico hypoxic zone to less than 5,000 square kilometers by the year 2015….*

Within Basin Goal: To restore and protect the waters of the 31 States and Tribal lands within the Mississippi/Atchafalaya River Basin through implementation of nutrient and sediment reduction actions to protect public health and aquatic life as well as reduce negative impacts of water pollution on the Gulf of Mexico.

Quality of Life Goal: To improve the communities and economic conditions across the Mississippi/Atchafalaya River Basin, in particular the agriculture, fisheries and recreation sectors, through improved public and private land management and a cooperative, incentive-based approach.

*The Task Force understands the difficulty of meeting the 2015 goal so is therefore including a revision that takes into account the uncertainty of the task but attempts to maintain momentum and progress achieved to date. As such, at this time, the Task Force accepts the advice of EPA's Science Advisory Board (2008) on this topic… "The 5,000 km^2 target remains a reasonable endpoint for continued use in an adaptive management context; however, it may no longer be possible to achieve this goal by 2015…it is even more important to proceed in a directionally correct fashion to manage factors affecting hypoxia than to wait for greater precision in setting the goal for the size of the zone. Much can be learned by implementing management plans, documenting practices, and measuring their effects with appropriate monitoring programs."

–Gulf Hypoxia Action Plan 2008

U.S. EPA Memo on State Nutrients Framework

The Recommended Elements of a State Nutrients Framework memorandum was released to U.S. EPA regional offices and states in 2011 by the Assistant Administrator of Water, Nancy Stoner. Recommendations included:

- Prioritizing watersheds on a statewide basis for nitrate-nitrogen and total phosphorus loading reductions
- Setting watershed load reduction goals based on the best information available
- Ensuring the effectiveness of National Pollutant Discharge Elimination System (NPDES) point source permits in targeted or priority watersheds
- Addressing agricultural sources
- Addressing stormwater and septic system sources

- Establishing accountability and verification measures
- Conducting annual reporting of implementation activities and biannual reporting of load reductions and environmental impacts associated with each management activity in targeted watersheds
- Creating a work plan and schedule for numeric criteria development

Visit www2.epa.gov/sites/production/files/documents/memo_nitrogen_framework.pdf to read the complete memo.

Policy Working Group

Members

The Nutrient Loss Reduction Strategy Policy Working Group, convened by Illinois EPA and IDOA in March 2013, consisted of representatives from state and federal agencies, industry, universities, agriculture, wastewater treatment agencies, and non-governmental organizations (see Table 1.1 for complete membership). The group was charged with advising Illinois EPA and IDOA on:

- Scenarios for reducing nutrient losses through existing tools and programs
- Strategies for point source reductions in watersheds with high contributions of nutrients to the Mississippi River
- Implementation practices
- Approaches for prioritizing and targeting funding for implementation
- Strategies for promoting identified Best Management Practices (BMPs) in order to maximize widespread implementation throughout a priority watershed
- Accountability and verification measures, especially for non-point sources
- Annual reporting

Table 1.1. Policy Working Group members.

Member	Affiliation
Kay Anderson	American Bottoms Regional Wastewater Treatment
Tim Bachman	Urbana-Champaign Sanitary District
Howard Brown	Illinois Council on Best Management Practices
Dr. George Czapar	University of Illinois Extension
Dr. Mark David	University of Illinois at Urbana-Champaign, Department of Natural Resources and Environmental Sciences
Kerry Goodrich	U.S. Department of Agriculture, Natural Resources Conservation Service
Albert Ettinger	Attorney
Liz Hobart	Illinois Council on Best Management Practices
Dr. Stacy James	Prairie Rivers Network
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Dr. Gary Schnitkey	University of Illinois at Urbana-Champaign, Department of Agricultural and Consumer Economics
Dr. Cindy Skrukrud	Sierra Club
David St. Pierre	Metropolitan Water Reclamation District of Greater Chicago
Rod Weinzierl	Illinois Corn Growers Association
Warren Goetsch	Illinois Department of Agriculture
Marcia Willhite	Illinois Environmental Protection Agency

Subcommittees

Three subcommittees were created in December 2013 to identify source-specific nutrient reduction practices and develop central portions of the plan. The Point Source, Agricultural Non-Point Source, and Urban Non-Point Source subcommittees provided advice and feedback to state-agency-led writing teams responsible for crafting each section. Each subcommittee met at least twice during the drafting of the strategy, and drafts addressing subcommittee focus areas were released via email for member comments.

Facilitation

The Illinois Water Resources Center (IWRC) was contracted to provide facilitation to help develop the Illinois strategy. IWRC staff coordinated and conducted meetings, gathered background material, solicited and collected stakeholder feedback, and assembled the final Illinois NLRS document.

Steering Committee

The steering committee, comprised of Illinois EPA, IDOA, and IWRC staff members, was responsible for scheduling meetings, developing meeting agendas, and establishing goals for each event. State agency members of the committee were ultimately responsible for making final policy decisions for the Illinois NLRS, writing the strategy, collecting both public and Policy Working Group comments, and submitting the strategy to the directors of Illinois EPA and IDOA and U.S. EPA Region 5.

Collaborators

In addition to Policy Working Group members and the many meeting attendees who provided insight and feedback, the Illinois NLRS development process and final document greatly benefited from the efforts of many collaborators, including the:

- Illinois Department of Natural Resources
- Illinois State Water Survey
- U.S. Department of Agriculture Natural Resources Conservation Service
- U.S. Geological Survey Illinois Water Science Center
- University of Illinois

Regulatory and Administrative Framework

Clean Water Act

The Clean Water Act requires that states designate uses—aquatic life, drinking water, primary contact recreation, and fish consumption—for the waters within their jurisdictions and develop water quality standards designed to protect these designated uses (33 U.S.C. 1313 (c)). Water quality standards, which include numeric, narrative, and anti-degradation standards, are enforced through state regulatory programs and used to calculate effluent limits for permits, identify potential causes of water quality impairment, and calculate load limits for point and non-point sources contributing to impaired waters.

The law uses different tools to manage water pollution from point and non-point sources. Point sources are addressed through regulatory tools such as permits, inspections, and enforcement. Non-point sources are managed through voluntary, incentive-based programs focused on the implementation of best management practices.

Although the Clean Water Act mainly focuses on the control of water pollution close to the source, it also requires that states consider "downstream" impacts. States in the Mississippi River Basin use the national goal of minimizing the hypoxic zone in the Gulf as the basis for controlling nutrients that flow into the Mississippi and down to the Gulf.

Clean Water Act Implementation in Illinois

Most Illinois waters are designated general use, which includes the above-mentioned uses and the drinking water use. To secure these uses, Illinois EPA has set a total phosphorus standard for lakes greater than 20 acres and Lake Michigan, a nitrate standard for waters used as drinking water sources, and a narrative standard for offensive conditions, including excessive, unnatural growths of algae or aquatic plants (35 Ill. Adm. Code 302-304). Excessive nutrient levels may cause violations of these numeric and narrative standards and can also cause lake eutrophication, higher turbidity levels, lower water transparency readings, increased chlorophyll concentrations, decreased oxygen levels, unsightly algal blooms or scums, and undesirable tastes and odors in drinking water.

Point Sources

The Clean Water Act (33 U.S.C. 1342) and Illinois Environmental Protection Act (415 ILCS 5) require that point source contaminant discharges be managed through NPEDS permits. Administration of the NPDES permit program in Illinois is delegated to Illinois EPA. In general, the regulation of contaminant levels in point source effluent is focused on protecting designated uses of the water by limiting the concentration of pollutants with numeric water quality standards or ones that may contribute to the violation of a narrative standard. The permit program also limits the discharge of pollutants with Total Maximum Daily Load (TMDL) waste load allocations. Issuance and enforcement of NPDES permits with appropriate nutrient-related limits and requirements is the state's primary tool for minimizing point source nutrient loading to the Gulf of Mexico and reducing the impact of nutrients on local water quality.

Non-Point Sources

Section 319 of the Clean Water Act (33 U.S.C. 1329) authorizes funding for states to develop non-point source management programs and to fund both statewide activities and local or watershed-scale projects to control non-point source pollution. Section 319 funding can be used to develop watershed-scale water quality management plans that identify pollution sources and recommend implementation actions that address those sources.

Total Maximum Daily Load

Illinois EPA maintains a list of impaired waters—those waterbodies not meeting their designated uses based on Illinois EPA assessments—and develops TMDLs for each impaired waterbody segment. These establish load limits for the specific pollutants causing impairment. All TMDLs include a waste load allocation that limits point source loading and a load allocation that limits non-point source loading, both of which are necessary to improve water quality. Once established, a waste load allocation is a regulatory requirement implemented through the NPDES permit program. Load Allocations are in effect non-point source management goals that do not impose a regulatory requirement on non-point source discharges.

Illinois EPA has developed over 600 TMDLs that have been approved by U.S. EPA and are in various stages of implementation.

Photo by Yingkai Liu

Chapter 2

Goals and Milestones

The primary goals of the Illinois Nutrient Loss Reduction Strategy are to reduce the annual loading of nitrate-nitrogen and total phosphorus to the Mississippi River in accordance with the Gulf Hypoxia Action Plan 2008 (see chapter 1 for details) and address the impacts of nutrient pollution on local water quality.

Load reductions are measured against the average annual riverine loading of nitrate-nitrogen and total phosphorus for 1980-1996, which the science assessment (chapter 3) identified as the state's baseline loading. The ultimate goal of achieving a 45 percent reduction is intended to apply equally to the eight-digit Hydrologic Unit Code (HUC) watersheds of the Mississippi River Basin and will be met over time, with interim milestones as noted in Table 2.1. Because of annual load variability, progress will be measured based on five-year running averages.

Table 2.1. Watershed milestones and targets.

Nutrient	Phase 1 Milestones	Target
Nitrate-nitrogen	15 percent by 2025	45 percent
Total phosphorus	25 percent by 2025	45 percent

The loss reductions goals for point sources, agricultural non-point sources, and urban non-point sources are in proportion to their contribution, as shown in Figures 2.1, 2.2, and 2.3. For example, once the hypoxia-related target reduction for total phosphorus from point sources is achieved, point source discharges will not be obligated to reduce further to address loading to the Mississippi River.

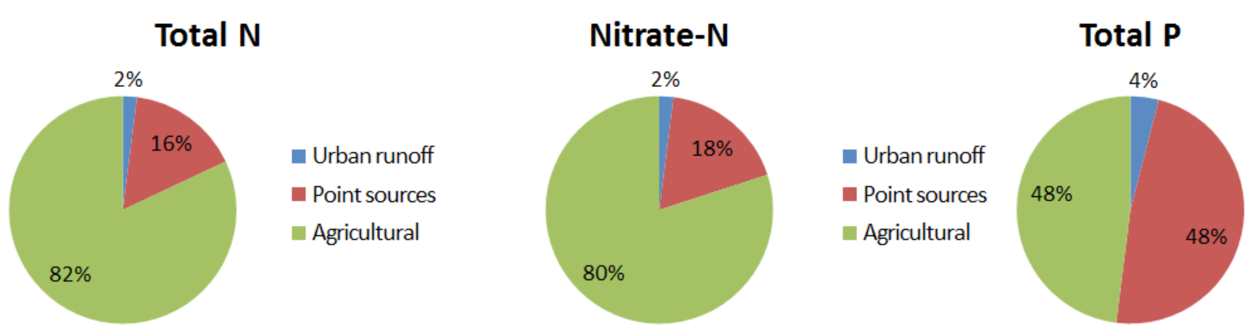


Figure 2.1. The proportion of nitrate and total phosphorus lost to the Mississippi River by source.

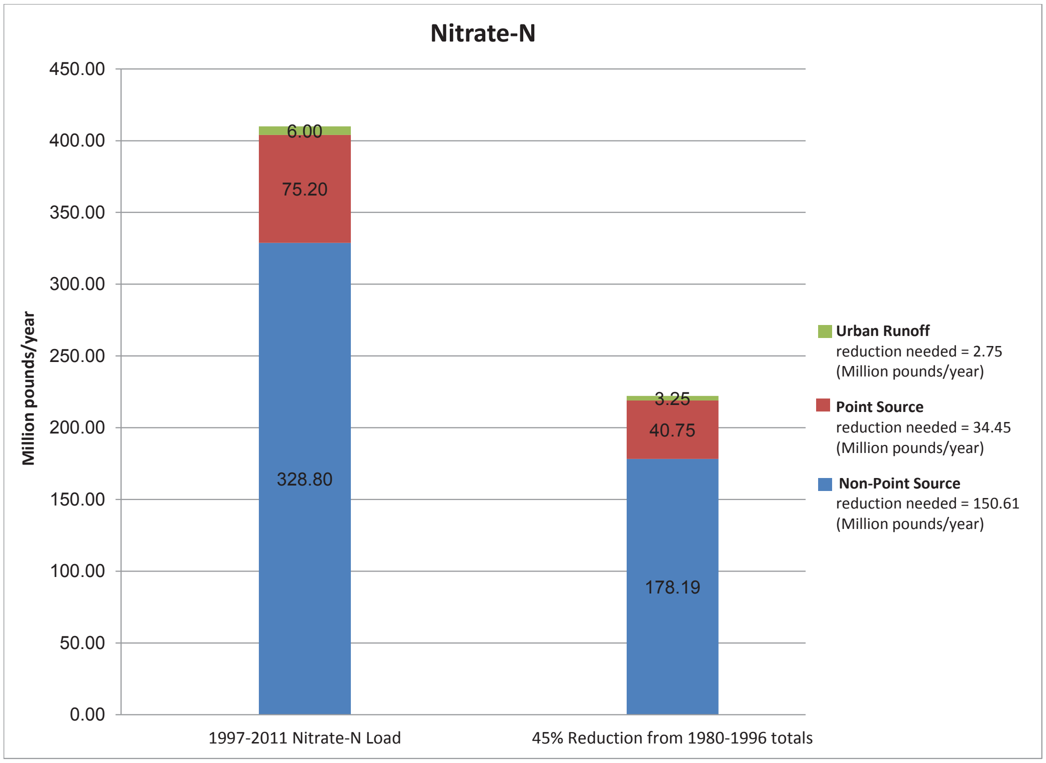


Figure 2.2. Nitrate-N reduction goal in pounds per year by source.

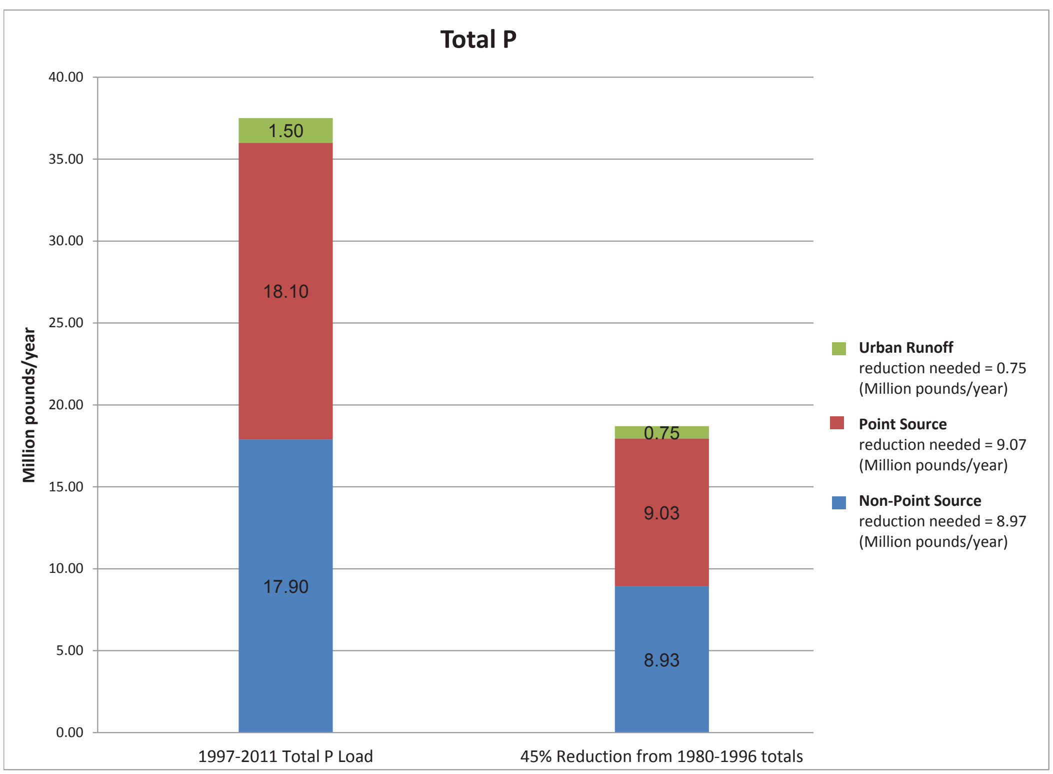


Figure 2.3. Total phosphorus reduction goal in pounds per year by source.

Reduction targets for impaired watersheds due to nutrients are established based on:

- Total Maximum Daily Loads, which have been and will continue to be developed
- Watershed-scale studies or load reduction strategies that establish reduction targets, such as the Fox River Study Group described in chapter 5
- Nutrient pollution reduction implementation plans that lead to the elimination of impairments caused by nutrients

The Illinois Environmental Protection Agency projects that the target reduction for point source contributions of total phosphorus can be met by 2025 through continued implementation of National Pollutant Discharge Elimination System permit limits, optimization of existing equipment, and implementation of technology-based approaches identified in plant-specific nutrient feasibility plans (see chapter 5).

For agricultural non-point sources, voluntary implementation of best management practices is expected to build on efforts already underway by farmers throughout the state and in watersheds with existing nutrient plans. It is expected that the implementation of best management practices will increase with additional outreach, education, and incentives.

Photo by Jennifer Byard

Chapter 3
Science Assessment

Mark B. David, Gregory F. McIsaac, Gary D. Schnitkey, George F. Czapar, and Corey A. Mitchell; peer reviewed by academics in the Upper Mississippi region

Introduction

Illinois is a highly agricultural state but with several major metropolitan areas. There are more than 22 million acres of corn and soybeans (60 percent of the state's land area), much of it tile drained, and a population of nearly 13 million people (fifth nationally). Consequently, both point and non-point sources of nitrogen and phosphorus are added to the streams and rivers of the state, with these nutrients being transported to the Mississippi River and the Gulf of Mexico (David and Gentry, 2000; David et al., 2010; Jacobson et al., 2011). The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force has a goal to reduce the hypoxic zone in the northern Gulf of Mexico to a five-year running average of 5,000 km^2 (approximately 1,900 sq. mi) by 2015 (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2008). To meet this goal, the U.S. Environmental Protection Agency (U.S. EPA) Science Advisory Board recommended a 45 percent reduction from the 1980-1996 average total nitrogen and phosphorus stream loads in the Mississippi River Basin. Because nitrate-nitrogen is thought to be the primary nutrient leading to formation of the hypoxic zone each summer, with total phosphorus secondary, the focus for reducing total nitrogen is to reduce nitrate-nitrogen loads in the Mississippi River Basin (U.S. EPA, 2007). This report provides the scientific basis for a nutrient reduction strategy for Illinois by: (1) determining the current conditions of nutrient sources in Illinois and the export from both point and non-point sources by rivers in the state, (2) describing practices that could be used to reduce these losses to surface waters and providing estimates for the effectiveness of these practices throughout Illinois, and (3) estimating the costs of the statewide application of these methods to reduce nutrient losses and meet Gulf of Mexico hypoxia goals.

In this analysis, we used U.S Geological Survey (USGS) stream flow data and nitrogen and phosphorus concentrations from the Illinois Environmental Protection Agency (Illinois EPA) and USGS to estimate major watershed stream loads for the state for the 1980-2011 water years. In addition, we directly estimated nitrogen and phosphorus point source loads, while nitrogen and phosphorus non-point sources were calculated by subtracting point sources from total nitrogen and phosphorus loads. These estimates were compared to values previously published by David and Gentry (2000) to provide perspective from earlier studies in Illinois. Urban non-point sources were estimated using published values and urban land areas in Illinois. We then applied a 45 percent reduction target or goal to the 1980-1996 stream loads of nitrate-nitrogen and total phosphorus for the state to determine the goal of a state nutrient reduction strategy. The next step was estimating nitrate-nitrogen and total phosphorus yields (both point and non-point) for the eight-digit Hydrologic Unit Code (HUC) watersheds in Illinois to connect nutrient yields with listed watersheds (stream segments and lake acres that do not meet water quality criteria for dissolved oxygen, total phosphorus, nitrate-nitrogen, aquatic plants, or aquatic algae) at this scale. This allowed us to rank and determine critical watersheds for nutrient reductions. We then estimated reductions in nutrient loads for various point and non-point practice changes, estimated costs per acre for agricultural practices and nutrient reductions per pound for both point and non-point sources, and scaled our estimates to the entire state. Finally, we developed various scenarios to reduce nitrate-nitrogen and total phosphorus loads by either 20 or 45 percent. Twenty percent was chosen to be roughly half of the 45 percent reduction target.

Current Conditions

Point Source Nutrient Loads

Nitrogen and phosphorus point source data are available through the U.S. EPA Integrated Compliance Information System (ICIS). We began with Illinois EPA's analysis (Mosher, 2013) of total phosphorus data in ICIS, from which Mosher received information on 1,660 point sources of phosphorus in Illinois for 2009. Mosher (2013) concluded that the ICIS tools did not allow an accurate estimation of point source phosphorus loadings in Illinois. As a result, Illinois EPA used phosphorus data from 42 facilities provided by the Illinois Association of Wastewater Agencies (IAWA), including data provided after Mosher's report, along with discussions with cooling water dischargers to recalculate phosphorus concentration and loads for the largest 108 dischargers listed in ICIS. For our analysis we added data from Decatur's publicly owned treatment works (POTW). Illinois EPA found some important errors in the ICIS output and recalculated the top 108 sources in the data from the ICIS output (Mosher, 2013). The 108 sources included the 100 largest phosphorus sources in the state—and therefore most of the point source phosphorus load—in addition to eight sources provided by IAWA (Mosher, 2013). Mosher (2013) used total phosphorus concentrations either from values reported by facilities, Illinois EPA's knowledge of the facility, or the ICIS database. In our analysis of phosphorus, we examined the other major discharging facilities (hereafter referred to as majors) in the ICIS database, a total of 263 facilities that included the top 108 previously analyzed. Majors are nearly all treatment works with design flows >1 million gallons per day (MGD), but they also include a few treatment works that score >80 points on the National Pollutant Discharge Eliminating System (NPDES) Permit Rating Worksheet. As Illinois EPA had done for the top 108 sources, we used Illinois EPA's best estimate of the total phosphorus concentration for many of the industrial and agricultural facilities and a few POTWs that had very high total phosphorus concentrations in the ICIS database. For all others, we used the U.S. EPA ICIS value for total phosphorus, which was typically between 2.5 and 3 mg/L. Similar to Mosher (2013), we found that the original ICIS output overestimated the total phosphorus load by a large percentage. The ICIS estimate for the 263 majors was 29.4 million lb total P yr^{-1}, whereas our estimate was 16.6 million lb yr^{-1}. The ICIS major point source total phosphorus estimate was, therefore, 1.8 times too high (we believe our estimate is more accurate because we used actual data from dischargers in Illinois instead of the modeled values used by U.S. EPA). Based on this over prediction, we used U.S. EPA estimates multiplied by 0.565 for the other 1,397 total phosphorus point sources in the ICIS database. Because these 1,397 point sources were a small proportion of the overall point source phosphorus estimate and no other data were available for the wide range of sources in the data set, this was the best estimate we could make. A median of total phosphorus from the POTWs would not be appropriate to use for these varied point sources.

There are fewer measurements available for nitrogen because many facilities have been monitoring only ammonia concentrations. We made a request through IAWA for nitrogen data for the 2008-2012 period and received data from 34 major facilities (requests went out by email to all IAWA members on March 5, 2013, with a reminder on April 8, 2013 from Robin Ellison of IAWA). Three of the facilities only reported ammonia, but 31 reported total nitrogen or nitrate-nitrogen, with most reporting both. Some had five years of data, some only one. All reported flow. Facility size ranged from 1.3 to 712 MGD, with a median of 12 MGD. For typical plants (large Chicago plants excluded), the average total nitrogen concentration was 16.8 mg/L, with a nitrate-nitrogen concentration of 14.9 mg/L. This average is based on data from 26 facilities, mostly for 2008-2012. Illinois EPA made a request to ICIS for all nitrogen data, and 392 sources were reported, all POTWs. These are the only point sources in Illinois with a permit for nitrogen, far fewer than the 1,660 permitted for phosphorus. Because ICIS reported only ammonia data for nearly all plants, only flow data could be used from this source, and no ICIS nitrogen concentration data were used in our analysis. Annual loads were directly calculated for the 31 plants that reported nitrate-nitrogen or total nitrogen data. For the other 361 plants in the ICIS database (392 total sources minus the 31 that reported concentrations to us), the flow from ICIS and the average total nitrogen and nitrate-nitrogen concentrations reported above were used to estimate the source. Data for both the phosphorus and nitrogen estimates were available for all seven Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) plants, which was important given that MWRDGC operates the largest plants in the state.

Table 3.1. Point source total phosphorus loads for the entire state and by major river basins. The category "all other basins" includes point sources outside the eight major basins.

	All 1,660 sources	Majors (263)
	million lb yr^{-1}	
Rock River	1.01	0.89
Green River	0.03	0.02
Illinois River	14.6	13.8
Kaskaskia River	0.52	0.4
Big Muddy	0.21	0.17
Little Wabash	0.16	0.14
Embarras River	0.1	0.08
Vermilion River	0.22	0.2
All other basins	1.12	0.94
State sum	18	16.6
State (David & Gentry, 2000)	14.7	

Table 3.2. Point source total nitrogen and nitrate-nitrogen loads for the entire state and by major river basin. The category "all other basins" includes point sources outside the eight major basins.

	Total N	Nitrate-N
	million lb yr^{-1}	
Rock River	3.94	3.48
Green River	0.11	0.09
Illinois River	75.2	64.4
Kaskaskia River	2.2	1.94
Big Muddy	1.21	1.08
Little Wabash	0.48	0.44
Embarras River	0.6	0.53
Vermilion River	1.54	1.37
All other basins	2.07	1.76
State sum	87.3	75.2
State (David & Gentry, 2000)	86	

Point source total phosphorus was estimated at 18 million lb yr^{-1}, with most from the major facilities in the state (16.6 million lb yr^{-1}) (Table 3.1). The estimated point source load of total nitrogen was 87.3 million lb yr^{-1}, with 75.2 million lb as nitrate-nitrogen (Table 3.2). Most of the point source nitrogen is from northern Illinois, with large loads in the Illinois and Rock rivers.

A comparison was made with previously published point source estimates for Illinois to see if our prior understanding of the importance of these nutrient sources was correct. Using completely different estimation techniques (per capita nitrogen in effluent) for the 1990s, David and Gentry (2000) reported a very similar total nitrogen estimate of 86 million lb yr^{-1} from point sources. More recently, David et al. (2010) estimated 123 million lb N yr^{-1} consumed in food, which is expected to be larger than the nitrogen discharged due to gaseous nitrogen losses during wastewater treatment and the nitrogen removed in biosolids. The estimate of point source phosphorus loads is larger than predicted by David and Gentry (2000) or Jacobson et al (2011) based on food consumption (13 million lb yr^{-1}). This is likely due to the inclusion of industrial point sources in the current study that were not considered in the earlier work.

Urban Runoff Nutrient Loads

Urban runoff was estimated using Illinois land cover data and published tables of nutrient loss per acre. We used two sets of land cover maps. The first was Illinois Land Cover: An Atlas (1996), a 1991-1995 analysis by the Illinois Department of Natural Resources (IDNR) using Landsat 4 and 5 Thematic mapper satellite imagery acquired during the 1991-1995 spring and fall seasons, with most of the data from 1992. This dataset has six urban land uses: high density, medium/high density, medium density, low density, transportation, and urban grassland. The newer 1999-2000 land cover data was a joint effort by the U.S. Department of Agriculture National Agricultural Statistics Service, the Illinois Department of Agriculture, and IDNR using Landsat 5 TM and Landsat 7 RTM+ satellite imagery acquired during the spring, summer, and fall seasons of 1999 and 2000. However, these newer data only divided urban areas into high density, medium/low density, and urban open space categories.

Nitrogen and phosphorus yields for urban areas were obtained from the report Preliminary Data Summary of Urban Storm Water Best Management Practices (U.S. EPA, 1999). Table 4-3 was used from this report, but is not shown here. These estimates were derived from several different studies of typical urban area nutrient yields originally from Horner et al. (1994). We then multiplied the published estimates for nutrient loads per acre by the actual acres of each land cover type. For the 1999-2000 land cover, we used nutrient yield averages from different land cover classes listed in Table 4-3 to match the three categories of land cover data available. We also used data for nitrate-nitrogen and total nitrogen urban runoff loads from a study conducted in Baltimore (Groffman et al., 2004), total nitrogen from a study in Seattle (Herrera Environmental Consultants, 2011), total phosphorus from estimated inputs to the DuPage River (DuPage River Salt Creek Workgroup, 2008), and total phosphorus in urban runoff from an Illinois EPA summary (Illinois EPA, 1986). Each of these data sources were combined with the land cover data described above.

Land cover data indicated that there are about 2.3 million acres of urban land in Illinois. We estimate that urban runoff is a source of about 1.5 million lb total P yr^{-1}, 6 million lb nitrate-N yr^{-1}, and 8.3 million lb total N yr^{-1}. These are approximate values given the approach used but are likely around the right order of magnitude. There was little difference in the estimates using the two land cover databases.

Riverine Nutrient Loads

We used stream flow and nitrogen and phosphorus concentrations for the eight major rivers in the state with available data, which represents 74 percent of the state area (Table 3.3 and Figure 3.1). USGS flow data and Illinois EPA and USGS data were used to calculate annual fluxes during 1980-2011 for nitrate-nitrogen, total nitrogen, dissolved reactive phosphorus (DRP), and total phosphorus. The results were extrapolated to represent the state (56,371 sq. mi). This generally follows methods used by David and Gentry (2000). For the Rock River, 54 percent of the drainage at Joslin, where the gage is located, is in Wisconsin. David and Gentry (2000) estimated the Illinois load as 46 percent of the load at Joslin, but we used a different method. We calculated the load for the Rock River at Rockton, Illinois, which is mostly drainage from Wisconsin. We then subtracted the Rockton load from that at Joslin, giving us the load from Illinois sources (3,187 sq. mi) only.

Table 3.3. River systems, location and station number of discharge and water quality data, drainage area, and fraction of drainage area in Illinois used in estimating export of nitrogen and phosphorus by surface water from Illinois.

River system	Gage location	USGS station number	Drainage area (sq. mi)	Fraction in Illinois (percent)
Rock	Joslin	05446500	9,549	46
Rock	Rockton	05437500	6,362	
Green	Geneseo	05447500	1,003	100
Illinois	Valley City	05586100	26,743	93
Kaskaskia	Venedy Station	05594100	4,393	100
Big Muddy	Murphysboro	05599500	2,169	100
Little Wabash	Carmi	03381500	3,102	100
Embarras	Ste. Marie	03345500	1,516	100
Vermilion	Danville	03339000	1,290	100

A variety of methods can be used to determine the annual load for a river using continuous daily flow and infrequent nutrient concentration measurements. There has been much discussion in the literature about the advantages and disadvantages of each method. Based on our assessment of the literature and current techniques available, interpolation is thought to be the best method for highly soluble nutrients such as nitrate-nitrogen in larger rivers. And because nitrate-nitrogen is a large percentage of total nitrogen, interpolation can be used for total nitrogen as well. However, for phosphorus in smaller rivers, there is a strong concentration response to flow, and high flow loads can be underestimated with interpolation when sampling is infrequent. The USGS Weighted Regressions on Time, Discharge, and Season (WRTDS) technique (Hirsch et al., 2010) fits a relationship that includes flow and, therefore, better estimates the high flow days that are critical to estimating phosphorus loads (Royer et al., 2006).

We conducted linear interpolation to estimate daily nutrient concentrations between sampling days using SAS version 9.2 and the Proc Expand procedure. Daily flow and measured nutrient concentrations were the input data, with daily flow and daily concentration the output. With this procedure, the observed values are present in the final data set as they are not replaced with estimated values.

The WRDTS load estimates were calculated using software developed and provided by USGS (available at github.com/USGS-CIDA/WRTDS/wiki). WRDTS estimates are based on regressions with discharge, time, and seasonality. The user can specify the relative weightings for each of these factors by changing the value of three variables: windowY for time, windowQ for discharge, and WindowS for seasonality. The model developers recommend default values of 10, 2, and 0.5, respectively, for these parameters. Daily load estimates produced

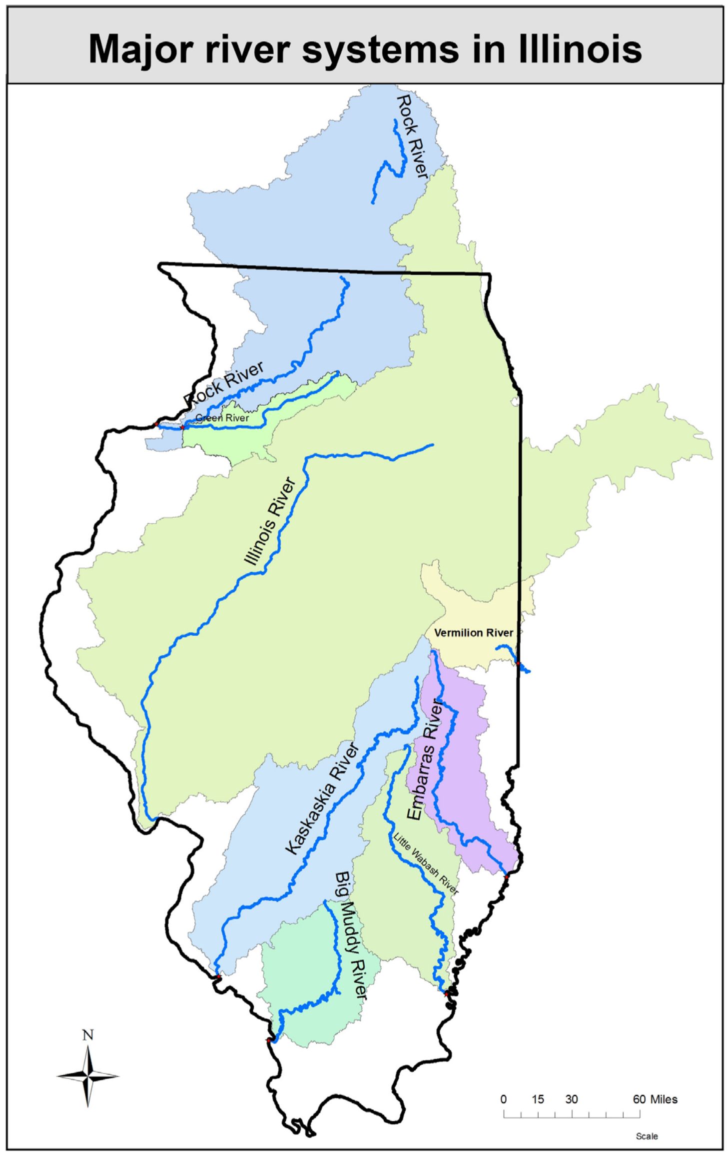


Figure 3.1. The eight major river systems used in estimating state nutrient loads. Note that gaging stations are upriver from the state boundary, so the estimated area is smaller.

by WRDTS with the default weightings were compared to the observed loads on the days when sample concentrations were measured by two different methods. First, a linear regression was conducted between observed and model-estimated loads, with the intercept set to zero. If the slope of the regression line deviated substantially from 1, or if the coefficient of determination was less than 0.8, alternative values for weightings were considered. Secondly, the WRDTS software calculates a flux bias statistic, which estimates the average deviation of the model load from the measured loads. If the flux bias statistic indicated a bias of 10 percent or greater, we used WRDTS with variables appropriate for the model to estimate loads. The weighting values that produced load estimates with the lowest flux bias statistic and the greatest correspondence between observed and model-estimated daily loads were considered the best estimates.

This analysis was informed by communication with USGS model developers. For the Illinois River, the seasonality parameter was reduced to 0.25. Sprague et al. (2011) conducted and published an analysis of Illinois River nitrate-nitrogen loads and found a seasonality weighting of 0.25 was appropriate. The default weightings produced an unusually large flux bias on the Embarras River, and Hirsch recommended reducing the discharge weighting from 2 to 1 in personal communication. This substantially reduced the flux bias and improved the correspondence between the estimated and observed loads. This weighting was also found to reduce the bias and improve the correspondence for both DRP and total phosphorus loads in the Kaskaskia and Vermilion rivers and for estimating DRP loads for the Rock River at Joslin and the Green River.

For all eight rivers, we calculated and compared annual loads for 1980-2011 using both interpolation and WRDTS for nitrate-nitrogen, DRP, and total phosphorus and using interpolation alone for total nitrogen. For nitrate-nitrogen, interpolation and WRDTS gave results that differed by less than 10 percent for most rivers. The Embarras River was an exception for which WRDTS produced estimates that were 15 to 20 percent larger than interpolation. For DRP and total phosphorus, both methods gave similar loads for the larger rivers, such as the Illinois. For smaller rivers, WRDTS gave larger loads in years with higher flows. This comparison supported our use of interpolation for nitrate-nitrogen and total nitrogen and WRDTS for DRP and total phosphorus.

Table 3.4 shows the average annual riverine water estimated for the entire state based on the eight major rivers as well as nitrogen and phosphorus loads for the two periods of interest: 1980-1996 and 1997-2011. There was a small (1 percent) increase in water flow from the early to later period, with small increases in nitrate-nitrogen (1.4 percent) and total nitrogen (1.7 percent) loads. These changes are within the errors of our estimation methods and suggest little change with time. However, total phosphorus increased by

9.3 percent, with most of this increase in DRP (20.1 percent). The David and Gentry (2000) estimate for the total phosphorus load during 1980-1997 was likely lower due to interpolation being used to estimate loads. Total nitrogen and water loads were similar to what David and Gentry (2000) estimated. Point sources were 18.4 percent of the nitrate-nitrogen loads for 1997-2011, 16.3 percent of total nitrogen, and 48 percent of total phosphorus, which is nearly identical to previous estimates by David and Gentry (2000) for an earlier time period. Nutrient sources that contribute to the riverine load for the state are shown as a percent of the total in Figure 3.2.

The increase in water flow was due to unusually high flows compared to the long-term average during 2008-2011, which followed relatively lower flows during 1997-2007 (Figure 3.3). Linear regression indicated no significant trend in annual flow for the 1980-2011 period. Figure 3.3 includes a Locally Weighted Scatterplot Smooth (LOESS) curve calculated using SAS Ver. 9.2 that can be used to describe the relationship between Y and X without assuming linearity or normality of residuals and is a robust description of the data pattern (Helsel and Hirsch, 2002). Annual nitrate-nitrogen and total phosphorus loads had different temporal patterns, with nitrate-nitrogen having no trend through time but total phosphorus increasing (Figure 3.4). A linear regression of annual total phosphorus loads with annual water flux and year had an R^2 of 0.97, with both water and year significant at the $p < 0.0001$ level. Annual loads of DRP had a similar result, with an R^2 of 0.96. Therefore, the increase in annual phosphorus flux appears to be related to water flux and possibly factors such as changing point source inputs or agricultural practices (e.g., fertilizer form, placement, and timing, manure practices, and tillage changes), although these were not evaluated.

For annual loads of nitrate-nitrogen, the Illinois, Embarras, Little Wabash, Big Muddy, and Vermilion all declined between 1980-1996 and 1997-2011, whereas the Rock, Green, and Kaskaskia increased, as did the state load (Figure 3.5). The greatest change was for the Rock River, where the load increased 66 percent between these two periods, while flow increased 12 percent. Because we estimated the load for the Rock by subtracting the station at Rockton from the load at Joslin, the resulting load is representative of Illinois only, and the increase in annual nitrate-nitrogen loads was a result of greater losses from Illinois. For total phosphorus, all rivers except the Green, Vermilion, and Embarras increased, leading to an overall 10 percent increase for the state. This analysis of major rivers indicates that the increase and decrease in nitrate-nitrogen riverine loads led to no change in the overall state export, but there were differences through time within Illinois watersheds.

We compared Illinois loads to overall Mississippi River Basin loads available from the USGS. In 1997-2011, Illinois contributed about 20 percent of the nitrate-nitrogen load, 11 percent of the total phosphorus load, and 7 percent of the water flow to the Gulf of Mexico.

Table 3.4. Water, nitrate-nitrogen, total nitrogen, DRP, and total phosphorus loads for Illinois for 1980-1996 and 1997-2011, along with David and Gentry (2000) estimates as a comparison. Point source loads are also shown as well as point sources as a percent of the recent loads.

	Water	Nitrate-N	Total N	DRP	Total P
	10^{12} ft^3 yr^{-1}	million lb yr^{-1}			
David and Gentry (2000)	1.6		538		31.3
1980-1996	1.7	404	527	15.4	34
1997-2011	1.72	410	536	18.5	37.5
Urban runoff		6	8.3		1.5
Point sources		75.2	87.3		18.1
Point source percent of 1997-2011 load		18.4	16.3		48
David and Gentry (2000) point source percent of load			16		47

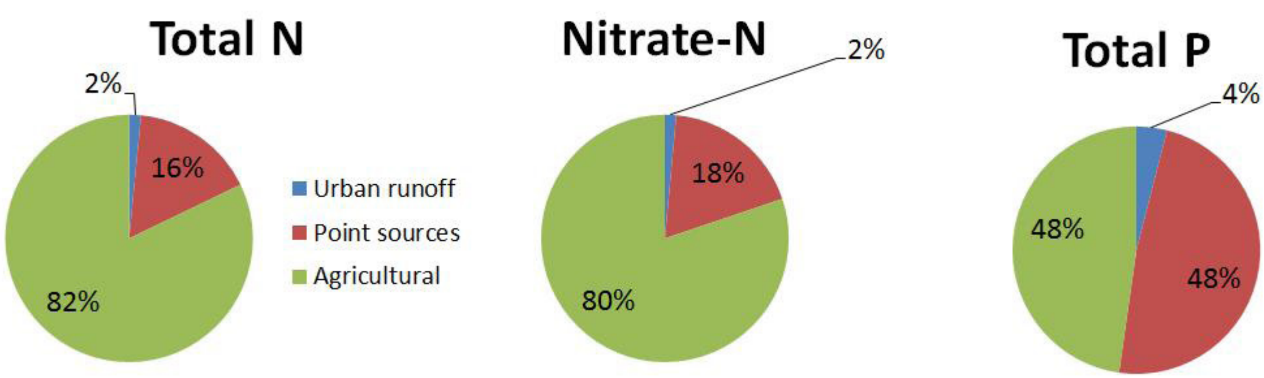


Figure 3.2. Nutrient sources in Illinois contributing to riverine nutrient export from the state.

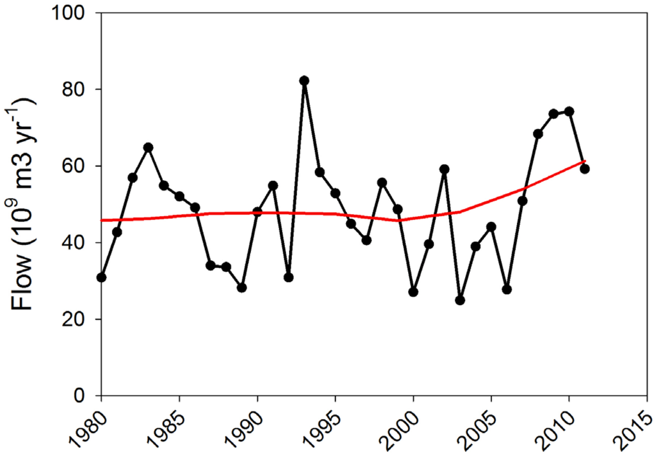


Figure 3.3. Annual water flows from Illinois for the 1980-2011 water years. The LOESS trend fit is shown in red.

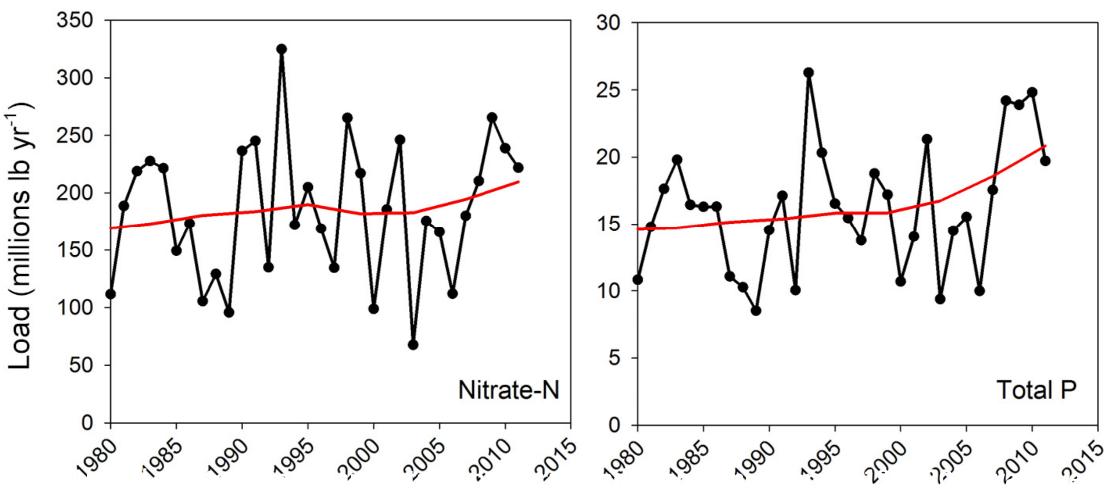


Figure 3.4. Annual nitrate-nitrogen and total phosphorus loads from Illinois for the 1980-2011 water years. The LOESS trend fit is shown in red.

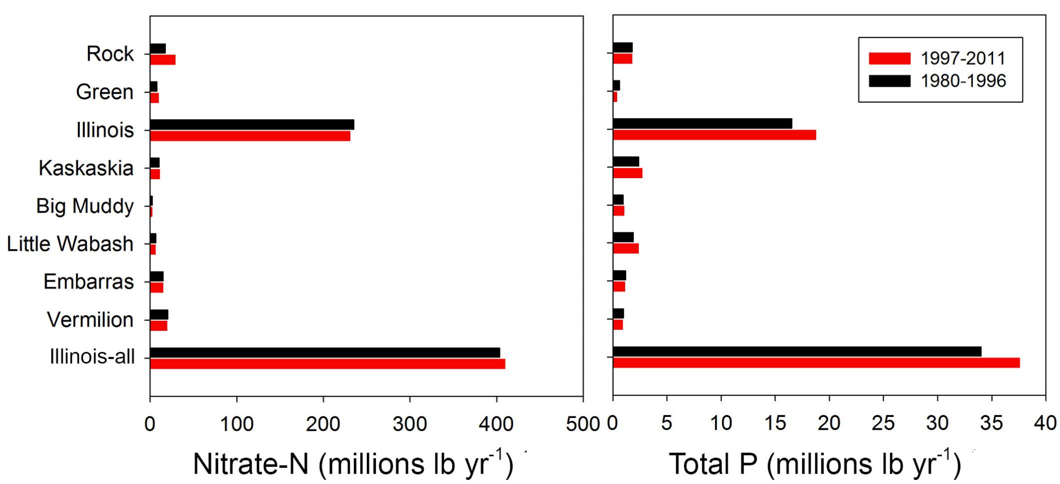


Figure 3.5. Riverine loads of nitrate-nitrogen and total phosphorus averaged for 1980-1996 and 1997-2011.

DRP was about half of the total phosphorus, but it has increased as a percent over the past 10 years (Figure 3.6). It was consistently about 45 percent of total phosphorus in the 1980s and 90s but has been greater and more variable since. Declines in particulate phosphorus loads are likely related to reduced erosion from the adoption of conservation tillage and possibly increased tile drainage, whereas increases in DRP could be due to the reduced incorporation of phosphorus fertilizers (and more intense winter and spring storms), increased population, and increased tile drainage.

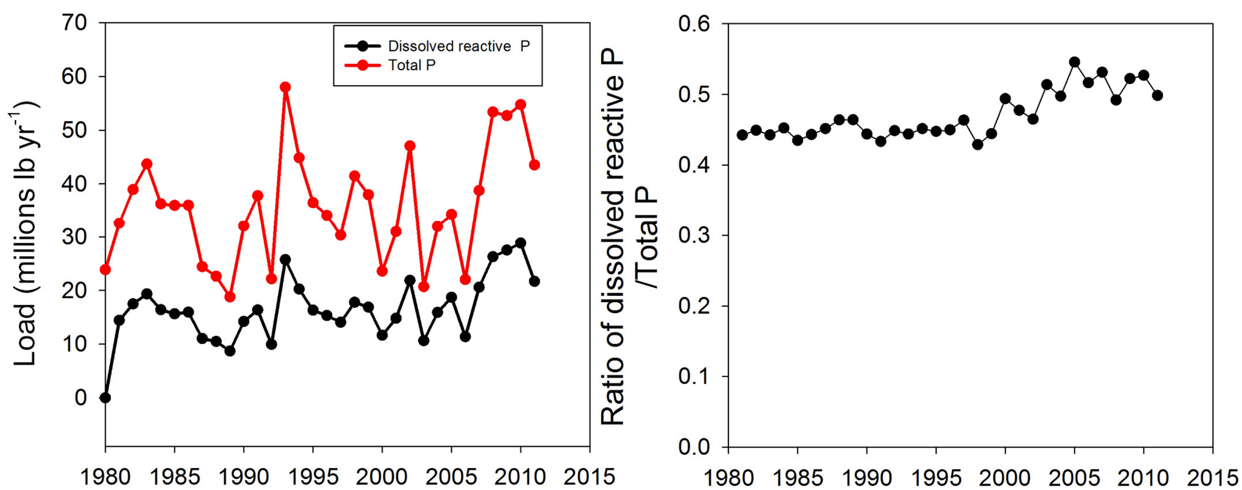


Figure 3.6. DRP and total phosphorus loads by water year for 1980-2011 along with the ratio of DRP to total phosphorus.

Riverine Nutrient Yields

Riverine nutrient loads are influenced by the size of a watershed. Larger watersheds typically produce larger flows and nutrient loads. Another way to examine nutrient losses from a watershed, and to compare watersheds, is to divide the nutrient load at the outlet by the area of the watershed to determine the yield. This allows watersheds of differing sizes to be compared by their nutrient loss per unit of land. Yields of total nitrogen and nitrate-nitrogen varied greatly across the state, with the tile-drained watersheds having much larger yields than the non-tiled, southern Illinois watersheds (Figure 3.7). In addition, some of the watersheds in southern Illinois are not as intensely agricultural. The state average nitrate-nitrogen yield was 11.3 lb/acre/yr averaged for the 1997-2011 period, but this varied from 1.4 (Big Muddy) to 23 (Vermilion) lb/acre/yr. Total phosphorus yields were less variable and averaged 1.1 lb/acre/yr, with a range of 0.55 to 1.18 lb/acre/yr. When yields of nitrate-nitrogen and total phosphorus are viewed by source, the importance of point sources in the Illinois River and non-point sources in the other rivers is clearly shown (Figure 3.8).

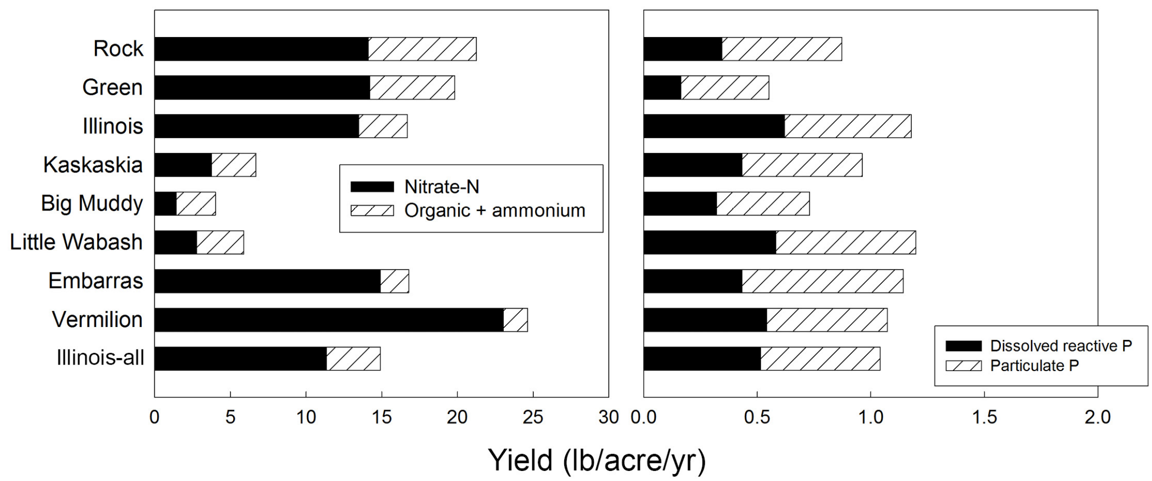


Figure 3.7. Nitrogen and phosphorus yields by watershed and for the state of Illinois averaged for the 1997-2011 water years.

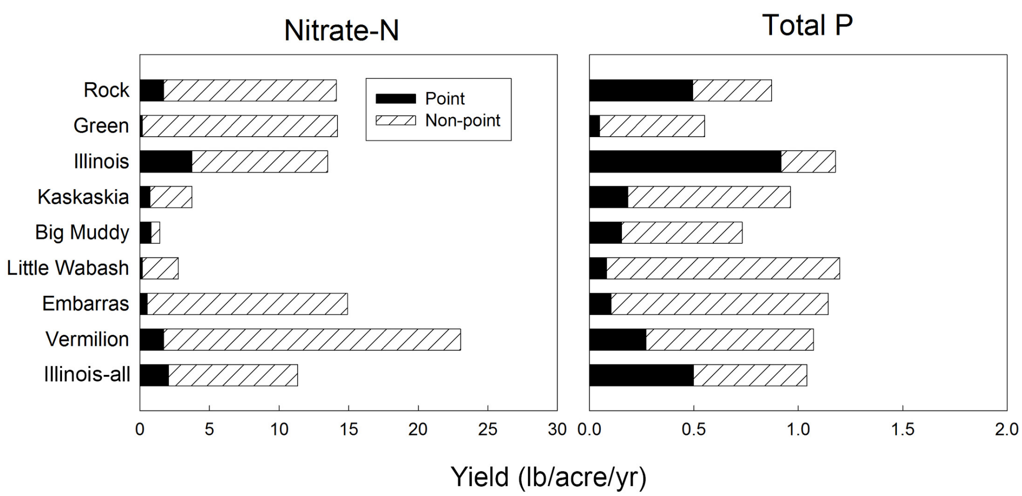


Figure 3.8. Nitrate-nitrogen and total phosphorus yields by source averaged for the 1997-2011 water years.

Riverine Nutrient Load Goal or Target

To meet a 45 percent reduction of the 1980-1996 average riverine loads of nitrate-nitrogen and total phosphorus, the nitrate-nitrogen load target is 222 million lb yr-1 and total phosphorus is 18.7 million lb yr-1. Given that the 1997-2011 loads were greater than in 1980-1996, this would require a 46 percent reduction from those loads for nitrate-nitrogen and 50 percent for total phosphorus. Figure 3.9 shows loads by river and for the state and the reduction goal. To meet the nitrate-nitrogen target, the focus must be on agricultural sources, mostly in northern and central Illinois. Reductions in point sources could meet a large part of the total phosphorus target, but additional reductions from agriculture throughout the state will probably be needed. As Figure 3.10 shows, the target for nitrate-nitrogen has only been met during low flow years. Additionally, the total phosphorus target was only met during the 1988 drought, although other dry years came close. Consistently meeting the target will take major reductions from all sources.

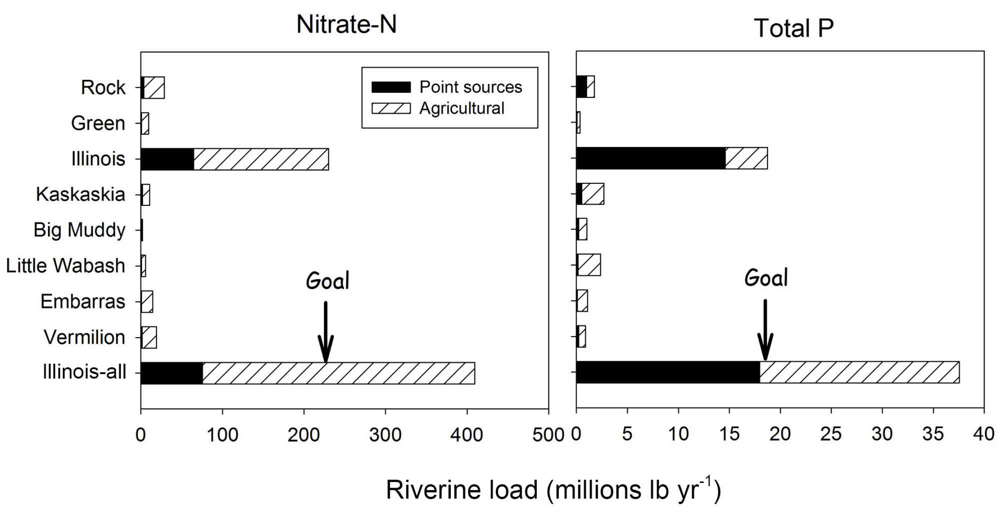


Figure 3.9. Riverine loads for 1997-2011 by source. The 45 percent reduction goal based on the 1980-1996 riverine load averages is marked by arrows.

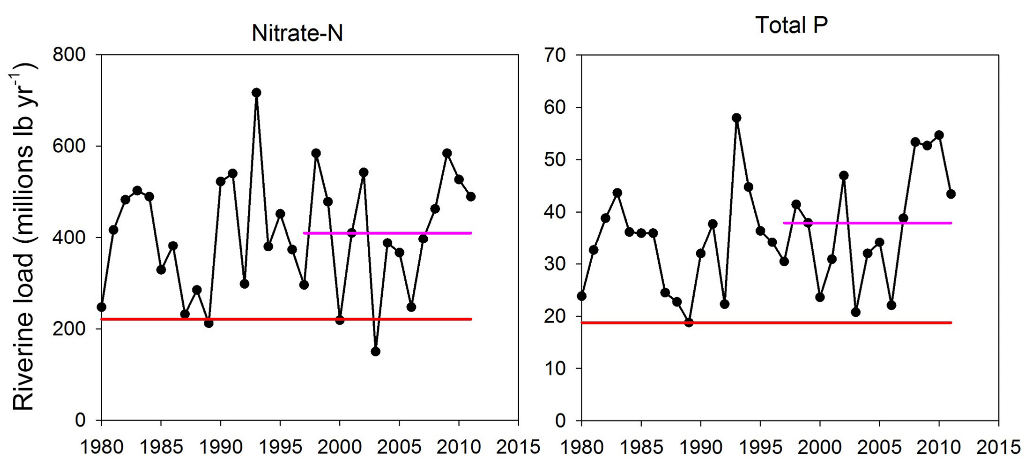


Figure 3.10. Riverine nitrate-nitrogen and total phosphorus loads for the 1980-2011 water years. Target load is shown in red, and the average load for the last 15 years is in purple.

Critical Watersheds

Methods Used to Facilitate Critical Watershed Identification

To support the determination of critical watersheds in the state, we evaluated nutrient yields at the HUC8-level (Figure 3.11). There are 50 HUC8s in Illinois that drain into the Mississippi River and one that drains into Lake Michigan. They range in size from 17 to 2,436 sq. mi, with an average size of about 1,100 sq. mi. The HUC8s with a small area in Illinois are actually larger, but they straddle two states. For each HUC8, we looked for available Illinois EPA nutrient data combined with USGS stream flow gauges. In some of the HUC8s, flow and nutrient concentration data were available for a river that drained a large part of the HUC8. In others, the gauged drainage area was much smaller than the overall HUC8. In a few, more than one river gauge was used, and in others, the estimate was made by calculating the difference between upstream and downstream monitoring sites. For the HUC8s without any available data, averages were taken from the surrounding HUC8s with estimated nutrient yields. For the HUC8s with both USGS stream flow gauges and Illinois EPA nitrate-nitrogen and total phosphorus data for 1997-2011, we used these data to estimate annual average nutrient yields in pounds of nitrogen or phosphorus per acre per year. As we did for the large rivers in the state, linear interpolation was used for the nitrate-nitrogen estimates and WRDTS for total phosphorus. For nearly every site, little or no concentration data were available for 2007-2008, and those years were not included

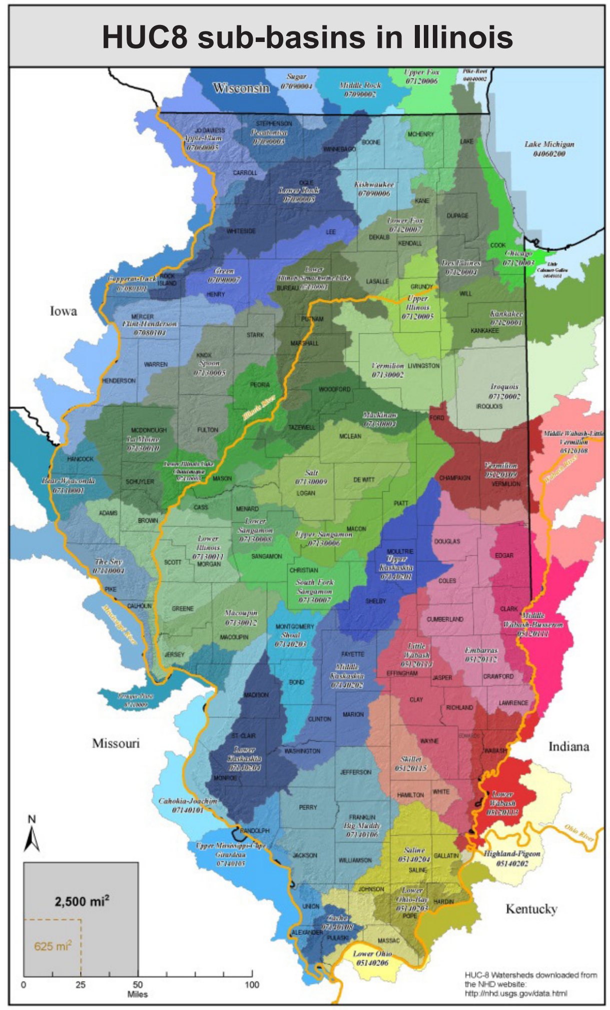


Figure 3.11. HUC8 sub-basins in Illinois.

when concentration data were not available. This monitoring data allowed us to directly calculate overall nitrate-nitrogen and total phosphorus yields for 39 of the 50 HUC8s, including seven that were calculated using the difference between upstream and downstream sites. We also disaggregated point source nitrate-nitrogen and total phosphorus estimates by HUC8 and subtracted the point source nitrate-nitrogen or total phosphorus yield from the total nutrient yields to obtain estimates of both point and non-point source nutrient yields for each HUC. This worked well for all except three in northeastern Illinois, where the point source yields were quite high and not reflected in the available river data. In those HUC8s, we set the total nutrient yield equal to the point source yield and assumed non-point sources were zero. Data were not available to allow us to determine the urban non-point source contribution in the three northeastern HUC8s, as the point source loads were so much greater than the stream loads estimated from water quality data. In addition, urban density values were not easily available by HUC8.

Nitrate-Nitrogen and Total Phosphorus Yields by HUC8

Figures 3.12-3.15 show total, point source, and non-point source nitrate-nitrogen and total phosphorus yields by HUC8. For nitrate-nitrogen, the greatest yields were found in the tile-drained northern two-thirds of Illinois, where tile drainage is common and land-use is dominantly row crop agriculture. Statewide nitrate-nitrogen yields ranged from 0.7 to 42 lb/acre/yr, with an average of 13 lb/acre/yr. The non-point source yield average was 10 lb/acre/yr, with 27 HUC8s greater than 10 lb/acre/yr. For point sources, the Chicago and Des Plaines HUC8s had very large nitrate-nitrogen yields of 40.9 and 38.3 lb/acre/yr, respectively.

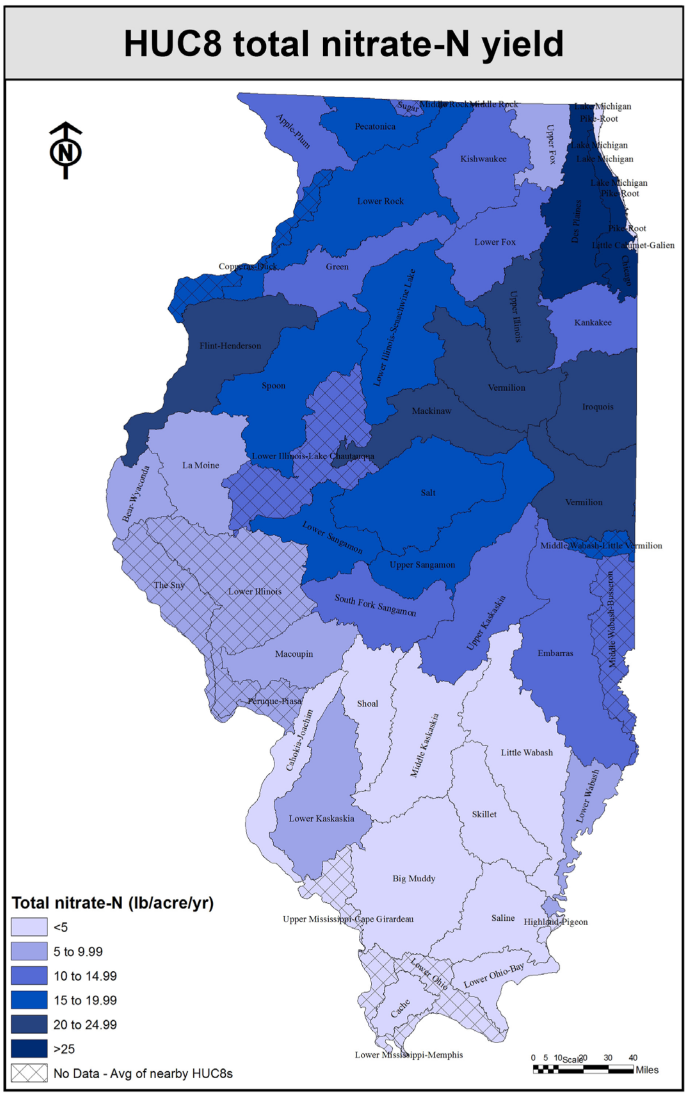


Figure 3.12. Total nitrate-nitrogen yields by HUC8 in Illinois.

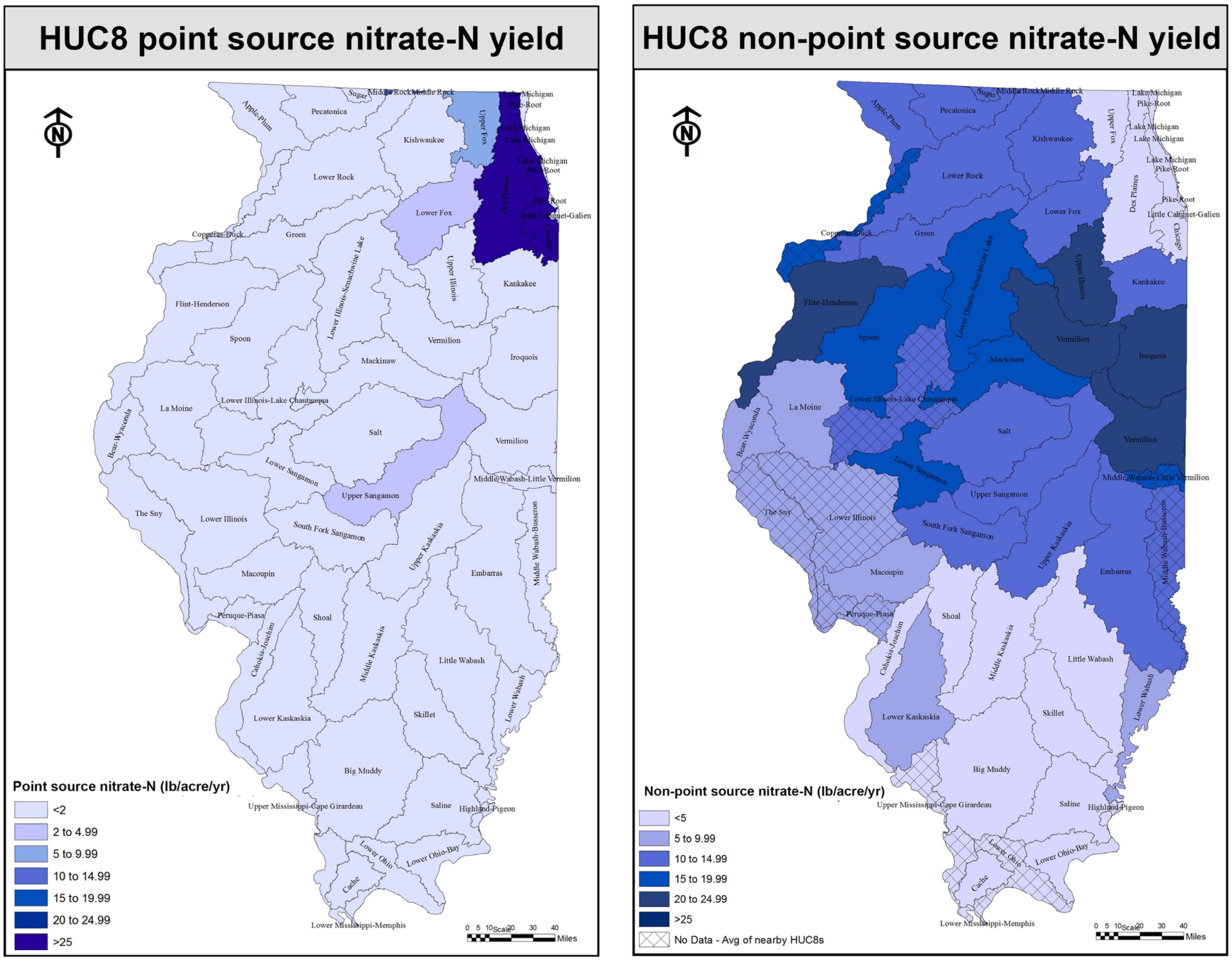


Figure 3.13. Point and non-point source nitrate-nitrogen yields by HUC8 in Illinois.

For total phosphorus, the average yield was 1.4 lb/acre/yr and ranged from 0.42 to 9.74 lb/acre/yr across the HUC8s in the state (Figure 3.14). Non-point source total phosphorus yields were typically greater in the southern Illinois HUC8s, with the smallest yields in northern Illinois (Figure 3.15). Point source total phosphorus yields were very large in the Chicago area, the Upper Sangamon HUC8 (due to the sewage treatment plant discharge in Decatur), and along the Mississippi River in some HUC8s. The Chicago and Des Plaines HUC8 point source phosphorus yields were 9.74 and 6.65 lb/acre/yr, respectively.

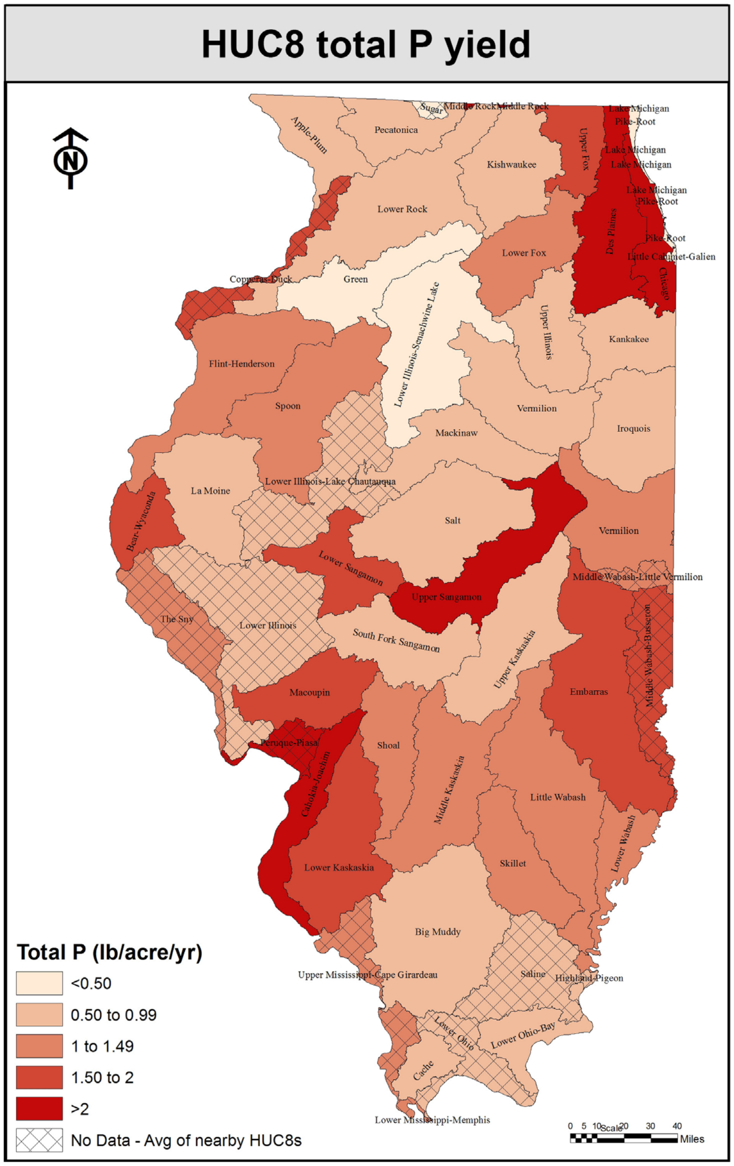


Figure 3.14. Total phosphorus yields by HUC8 in Illinois.

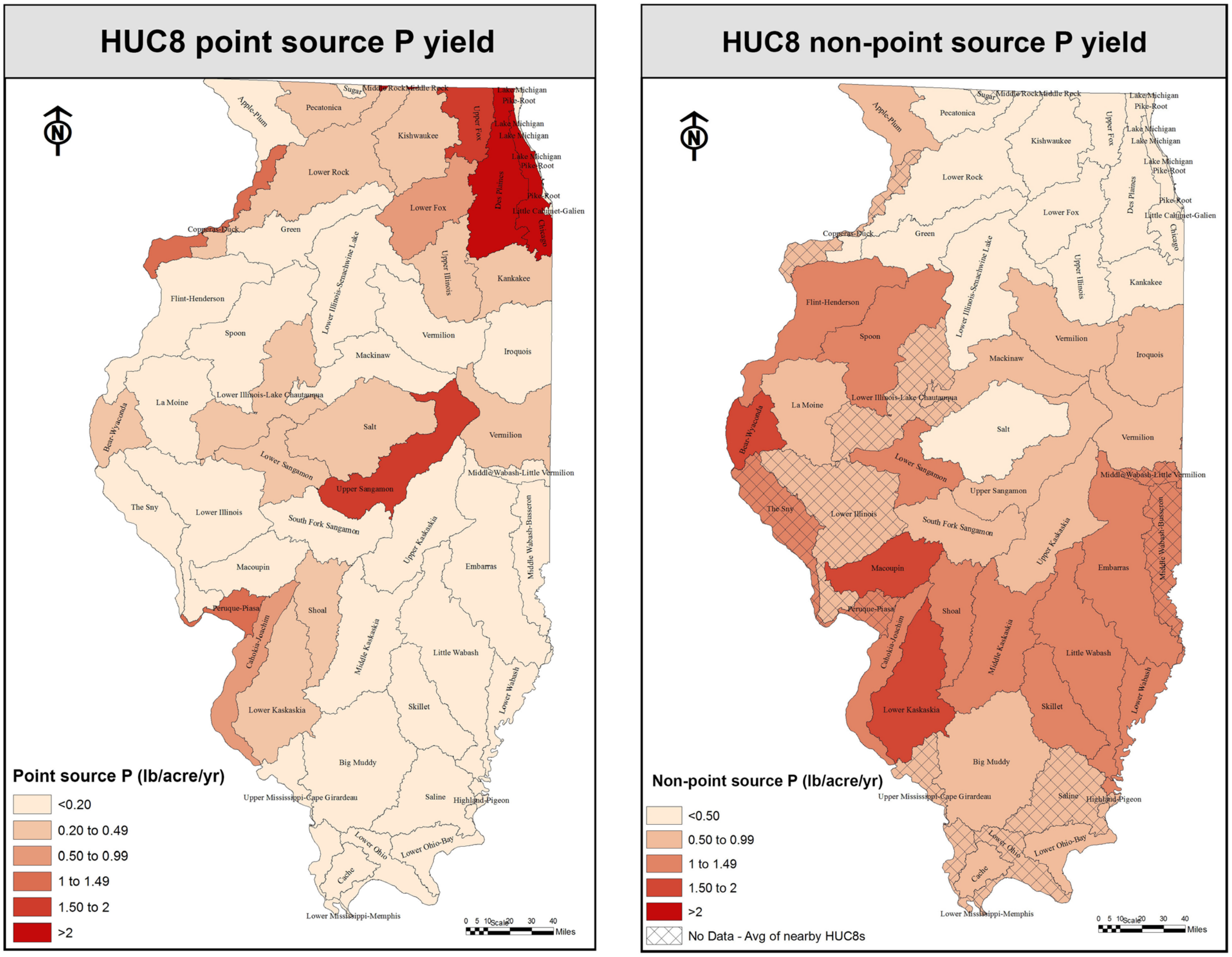


Figure 3.15. Point and non-point source total phosphorus yields by HUC8 in Illinois.

303(d)/305(b) Impaired Waters in 2012

We conducted an analysis to determine if yields of nitrate-nitrogen or total phosphorus were related to the miles of impaired streams or acres of lakes reported in the 2012 integrated report. We included assessed 2012 303(d) listed streams as well as 305(b) impaired streams and lakes by HUC8 if they were listed for dissolved oxygen, total phosphorus, nitrate-nitrogen, aquatic plants, or aquatic algae (Figure 3.16). There were 4,070 stream miles on the 303(d) list, 4,346 stream miles on the 305(b), and 127,270 lake acres on the 305(b) assessment. We located them within each of the HUC8s and summed the stream miles or acres of lakes by HUC8. Finally, a correlation analysis was conducted to determine if nitrate-nitrogen or total phosphorus yields were related to the miles of impaired streams or acres of lakes. There were no strong relationships. HUC8 non-point source nitrate-nitrogen yields were significantly related to 305(b) stream miles ($p=0.002$) and 305(b) lake acres ($p=0.011$). However, this relationship was negative, suggesting that the greater the nitrate-nitrogen yield from non-point sources the fewer impaired stream miles or lake acres. Total phosphorus yield by HUC8 was not statistically correlated with impaired stream miles or lake acres.

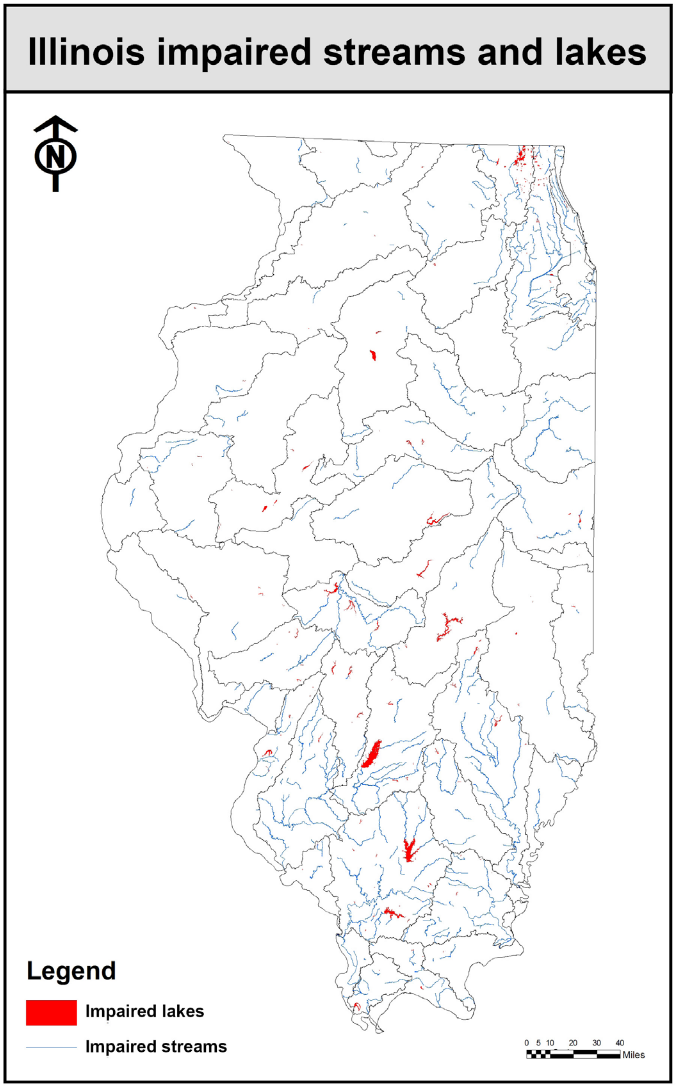


Figure 3.16. Impaired streams and lakes in Illinois. Impaired is defined as those found on the 305(b) assessment for total phosphorus, dissolved oxygen, nitrate-nitrogen, aquatic plants, or aquatic algae.

Agricultural Practices and Nutrient Losses by Major Land Resource Areas in Illinois

To examine agriculture throughout Illinois, we used data on Major Land Resource Areas (MLRAs) published in 2006 by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). MLRAs are geographically associated land resource units based on climate, soils, and land use. There are 15 MLRAs in Illinois, but several have only a small area in the state. Therefore, we combined the state's MLRAs into a total of nine as described in Table 3.5 and shown in Figure 3.17.

Information on planted crop acres and yields were obtained from the USDA National Agricultural Statistics Service (NASS) survey data by county for 2008-2012 and then summed by MLRA (Table 3.6). More than 12 million acres of corn and about 9 million acres of soybeans were planted each year in Illinois. The third most planted crop was wheat, but there was less than 1 million acres planted annually. Using tile-drained acres per county from David et al. (2010), we estimated that 9.7 million acres in the state were tile drained, with most in MLRA groupings 2, 4, and 7. We assumed all drained acres were in corn and soybean production. Corn and soybean yields were greatest in northern and central Illinois and least in southern Illinois.

Fertilizer nitrogen usage per county averaged over the 1997-2006 time period was obtained from David et al. (2010). David et al. (2010) used annual state-level fertilizer sales, with county usage determined by using NASS Census of Agriculture county-level data on fertilizer, lime, and soil conditioner expenditures from 1997 and 2002 and by estimating other years by interpolation.

Because statewide nitrogen fertilizer sales were 4 percent greater in 2008-2012 compared to the David et al. (2010) average during 1997-2006, we increased our MLRA-specific estimates by this percentage. To estimate the amount of nitrogen fertilizer used per acre of corn, we assumed 100 lb/acre/yr was used on wheat and that the remainder was applied to corn. No reduction in non-farm nitrogen, which is a small percentage of nitrogen sales in Illinois, was assumed. Manure nitrogen data came from David et al. (2010) and were adjusted for pastured cattle since manure from this source is not applied to production crops. David et al. (2010) looked at overall nitrogen balances in a region, and the manure numbers included all cattle, both grain-fed and pastured. Cattle on feed data were obtained from NASS by county to adjust the manure values for pastured cattle. We assumed all remaining manure nitrogen was applied to corn and that all was plant-available. Depending on the manure type, only some of the nitrogen would likely be available in the first year of application. However, this assumption has only a small effect on estimated nitrogen rates, because manure amounts were low in most of Illinois. Row crops were defined here as the sum of corn, soybean, and wheat acres.

We then estimated nitrogen application rates for acres where corn and soybeans are rotated and acres with continuous corn by adjusting the total fertilizer nitrogen application in combination with the acres of corn and soybean during 2008-2012 (Table 3.7). We assumed that continuous corn is typically fertilized at a rate of 40 lb/acre/yr greater than a corn and soybean rotation (University of Illinois, 2012a). The recommended amount of nitrogen fertilizer for both was determined using the Maximum Return to Nitrogen (MRTN) calculator (Iowa State University, 2013) assuming a 10:1 ratio of corn price to nitrogen fertilizer price. For the central and northern Illinois MLRAs, the estimated fertilizer-plus-manure rate for corn/soybean or continuous corn was about the same or less than the MRTN, suggesting that Illinois farmers are on average applying the recommended nitrogen fertilizer rate for corn. For the southern Illinois MLRAs, the rate was well above the MRTN. However, there are few corn acres in two of the MLRAs where this was true (8 and 9), and the estimates are subject to large errors.

To obtain nitrate-nitrogen yields per row crop acre, we integrated non-point source nitrogen yields in each HUC 8 across each MLRA to determine the average load of nitrate-nitrogen. The overall nitrate-nitrogen loads were then divided by row crop acres to get the nitrate-nitrogen yield per row crop acre (Table 3.8). This analysis assumes no nitrate-nitrogen is lost from non-row crop agricultural lands (e.g., pasture). The resulting values ranged from 3.9 to 7.4 lb/acre/yr in southern Illinois and 19.6 to 31.3 lb/acre/yr in central and northern Illinois. This pattern can be explained by tile drainage in all MLRAs except MLRA 3, the northwestern corner of Illinois. This is a karst region with high livestock density, and the high nitrate-nitrogen yield may be explained by these factors. To develop the nitrate-nitrogen yield losses that will be used to determine the reduction in yields due to changes in management practices, we partitioned the nitrate-nitrogen yield per row crop acre into losses from tile-drained land and losses from non–tiled land in MLRAs 1, 2, 4, 6, and 7. These MLRAs have substantial tile-drained acres and larger nitrate-nitrogen yields as a result. Nitrate-nitrogen yields from tile-drained MLRAs ranged from 26 to 43 lb/acre/yr, whereas yields from non-tiled land ranged from 3.9 to 11.8 lb/acre/yr, with the exception of MLRA 3, the northwest corner of Illinois discussed earlier, which had a nitrate-nitrogen yield of 31 lb/acre/yr.

Data on fertilizer phosphorus usage per county came from Jacobson et al. (2011), which was a mass balance study that estimated phosphorus usage for every acre in a county using 1997-2006 crop year averages. We adjusted this rate by dividing the total phosphorus applied to a county by the sum of corn, soybean, wheat, and hay acres (Table 3.9). Data on manure phosphorus also came from Jacobson et al. (2011) and was adjusted in the same way as fertilizer phosphorus. In addition, data on cattle feed were obtained from NASS by county to adjust the manure values, allowing pastured cattle manure phosphorus to be subtracted from overall manure phosphorus. Fertilizer phosphorus application rates on cropland ranged from 11 to 14.9 lb/acre/yr, with little variation across the MLRAs, and manure phosphorus rates ranged from 1.2 t 5.4 lb/acre/yr. The largest manure phosphorus rate was in MLRA 3 in northwestern Illinois, where there was a high density of livestock. Total phosphorus yields per row crop acre ranged from 0.68 to 2.82 lb / acre/yr, with greater losses in southern Illinois and the least in northeastern Illinois.

These data will be the basis for applying nutrient reduction practices by MLRA across Illinois.

Table 3.5. MLRAs in Illinois combined into nine categories for this analysis. The bolded MLRA numbers will be used throughout our analysis.

		Landscape		Climate		
MLRA	**Description**	**Elevation m (ft)**	**Local relief m (ft)**	**Precipitation mm (in)**	**Annual temperature °C (°F)**	
95B	Southern Wisconsin and Northern Illinois Drift Plain	200-300 (660-980)	8 (25)	760-965 (30-38)	6-9 (43-48)	170
97	Southwestern Michigan Fruit and Truck Crop Belt	200-305 (600-1000)	2-5 (5-15)	890-1,015 (35-40)	8-11 (47-52)	200
98	Southern Michigan and Northern Indiana Drift Plain	175-335 (570-1,100)	15 (5)	735-1,015 (29-40)	7-10 (44-50)	175
110	Northern Illinois and Indiana Heavy Till Plain	200 (650)	3-8 (10-25)	785-1,015 (31-40)	7-11 (42-52)	185
105	Northern Mississippi Valley Loess Hills	200-400 (660-1,310)	3-6 (10-20)	760-965 (30-38)	6-10 (42-50)	175
108A	Illinois and Iowa Deep Loess and Drift, Eastern Part	200-300 (660-985)	1-3 (3-10)	890-1,090 (35-43)	8-12 (47-54)	95
108B	Illinois and Iowa Deep Loess and Drift, East-Central Part	200-300 (660-985)	1-3 (3-10)	840-990 (33-39)	8-12 (47-54)	185
113	Central Claypan Areas	200 (660)	1.5-3 (5-10)	915-1,170 (36-46)	11-14 (51-57)	205
115A	Central Mississippi Valley Wooded Slopes, Eastern Part	100-310 (320-1,020)	3-15 (10-50)	1,015-1,195 (40-47)	11-14 (53-57)	210
114B	Southern Illinois and Indiana Thin Loess and Till Plain, Western Part	105-365 (350-1,190)	3-15 (10-50)	940-1,170 (37-46)	11-14 (52-56)	210
115C	Central Mississippi Valley Wooded Slopes, Northern Part	130-270 (420-885)	3-6 (10-20)	865-1,015 (34-40)	9-13 (48-55)	200
120A	Kentucky and Indiana Sandstone and Shale Hills and Valleys, Southern Part	105-290 (345-950)	Varies widely	1,145-1,370 (45-54)	13-14 (55-58)	210

		Landscape		Climate		
MLRA	Description	Elevation m (ft)	Local relief m (ft)	Precipitation mm (in)	Annual temperature °C (°F)	
115B	Central Mississippi Valley Wooded Slopes, Western Part	100-310 (320-1,020)	3-15 (10-50)	965-1,220 (38-48)	12-14 (53-57)	205
131A	Southern Mississippi River Alluvium	0-100 (0-330)	Max 5 (15)	1,170-1,525 (46-60)	14-21 (5-69)	210
134	Southern Mississippi Valley Loess	25-185 (80-600)	3-6 (10-20)	1,195-1,525 (47-60)	14-20 (57-68)	215

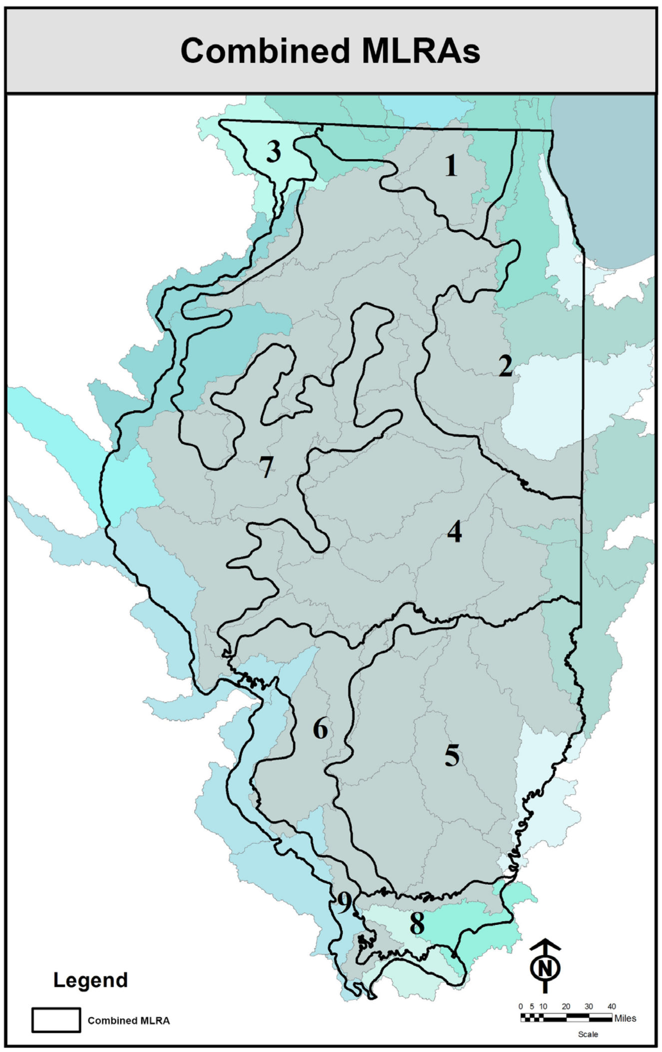


Figure 3.17. Combined MLRAs shown with HUC8s overlaid.

Table 3.6. Summary of agricultural management by MLRA in Illinois showing corn, soybean, and wheat acres; drained acres; and average corn and soybean yields, all averaged for 2008-2012.

Combined MLRA	Description	Corn (1,000 acres)	Soybean (1,000 acres)	Wheat (1,000 acres)	Drained acres (percent of crop acres)	Corn yield (bushels/acre)	Soybean yield (bushels/acre)
MLRA 1	Northern Illinois drift plain	516	224	20	288 (39)	161	48
MLRA 2	Northeastern Illinois heavy till plain	1,532	1,112	42	2,064 (78)	150	39
MLRA 3	Northern Mississippi Valley	164	52	2	2 (10)	160	50
MLRA 4	Deep loess and drift	5,580	3,343	76	5,438 (61)	164	52
MLRA 5	Claypan	1,610	1,992	353	310 (9)	128	39
MLRA 6	Thin loess and till	664	690	161	227 (17)	130	42
MLRA 7	Central Mississippi Valley, northern	2,059	1,289	74	1,285 (38)	155	49
MLRA 8	Sandstone and shale hills and valleys	84	115	11	50 (25)	103	33
MLRA 9	Central Mississippi Valley, western	204	315	78	24 (5)	125	39
Sum		**12,412**	**9,132**	**817**	**9,706 (43)**		

Table 3.7. Estimated fertilizer and manure nitrogen application for corn/soybean rotations and continuous corn by MLRA in Illinois along with the recommended rates using the MTRN approach.

Combined MLRA	Description	Estimated corn/soybean fertilizer and manure (lb/acre/yr)	MRTN (10-1) corn/soybean (lb/acre/yr)	Estimated continuous corn fertilizer and manure (lb/acre/yr)	MRTN (10-1) continuous corn (lb /acre/yr)
MLRA 1	Northern Illinois drift plain	156	146	196	199
MLRA 2	Northeastern Illinois heavy till plain	151	155	190	197
MLRA 3	Northern Mississippi Valley	146	146	184	199
MLRA 4	Deep loess and drift	147	155	185	197
MLRA 5	Claypan	181	171	227	189
MLRA 6	Thin loess and till	157	171	198	189
MLRA 7	Central Mississippi Valley, northern	156	163	197	194
MLRA 8	Sandstone and shale hills and valleys	202	171	254	189
MLRA 9	Central Mississippi Valley, western	188	171	237	189

Table 3.8. Tile-drained cropland acres and nitrate-nitrogen yields per row crop acre along with yields divided into tile-drained and non-tile drained land by MLRA in Illinois.

Combined MLRA	Description	Drained cropland (1,000 acres)	Nitrate-N yield per row crop acre (lb/acre/yr)	Nitrate-N yield per tile-drained acre (lb/acre/yr)	Nitrate-N yield from non-tiled land (lb/acre/yr)
MLRA 1	Northern Illinois drift plain	289	20.4	43	6.6
MLRA 2	Northeastern Illinois heavy till plain	2,064	25.0	29	10.8
MLRA 3	Northern Mississippi Valley	21	31.3		31.3
MLRA 4	Deep loess and drift	5,438	19.6	26	9.9
MLRA 5	Claypan	310	6.6		6.6
MLRA 6	Thin loess and till	227	7.4	30	3.5
MLRA 7	Central Mississippi Valley, northern	1,285	24.5	46	11.8
MLRA 8	Sandstone and shale hills and valleys	50	3.9		3.9
MLRA 9	Central Mississippi Valley, western	24	4		4

Table 3.9. Phosphorus fertilizer and manure inputs, row crop acres, and total phosphorus yields per row crop acre by MLRA in Illinois.

Combined MLRA	Description	Estimated fertilizer (lb/acre/yr)	Estimated manure (lb/acre/yr)	Row crops (1,000 acres)	Total P yield per row crop acre (lb/acre/yr)
MLRA 1	Northern Illinois drift plain	14.9	3.9	760	0.71
MLRA 2	Northeastern Illinois heavy till plain	13.4	1.3	2,686	0.68
MLRA 3	Northern Mississippi Valley	13.4	5.4	218	1.72
MLRA 4	Deep loess and drift	13.6	2.3	9,000	0.96
MLRA 5	Claypan	11.7	2.4	3,954	1.74
MLRA 6	Thin loess and till	11.3	2.5	1,515	2.09
MLRA 7	Central Mississippi Valley, northern	13.6	3.4	3,421	1.45
MLRA 8	Sandstone and shale hills and valleys	11.3	1.3	210	2.82
MLRA 9	Central Mississippi Valley, western	11	1.6	597	2.82
Sum				**22,362**	

Point Source Reductions and Cost Estimates

We estimated potential reductions in point sources for both total phosphorus and nitrate-nitrogen. It is important to keep in mind that point source nitrate-nitrogen was only estimated at 18 percent of the load for the state, whereas total phosphorus was 48 percent of the state load. For total phosphorus, we estimated the overall reduction from all major point sources lowering phosphorus discharge concentrations to either 1 or 0.3 mg/L-1. We also estimated reductions for scenarios where only the top 20, 30, or 50 majors lowered their discharge concentrations (Table 3.10). From these results, it is clear that most of the potential reduction comes from lowering the current discharge concentrations of 2.5-3.0 mg/L-1 to 1mg/L-1. In addition, lowering phosphorus discharge from the top 20 major sources accounted for 58 percent of the estimated reduction in total phosphorus. A few very large plants in Illinois produce a large portion of the state's point source total phosphorus, and reductions from these facilities lead to large reductions in the statewide estimated total phosphorus loads.

After reviewing other states' nutrient reduction plans and various reports on possible nutrient decreases from sewage effluent, we estimated the costs and reductions that would occur if all majors lowered their effluent concentrations to 10 mg nitrate-N/L-1 and 1mg total P/ L-1. For point source reduction costs, we used the following sources:

- U.S. EPA Municipal Nutrient Removal Technologies Reference Document (U.S. EPA, 2008)
- Nutrient Removal Study North Shore Sanitary District, Illinois (Donohue & Associates, 2010)
- Utah Statewide Nutrient Removal Cost Impact Study (CH2MHILL, 2010)
- Minnesota Nutrient Reduction Strategy (Minnesota, 2013)
- Iowa Nutrient Reduction Strategy (Iowa, 2013)
- Water Policy Working Paper #2005-011 (Jiang et al., 2005)
- Cost/Benefit Study of the Impacts of Potential Nutrient Controls for Colorado Point Source Discharges (Camp Dresser & McKee Inc., 2012)

U.S. EPA (2008) provided the annual per pound cost of lowering nitrogen or phosphorus discharges from eight plants in the United States and Canada. We used the median nitrogen and phosphorus costs for these eight plants. For the three North Shore plants in Illinois, we estimated decreases in discharge for each plant based on several different technologies and used the median value for our overall estimate. There were 20 plants in the Utah study that calculated a net present cost. We adjusted this value to annual dollars per pound reduced and again took the median value. The 2005 construction costs in Jiang et al. (2005) were escalated to 2013 dollars using the construction cost index. Iowa and Minnesota costs came from their 2013 nutrient reduction plans. We had to estimate the decrease in nitrogen or phosphorus pounds for these studies since these values were not given. We assumed current total phosphorus concentrations of 2.78 mg/L-1 and current nitrate-nitrogen concentrations of 16.8 mg/L-1 in all plants that would be affected. These values are the statewide averages from our evaluation of point source nutrient concentrations in Illinois. We also used the statewide average from the Colorado study adjusted to annual costs. Finally, we took the mean cost estimate from the seven different studies (ranging from $2.42 to $33.23/lb for total phosphorus and $1.34 to $5.67/lb for total nitrogen) to reach an overall cost estimate of $13.71/lb of total phosphorus reduced to a 1 mg/L-1 standard and $3.30/lb of nitrate-nitrogen reduced to a 10 mg/L-1 standard. When applied to all major point sources in the state, 14 and 8.3 million lb of nitrate-nitrogen and total phosphorus, respectively, would be reduced at an annual cost of $46 million and $114 million/yr. There would be substantial first year construction costs, but these were annualized over a 20-year period at an interest rate of 4.5 percent.

These costs are averages, and the cost would vary greatly depending on a plant's current configuration and treatment process. Plants that could effectively do biological nutrient removal would likely have much lower costs than those that would do chemical treatment alone. In addition, larger plants can typically reduce nutrients at a cheaper per pound rate compared to small plants. As plant size approaches 1 MGD or less, costs increase greatly. As a final comment, point source reductions to lower standards (0.5 or 0.1 mg/L-1 and 3 mg/L-1) would cost much more per pound reduced. We were not able to find enough information on these costs to make good estimates, but the literature suggests as much as a 10 times greater costs per pound.

Table 3.10. Point source phosphorus estimates at two limits, number of majors reduced, and percent of target reduction.

Point source limit (mg/ L^{-1})	Million lb reduced	Percent of target (18.8 million lb)
All majors to 1	8.3	44
Top 20 majors to 1	4.8	26
Top 30 majors to 1	5.4	29
Top 50 majors to 1	6.1	32
All majors to 0.3	13.1	70
Top 20 majors to 0.3	8	42
Top 30 majors to 0.3	8.9	47
Top 50 majors to 0.3	9.9	52

Non-Point Source Nitrate-Nitrogen Reduction Practices

We considered a full range of practices that could be applied in Illinois to reduce nitrate-nitrogen losses from agricultural fields. We used the Iowa Nutrient Reduction Strategy literature review (Iowa, 2013) and the Lake Bloomington study (David et al., 2008) as the basis for understanding what might work well in Illinois and then made modifications based on Illinois conditions. Practices are divided into three groups: in-field, edge-of-field, and land use change (Table 3.11). We took the per acre costs presented in Appendix A and estimated the overall costs in dollars per pound reduced if the practice or scenario was fully implemented in the state. At this stage, the results cannot be added together because one practice may affect the removal effectiveness of another.

In-Field Practices

Our analysis suggested that producers in most of the state apply nitrogen fertilizer at rates similar to the MRTN calculator recommendation. However, it is likely that not all producers are following this guideline, so we assumed 10 percent are well above the MRTN and that reducing their nitrogen rate to the MRTN would result in a 10 percent reduction in nitrate-nitrogen losses per acre (reduction percent from Iowa, 2013). When applied to corn acres in the state, this would reduce the overall nitrate-nitrogen load by 2.3 million lb yr-1, or 0.6 percent of the baseline. This isn't a large reduction, but the cost is negative, meaning that producers would save money.

The impact of nitrification inhibitors was estimated at 4.3 million lb yr-1 of reduced nitrate-nitrogen losses. Assumptions included: using an inhibitor for fall-applied nitrogen will result in a 10 percent per acre reduction in loss (Iowa, 2013); 50 percent of the nitrogen in the northern two-thirds of Illinois (MLRAs 1, 2, 4, 6, and 7) is applied in the fall; and 50 percent of that nitrogen currently includes an inhibitor. These assumptions came from analysis of fertilizer sales information, surveys, and discussions with industry representatives. The related cost is $2.33/lb removed.

We made two estimates for changing fertilizer timing. The first was that no nitrogen was applied to tile-drained acres in the fall. Based on results from Clover (2005) and Gentry et al. (2014), we used a 20 percent reduction in nitrate-nitrogen losses in central Illinois and a 15 percent reduction in northern Illinois. Central Illinois has warmer temperatures and typically has greater tile flow in winter and early spring, leading to potentially greater losses from fall-applied nitrogen. Iowa (2013) estimated a 6 percent reduction using data from both Iowa and its surrounding states, but they have lower temperatures and less precipitation in their tile-drained region than Illinois. These assumptions led to a 26 million lb yr-1 reduction, or 6.4 percent of the baseline. We also estimated a split application of 50 percent fall and 50 percent spring for a given field. Because there are no measurements for this nitrogen system, we assumed it would be half as effective at reducing nitrate-nitrogen losses as moving all fertilizer nitrogen currently applied in the fall to the spring. Therefore, the estimated reduction in load was 13 million lb yr-1. Although there are no data available on the potential nitrate-nitrogen response in tile drains, we did make an estimate for a fertilizer system that includes three applications: some in the fall with an inhibitor (40 percent), at planting as a carrier for herbicides or a starter fertilizer (10 percent), and in mid-June as side-dressing (50 percent). The Clover (2005) data did show a 20 percent reduction in nitrate-nitrogen losses from tile drains when spring and side-dressing applications were compared. Therefore, given the three-way split, we have included an estimate similar to the reduction from the fall-to-spring timing change. Costs for timing changes ranged from $3.17 to $6.22/lb removed.

The cost estimate for switching from fall to spring was $18/acre (see Appendix B for a complete presentation of how this cost was determined). This would be a substantial increase (12 percent) in fertilizer costs that totaled $148/acre in 2014 for central Illinois high-productivity farmland. An Illinois State University report from a project funded by the IDOA Fertilizer Research and Education Council estimated the costs of switching from fall to spring for all farmers at $0.1-1.5 billion/yr (O'Rourke and Winter, 2009). Given a typical planting year of 12 million corn acres, these costs would range from $9.79 to $120.33/acre. The $18/acre estimated here is within that range. Much of the higher end of the O'Rourke and Winter (2009) costs are based on reduced corn yields due to delayed planting by as much as 14 days. These costs are indeed quite high and would be avoided by farmers. We assumed that the additional fertilizer transport, storage, and application capacity needed would be built over time such that delayed planting losses would be minimal. The analysis and projections here assume that the change from fall to spring nitrogen fertilization would not be regulated or implemented immediately but would be voluntary so that a reduction in fall application would occur gradually across many years.

The other major in-field management change considered was the use of cover crops. There have been many studies on the effectiveness of cover crops but fewer on the impacts on tiled-drained fields specifically. Iowa (2013) calculated a 31 percent reduction in nitrate-nitrogen losses from a rye cover crop and 28 percent from oat. We therefore assumed a 30 percent reduction in nitrate-nitrogen losses using a generic grass cover crop. When applied to all tile-drained acres in Illinois, a cover crop led to the largest nitrate-nitrogen reduction of any practice: 84 million lb yr-1, or 20.5 percent of the baseline. When applied to all non-tiled acres, the reduction was 32 million lb yr-1. The costs for cover crops were quite different between tile-drained ($3.21/lb removed) and non-drained lands ($10.62/lb removed) because nitrate-nitrogen loss per acre is so much greater on the tile-drained lands, reducing costs per pound. This calculation does not mean that cover crops take up more nitrogen on tile-drained fields, only that the leaching losses are larger, and, therefore, the reduction is greater, reducing the cost per pound.

Edge-of-Field Practices

We estimated the effectiveness of three edge-of-field practices: bioreactors, wetlands, and buffers. Bioreactors are trenches filled with wood chips that are located on the edge of fields and intercept tile flow. Iowa (2013) estimated their effectiveness at a 43 percent reduction in nitrate-nitrogen loss from a field. There are few estimates of bioreactor effectiveness in Illinois. Much of the modeled effectiveness (and needed retention times) has been based on a water temperature of 20°C reported by Chun et al. (2010) for a short-term field test conducted near Decatur, Illinois on June 25 and 30, 2007. Tile water in Illinois is typically much colder than that during the typical flow period of January to early July, with temperatures at only about 5-10°C during much of the winter and spring flow periods. These lower temperatures would greatly reduce removal rates (Christianson et al., 2012). In addition, bioreactors may have larger rates of removal during the first year or two following installation as some of the fresh wood chip material degrades rapidly. Most measurements reported to date were taken during only the first year or two following installation. Therefore, we used a conservative value of 25 percent removal and assumed that 50 percent of all tile-drained land received a bioreactor, reducing nitrate-nitrogen loads by 35 million lb yr-1, or 8.5 percent of the baseline. Bioreactors have a large upfront cost, but this is one of the lower cost practices we evaluated at $2.21/lb of nitrate-nitrogen.

For constructed wetlands, we assumed a 50 percent reduction in nitrate-nitrogen losses, whereas Iowa (2013) assumed a 52 percent reduction. Our constructed wetlands are typically put at the end of individual tile lines at a wetland area/drainage ratio of 5 percent and are smaller in size (0.5-2 acres). The wetlands in Iowa are typically many acres in size and are fed by drainage areas of 1,000-2,000 acres. They intercept tile mains we do not typically have in Illinois. Kovacic et al. (2000) conducted the most complete constructed wetland study in Illinois and measured a 37 percent reduction in tile nitrate-nitrogen loads to the river. When they included seepage reductions, the overall estimate increased to 45 percent. Groh et al. (2015) evaluated the same wetlands studied by Kovacic et al. (2000) 18 and 19 years after construction. The wetlands were still working well and had an estimated total nitrate removal of 62 percent. Kovacic et al. (2006) studied two constructed wetlands near Bloomington, Illinois that received both surface runoff and tile flow as inputs. They measured a 36 percent reduction in nitrate export from these wetlands. We assumed that wetlands were placed on 35 percent of tile-drained acres. This would lead to a 49 million lb yr-1 reduction, or 11.9 percent of the baseline, at a cost of $4.05/lb removed.

Buffers along agricultural ditches and streams can reduce nitrate-nitrogen losses by increasing plant uptake and denitrification in the water that seeps through them. In tile-drained landscapes, much of the drainage water bypasses buffers, and estimating the water that does flow through them is difficult. In the non-tile-drained regions of the state, buffers can be effective at reducing nitrate-nitrogen losses to streams, although the current stream loads are much lower than in tile-drained regions. To estimate the potential reductions from planting grass riparian buffers along streams, we first conducted a GIS analysis to identify stream segments with existing buffers (defined as vegetation other than a row crop within 100 ft of the stream). Approximately 64 percent of the state's agricultural stream miles do not have buffers, and, therefore, nitrate-nitrogen loads could be reduced if buffers were planted. Iowa (2013) used state-specific studies and a complex analysis to determine the amount of water and nitrate-nitrogen that would pass through buffers. This analysis was beyond the data available for Illinois. To estimate nitrate-nitrogen removal by buffers, we used Iowa's (2013) ratio for total phosphorus to nitrate-nitrogen removed and our total phosphorus estimate for Illinois (see below). If buffers were installed on all agricultural streams currently without buffers, we estimate that nitrate-nitrogen would be reduced by 36 million lb yr-1 statewide, or 8.7 percent of the baseline, at a cost of $1.63/lb. This is a crude estimate, but we believe it is the correct magnitude, although it is likely to vary throughout the state due to differences in soils and lateral flow paths.

One edge-of-field practice we did not include in our cost estimates is drainage water management (DWM). This practice involves raising the outlet of the tile system with a control structure to as little as 6 in below the soil surface during periods when the field does not need to be worked, such as winter and early spring (Frankenberger et al., 2006; Skaggs et al., 2012). This practice works best on flat fields (less than 0.5 percent slope) with new patterned tile systems but can be retrofitted on existing systems. Research has shown that reductions in nitrate-nitrogen loss can be as much as 82 percent and are nearly the same as the water reduction that occurs as a result of raising the tile outlet (Skaggs et al., 2012). In Illinois, Cooke and Verma (2012) found that DWM reduced nitrate-nitrogen by 37-79 percent, which is similar to reductions measured by Woli et al. (2010). However, most of these studies have been on small fields, often just a few acres, and there is little understanding of what happens to the water and nitrates held back. Nearly all studies have shown that most of the water does not drain out when the tile outlet is lowered. If the water and nitrate-nitrogen move through lateral seepage due to the tile being raised to a nearby ditch or tile system, then the effectiveness at the watershed scale would be greatly reduced. A recent study by Sunohara et al. (2014) showed that DWM could increase seepage both laterally and into groundwater, which could limit its effectiveness. However, the authors also indicated more research was needed because their study was conducted only during the growing season rather than during winter and early spring, when we really expect this practice to be utilized. Given these uncertainties, we did not include DWM in any scenario. However, this is a practice that could perform well on some fields and could be used to reduce both nitrate and total phosphorus losses from tile-drained fields.

Two other practices that were not included but could fit some fields and watersheds are two-stage ditches (Roley et al., 2012) and saturated lateral buffers (Jaynes and Isenhart, 2014). Two-stage ditches modify the typical trapezoidal channel so that floodplains are constructed alongside the stream channel. During high flow, water spreads onto the floodplains, decreasing its velocity (Roley et al., 2012). Removal of denitrification is increased, but overall nitrate removal has been found to be quite limited at high flows. Saturated lateral buffers, which are currently being evaluated at several Illinois locations, allow a fraction of tile flow to be routed through a riparian buffer. Published results on these practices are limited, but they could be utilized to reduce nitrate losses where appropriate.

Land-Use Changes

Two estimates were made for land-use changes. The first looked at the impact of planting perennial crops on land converted to row crops from pasture between 1987 and 2007, which totaled 1.1 million acres according to NASS Census of Agriculture data. We estimated that this conversation would result in a 90 percent reduction in nitrate-nitrogen losses based on results from Iowa (2013) and recent work with biofuels on the University of Illinois South Farms (Smith et al., 2013). The estimated nitrate-nitrogen reduction would be 10 million lb yr-1, a 2.6 percent reduction from the baseline, at a cost of $9.34/lb.

As an additional estimate, we calculated the reduction in nitrate-nitrogen if 10 percent of corn/soybean tile-drained land were converted to perennials, again assuming a 90 percent reduction per acre. This 1 million-acre change would lead to a 25 million lb yr-1 reduction from the state, or 6.1 percent of the baseline, at a cost of $3.18/lb. This cost is much less than the other land-use changes described above because the land is 100 percent tile-drained, leading to much larger reductions per acre.

Table 3.11. Example statewide results for nitrate-nitrogen reductions, with shading to represent in-field, edge-of-field, land use, and point source practices or scenarios.

Practice/scenario	Nitrate-N reduction per acre (percent)	Nitrate-N reduced (million lb)	Nitrate-N reduction from baseline (percent)	Cost ($/lb removed)
Reducing N rate from background to MRTN on 10 percent of acres	10	2.3	0.6	-4.25
Nitrification inhibitor with all fall-applied fertilizer on tile-drained corn acres	10	4.3	1	2.33
Split application of 50 percent fall and 50 percent spring on tile-drained corn acres	7.5-10	13	3.1	6.22
Spring-only application on tile-drained corn acres	15-20	26	6.4	3.17
Split application of 40 percent fall, 10 percent pre-plant, and 50 percent side dress	15-20	26	6.4	
Cover crops on all corn/soybean tile-drained acres	30	84	20.5	3.21
Cover crops on all corn/soybean non-tiled acres	30	33	7.9	11.02
Bioreactors on 50 percent of tile-drained land	25	35	8.5	2.21
Wetlands on 35 percent of tile-drained land	50	49	11.9	4.05
Buffers on all applicable crop land (reduction only for water that interacts with active area)	90	36	8.7	1.63
Perennial/energy crops equal to pasture/hay acreage from 1987	90	10	2.6	9.34
Perennial/energy crops on 10 percent of tile-drained land	90	25	6.1	3.18
Point source reduction to 10 mg/L		14	3.4	3.3

Non-Point Source Total Phosphorus Reduction Practices

Total Phosphorus Losses and Soil Erosion Estimates

Phosphorus tends to adsorb to soil particles. As a result, non-point source total phosphorus losses from agriculture tend to be associated with surface runoff and soil erosion. Under certain conditions, leaching and subsurface flow can be significant pathways of dissolved phosphorus losses, which we will not address because it is difficult to estimate and thought to be a minor source on average. For the statewide assessment, we obtained estimates from the Illinois Department of Agriculture (IDOA) on cropland erosion for approximately 50,000 points in the state, which are based on a tillage transect survey conducted in the spring of 2011 by soil and water conservation districts. This survey collects information on residue cover, planted crops, slope, and other factors to estimate the long-term average sheet and rill erosion rates from each survey point using the universal soil loss equation (USLE) and the revised USLE (RUSLE). USLE was developed in the 1950s. RUSLE, released in the 1990s, is based on more extensive data and often produces lower erosion estimates, especially for steeper slopes, due to a modification in the slope steepness factor. We considered the RUSLE erosion estimate to be the more accurate estimate of cropland sheet and rill erosion, but we also used the USLE estimate in conjunction with a compatible sediment delivery formula to estimate total phosphorus losses at the watershed scale. Neither method estimates erosion or total phosphorus loads from ephemeral gullies, large gullies, or stream channel erosion.

The average sheet and rill erosion rates estimated with RUSLE for each of the nine modified MLRAs were highly correlated with the riverine non-point source total phosphorus yields leaving the MLRAs (Figure 3.18). The non-point source total phosphorus yields were calculated from the riverine total phosphorus loads minus the point source inputs and divided by the total land area in the MLRA.

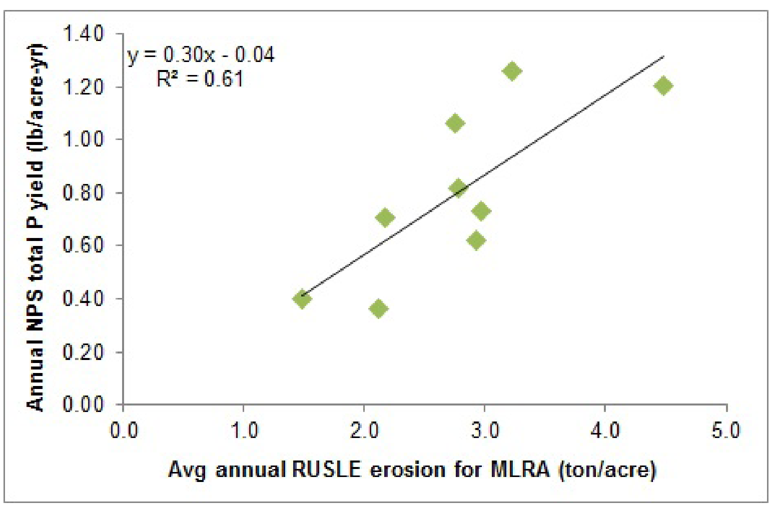


Figure 3.18. Non-point source total phosphorus yield for 1997-2011 from the nine modified MLRAs plotted as a function of average cropland RUSLE erosion rates within the MLRAs.

The riverine non-point source total phosphorus leaving the MLRA does not all originate from cropland erosion, and not all soil eroded in a given year reaches the watershed outlet. As surface runoff travels from cropland to larger rivers, some of the eroded soil is deposited in lower, adjacent fields, buffers, and grass waterways as well as flood plains, stream beds, and rivers. The fraction of eroded soil that arrives at a watershed outlet has been estimated using sediment delivery ratios (SDR). An early and widely used equation for estimating SDR in conjunction with USLE estimates of erosion is:

$$SDR = 0.42*(Area)^{-0.125} \qquad \text{Equation [1]}$$

where Area = watershed area in square miles.

The actual SDR will depend on more factors than area, such as slope, rainfall characteristics, and vegetation, but limitations on time and resources did not allow us to evaluate these factors. For the purpose of calculating rough approximations, the above equation was used to estimate SDR for each modified MLRA using the area of the MLRA. This equation was developed when the USLE was used to estimate erosion and was, therefore, only used in conjunction with USLE estimates of erosion. We used the RUSLE estimates of erosion to calculate the proportion of fields that were eroding at rates greater than soil loss tolerance (T) and to develop estimates of total phosphorus load under the different nutrient reduction scenarios described below.

Based on observed sediment and total phosphorus loads in Illinois from small watersheds (Russell, 2013) of 11-67 sq. mi, we used an average of 1.5 lb total P/ton of sediment load. The average annual non-point source total phosphorus loads draining from the MLRAs for 1997-2011 were highly correlated with the total phosphorus loads estimated using the average USLE erosion rates multiplied by the corresponding cropland area (including hay), SDR, and 1.5 lb total P/ton of sediment (Figure 3.19). The 1.5 lb/ton of sediment includes an unknown fraction of DRP that may have originated from a variety of sources, including desorption from cropland soils that were not eroded (discussed below), desorption from deposited sediments, leaching and subsurface transport of phosphorus, or other non-point source phosphorus sources.

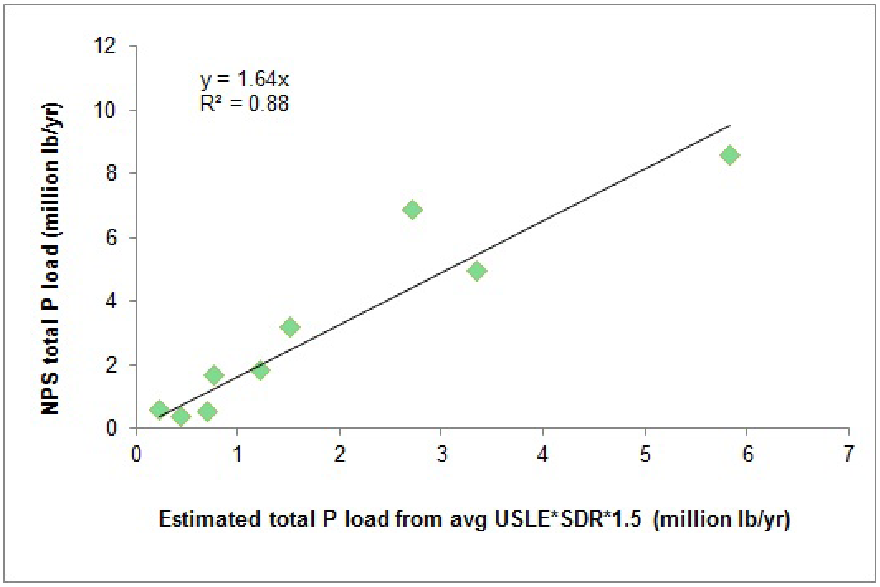


Figure 3.19. Annual average non-point source total phosphorus loads from the modified MLRAs plotted as a function of loads estimated from the average USLE erosion rates, cropland area, and SDR and assuming 1.5 lb total P/ton of sediment.

The high correlation in Figure 3.19 is partly a result of the MLRAs' variation in size. The highest loads come from the largest MLRAs. However, the correlation between total phosphorus yield and soil erosion rates (Figure 3.18) is also a factor. If we accept the estimates of USLE and SDR, the slope of the line (1.64) indicates that the non-point source total phosphorus loads carried by the rivers draining the MLRAs are 64 percent higher than estimated from cropland erosion. In other words, approximately 60 percent of the non-point source total phosphorus appears to be associated with cropland sheet and rill erosion. The other 40 percent could conceivably come from ephemeral gully erosion, stream bank erosion, leaching of dissolved phosphorus, desorption of soil phosphorus to runoff, other non-point source sources, and estimation inaccuracy.

There is considerable uncertainty surrounding the total phosphorus estimates associated with erosion. For an alternative estimate, we ignored the SDR and used the average RUSLE estimates of erosion and found a strong correlation with the non-point source total phosphorus load from the MLRAs (Figure 3.20). In this case, the slope is 0.32, which implies an average SDR of 0.32 if we assume all other non-point sources of total phosphorus were negligible. In comparison, the SDRs calculated by Equation (1) ranged from 0.12 to 0.18 for the different MLRAs. A portion of the total phosphorus carried with eroded sediment is DRP that desorbed from non-eroded soil during runoff events. Sharpley et al. (2003) estimated that approximately 20 percent of the total phosphorus in runoff from cropland is desorbed DRP. Controlling erosion by reducing tillage is not likely to reduce this movement of phosphorus and may actually increase it. Thus, in estimating the impacts of erosion reduction measures on total phosphorus loads, we assumed that 80 percent of the estimated total phosphorus associated with erosion is attached to eroded soil and can be reduced by erosion control measures. We applied this assumption only to the total phosphorus estimate based on RUSLE. For our total phosphorus load estimate based on the USLE, we assumed the desorbed DRP is a portion of the 40 percent of the observed non-point source total phosphorus load that was in excess of our USLE-based estimate.

Cropland Erosion Estimates

According to data collected in the IDOA tillage transect survey, the statewide average RUSLE erosion rate from all cropland, including hay, was 2.4 ton/acre in 2011. On cultivated cropland (corn, soybean, and wheat), the RUSLE average was 2.6 ton/acre and the USLE average was 3.6 ton/acre. This latter value is similar to the 2007 USDA National Resource Inventory (NRI) estimate of 3.9 ton/acre of sheet and rill erosion from cultivated cropland in Illinois, which was estimated using USLE. The NRI continues to use the USLE estimates to allow for consistent comparisons with earlier erosion estimates.

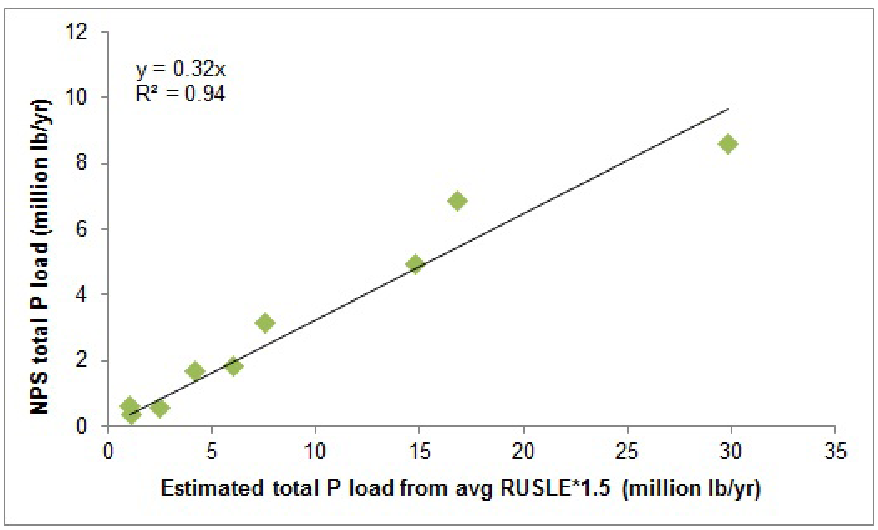


Figure 3.20. Average annual total phosphorus loads from the modified MLRAs plotted as a function of average RUSLE erosion estimates from all cropland in the MLRAs (including hay) times 1.5 lb total P/ton of sediment.

Federal and state policies have been enacted to discourage landowners from allowing soil erosion on their cropland to exceed T, which is considered the maximum rate of erosion that does not damage the productive potential of the soil. Values of T are 1-5 ton/acre/yr, depending on soil characteristics. According to the IDOA analysis of the 2011 tillage transect data, 15.8 percent of Illinois cropland is eroding at rates exceeding T (IDOA, 2011). In their analysis, IDOA excluded erosion estimates of zero, assuming these to be the result of erroneous or incomplete data entry. When we included these zero estimates, we found that 15.4 percent of the sampled cropland was eroding in excess of T (Figure 3.21). Many of these zero values included cropland in hay or in the Conservation Reserve Program (CRP), which have low erosion rates. Furthermore, it is likely that incomplete or incorrect data entry also resulted in some erroneously high erosion estimates. Eliminating only erosion estimates of zero may produce an upward bias in aggregate erosion statistics, although that bias appears to be relatively small.

Our estimates for reducing non-point source total phosphorus loads by changing in-field management practices focus on practices that could reduce erosion rates to T or less on the acres that appear to be eroding at a higher rate. It is interesting to note that the percentage of cropland acres with RUSLE estimated erosion rates greater than T has increased from 13.5 percent in 1997 (Figure 3.21). The highest average erosion rates and the largest percentage of cropland with erosion rates exceeding T were in the southern portion of the state (Table 3.12), where rainfall erosivity is higher and slopes tend to be steeper than in other parts of the state.

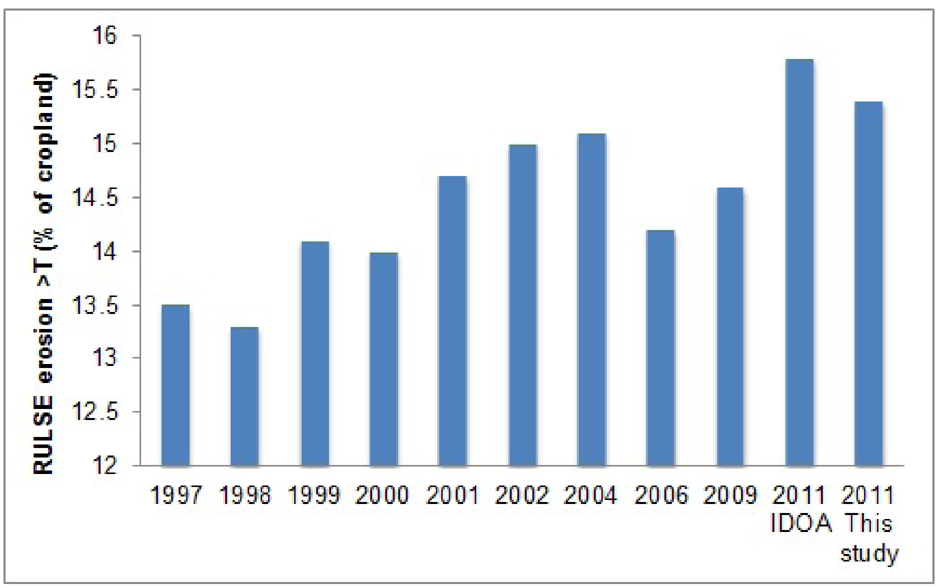


Figure 3.21. Percentage of Illinois cropland with RUSLE erosion estimates exceeding T. IDOA's 2011 results eliminated observations with erosion rates of zero, while our analysis included those values (data from IDOA, 2011).

Table 3.12. Extent of cropland area with RUSLE erosion estimates exceeding T, the average amount of erosion exceeding T on these acres, and the estimated riverine load of total phosphorus associated with erosion exceeding T.

	Cropland with RUSLE erosion >T		Avg. RUSLE	Estimated riverine total P load associated with erosion >T	
MLRA			Erosion >T	USLE*SDR*1.5	RUSLE*0.32*1.5*0.8
	percent	1,000 acres	ton/acre	million lb/yr	
1	9	76	2.7	0.15	0.08
2	7	178	2.2	0.13	0.15
3	21	51	3.8	0.18	0.08
4	9	805	3.2	1.07	0.98
5	22	911	3.4	0.7	1.19
6	27	418	3.8	0.52	0.61
7	15	542	4	1.01	0.83
8	18	44	7.3	0.09	0.12
9	27	171	7	0.34	0.46
Total		3,196		4.2	4.5

Approximately 3.2 million cropland acres in the state have RUSLE erosion estimates exceeding T. If erosion on these fields were reduced to T, we estimate that the total phosphorus leaving the state in rivers may be reduced by 4.2-4.5 million lb/yr, depending on the method used to estimate the relationship between cropland erosion and riverine phosphorus loads. Although the highest erosion rates exceeding T are in MLRAs 8 and 9, these MLRAs are relatively small and do not contribute a large portion of the statewide total phosphorus loads from cropland with erosion greater than T. MLRAs 4, 5, and 7 contribute a larger portion of this total phosphorus load because of their size and high average rate of erosion.

The sites with high erosion tend to have higher-than-average slopes, and 1.8 million acres are in annual cropland with conventional tillage (Table 3.13). Converting these acres to some form of reduced or conservation tillage would reduce erosion by 50 percent on average. We estimate that this conversion would reduce total phosphorus loading by 1.8-2.8 million lb/yr at a cost of -$16.60/lb removed (Table 3.14), assuming no reduction in crop yields.

Table 3.13. Acres of corn, soybeans, and wheat in various tillage systems with RUSLE erosion estimates greater than T, and the estimated reductions in total phosphorus loads from a 50 percent reduction in erosion by converting the conventional tilled area to a combination of reduced, mulch, or no-till.

	Acres by tillage				Estimated reductions in total P loads	
MLRA	Conventional	Reduced	Mulch	No-till	USLE est.	RUSLE est.
	1,000 acres				million lb/yr	
1	50	14	10	6	0.08	0.07
2	105	52	21	6	0.07	0.12
3	9	16	26	9	0.02	0.02
4	419	249	88	63	0.39	0.64
5	634	175	89	113	0.45	0.87
6	242	87	40	67	0.24	0.37
7	254	202	78	68	0.34	0.47
8	30	9	5	30	0.04	0.07
9	86	36	21	54	0.12	0.21
Total	1,829	841	377	414	1.8	2.8

Among the acres eroding greater than T, there are approximately 1.6 million acres of corn, soybeans, and wheat that are already in some form of reduced tillage. If these acres included winter cover crops in their rotation, which would cause a 50 percent reduction in erosion, we estimate that total phosphorus loads would be reduced by 1.9-2.3 million lb/yr. Alternatively, if these acres were converted to perennial crops, such as for biofuels, hay, or CRP, which would result in a 90 percent reduction in soil erosion, we estimate that total phosphorus loads may be reduced on the order of 3.5-6.5 million lb/yr, depending on the method of estimation used. The lower estimate would cost $40.40/lb removed.

If winter cover crops were planted on all 21.5 million acres of corn and soybeans, we estimate an average total phosphorus loss reduction of 30 percent on these acres, which translates to a statewide load reduction of around 4.8-6.1 million lb/yr. The lower estimate would cost $130.40/lb removed. This 30 percent average reduction assumed for the 21.5 million acres is less than the 50 percent reduction assumed for the sites eroding greater than T, because there is less average erosion and total phosphorus loss to reduce. However, the aggregate load reduction is greater because of the larger area considered (21.5 million acres compared to 1.6 million acres).

If 1.1 million acres of the land that had been in hay or pasture in 1987 but is currently in corn/soybean rotation were converted to perennial hay or energy crops, we estimate that the statewide reduction in total phosphorus load would be approximately 0.9-1.1 million lb/yr, depending on the method used. This estimate assumes a 90 percent reduction in erosion from the average phosphorus rates from corn/soybean in each MLRA. The lower estimate would cost $102.30/lb removed.

If 10 percent of the corn/soybean rotation acres on tile-drained land were converted to perennial hay or energy crops, the statewide reduction would be approximately 0.3 million lb/yr at a cost of $250.07/lb removed. This estimate assumes a 50 percent reduction in phosphorus loss per acre.

For all scenarios described above, our assumptions of 30, 50, or 90 percent reductions in erosion are rough approximations. More precise estimations will require more detailed assessments of current landscape characteristics and the cropping systems that would replace current practices. Additionally the impact of ephemeral gulley erosion associated with total phosphorus load and the potential of grassed waterways to reduce this source of sediment and total phosphorus is highly uncertain. The Illinois office of NRCS has expressed an interest in producing estimates of ephemeral gully erosion (personal communication from Mr. Kerry Goodrich, State Resource Conservationist, USDA NRCS).

It should also be noted that the average USLE soil erosion rates on cropland in Illinois, including hay, declined from 6.2 ton/acre in 1982 to 4 ton/acre in 1997 according to NRI. Between 1997 and 2007, average erosion rates declined only slightly to 3.8 ton/acre. Applying our analysis to NRI data suggests that the decline in USLE erosion estimates for 1982-1997 would have been accompanied by a decline in total phosphorus loads of about 14.6 million lb/yr, but we see no such decline in the aggregate total phosphorus loads (including point sources) in the seven major river basins (Figure 3.22). We do not have reliable historical data on point source loads, but it is possible that a decline in non-point source total phosphorus loads due to erosion control may have been partially offset by an increase in point source inputs. Non-point source total phosphorus reductions may also have been offset by legacy effects in which the phosphorus in stream sediments was desorbed as non-point source inputs declined. Almost all of the increase in recent years was due to DRP rather than particulate phosphorus loads, which may implicate urban point sources as well as leaching from cropland and runoff of unincorporated phosphorus fertilizers. Furthermore, the years after 2007 included some record-setting rainfall and flooding events that increased erosion and total phosphorus losses by more than is reflected in the USLE estimates, which are calculated based on long-term average annual rainfall erosivity values from prior decades.

Trends in total phosphorus loads are often difficult to detect because of large year-to-year variations in river discharges. USGS has developed a method of flow normalization that attempts to eliminate the influence of these variations on concentration and constituent flux. Using this technique to examine individual river basins reveals that the flow-normalized total phosphorus concentrations and loads in the Rock, Green, and Embarras rivers declined by 30-60 percent between 1985 and 2011. For the Illinois, Kaskaskia, Little Wabash, and Big Muddy rivers, flow-normalized concentrations and fluxes increased by about 4-20 percent. For the Vermilion River at Danville, flow-normalized concentration declined 30 percent, but flow normalized flux increased only 1 percent. Almost all the decline in the Rock River occurred above Rockton, which is the Wisconsin portion of the basin. When the flow-normalized flux at Rockton is subtracted from that at Joslin and added to the other fluxes, the state total increased by 10 percent in 1985-2011. Further research is needed to understand this variation on patterns across the state and why there was no decline in total phosphorus loads despite the large reductions in USLE erosion estimates in the 1980s and early 1990s.

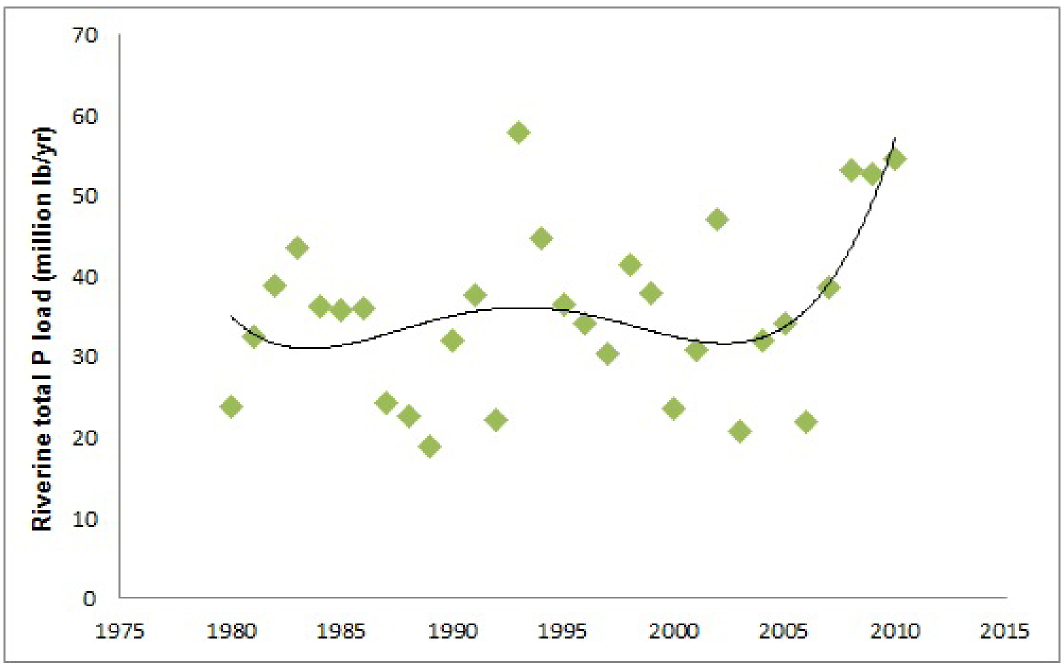


Figure 3.22. Estimated annual riverine total phosphorus loads leaving Illinois based on observed stream flows, periodic concentration measurements, and the WRDTS method of load calculation. The green diamonds indicate individual year loads, and the black line is a polynomial best fit trend line intended to illustrate unusually high phosphorus loads after 2007. This line is not intended to forecast future trends.

Soil Test Phosphorus

The vast majority of the phosphorus in soil is in organic forms not immediately available for crop uptake. A variety of soil tests have been developed to estimate the relatively small portion of total soil phosphorus that is readily available to crops. This is generally referred to as soil test phosphorus (STP) or the Olsen, Bray, or Mehlich forms of phosphorus, depending on the specific laboratory procedures used. Since STP is usually a small fraction of the total soil phosphorus, normal variations in STP have little influence on the magnitude of phosphorus transported with eroded sediment. On the other hand, many studies have shown a strong linear relationship between STP and DRP in surface runoff (Sharpley et al., 2003). Sharpley et al. (2003) also estimated that about 20 percent of total phosphorus loss in cropland runoff occurred in the form of DRP as correlated with STP. For the purpose of estimating the influence of STP levels on total phosphorus loss in Illinois rivers, we assumed that 20 percent of the riverine non-point source total phosphorus loads from MLRAs was from desorption of soil phosphorus to DRP in surface runoff.

Fernandez et al. (2012) measured STP in 547 Illinois corn fields prior to harvest in September and October of 2007 and 2008. They reported that 59 percent of fields sampled exceeded recommended soil phosphorus levels to achieve maximum crop yields. They also reported that these fields could achieve maximum crop production for six years without additional phosphorus fertilizer applications. Delaying additional fertilizer amendments for this period would reduce the STP and reduce the DRP in runoff from these fields. We estimated a reduction in DRP loss in runoff from cropland that might occur if the average STP values reported by Fernandez et al. (2012) were reduced to the STP maintenance levels (30, 33, and 35 ppm for the high, medium, and low phosphorus-supplying regions, respectively). This corresponds to a 50 percent reduction in STP in the high phosphorus-supplying region, a 37 percent reduction in the medium phosphorus-supplying region, and a 12 percent reduction in the low phosphorus-supplying region. If DRP in runoff is a linear function of STP concentration, as indicated by Sharpley et al. (2003), reducing STP would lead to a proportional reduction in DRP loss from cropland. Assuming that this DRP contribution is 20 percent of the average observed non-point source total phosphorus loads for each MLRA, we calculated a reduction of DRP loss for each MLRA based on the proportion of the MLRA in the high, medium, and low phosphorus-supplying regions, assuming the average STP values reported by Fernandez et al. (2012) were representative of these regions. The total reduction for the state was 1.9 million lb/yr at a cost of -$48.750/lb reduced.

The STP maintenance levels mentioned above are considered appropriate for fields likely to include wheat, oats, or alfalfa in their rotation. According to the Illinois Agronomy Handbook (University of Illinois, 2012a), STP levels of 20 ppm of total phosphorus can produce maximum yields in a corn/soybean rotation. Assuming STP values from Fernandez et al. (2012) largely represent fields in corn/soybean rotation, reducing average STP values to 20 ppm of total phosphorus, and following the procedures described above, we estimated a 3.2 million lb/yr reduction in DRP in runoff.

Edge-of-Field Practices

To estimate the potential reductions from planting grass riparian buffers along streams, we first conducted a GIS analysis to identify the miles of streams that currently have buffers. Approximately 64 percent of the stream miles in the state do not have buffers. Therefore, phosphorus loads could be reduced if buffers were established on these streams. We assumed that an average of 70 percent of the non-point source total phosphorus load from each MLRA originated as subsurface drainage and surface runoff. Riparian buffers could reduce phosphorus in surface runoff but not in subsurface drainage. For non-tile-drained land, we assumed that a 35 ft-wide riparian buffer would reduce total phosphorus loads from cropland without buffers by 50 percent. There would be considerably less surface runoff interacting with the buffer on tile-drained land, so we assumed adding a 35-ft-wide buffer would reduce total phosphorus loads by 25 percent in these areas. From these assumptions, we estimated that planting 35 ft-wide riparian buffers on all streams lacking any buffer would reduce total phosphorus loss by 4.8 million lb/yr at a cost of $11.97/lb reduced. Measurements of phosphorus reductions from perennial buffers have been highly variable. Iowa (2013) used an average reduction of 58 percent but reported a range from -10 percent (i.e., an increase in total phosphorus load) to 98 percent. Our assumed estimated reductions were based on professional judgment informed by empirical results published in relevant literature.

The literature on the effectiveness of wetlands at removing total phosphorus reports highly variable results (e.g., Kovacic et al., 2000). Unlike nitrate-nitrogen, which can be removed from aquatic systems when it is converted to its gaseous forms in anaerobic conditions, total phosphorus cycles through wetland vegetation and can be released as DRP from decaying wetland vegetation and bottom sediments. Consequently, we assumed no net reduction in total phosphorus loads from additional constructed wetlands.

Although not estimated, there are other edge-of-field practices that can be used to reduce sediment losses, including strip cropping, terraces, and water and sediment control basins. See Czapar et al. (2008) for a summary and discussion of the effectiveness of these practices.

Table 3.14. Example statewide results for total phosphorus reductions by practice/scenario with shading to represent in-field, edge-of-field, land use changes, and point source practices or scenarios.

Practice/scenario	Total P reduction per acre (percent)	Total P reduced (million lb)	Total P reduction from baseline (percent)	Cost ($/lb removed)
1.8 million acres of conventional till eroding >T converted to reduced, mulch, or no-till	50	1.8	5	-16.6
P rate reduction on fields with soil test P above the recommended maintenance level	7	1.9	5	-48.75
Cover crops on all corn/soybean tile-drained acres	30	4.8	12.8	130.4
Cover crops on 1.6 million acres eroding >T currently in reduced, mulch, or no-till	50	1.9	5	24.5
Wetlands on 25 percent of tile-drained land	0	0	0	
Buffers on all applicable crop land	25-50	4.8	12.9	11.97
Perennial/energy crops equal to pasture/hay acreage in 1987	90	0.9	2.5	102.3
Perennial/energy crops on 1.6 million acres >T currently in reduced, mulch, or no-till	90	3.5	9	40.4
Perennial/energy crops on 10 percent of tile-drained land	50	0.3	0.8	250.07
Point source reduction to 1 mg/L (majors only)		8.3	22.1	13.71

Statewide Scenarios with Costs

The final steps in our analysis were to combine practices and scenarios for nitrate-nitrogen and total phosphorus reductions to develop overall statewide nitrogen and phosphorus scenarios for reaching either the 20 or 45 percent reduction target for each nutrient individually and together. These scenarios take into account the fact that one practice may alter the effectiveness of another. Table 3.15 presents the nitrate-nitrogen scenarios we developed, three for 45 percent reductions and three for 20 percent reductions. All nitrate-nitrogen scenarios include the MRTN rate applied to all MLRAs because it is a negative cost to farmers. Scenario N1 also includes a spring-only nitrogen application with cover crops, bioreactors, wetlands, and buffers to reach a 45 percent reduction in nitrate-nitrogen at a cost of $3.96/lb and $728 million/yr. This scenario carries the least cost as it maximizes the practices with the lowest costs per pound removed, such as bioreactors, buffers, and cover crops on tile-drained acres.

Scenario N2 uses mostly cover crops, perennials, and bioreactors, as well as point source reductions, to reach a 45 percent reduction in nitrate-nitrogen. The cost of this strategy is $4.67/lb reduced, or $858 million/yr. The final scenario is N3, which replaces the spring-only fertilizer application and bioreactor strategies with wetlands and adds buffers. This strategy has a cost of $4.48/lb reduced, or $830 million/yr. There is some total phosphorus reduction, around 20-30 percent, with many of the nitrogen practices.

Scenarios N4-6 all estimate a 20 percent reduction in nitrate-nitrogen, with N4 and N5 each costing the least at $3.00/lb removed. This scenario includes MRTN, a spring-only nitrogen application, a small percentage of cover crops, and both bioreactors and wetlands. Scenario N5 comes in at a similar cost by keeping the bioreactors and wetlands but replacing the fertilizer timing with cover crops on 35 percent of tiled-drained acres. The final scenario, N6, shows the level of cover cropping needed for a 20 percent reduction. The cost for this scenario would be substantially higher. However, there is much greater phosphorus removal with N6 than either N4 or N5.

Table 3.15. Example statewide nitrate-nitrogen scenarios.

Name	Combined practices and scenarios	Nitrate-N (percent reduction)	Total P (percent reduction)	Cost of reduction ($/lb)	Annualized costs (million $/yr)
N1	MRTN rate, spring-only N application, cover crops on 70 percent of tile-drained and 45 percent non-tiled acres, bioreactors on 50 percent of acres, wetlands on 30 percent of acres, all ag streams have buffers	45	20	3.96	728
N2	MRTN rate, spring-only N application, cover crops on 100 percent of tile-drained and 70 percent of non-tiled acres, bioreactors on 75 percent of acres, perennial crops on non-tiled acres, point source to 10 mg/L	45	33	4.67	858
N3	MRTN rate, cover crops on 100 percent of tile-drained and 70 percent of non-tiled acres, wetlands on 20 percent of acres, perennial crops on non-tiled acres, all ag streams have buffers, point source to 10 mg/L	45	24	4.48	830

Name	Combined practices and scenarios	Nitrate-N (percent reduction)	Total P (percent reduction)	Cost of reduction ($/lb)	Annualized costs (million $/yr)
N4	MRTN rate, spring-only N application, cover crops on 5 percent of tile-drained acres, bioreactors on 50 percent of acres, wetlands on 15 percent of acres	20	0.3	3.00	246
N5	MRTN rate, cover crops on 35 percent of tile-drained acres, bioreactors on 50 percent of acres, wetlands on 15 percent of acres	20	2	3.00	246
N6	MRTN rate, cover crops on 75 percent of tile-drained and 55 percent of non-tiled acres	20	8	4.78	394

In Table 3.16, we present statewide scenarios for total phosphorus. Scenario P1 includes reducing phosphorus fertilizer application, reduced tillage, adding buffers, and reducing point source contributions to reach a 45 percent reduction in total phosphorus at a cost of $48 million/yr. Because most of the agricultural practices save money, the overall cost is reduced. However, there is a positive cost of $114 million/yr for point source phosphorus reductions. Scenario P2 also includes a reduction in phosphorus fertilizer and tillage but adds cover crops so all agricultural practices are in-field. This scenario costs $36.44/lb reduced, or $615 million/yr. Scenario P3 adds perennials on many acres as an alternative at a cost of $41.24/lb reduced. However, this scenario has the greatest nitrate-nitrogen reductions—37 percent compared to only 7 percent with scenario P1.

Table 3.16. Example statewide total phosphorus scenarios.

Name	Combined practices or scenarios	Nitrate-N (percent reduction)	Total P (percent reduction)	Cost of reduction ($/lb)	Annualized costs (million $/yr)
P1	No P fertilizer on 12.5 million acres above STP maintenance, reduced till on 1.8 million conventionally tilled acres eroding >T, buffers on all applicable lands, point source to 1 mg/L	7	45	2.84	48
P2	No P fertilizer on 12.5 million acres above STP maintenance, reduced till on 1.8 million conventionally tilled acres eroding >T, cover crops on all corn/soybean acres, point source to 1 mg/L	29	45	36.44	615

Name	Combined practices or scenarios	Nitrate-N (percent reduction)	Total P (percent reduction)	Cost of reduction ($/lb)	Annualized costs (million $/yr)
P3	No P fertilizer on 12.5 million acres above STP maintenance, reduced till on 1.8 million conventionally tilled acres eroding >T, cover crops on 87.5 percent of corn/soybean acres, buffers on all applicable lands, perennial crops on 1.6 million acres >T and 0.9 million additional acres	38	45	41.24	696
P4	No P fertilizer on 12.5 million acres above STP maintenance, reduced till on 1.8 million conventionally tilled acres eroding >T, buffers on 80 percent of all applicable land	6	20	-10.40	-78
P5	No P fertilizer on 12.5 million acres above STP maintenance, reduced till on 1.8 million conventionally tilled acres eroding >T, point source to 1 mg/L on 45 percent of discharge	0	20	-9.73	-73
P6	No P fertilizer on 12.5 million acres above STP maintenance, reduced till on 1.8 million conventionally tilled acres eroding >T, cover crops on 1.6 million acres eroding >T and 40 percent of all other corn/soybean acres	11	20	22.93	172

To reach a 20 percent reduction in total phosphorus, scenarios P4 and P5 use fertilizer reductions and reduced tillage along with either buffers or point source reductions. The cost of these scenarios is between -$73 and -$78 million/yr. The final scenario, P6, uses all in-field practices (i.e., there is no reduction of row crop acres) and costs $172 million/yr for a 20 percent reduction in total phosphorus.

The final analysis was to develop scenarios that met the mid- and long-term target reductions for both nitrate-nitrogen and total phosphorus. To illustrate the range of practices and costs involved, we again developed three scenarios for reaching the 45 percent target and another three for achieving a 20 percent reduction (Table 3.17). Scenario NP1 is the cheapest at $438 million/yr but only achieves a 35 percent nitrate-nitrogen reduction. We present it to show that reducing both nitrate-nitrogen and total phosphorus by 45 percent is quite a bit more expensive than this scenario. Scenario NP2 hits both targets and includes fertilizer nitrogen and phosphorus changes, reduced tillage, cover crops on all corn and soybean land, and point source reductions. These are extensive practice changes that would cost $878 million/yr. Scenario NP3 achieves the 45 percent reductions by including land use changes and costs $827 million/yr.

A 20 percent reduction in nitrate-nitrogen and total phosphorus can be achieved for $76 million/yr (scenario NP4) due to the cost savings from using less nitrogen and phosphorus fertilizer. Scenario NP5 used both agricultural and point source reductions to reach the 20 percent reductions at a cost of $173 million/yr. Finally, scenario NP6 demonstrates the costs for only agricultural practices, which is substantially greater at $244 million/yr.

Costs by practice for each of the combined scenarios are presented in Table 3.18 to illustrate how the total costs were calculated. Three practices have negative costs (MRTN, reduced phosphorus fertilizer, and reduced tillage), whereas cover crops and point source phosphorus have some of the higher costs.

None of these scenarios include any potential changes in yields, which might occur in some cases. This is beyond the scope of what we can estimate. Many of the practices (e.g., bioreactors and wetlands) also include large first year costs that would likely require phased implementation. There are also many other considerations that could affect any of the scenario estimates. We refer readers to the excellent summary of these considerations in section 2.4 of the Iowa science document (Iowa, 2013).

Table 3.17. Example statewide nitrate-nitrogen and total phosphorus scenarios.

Name	Combined practices and scenarios	Nitrate-N reduction (percent)	Total P reduction (percent)	Cost of reduction ($/lb)	Annualized costs (million $/yr)
NP1	MRTN, spring-only N application, bioreactors on 50 percent of acres, wetlands on 35 percent of acres, no P fertilizer on 12.5 million acres above STP maintenance, reduced till on 1.8 million conventionally tilled acres eroding >T, buffers on all applicable lands, point source to 1 mg total P/L and 10 mg nitrate-N/L	35	45	**	438
NP2	MRTN, spring-only N application, bioreactors on 50 percent of acres, wetlands on 10 percent of acres, no P fertilizer on 12.5 million acres above STP maintenance, reduced till on 1.8 million conventionally tilled acres eroding >T, cover crops on all corn/soybean acres, point source to 1 mg total P/L and 10 mg nitrate-N/L	45	45	**	878

Name	Combined practices and scenarios	Nitrate-N reduction (percent)	Total P reduction (percent)	Cost of reduction ($/lb)	Annualized costs (million $/yr)
NP3	MRTN, spring-only N application, bioreactors on 30 percent of acres, no P fertilizer on 12.5 million acres above STP maintenance, reduced till on 1.8 million conventionally tilled acres eroding >T, cover crops on 87.5 percent of corn/soybean acres, buffers on all applicable lands, perennial crops on 1.6 million acres >T and 0.9 million additional acres	45	45	**	827
NP4	MRTN, spring-only N application, bioreactors on 53 percent of acres, no P fertilizer on 12.5 million acres above STP maintenance, reduced till on 1.8 million conventionally tilled acres eroding >T, buffers on 80 percent of all applicable land	20	20	**	76
NP5	MRTN, spring-only N application, bioreactors on 45 percent of acres, wetlands on 15 percent of acres, no P fertilizer on 12.5 million acres above STP maintenance, reduced till on 1.8 million conventionally tilled acres eroding >T, point source to 1 mg total P/L and 10 mg nitrate-N/L on 45 percent of discharge	20	20	**	173
NP6	MRTN, spring-only N application, no P fertilizer on 12.5 million acres above STP maintenance, reduced till on 1.8 million conventionally tilled acres eroding >T, cover crops on 1.6 million acres eroding >T and 40 percent of all other corn/soybean acres	24	20	**	244

Table 3.18. Combined nitrate-nitrogen and total phosphorus scenarios with costs by practice.

Practice	NP1	NP2	NP3	NP4	NP5	NP6
	million $/yr					
MRTN	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8
N fertilizer timing	82	82	82	82	82	82
Bioreactors	77	77	46	82	69	
Wetlands	195	56			84	
Buffers	58		58	46		
Cover crops		637	557			296
Perennials			218			
Reduced P fertilizer	-94	-94	-94	-94	-94	-94
Reduced tillage	-30	-30	-30	-30	-30	-30
Point source P	114	114			51	
Point source N	46	46			21	
Sum	438	878	827	76	173	244

Conclusions

This report has described the current state and long-term trends of nutrients in Illinois rivers, as well as the sources of those nutrients. For 1997-2011, Illinois had annual riverine nitrate-nitrogen and total phosphorus loads of 536 and 37.5 million lb, respectively. Agricultural sources contributed around 80 percent of the nitrate-nitrogen exported by rivers, with 18 percent from point sources and 2 percent from urban runoff. Agriculture and point sources each contributed 48 percent of the riverine total phosphorus loads, whereas 4 percent was from urban runoff. A 45 percent reduction target would require major changes in both point and agricultural sources. Because several of the practices recommended save money, a 35 percent reduction in nitrate-nitrogen and a 45 percent reduction in total phosphorus could be met at an annualized cost of $438 million/yr over 20 years. Achieving the additional 10 percent in nitrate-nitrogen reduction would lead to annualized costs of about $850 million/yr.

It should be noted that the estimates of potential nutrient reductions provided in this report are rough estimates based on existing research literature, data, and professional judgment. Limitations of time, resources, and data did not allow us to conduct more detailed analysis, but future refinements are encouraged. To calculate our estimates, we used a single effectiveness percentage instead of a range. However, there are many uncertainties surrounding the effectiveness of a given practice at reducing nitrogen or phosphorus losses in any one field or year, and this must be taken into account when our results are interpreted. More research is needed to provide these estimates, and it is currently underway in the state. The phosphorus assessment did not include stream bed and bank erosion as sources of phosphorus, nor did we include losses of phosphorus from ephemeral gulley erosion. Data are not currently available to estimate these potential sources of phosphorus throughout Illinois. Reliable data on fertilizer and manure management practices would greatly enhance the reliability of future assessments of nutrient losses and the likely impacts of conservation efforts.

Photo by Thomas Durbin

Chapter 4
Watershed Prioritization

Introduction

The U.S. Environmental Protection Agency (U.S. EPA) Recommended Elements of a State Nutrients Framework (Stoner, 2011) recommends that states developing a nutrient loss reduction plan prioritize watersheds for reduction actions. Priority watersheds are those expected to have the greatest capacity to reduce high volumes of nutrient losses annually.

Three separate priority lists were developed specifically for the Illinois Nutrient Loss Reduction Strategy: agricultural watersheds for total phosphorus loss, agricultural watersheds for nitrate-nitrogen loss, and point source watersheds for total phosphorus and nitrate-nitrogen loss. An additional list was developed based on the agricultural industry's Keep it for the Crop (KIC) priority watershed list. Each of these four categories will be addressed separately. While all watersheds are important to nutrient reduction goals and will receive consideration for funding programs aimed at reducing nutrient losses or inputs into Illinois waters, the watersheds on these lists will be targeted for funding, outreach, and implementation programs and will be more closely monitored for nutrient loss improvements.

Prioritization Process

> Improving both local water quality and hypoxic conditions in the Gulf of Mexico were equally weighted when identifying priority watersheds.

Priority watersheds were identified using total phosphorus and nitrate-nitrogen loading data from the science assessment (chapter 3), information on local water quality conditions, and knowledge of watershed-based planning infrastructure. Watersheds were assigned individual scores for each category, which were then added together for a total prioritization score. Appendix A shows the results for the 51 watersheds identified in the science assessment. The watersheds with the highest score will be targeted for nutrient loss improvements.

The science assessment evaluated eight-digit Hydrologic Unit Code (HUC) watersheds within Illinois (including some that cross state lines), detailing estimated point and non-point source nutrient contributions in the millions of pounds per year for each HUC8 watershed. Each watershed was scored for its estimated contribution of nitrate-nitrogen and total phosphorus separately and from point and non-point sources:

- The top five watersheds received eight points.
- The next top five watersheds received six points.
- The following six watersheds received four points.
- The middle 16 watersheds received two points.
- The rest received zero points.

Water quality conditions were analyzed using the Illinois Integrated Water Quality Report (Illinois EPA, 2014), which presents water quality information on the assessed lakes and streams within Illinois and identifies waterbodies that do not meet designated uses. Scores were assigned based on a watershed's overall percentage of assessed waterbodies that met designated uses. Only those designated uses that might be impacted by excessive nutrients (aquatic life, public water supply, primary contact, secondary contact, aesthetic quality, and indigenous aquatic life) were used for the prioritization process. The worst and best watersheds for water quality received the least number of points, while mid-range watersheds received the most:

- Watersheds with 0-10 percent and 91-100 percent received one point.
- Watersheds with 11-20 percent and 81-90 percent received two points.
- Watersheds with 21-30 percent and 71-80 percent received three points.
- Watersheds with 31-40 percent and 61-70 percent received four points.
- Watersheds with 40-60 percent received five points.

Watersheds were assigned one point for each watershed-based plan within a HUC8, as reported by the Research Management Mapping Service (see www.rmms.illinois.edu). One point was also assigned to an active Natural Resource Conservation Service watershed-based group not represented by a watershed-based plan within a HUC8. The total points awarded for watershed-based plans were capped at eight. This prevented a bias toward watersheds with an abundance of plans and ensured the focus remained on load reduction and the potential for water quality improvement.

Within the HUC8 priority watersheds, all HUC12 watersheds will be considered priorities. Further focus on the targeting efforts will be explored during future Policy Working Group efforts described in this strategy.

Priority Watersheds for Agricultural Non-Point Sources

Total Phosphorus

Three watersheds are considered a priority for addressing total phosphorus losses from agricultural non-point sources contributing to Gulf hypoxia:

- Big Muddy River Watershed (07140106)
- Embarras River Watershed (05120112)
- Little Wabash River Watershed (05120114)

Nitrate-Nitrogen

Five watersheds are considered a priority for addressing nitrate-nitrogen losses from agricultural non-point sources contributing to Gulf hypoxia:

- Lower Illinois-Senachwine Lake Watershed (07130001)
- Lower Rock River Watershed (07090005)
- Mississippi North Central Watershed/Henderson Creek (07080104)
- Vermilion-Illinois River Watershed (07130002)
- Vermilion-Wabash River Watershed (05120109)

The two Vermilion River priority watersheds are included to augment the successes those watersheds are seeing as part of the KIC program.

Keep it for the Crop Priority Watersheds

In 2011, during development of the KIC program, Illinois EPA and the Illinois Department of Agriculture worked with the Illinois Council on Best Management Practices to identify priority watersheds where implementation and outreach could begin. It was decided that prioritizing watersheds should result in improving local water quality concerns, specifically the public and food-processing water supply designated uses. The criteria used to select the initial priority watersheds were twofold. The watershed had to contain a waterbody designated as a public water supply source, and that waterbody must have an approved Total Maximum Daily Load (TMDL) for nitrate-nitrogen. With an approved TMDL, the pollutant reduction goals for each impaired waterbody had already been determined. In addition to nitrate-nitrogen TMDLs, watersheds containing lakes also must have approved TMDLs for total phosphorus as they exceeded the total phosphorus water quality standard for lakes.

The initial priority watersheds selected included:

- Lake Bloomington Watershed
- Lake Vermilion Watershed
- Salt Fork Vermilion River Watershed
- Vermilion River Watershed (Illinois River Basin)
- Lake Decatur Watershed
- Lake Mauvaise Terre Watershed

Two additional KIC watersheds were added in 2013:

- Lake Springfield Watershed (TMDL not yet complete)
- Evergreen Lake Watershed

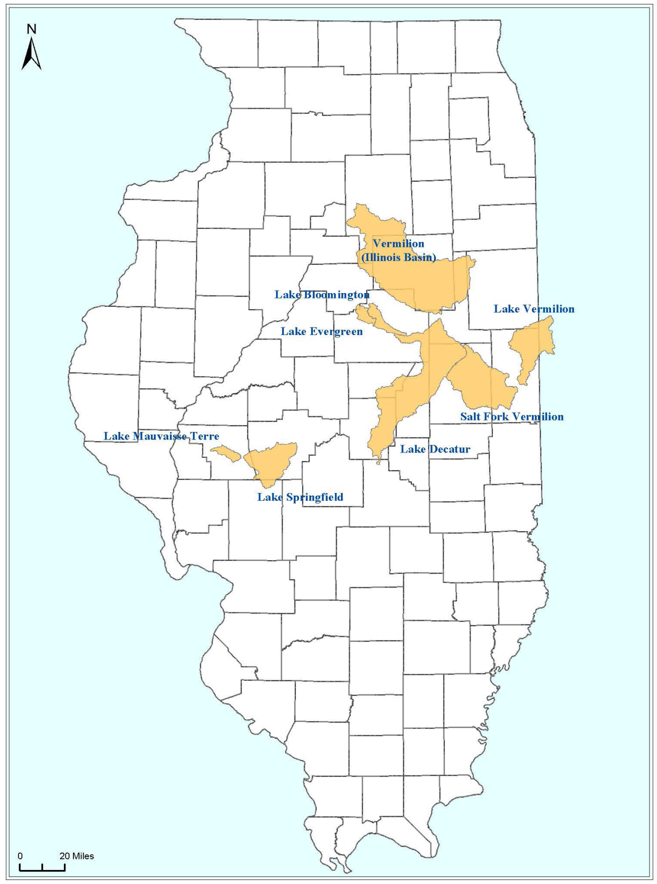


Figure 4.1. KIC priority watersheds.

Priority Watersheds for Point Sources

The primary nutrient concern for point source effluent is total phosphorus, and the highest priority watersheds are already the focus of point source reduction efforts for total phosphorus. However, the five priority watersheds for point source contributions are those that rank high in both total phosphorus and nitrate-nitrogen loading:

- Upper Fox River Watershed (07120006)
- Des Plaines River/DuPage River Watershed (07120004)
- Upper Sangamon River Watershed (07130006)

- Lower Rock River Watershed (07090005)
- Illinois River-Senachwine Lake Watershed (07130001)

While the Chicago/Little Calumet Watershed (07120003) does contribute a substantial total phosphorus load (3.69 million lb/yr), it does not rank at the top of the prioritization due to current water quality and the lack of watershed-based plans in the watershed. This watershed will be considered when addressing point source inputs and will be considered an ad hoc priority for point sources.

Nutrient Loss Reductions in Priority Watersheds

Organizations in both point and non-point source priority watersheds will be notified of the status of their watersheds and the necessity of developing a watershed-based plan, if an approved one is not already in place, that will guide the implementation of nutrient loss reduction practices. These groups will be given the opportunity to request funding from Illinois EPA and other participating partners for watershed-based planning or implementation projects. Watersheds with existing plans and organizations with ready, willing, and able participants will be given priority for loss reduction activities. Funding provided for nutrient loss reduction activities will be based on the amount requested and the ability to implement nutrient loss reduction activities. Requests for prioritization will be considered and funding may be redirected to watersheds where organizations are ready to implement a nutrient loss reduction plan.

Priority for funding and other activities will also be given within a watershed based on the nutrients of concern, the practices with the highest benefit for loss reduction, and the landscape settings that will provide the greatest benefit. The Agricultural Water Quality Partnership Forum (see chapter 9) will guide efforts to align funding priorities across agency programs, as well as coordinate outreach and education efforts needed from all partners. Similarly, the Urban Stormwater Working Group (see chapter 9) will strategize practices and implementation efforts in urban watersheds.

Partners are encouraged to provide funding for activities and practices related to their organizations and to support the implementation of and outreach for programs that are in keeping with this strategy.

Illinois Nutrient Loss Reduction Strategy priority watersheds

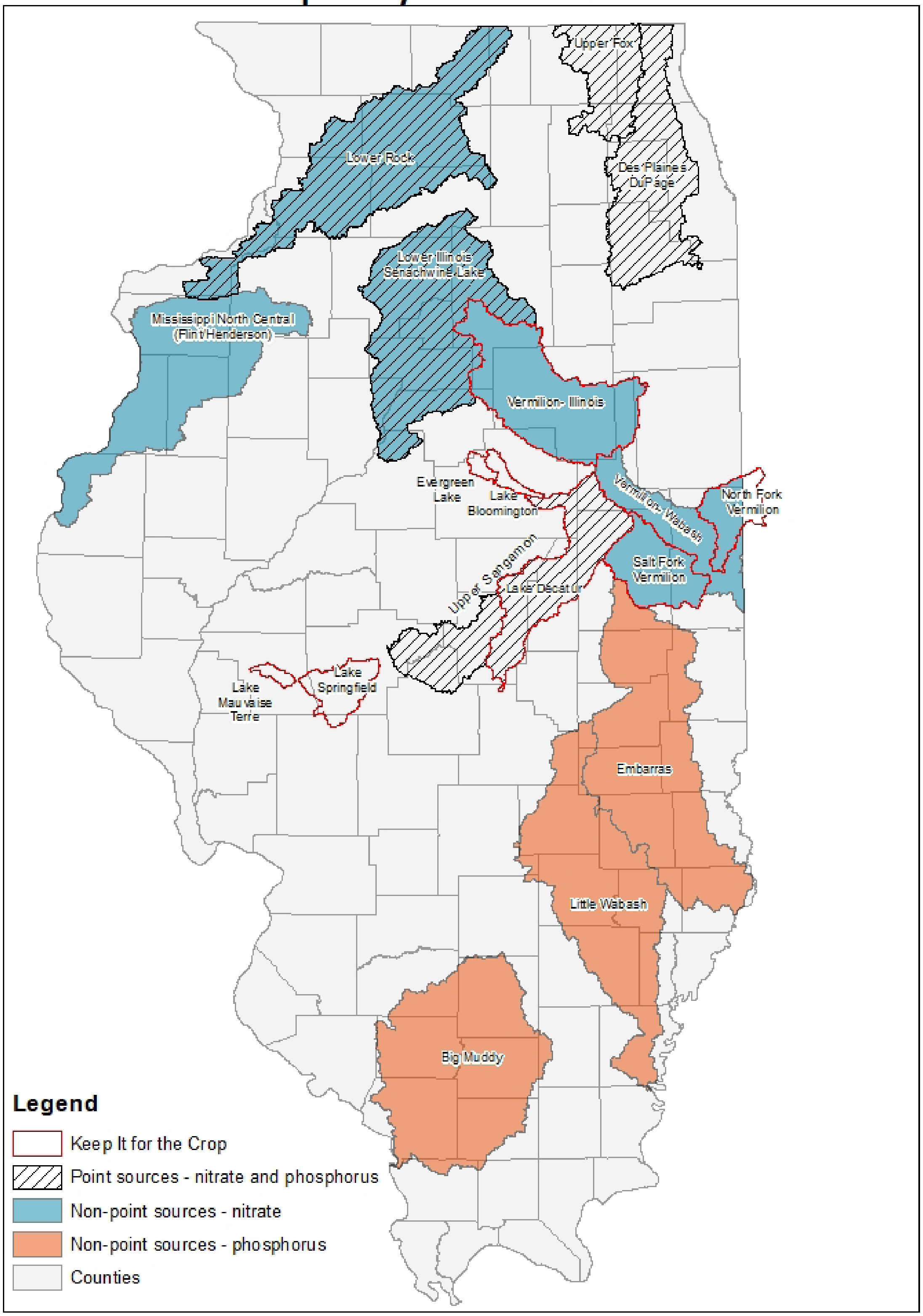


Figure 4.2. Priority watersheds for nutrient loss reduction.

Chapter 5

Nutrient Loss Reduction Strategy for Point Sources

Point Source Contributions

Point sources of water pollution, such as discharges from publicly owned treatment works (POTW) and industrial wastewater treatment plants, are significant sources of total phosphorus and nitrate-nitrogen loading into Illinois waters. Domestic sewage and industrial or power plant wastewater can have significant concentrations of nutrients, requiring treatment to minimize the amounts discharged to receiving rivers, streams, or lakes. Discharges from point sources can contribute to local water quality impairments as well as to Gulf of Mexico hypoxia.

The collective annual nutrient loading from point sources in Illinois is 18.1 million lb of total phosphorus and 87.3 million lb of nitrate-nitrogen. According to the science assessment (chapter 3), nutrient loading to the Mississippi River from point sources represents 16 percent of the statewide total for nitrate-nitrogen, and 48 percent of the statewide total for total phosphorus. Eighty-six percent of the statewide total of point source loading occurs in the Illinois River Basin. The science assessment also identified the eight-digit Hydrological Unit Code (HUC) watersheds with the highest loading of total phosphorus and nitrate-nitrogen from point sources: Chicago River, Des Plaines River, Upper Fox, Upper Sangamon River, and Lower Rock River.

Current Programs and Projects Supporting Nutrient Reduction Goals

Permit Limits for Phosphorus

As a result of the implementation of state laws, board-adopted standards, and other actions, 36 percent of major municipal dischargers currently have total phosphorus limits in their National Pollutant Discharge Elimination System (NPDES) permits, which represent 70 percent of the regulated discharge statewide from major municipal sources. A smaller number of major municipal dischargers have nitrate-nitrogen goals (10 mg/L).

Effluent limits for total phosphorus in NPDES permits are established in accordance with pertinent state laws and existing best practices, including:

- 35 Ill. Adm. Code 304.123(g), which sets an effluent limit of 1 mg/L for new or modified POTWs discharging more than 1 million gallons/day (MGD) and industrial discharges of 25 lb total P/day or more.
- 35 Ill. Adm. Code 304.123(b), which sets an effluent limit of 1 mg/L for discharges to or up stream of a lake.
- 35 Ill. Adm. Code 302.105, which requires the Illinois Environmental Protection Agency (Illinois EPA) to evaluate whether total phosphorus and nitrate-nitrogen discharges have the potential to degrade water quality and, therefore, must have a total phosphorus permit limit and/or a nitrate-nitrogen goal.
- 35 Ill. Adm. Code 302.203, which defines a narrative standard for unnatural algae or plant growth that, if exceeded, results in a waterbody being listed in the Illinois Integrated Water Quality Re port. Dischargers to these listed streams are subject to total phosphorus limits if the discharges cause or contribute to algae or plant growth problems.
- Voluntary acceptance of permit limits.

Watershed Planning

Fox River Study Group

The Fox River Study Group (FRSG) is a diverse coalition of stakeholders working together to preserve and enhance water quality in the Fox River Watershed. It is led by a nine-member board with representatives from Aurora, Elgin, the Friends of the Fox River, the Fox River Water Reclamation District (Elgin area), the Fox Metro Water Reclamation District (Aurora area), the Fox River Ecosystem Partnership, the Sierra Club, and the Tri-Cities (Batavia, Geneva, and St. Charles). Illinois EPA and the Illinois State Water Survey (ISWS) advise the group. Representatives from numerous other communities, wastewater agencies, and engineering firms participate in FRSG meetings, provide financial support, and contribute to the group's monthly all-volunteer Fox River mainstem and tributary monitoring effort, now in its thirteenth year of data collection.

> Watershed planning efforts are strongly encouraged as an effective way to address high-priority local water quality problems. Nutrient reduction efforts need to be given appropriate priority when considering the investments needed to attain local stream use goals.

FRSG began meeting in the summer of 2001 to plan for how to address impairments in the river, which at the time were low dissolved oxygen levels and high concentrations of fecal coliform bacteria. ISWS completed a review of all available data on the Fox River in 2004 and determined that total nitrogen, total phosphorus, dissolved oxygen, pH, and fecal coliform bacteria were not meeting Illinois water quality standards or recommendations. Segments of the Fox River have also been listed as impaired due to aquatic algae in recent 303(d) reports.

ISWS has developed computer models for FRSG of the Fox River watershed downstream of the Stratton Dam, including 33 watershed loading models and a Fox River mainstem receiving stream model. These were calibrated using data collected by FRSG members as well as low flow and storm event data collected by ISWS and Deuchler Environmental. Currently, FRSG, working with the consulting firm Limnotech and ISWS, is using the models to evaluate alternative management scenarios, including dam removal (13 dams remain on the Fox River mainstem) and nutrient reductions from point sources, urban runoff, and agricultural runoff in order to complete the development of the Fox River Implementation Plan. This plan, scheduled to be completed by December 2015, will include needed reductions in total phosphorus discharges and in-stream projects to resolve the dissolved oxygen and algal impairments of the Fox River. Municipalities and water reclamation districts will be responsible for developing plans to implement needed total phosphorus reductions at their facilities.

Additionally, the publicly owned major municipal wastewater treatment plants (WWTP) that are members of FRSG are working with Illinois EPA to include a placeholder special condition of a total phosphorus effluent limit of 1 mg/L in their respective NPDES permits. The special condition also requires permittees to develop a total phosphorus removal feasibility report on the method, time frame, and costs for reducing total phosphorus loading to levels equivalent to monthly average discharges of 1 mg/L and 0.5 mg/L on a seasonal basis and on a year-round basis. The special condition language in the permit requires permittees to implement the Fox River Implementation Plan. The appropriate total phosphorus limit will be incorporated into the permits during the permit renewal process and will become effective within five years of the permit being issued.

DuPage River Salt Creek Workgroup

This group was formed in 2005 in response to the listing of the east and west branches of the DuPage River and Salt Creek as impaired waterbodies. The DuPage River Salt Creek Workgroup (DRSCW) is made up of local communities, POTWs, and environmental organizations in the watershed. The east and west branches of the DuPage River and Salt Creek are located in northeastern Illinois, including portions of Cook, DuPage, and Will counties and encompass an area of approximately 350 sq. mi of urbanized watershed. These waterbodies are listed on the 303(d) list, and dissolved oxygen is listed as one of the causes of impairment.

Major improvements in channel, in-stream, and riparian habitats and non-point source pollutant reductions are essential to making significant progress towards attaining Clean Water Act (33 U.S.C. 1251-1387) goals. DRSCW uses monitoring data to identify priority stressors and to prioritize impaired streams for restoration activities. The list of 42 prioritized stressors includes land cover (industrial area, road density), water chemistry (chlorides, total suspended solids, nutrients), and habitat (buffer width, channel sinuosity).

The workgroup is developing a proposal for POTW members to substantially increase financial commitments to restoration efforts. The proposal also calls for members to concurrently reduce total phosphorus loading from point sources by modifying operations with existing plant tankage, reduce non-point total phosphorus sources, evaluate the potential for a watershed-scale total phosphorus trading program, and continue high-density stressor-response analysis of the impacts of nutrients on overall stream biological health at the watershed scale to try to identify threshold levels needed to develop in-stream standards. These terms are expected to be incorporated into the NPDES permits of participating major municipal facilities and will include total phosphorus effluent limits and schedules for meeting those limits.

Hickory Creek Watershed Planning Group

Hickory Creek, a vital sub-watershed of the Lower Des Plaines Watershed, has seen significant environmental degradation in recent years. Intense residential and commercial development has led to heavy silt load pollution from construction, increased erosion due to higher stormwater volumes, the replacement of natural drainage with storm sewer systems, and additional discharges of treated wastewater. In response, a team of southwest suburban municipalities and environmentally-focused non-profits created the Hickory Creek Watershed Planning Group (HCWPG) to improve the water quality in the watershed. The group completed the Hickory Creek Watershed Plan in 2011.

HCWPG currently includes representatives from the City of Joliet, the Village of New Lenox, the Village of Frankfort, the Village of Homer Glen, the Village of Mokena, the Village of Tinley Park, the Village of Orland Park, the Forest Preserve District of Will County, Will County Stormwater, the Sierra Club, Prairie Rivers Network, the Center for Neighborhood Technology, Geosyntec, and Huff & Huff. The group is working to effectively reduce non-point source pollution, achieve water quality and habitat improvements, and engage with a wide range of audiences. They are documenting sources of non-point source pollutants to facilitate the preparation of action plans, implementing simple demonstration best management practices, participating in community education and outreach, and evaluating the ability of local projects to address watershed nutrient loss reduction goals for both point and non-point sources. HCWPG is in the early stages of developing a third-party Total Maximum Daily Load (TMDL) to address water quality issues in the watershed. They are also concentrating on addressing impairments from chloride, total phosphorus, and dissolved oxygen through the removal of Pilcher Park dam.

The current NPDES permits for the Village of New Lenox Plant No. 1, Frankfort Regional, Illinois American Oak Valley, and the Village of Modena include a monthly average effluent limit of 1 mg/L for phosphorus. Permits include a monthly average effluent limit of 1 mg/L total phosphorus. Other point source dischargers in the HCWPG will receive interim total phosphorus effluent limits of 1 mg/L upon permit renewal and water quality based total phosphorus effluent limits in future permits in accordance with state water quality standards and a third-party TMDL. A TMDL prepared either by Illinois EPA or a third party is expected to be completed in time to set water quality-based effluent limits in the next permit.

Des Plaines River

The preliminary meetings of a new watershed group for the Des Plaines River have included planning to evaluate stressors in the watershed, including sources of impairment for dissolved oxygen and by excess algae. It is anticipated that a stakeholder-led effort will emerge to (among other actions) determine the nutrient loss reductions needed to restore the Des Plaines River and implement a plan to achieve the needed reductions.

Point source dischargers in the Des Plaines River watershed group will receive interim total phosphorus effluent limits of 1 mg/L upon permit renewal and water quality based total phosphorus effluent limits in future permits in accordance with state water quality standards and a third-party TMDL. A TMDL prepared either by Illinois EPA or a third party is expected to be completed in time to set water quality-based effluent limits in the next permit

Permit Limits for Metropolitan Water Reclamation District of Greater Chicago

The Metropolitan Water Reclamation District of Greater Chicago (MWRDGC), which operates the largest wastewater treatment plants in the state, adopted a resource recovery approach to reducing total phosphorus in the effluent from its largest water reclamation plants. When the permits for the Calumet, Stickney, and O'Brien plants, which discharge a total of 5.7 million lb P/yr and are a primary contributor to total phosphorus loading to the Illinois River, were renewed in 2013, total phosphorus limits of a monthly average of 1 mg/L were included for implementation in the next 4-10 years.

Total Maximum Daily Loads

TMDLs developed for impaired watersheds include point source waste load allocations (WLAs) for total phosphorus and nitrate-nitrogen. WLAs vary depending on the importance of point sources in a watershed and the degree to which the water quality standard is being exceeded. Reduction goals vary for point sources in the 19 TMDLs with point source contributions that are nutrient-related. These are being incorporated into NPDES permits at renewal or modification stages of the permitting process. At the time of publication, 76 TMDLs were under development.

Concentrated Animal Feeding Operations

Discharges from concentrated animal feed operations (CAFOs) can be a significant source of nutrient pollution. Illinois EPA has identified 249 large CAFOs in Illinois. Of these, 60 have been inspected to determine if there are ongoing discharges. As a result of these inspections and previous enforcement actions, 29 are covered under the general CAFO NPDES permit. Illinois EPA has committed to performing compliance inspections annually at 20 percent of the permitted CAFOs and 20 percent of the large unpermitted CAFOs. The field staff continues to inspect and evaluate other livestock operations not identified as large CAFOs to verify discharges and determine if NPDES permits are required. See chapter 6 for more discussion on nutrient management strategies for livestock operations.

State Revolving Fund

The State Revolving Fund provides low-interest loans for wastewater treatment infrastructure. This includes wastewater treatment plant upgrades needed for nutrient removal, green infrastructure, urban stormwater treatment, and control of combined and sanitary sewer overflows. Under the Clean Water Initiative, the capacity of the loan program has expanded—wastewater loans totaled approximately $360 million in fiscal year 2013. The capacity of the loan program will be maintained to ensure adequate funding is available to finance improvements required under NPDES permits.

Anticipated Nutrient Reductions from Existing Efforts

The implementation of a 1 mg/L total phosphorus limit in the NPDES permits of major municipal dischargers in the highest loading watersheds, which is already in progress, will address the bulk of the point source total phosphorus reductions needed to reach the national hypoxia goal. As Table 5.1 shows, loading of total phosphorus will be reduced by 3.1 million lb, or approximately 33 percent of the point source reduction goal, once these limits are fully implemented at the MWRDGC Calumet, Stickney, and O'Brien plants.

Table 5.1 MWRDGC plants' total phosphorus totals and projected reduction.

Facility	Current avg. flow (MGD) *	Current avg. conc. (mg/L) *	Current avg. load (million lb/yr) *	Future avg. conc. (mg/L)	Future avg. load (million lb/yr)**	Load reductions (million lb/yr)
Calumet	259.7	3.1	2.4	0.7	.55	1.9
Stickney	715.2	1.08	2.3	0.7	1.5	.82
O'Brien	236.3	1.35	.97	0.7	.5	.47
Total			5.7		2.6	3.1

**Values were obtained by taking the average of yearly average data from 2007-2012. Yearly average flow and total phosphorus concentration data were compiled from daily measurements.*

***Assumes a practical annual average effluent concentration of 0.7 mg/L.*

****Table developed using Illinois EPA data.*

Major municipal dischargers in the Fox River, Des Plaines River, and DuPage River/Salt Creek watersheds will also achieve significant reduction in total phosphorus loading. These reductions are expected in the next 3-10 years (perhaps longer in the DuPage/Salt Creek watershed). Table 5.2 details the number of major municipal dischargers in these watersheds, as well as others statewide, that currently have total phosphorus limits and the reductions in total phosphorus loading expected within 10 years once a 1 mg/L total phosphorus limit is implemented (assuming a practical annual average effluent concentration of 0.7 mg/L). Limiting total phosphorus in NPDES permits of major municipal dischargers in other watersheds in the Illinois River Basin, as well as other basins, will be required to complete the reduction needed to meet the point source component of the national hypoxia goal.

Photo by Jennifer Byard

Table 5.2. Potential total phosphorus reductions from major municipal point sources at 0.7 mg/L.

Region	Number of major facilities	Facilities with total p limits*	MGD		Million lb/yr		
			DAF	Actual flow	Current load	Future load**	Load reduction
MWRDGC†	3	3	1,887	1,211	5.67	2.58	3.09
Des Plaines	29	18	249	205	0.92	0.44	0.48
Fox	30	28	165	122	0.31	0.26	0.05
Dupage/Salt	31	5	212	168	1.32	0.36	0.96
Downstate	124	37	676	526	5.09	1.12	3.97
Totals	217	91	3,189	2,232	13.31	4.76	8.55††

* Number of facilities with total phosphorus limits has increased in the Des Plaines, Fox, and downstate regions, thus decreasing the current load and load reduction numbers for these regions.

** Future load equals actual flow multiplied by 0.7 (annual average effluent concentration) multiplied by 8.34 (conversion rate) multiplied by 365 days divided by 1,000,000

† The three large MWRDGC plants currently have permit conditions that dictate phosphorus limits within the next several years. In this table, the reductions that will be realized from these limits are counted as future, not existing, reductions.

†† The current load number will continue to decrease as more facilities meet the 0.7 mg/l limit, which in turn will decrease the load reduction number.

**Table developed using Illinois EPA data.*

Future Regulatory Actions

Water Quality Standards

In addition to the development of numeric nutrient criteria (see discussion in chapter 8), Illinois EPA is working on a revised narrative standard for offensive conditions and a new standard for low total phosphorus streams. A proposal to the Illinois Pollution Control Board is planned during calendar year 2014.

The narrative standard for offensive conditions (35 Ill. Adm. Code 302.203) prohibits unnatural excessive algal or plant growth. This standard is intended to address mainly aesthetic issues that may limit the use of waterways. A potential tie to the aquatic life designated use is logical, although not explicit. Illinois EPA plans to revise and strengthen the narrative to make it clear when excessive algal or plant growth is considered a threat to the aquatic life use. The intent is that total phosphorus be identified as a cause of aquatic life use impairment, establishing a clearer basis to regulate point sources that contribute total phosphorus to the impaired stream segments.

A new standard will be proposed for Illinois streams that are already low in total phosphorus concentration to assure that any new discharges do not increase total phosphorus levels. The rule will designate streams that have been identified as low total phosphorus streams subject to this new standard and will detail the process for identifying and designating additional streams.

> The principal mechanism for point source implementation is NPDES permit requirements. Illinois EPA will issue NPDES permits in compliance with state and federal regulations pursuant to the Clean Water Act to help meet national hypoxia goals by lowering point source loading of total phosphorus in Illinois.

Industrial Discharges

Illinois EPA will review existing information and gather additional data as needed to more comprehensively identify industrial dischargers that may be significant sources of total phosphorus or nitrate-nitrogen. Additional data may be gathered by requiring effluent monitoring by major industrial dischargers. Once significant industrial sources of nutrients are identified, appropriate actions to address industrial discharges will be determined in consultation with stakeholders, documented by amending this strategy, and implemented.

Local Water Quality Impairments

Discharges that cause or contribute to nutrient-related impairments will be addressed through appropriate limits in NPDES permits. Illinois EPA views the 1 mg/L total phosphorus limit as a starting point. It is expected that better performance can be achieved over time by encouraging the use of more sustainable technology that will lead to lower discharge levels. The nutrient-related permit conditions in the NPDES permits for the Fox River dischargers establish a 1 mg/L permit limit. They also require that each permittee determine the actions needed to lower total phosphorus effluent concentrations enough to address dissolved oxygen and algal problems in the watershed. This will likely be the model used in other watersheds with local water quality problems related to nutrients.

Nutrient Loss Reduction Feasibility Plan

As part of NPDES permit renewal, Illinois EPA will require major dischargers to submit facility plan reports regarding technology-based treatment alternatives for nutrients with the following components:

- An evaluation of biological nutrient removal (BNR), whether retrofitted in an existing facility or included in a new one. Because of its performance, overall sustainability, and lower indirect environmental impacts, the preference is to implement this technology where practical as a retrofit in an existing facility over chemical precipitation for total phosphorus.

- A plan for optimizing operations to achieve the lowest nitrate-nitrogen and total phosphorus effluent levels possible with existing equipment.
- An itemized list of cost-effective nutrient loss reduction projects and technologies.
- An evaluation of possible levels of reduction.
- A discussion of potential local impacts and benefits of reductions.
- A timeline for implementation.

For point sources discharging in watersheds without nutrient-related impairments, Illinois EPA will work with the permittee to identify appropriate elements, sequences, and timelines for implementation. Agreed-upon plans will then be incorporated into the renewed NPDES permit. Illinois EPA may include numeric goals for nutrients but would not include permit limits for discharges that do not impact waters with nutrient-related impairments. Illinois EPA will press for shorter implementation timelines and more aggressive reductions in priority watersheds.

Future Strategic Actions

Nitrogen Reduction

Illinois EPA will review existing effluent monitoring data, identify and collect additional data needed to assess current conditions, and use this information to identify potential strategic actions to reduce nitrate-nitrogen discharge levels. Illinois EPA will work with stakeholders to appropriately amend this strategy as a result of these actions.

> The application of total phosphorus reduction technology from point sources is expected to achieve some level of nitrate-nitrogen removal. Antidegradation determinations and TMDLs have and will continue to result in progress toward nitrate-nitrogen reduction goals.

Biological Nutrient Removal

In permits with a total phosphorus limit, Illinois EPA will encourage implementation of BNR technology. To promote this technology, Illinois EPA may provide flexible compliance schedules, long-term average total phosphorus limits, or other conditions consistent with the Clean Water Act and state and federal regulations. Encouraging BNR is also expected to lead to a reduction in nitrate-nitrogen.

Planning

Where possible, Illinois EPA will work with local watershed groups to meet the nutrient loss reduction objectives in this strategy. As part of this, Illinois EPA will consider using permit language requiring nutrient facility planning and cost-effective implementation of control technologies using existing infrastructure and without permanently giving up needed capacity. Where feasible, minor improvements at the plants will be employed to meet the objectives of this strategy.

Trading Programs

Illinois EPA will promote trading, urban/rural partnerships, or other offsets as part of watershed planning and implementation efforts and may use such trading when considering NPDES permits after an appropriate, enforceable, and transparent program has been developed. Any future trading programs will incorporate best practices and meet all Clean Water Act requirements, including the protection of local water quality. Dischargers should participate in the development of watershed pollution cleanup plans that include studies investigating the total phosphorus reductions needed to meet narrative and dissolved oxygen standards, interim total phosphorus limits, and implementation strategies designed to meet water quality standards over time.

Assuring Adequate Funding

Illinois EPA expects a surge in POTW treatment needs, particularly those associated with point sources in areas where numeric discharge limits are imposed for nutrients, which are largely expected to be imposed within a 10-year window. The State Revolving Fund priority system will need be adjusted in order to ensure appropriate priority is given to these projects.

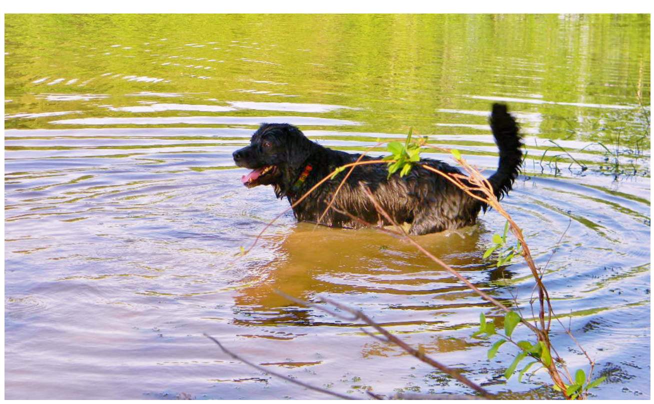


Photo by Marilyn Sanders

Chapter 6

Nutrient Loss Reduction Strategies for Agricultural Non-Point Sources

Agricultural Contributions

Agricultural runoff is a significant source of total phosphorus and nitrate-nitrogen loading into Illinois waterbodies. Total phosphorus losses are typically due to soil erosion into surface waters, while nitrate-nitrogen losses commonly occur when nutrients are carried in water via tile drainage. However, both nutrients can be lost by either route, and both routes affect surface and ground water quality.

According to the Illinois science assessment (chapter 3), agricultural runoff contributes 80 percent of the nitrate-nitrogen and 48 percent of the total phosphorus losses exported from the state. The non-point source nitrate-nitrogen yield average was estimated at 10 lb/acre/yr, with 27 eight-digit Hydrologic Unit Code (HUC) watersheds showing greater losses. The greatest nitrate-nitrogen losses were found in the tile-drained northern two-thirds of the state, where artificial drainage is common and the land use is dominated by row crop agriculture. Total phosphorus non-point source losses were estimated at an average yield of 1.4 lb/acre/yr and were typically greater in southern Illinois and lower in the northernmost parts of the state. See Figure 6.1 on the following page.

Current Programs and Projects Supporting Nutrient Reduction Goals

State Programs and Projects

Section 319

Section 319 is a grant program under the Clean Water Act (33 U.S.C. 1329) that disburses funds to states with approved non-point source management plans. States in turn can competitively award grants to qualified applicants to support non-point source pollution control.

Through technical and financial assistance, and to facilitate the planning process, the Illinois Environmental Protection Agency (Illinois EPA) encourages the development of watershed-based plans

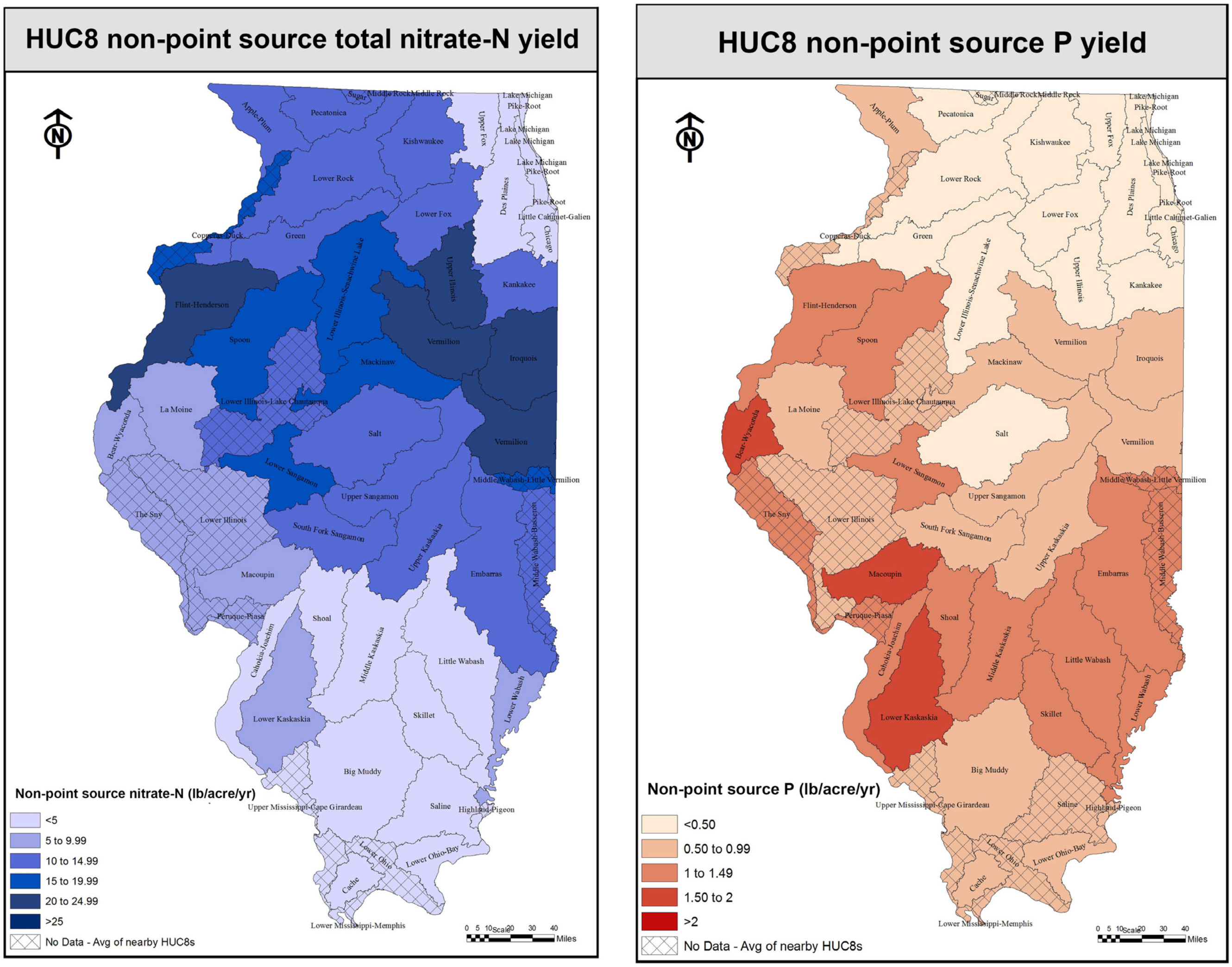


Figure 6.1. Non-point source nitrate-nitrogen and total phosphorus yields by HUC8.

consistent with current watershed planning principles. Plan development and monitoring is tracked through the Research Management Mapping Service. Visit www.rmms.illinois.edu for more information.

By implementing agricultural best management practices (BMPs), the Section 319 program alone has reduced annual loads of nitrate-nitrogen by 805,000 lbs/yr, total phosphorus loads by 381,000 lbs/yr, and sediment loads by 531,000 tons/yr. Examples of agricultural BMPs completed through Section 319 funding include 147,000 acres of nutrient management, which is estimated to have reduced nitrate-nitrogen loads by 110,000 lbs/yr, total phosphorus by 54,000 lbs/yr, and sediment by 37,000 tons/yr. Filter strip BMPs on 14,000 acres also account for annual reductions of 330,000 lbs of nitrate-nitrogen, 167,000 lbs of total phosphorus, and 107,000 tons of sediment.

State Revolving Fund

Funding for non-point source pollution control projects, including agricultural sources, is available through the State Revolving Fund loan program as a result of recent eligibility expansions under the Clean Water Initiative (Public Act 98-0782) designed to address stormwater runoff, which can contribute to nutrient loading in Illinois waters.

Conservation Reserve Enhancement Program

The Illinois Conservation Reserve Enhancement Program (CREP) is a state incentive program tied to the U.S. Department of Agriculture (USDA) Federal Conservation Reserve Program (CRP). CREP achieves long-term environmental benefits by allowing 232,000 acres of eligible environmentally-sensitive land within the Illinois and Kaskaskia River watersheds to be restored, enhanced, and protected over periods ranging from 15 years to perpetuity. CREP is driven by locally-led conservation efforts, as evidenced by increased landowner support, and employs a variety of BMPs to protect and restore riparian corridors. This program is a prime example of how partnerships between landowners, governmental entities, and non-governmental organizations can work to address watershed quality concerns.

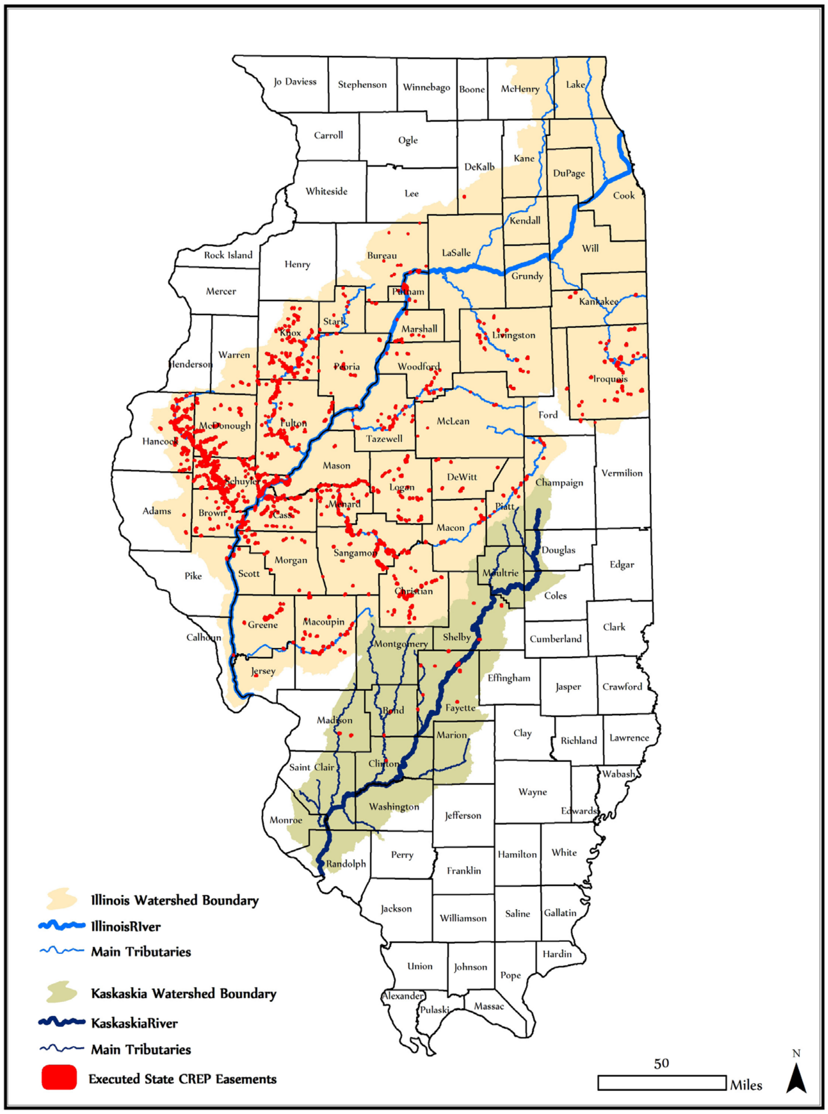


Figure 6.2. Conservation Reserve Enhancement Program easements.

CREP is one of many tools used by the Illinois Department of Natural Resources (INDR) and its conservation partners to implement the Illinois Comprehensive Wildlife Action Plan, which provides a framework for restoring critical habitats, increasing plant diversity, and expanding habitats for species in greatest need of conservation in a predominately agricultural landscape.

Since CREP's inception in 1998, 135,517 acres have been enrolled in federal CREP contracts at an average rental rate of $188.6/acre. The state has also successfully executed 1,316 CREP easements, protecting 83,273 acres. These easements have prevented approximately 150,000 lbs of nitrate-nitrogen at an average of 3.15 lbs/acre, 42,263 lbs of total phosphorus at an average of 0.87 lbs/acre, and 34,084 tons of sediment at an average of 0.7 tons/acre from entering the Illinois and Kaskaskia rivers each year.

Partners for Conservation Cost-Share Program

The Illinois Department of Agriculture (IDOA) administers several initiatives promoting advanced nutrient management, conservation tillage, and the use of cover crops. These programs reduce soil erosion, sedimentation, and nutrient runoff, leading to improved water quality. IDOA's Partners for Conservation (PFC) cost-share program provides funding for the implementation of cultural (e.g., no-till and cover crops) and structural (e.g., grassed waterways and terraces) conservation practices. PFC funds are allocated annually to local soil and water conservation districts (SWCDs) for distribution to eligible landowners for carrying out BMPs that will benefit the environment.

The 97 local SWCDs throughout Illinois play a key role in fostering locally-led conservation work in rural and urban areas. They conduct outreach to increase public awareness of the importance of natural resource conservation. In addition, they hold landowner signups to build conservation projects and prioritize project proposals for funding based on the environmental benefits. Their technical staff provides landowners conservation practice design and construction oversight. The SWCDs are a very important asset in the delivery of IDOA's soil and water conservation programs to rural and urban customers. They also assist the USDA Natural Resources Conservation Service (NRCS) in the construction of conservation projects through various programs authorized by the U.S. Farm Bill.

Conservation practices eligible for cost-share assistance through PFC include terraces, grassed waterways, water and sediment control basins, grade stabilization structures, crop residue management, cover crops, and nutrient management plans. A total of 6,733 PFC projects were completed by landowners from 2006-2012. Although the state's portion of the cost of these projects totaled almost $17 million, this amounts to approximately 50 percent of the cost of construction, with a little less than half of the cost contributed by landowners.

These projects reduced soil erosion on 68,088 acres of cropland. The installed practices also reduced nutrient loading to streams throughout the state by an estimated 403,089 lb of nitrate-nitrogen and 200,686 lb of total phosphorus. Sediment delivery was reduced by 170,587 tons, which translates to an estimated 8,529 semi-trailer loads of sediment kept out of Illinois waterways.

Streambank Stabilization and Restoration Program

In an effort to stabilize and restore severely eroding stream banks that would otherwise contribute sediment to the state's rivers and tributaries, IDOA with, assistance from SWCDs, administers the Streambank Stabilization and Restoration Program (SSRP). Severely eroding stream banks can contribute as much as 30-50 percent of the sediment entering waterways from all sources. The SSRP, funded under PFC, provides funds to construct low-cost techniques to stabilize eroding stream banks. Examples of these practices include rock riffles, stone toe protection, and bendway weirs. During 2004-2012, 58 miles of eroding stream banks were stabilized, resulting in a 61,389 ton reduction in sediment delivery. Loading of nitrate-nitrogen was also reduced by 107,214 lb and total phosphorus by 57,308 lb.

Federal Programs and Projects

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is a voluntary program originally authorized under the 1996 Farm Bill (Pub. L. 104-127) and re-authorized in the 2014 Farm Bill (Pub. L. 113-79). Eligible program participants receive financial and technical assistance to implement conservation practices or activities such as conservation planning that address natural resource concerns on their land. NRCS staff works with applicants to develop an EQIP plan of operations that identifies the appropriate conservation practices needed to address identified natural resource concerns. Natural resource concerns include improvement of soil, water, plant, animal, air, and related resources on agricultural land and non-industrial private forestland.

> The USDA NRCS provides technical and financial assistance to agricultural producers and landowners. NRCS works in close partnership with farmers and ranchers, local and state governments, federal agencies, and non-governmental organizations to maintain healthy and productive working landscapes. There are 94 NRCS field offices in Illinois in addition to the state office in Champaign, which administers federal conservation programs. These programs provide financial assistance for the implementation of conservation practices that can help reduce the loading of nitrate-nitrogen and total phosphorus to improve water quality in Illinois and address the Gulf of Mexico hypoxia. While these federal programs address resource concerns besides water quality, such as air, wildlife, and energy, there are often additional water quality benefits that can be gained.

Applications for EQIP are accepted on a continuous basis, and NRCS establishes submission deadlines for evaluation and ranking of eligible applications. Applications are ranked based on a number of factors, including the environmental benefits and cost effectiveness of the proposal. Payments are made to participants after the conservation practices and activities identified in the plan are implemented. Contracts can last up to 10 years. Information on practices available for funding in Illinois can be found at www.nrcs.usda.gov/wps/portal/nrcs/main/il/programs/financial/. NRCS conservation practices for Illinois can be found in section IV of the Field Office Technical Guide at efotg.sc.egov.usda.gov/efotg_locator.aspx?map.

Conservation Stewardship Program

The Conservation Stewardship Program (CSP) helps agricultural producers maintain and improve their existing conservation systems and adopt additional conservation activities to address priority resources concerns. Participants earn CSP payments for conservation performance—the higher the performance, the higher the payment.

Through CSP, participants can take additional steps to improve soil health, air and habitat quality, water quality and quantity, and energy conservation on their land. CSP provides two types of payments through five-year contracts: annual payments for installing new conservation activities and maintaining existing practices and supplemental payments for adopting a resource-conserving crop rotation. Producers may be able to renew a contract if they have successfully fulfilled the initial contract and agree to achieve additional conservation objectives.

Easement Programs

NRCS offers voluntary easement programs to landowners who want to maintain or enhance their land in ways that are beneficial to the environment. The 2014 Farm Bill authorized the Agricultural Conservation Easement Program (ACEP) and the Healthy Forests Reserve Program (HFRP). ACEP provides financial and technical assistance to help conserve agricultural lands and wetlands and their related benefits. ACEP consolidates programs authorized by previous Farm Bills, including the Wetlands Reserve Program (WRP), Grassland Reserve Program, and Farm and Ranch Lands Protection Program. Under ACEP, NRCS helps Indian tribes, state and local governments, and non-governmental organizations protect working agricultural lands and limit non-agricultural uses of the land. Under the easement component of WRP, NRCS helps restore, protect, and enhance enrolled wetlands. HFRP helps landowners restore, enhance, and protect forestland resources on private lands through easements and financial assistance. Through HRFP, landowners can promote the recovery of endangered or threatened species, improve plant and animal biodiversity, and enhance carbon sequestration.

Regional Conservation Partnership Program

This program, which competitively awards funds to conservation projects designed by local partners specifically for their region, was authorized in the 2014 Farm Bill. The Regional Conservation Partnership Program (RCPP) provides assistance to producers through partnership agreements and program contracts or easements. RCPP encourages partners to join in conservation efforts by leveraging RCPP funding for conservation activities in select project areas. Illinois has set priorities for water quality, soil health, and soil erosion for funding proposals. Additional RCPP information is available at www.nrcs.usda.gov/wps/portal/nrcs/main/il/programs/farmbill/rcpp/.

IDOA is a primary partner in three project applications currently under review. The applications focus on greatly expanding current statewide conservation cropping programs to improve soil health throughout the state, establishing extensive, targeted suites of BMPs in priority watersheds to improve water quality in these key areas, and reducing soil erosion and runoff in counties adjacent to the Mississippi River. Illinois EPA and several non-profit organizations are partners on the first two applications. IDOA partnered with Iowa, Minnesota, Missouri, Wisconsin, and the Upper Mississippi River Basin Association on the third.

Cost-Share and Technical Assistance Funding

The Illinois office of NRCS receives fiscal year allocations from USDA for the programs and initiatives they are authorized to administer. For program funding information for fiscal years 2005-2012, visit www.nrcs.usda.gov/Internet/NRCS_RCA/reports/cp_il.html#ncpd.

Mississippi River Basin Initiative

The Mississippi River Basin Initiative (MRBI) was developed to improve the health of the Mississippi River Basin, including water quality and wildlife habitat. Through this initiative, NRCS and its partners help producers in select watersheds voluntarily implement conservation practices that avoid, control, and trap nutrient runoff, improve wildlife habitat, and maintain agricultural productivity. These improvements are accomplished through a conservation systems approach to manage and optimize nitrate-nitrogen and total phosphorous within fields to minimize runoff and reduce downstream nutrient loading. NRCS will provide producers assistance with a system of practices that control soil erosion, improve soil quality, and provide wildlife habitat while managing runoff and drainage water for improved water quality.

Watersheds in Illinois eligible for MRBI funding in fiscal year 2014 include Big Bureau Creek, Senachwine Creek, and Indian Creek. The Salt Fork Vermilion River Watershed was previously eligible.

Driftless Area Landscape Conservation Initiative

Funded through EQIP, the Driftless Area Landscape Conservation Initiative offers financial assistance to agricultural producers for implementing practices that reduce erosion and sediment delivery to surface water and improve fish and wildlife habitats in the Illinois Driftless Area. This area encompasses a portion of northwestern Illinois that includes the Rock River Watershed and areas that drain directly into the Mississippi River.

National Water Quality Initiative

> Authorized in the 2008 Farm Bill, these federal initiatives target specific watersheds in Illinois to offer additional financial assistance through EQIP, CSP, and other NRCS programs to address specific resource concerns related to water quality. More information is available at www.nrcs.usda.gov/wps/portal/nrcs/main/il/programs/.

The National Water Quality Initiative provides financial assistance to help farmers and ranchers implement conservation systems to reduce nitrate-nitrogen, total phosphorous, sediment, and pathogen contributions from agricultural land. Eligible producers receive assistance under EQIP for installing conservation systems that may include practices such as nutrient management, cover crops, conservation cropping systems, filter strips, terraces, and, in some cases, edge-of-field water quality monitoring. Eligible watersheds in Illinois include Douglas Creek, Bonpas Creek, and Lake Vermilion. Illinois EPA has committed to long-term monitoring of Lake Debrey in the Lake Vermillion Watershed.

Industry-Related Programs and Projects

The Nutrient Research & Education Council

> Given increased concern over nutrient losses attributed to agriculture and budget cuts to both federal and state water quality research and outreach programs, Illinois agricultural organizations came together in 2010 to design and enact a new structure to define, implement, and sustain an overall strategy to minimize environmental impact, optimize harvest yield, and maximize nutrient utilization (a.k.a., MOM).

In 2012, a group of agricultural organizations, state agencies, and environmental groups, successfully worked with the Illinois General Assembly to enact changes to the Illinois Fertilizer Act (505 ILCS 80) to create the Nutrient Research & Education Council (NREC). NREC is a public-private partnership that assures a sustainable source of funding for nutrient research and education programs. NREC is made up of nine voting members from the agricultural sector and four non-voting members, including representatives from environmental groups, Illinois EPA, and academia. The partnership between NREC and IDOA ensures that a $.75/ton assessment on all bulk fertilizer sold in Illinois is allocated to research and educational programs focused on nutrient use and watter quality.

NREC funded two water quality research projects in 2013, including An Agronomic & Environmental Assessment of Cover Crops and Phosphorus Runoff Potential in Fields with Minimal Slope. Funding for these on-going projects totaled $320,048.

In 2014, NREC provided over $2.55 million to 14 projects, including educational and outreach programs, as well as several research projects addressing the need to reduce nutrient losses from agricultural sources and evaluating the effectiveness of various nutrient management practices in improving water quality. These projects include:

- Nitrogen Management Over Tile Drained Fields to Optimize Yields & Minimize Loss, University of Illinois
- A Field Scale Comparison of Nitrogen Efficiency Practices to Reduce Losses, Illinois State University
- Late Nitrogen Application in Southern Illinois to Minimize Losses, Southern Illinois University Carbondale
- An Agronomic & Environmental Assessment of Cover Crops, University of Illinois and Southern Illinois University Carbondale
- An Analysis of Farmer's Nitrogen Management Practices, Illinois State University
- A Paired Cover Crop Study to Determine Impact of Cover Crops on Water Quality, Illinois State University
- Phosphorus Runoff Potential in Fields with Minimal Slope, University of Illinois
- Keep it for the Crop (KIC), an education and outreach program that seeks to educate the agricultural sector on improving nutrient stewardship
- Discovery Farms, a program that will coordinate farm demonstration projects with university research results to identify and disseminate workable best management practices

For details on all NREC projects, visit www.illinoisnrec.org.

Keep it for the Crop Education and Outreach Program

The KIC Education and Outreach Program is the Illinois Council on Best Management Practices' (CBMP) comprehensive, collaborative program for science-based outreach and education. The program is designed to promote enhanced nutrient stewardship and the implementation of voluntary agricultural BMPs to reduce nutrient losses and improve water quality. The program consists of four different aspects:

education, training, demonstration, and communication to meet the following objectives:

- Information – Gather the most up-to-date and accurate information about the effectiveness of BMPs to improve water quality and other natural resources and the programs available to assist with adoption of these practices
- Awareness – Increase awareness of water quality and other natural resource issues, as well as the effectiveness and economic viability of adopting BMPs
- Participation – Increase farmer participation in available nutrient management, water quality, and conservation programs and increase the adoption of BMPs to improve water quality and other natural resources
- Demonstration – Use the Illinois Nutrient Loss Reduction Strategy (Illinois NLRS or the strategy) as a guide to demonstrate and track adoption of BMPs within the eight targeted watershed where CBMP has resources

KIC will focus on the eight priority watersheds designated by Illinois EPA as being impaired due to nitrate-nitrogen, total phosphorus, or both: Lake Springfield, Lake Evergreen, Lake Bloomington, Lake Vermilion, Salt Fork Vermilion River, Vermilion River-Illinois Basin, Lake Decatur, and Lake Mauvaise Terre.

KIC receives its primary financial support from NREC for its education, outreach, and research-based components. CBMP utilizes and supports the following programs and tools.

> Formed in 1998, Illinois CBMP is a non-profit entity made up of dues-paying member organizations, including the Illinois Corn Growers Association, Illinois Farm Bureau, Illinois Soybean Association, Illinois Fertilizer & Chemical Association, Illinois Pork Producers Association, Syngenta Crop Protection, Monsanto, and GROWMARK. Its mission is to identify and promote sound agronomic practices in the agricultural sector to address water quality concerns. Visit www.illinoiscbmp.org for more information.

Cover Crop Training Initiative

Cover Crop Training Initiative uses regional cover crop specialists to provide training, education, and outreach to promote the use of cover crops for nutrient management in production agriculture. During this three-year program, CBMP, with financial assistance from the National Fish and Wildlife Foundation (NFWF) and the Zea Mays Foundation, will train three regional cover crop specialists on how to establish cover crop demonstration sites and work with agricultural retailers, SWCDs, and IDOA to identify farmers statewide. Cover crop specialists will provide training sessions and work with farmers to encourage them to incorporate cover crops into their farming operations and to help them chose the best implementation strategy for their farms.

Agriculture departments at community colleges across Illinois are partnering on this initiative by providing trainers and training sites. Cooperation and communication among multiple participating community colleges will establish a network for agricultural education and outreach in Illinois and expand the impact of this program.

Lake Springfield Watershed Project

CBMP, with funding from Springfield City Water, Light & Power (CWLP) and NFWF, is engaged with Lake Springfield watershed partners, including the Sangamon County SWCD, on a program to measure stream quality and work with agriculture retailers and farmers to adopt management systems and BMPs that will ensure that nitrate levels in Lake Springfield remain consistently below the 10 ppm drinking water standard.

Demonstration Farms Partnership

This program will support and coordinate the efforts of several demonstration site programs, including CBMP demonstration farms sites, CBMP NFWF cover crop training demonstration sites, and soil health partnership sites. These programs seek to add edge-of-field water quality monitoring to farm scale demonstration sites that have implemented one or more BMPs to improve nutrient management, water quality, or soil health. The Illinois Demonstration Farms Partnership Program will support the establishment and continuation of water quality monitoring on these demonstration farms. These sites include both row crop and livestock production, allowing the program to evaluate the impact of a variety of BMPs, such as nitrogen management, cover crops, conservation tillage, drainage water management, and others, on farm operations, soil health, water quality, and other sustainability metrics. By collaborating and sharing technical expertise, educational and promotional resources, and in-field personnel, the effectiveness and impact of these programs will improve, providing further support to Illinois farmers in making BMP implementation decisions.

Keep it 4R Crop Program

This Illinois Fertilizer and Chemical Association's 4R nutrient stewardship program focuses on education and in-field work with agriculture retailers and their farmer customers to support fertilizer management practices focused on using the right source at the right rate at the right time in the right place. Program retailers and farmer customers work together to identify and implement practices in individual fields that minimize environmental impact, optimize harvest yield, and maximize input utilization. This program is funded by the fertilizer industry and supports on-farm nitrogen rate trials (N-WATCH) managing nitrogen as a system, as well as phosphorus placement trials where appropriate. All protocols for on-farm trials are provided by University of Illinois researchers. With permission of the farmer, results are shared with university staff to continually feed the Maximum Return to Nitrogen Rate (MRTN) calculator. This enables university researchers and extension specialists to use information gained from these in-field practices to educate growers on nitrogen and phosphorus management issues via seminars, Certified Crop Advisors training sessions, extension meetings, and various publications.

Nitrogen Rate Trials and the N-WATCH Program

N-WATCH is an on-farm nitrogen rate trial program. Nitrogen rate trials allow farmers and agricultural retail agronomists to identify the rate of nitrogen needed for a particular crop. Trial information also ensures that the MRTN calculator, the use of which is key to improving harvest yields and reducing nitrogen losses, remains current and relevant to the user industry.

N-WATCH soil testing is used as another engagement tool to expand education and outreach as well as to help farmers understand the movement of nitrogen in the soil and increase farmer adoption of the enhanced nutrient management and other BMPs. Pre- and post- N-WATCH surveys are completed throughout the project by cooperators to demonstrate changes in nutrient practices, and results are reported in aggregate by a watershed or, in some areas, at sub-watershed levels. Farmers are encouraged to follow-up with additional resources to learn more about BMPs and are given referrals to other programs.

Non-Profit Programs and Projects

The Nature Conservancy in Illinois

For more than 20 years, The Nature Conservancy (TNC), in conjunction with researchers at the University of Illinois, has worked with partners along the Mackinaw River watershed in central Illinois to reduce nutrient pollution through the targeted implementation of BMPs. These efforts have yielded three projects. The first used targeted outreach to encourage local agricultural producers to implement BMPs and identified the barriers preventing producers from doing so. Water monitoring that accompanied BMP implemen-

> The Nature Conservancy is an international conservation organization working to protect endangered lands and waters around the world. Their efforts at the local and state level have played an important role in reducing both nutrient runoff and loading in Illinois streams and rivers.

tation in these watersheds indicated that surface BMPs such as grassed waterways did not effectively reduce the nutrient loads carried by subsurface tile drainage. However, a pilot study on a nearby experimental farm did indicate that treatment wetlands that intercepted tile drains removed approximately 19-48 percent of nitrate-nitrogen and 47-57 percent of the total phosphorus from water. Consequently, TNC is pursuing a new initiative with industry, state, federal, and non-profit partners to strategically place treatment wetlands throughout targeted watersheds in the Mackinaw River Basin. This project will not only reduce the amount of nutrients leaving the state but will also contribute to safe drinking water for the City of Bloomington.

TNC is also reestablishing functional floodplains at two model restoration projects along the Illinois River: the 2,000-acre Spunky Bottoms Project in Brown County and the 6,600-acre Emiquon Project in Fulton County. While the main purposes of these projects are restoring and sustaining natural plant and animal communities and contributing to the health of the Illinois River, reestablishing natural floodplain habitats and ecological processes will provide water quality improvements. Wetland processes contributing to improved water quality include denitrification, sequestration of phosphorous in sediments, sediment cycling, and the breakdown of other pollutants. In addition, these projects will improve groundwater recharge, stormwater storage, carbon sequestration, and opportunities for education, recreation, and compatible economic development. Based on a wide variety of ongoing scientific research and monitoring, lessons learned at these sites are being shared broadly and are influencing restoration and management of other large floodplain rivers locally, regionally, nationally, and internationally.

Illinois Buffer Partnership

The Illinois Buffer Partnership is a statewide program that promotes and showcases the voluntary efforts of farmers, landowners, and communities to plant, maintain, and enhance conservation buffers that reduce soil erosion, improve water and soil quality, and provide wildlife and pollinator habitat. The program is led by Trees Forever in partnership with CBMP, Syngenta, GROWMARK, state and federal government agencies, and other private donors.

> Trees Forever is a non-profit organization in Iowa and Illinois whose mission is to plant and care for trees and the environment by empowering people, building community, and promoting stewardship. For more information, visit www.treesforever.org.

Between 10 and 20 Illinois Buffer Partnership participants are eligible annually to receive cost-share assistance, on-site assistance from Trees Forever field staff, project signs, and the opportunity to host a field day to highlight their projects. Conservation practices eligible for the Illinois Buffer Partnership include:

riparian buffers, livestock buffers, stream bank stabilization, wetland development, pollinator habitat, rain gardens, and agroforestry.

Since its inception in 2000, the Illinois Buffer Partnership has provided assistance to more than 200 demonstration projects across the state. Over 4,000 acres of conservation buffers have been planted, protecting more than 52 miles of Illinois streams. To date, 1,460 landowners and volunteers have planted 886,682 trees and shrubs and contributed 25,429 volunteer hours to site establishment, planting, and maintenance to make these conservation projects successful.

Nutrient Loss Reduction Best Management Practices

Practices to Reduce Nitrate Losses from Row Crop Areas

Fertilizer Application

Changes in nitrogen fertilizer application practices could significantly reduce nitrate-nitrogen losses. Effective application practices include applying nitrogen fertilizer according to MRTN rate, using nitrification inhibitors for fall-applied fertilizers, applying fall fertilizer after the soil temperature 4-in deep falls below 50○ F, switching from fall to spring applications, and splitting fertilizer applications to align with when plant uptake is greatest. All of these recommended practices are currently used throughout Illinois and, in most cases, the necessary technology, equipment, and management experience are widely available. Some of these practices may also result in cost savings for producers and higher crop yields.

> The goal of the Illinois NLRS is for farmers to select and apply the most beneficial practices for any given field. These practices are based on the science assessment and are those deemed by the Illinois Nutrient Loss Reduction Strategy Policy Working Group to have the greatest potential impact. This does not represent all practices that could result in nutrient loss reduction. The specific suite of practices appropriate for any given field will depend on many factors including soil characteristics, landscape position and hydrology, and current cropping and management practices.

Cover Crops

Cover crops effectively reduce both nitrate-nitrogen and total phosphorus losses while also improving soil tilth and other important properties. Illinois farmers currently plant 319,000 acres of cover crops. The adoption of cover crops as a routine management practice may provide the best means of achieving large reductions in nutrient losses, particularly in the southern two-thirds of the state. Successful transitioning to a cover crop system will require constant improvements in all aspects of management systems.

The conservation practices identified in this strategy for row crop and livestock operations, as well as additional practices, are eligible practice standards supported by NRCS conservation programs.

Edge-of-Field Practices

Edge-of-field practices, such as bioreactors and end-of-tile wetlands, are highly-effective at removing nitrates and have low long-term costs. However, they can have significant installation and maintenance costs, as well as the lost value of the land that would otherwise have been planted and harvested. Installation of these practices to date has been limited to research and demonstration projects. Buffers may provide some limited reductions in nitrate losses where shallow groundwater flows through the active root zone beneath the buffer but will not affect water flowing through a tile drain.

Table 6.1. Example statewide results for nitrate-nitrogen reductions by practice/scenario with shading to represent in-field, edge-of-field, and land use change practices or scenarios*.

Practice/scenario	Nitrate-N reduction per acre (percent)	Nitrate-N reduced (million lb)	Nitrate-N reduction from baseline (percent)	Cost ($/lb removed)
Reducing N rate from background to MRTN on 10 percent of acres	10	2.3	0.6	-4.25
Nitrification inhibitor with all fall-applied fertilizer on tile-drained corn acres	10	4.3	1	2.33
Split application of 50 percent fall and 50 percent spring on tile-drained corn acres	7.5-10	13	3.1	6.22
Spring-only application on tile-drained corn acres	15-20	26	6.4	3.17
Split application of 40 percent fall, 10 percent pre-plant, and 50 percent side dress	15-20	26	6.4	
Cover crops on all corn/soybean tile-drained acres	30	84	20.5	3.21
Cover crops on all corn/soybean non-tiled acres	30	33	7.9	11.02

Practice/scenario	Nitrate-N reduction per acre (percent)	Nitrate-N reduced (million lb)	Nitrate-N reduction from baseline (percent)	Cost ($/lb removed)
Bioreactors on 50 percent of tile-drained land	40	56	13.6	1.38
Wetlands on 25 percent of tile-drained land	40	28	6.8	5.06
Buffers on all applicable crop land (reduction only for water that interacts with active area)	90	36	8.7	1.63
Perennial/energy crops equal to pasture/hay acreage from 1987	90	10	2.6	9.34
Perennial/energy crops on 10 percent of tile-drained land	90	25	6.1	3.18

**See chapter 3 for a discussion of producer costs to implement these practices.*

Practices to Reduce Total Phosphorus Losses from Row Crop Areas

Fertilizer Application

Applying phosphorus fertilizers only when soil tests indicate total phosphorus levels are below Illinois Agronomy Handbook (University of Illinois, 2012a) recommendations is a key way to reduce total phosphorus losses across the state. Producers currently applying above these levels could also realize significant cost savings by implementing this practice. A University of Illinois Extension and industry initiative to increase awareness among producers, landowners, and advisers such as farm managers of crop needs and soil phosphorus levels could be very beneficial. A review of standard farm lease agreements for opportunities to address this issue and nutrients in general may also be helpful.

Tillage

The science assessment (chapter 3) shows the benefits of a renewed effort to reduce soil erosion losses on cropland with erosion rates greater than soil loss tolerance. Reductions in tillage intensity that leave greater amounts of crop residue on the surface after planting may result in less soil erosion and thus less phosphorus loss, as well as fuel savings to producers. However, the availability of appropriate planting equipment may limit adoption by small-acreage producers.

Edge-of-Field Practices

On fields with steep slopes and areas where ephemeral gullies form, water and sediment control basins have been shown to trap about 90 percent of sediment. Properly designed and maintained grassed waterways and other buffers such as filter strips are also effective in reducing sediment and total phosphorus delivery to streams and should be targeted to areas with relatively high sediment delivery rates.

Table 6.2. Example statewide results for total phosphorus reductions by practice/scenario with shading to represent in-field, edge-of-field, and land use change practices or scenarios*.

Practice/scenario	Total P reduction per acre (percent)	Total P reduced (million lb)	Total P reduction from baseline (percent)	Cost ($/lb removed)
1.8 million acres of conventional till eroding >T converted to reduced, mulch, or no-till	50	1.8	5	-16.6
P rate reduction on fields with soil test P above the recommended maintenance level	7	1.9	5	-48.75
Cover crops on all corn/soybean tile-drained acres	30	4.8	12.8	130.4
Cover crops on 1.6 million acres eroding >T currently in reduced, mulch, or no-till	50	1.9	5	24.5
Wetlands on 25 percent of tile-drained land	0	0	0	
Buffers on all applicable crop land	25-50	4.8	12.9	11.97
Perennial/energy crops equal to pasture/hay acreage in 1987	90	0.9	2.5	102.3
Perennial/energy crops on 1.6 million acres >T currently in reduced, mulch, or no-till	90	3.5	9	40.4
Perennial/energy crops on 10 percent of tile-drained land	50	0.3	0.8	250.07

**See chapter 3 for a discussion of producer costs to implement these practices.*

Practices to Reduce Nutrient Losses from Livestock Production

Manure Application

Livestock production does not contribute large volumes of nutrients to Illinois surface waters or the Gulf of Mexico. At the local level, however, livestock manure may be a significant source of total phosphorus. There are a number of appropriate manure application management practices available to producers, including:

- Applying manure at agronomic rates based on University of Illinois and USDA NRCS guidelines

- Injecting or immediately incorporating applied manure into the soil to minimize the potential for manure off-site movement

- Avoiding manure applications when precipitation is anticipated within 24 hours

- Following the appropriate application setback (as statutorily defined) when applying manure in critical areas

- Avoiding or minimizing manure applications to snow-covered or frozen areas

These practices can be a part of either formal or informal comprehensive nutrient management plans. Although these plans are often voluntary or are not routinely evaluated by a regulatory agency or a third-party evaluator, their development and use should be expanded throughout the livestock industry. These practices should be carefully followed to increase the levels of successful manure management and nutrient loss reduction from livestock facilities in the state.

Stormwater Runoff

Runoff from livestock feeding areas, feedlots, loafing areas, milking parlors, and other production areas can be highly nutrient-enriched and, if not managed appropriately, can flow into surface depressions or small ditches, which can lead to surface water nutrient contamination. Nutrient loss can be reduced in these areas through runoff management practices, including:

- Using clean water diversions whenever possible to keep uncontaminated water from coming into contact with manure

- Scrapping lot areas daily and removing and storing the resulting manure in an area protected from precipitation

- Collecting runoff from animal feeding and loafing and appropriately disposing of it via land application, treatment wetlands, filter strips, or other practices intended to keep runoff at the treatment site

- Treating silage leachate, milkhouse waste, or other liquids that have come into contact with manure as manure and storing it until conditions are appropriate for land application

- Protecting feeding areas whenever possible from precipitation to minimize the amount of feed lot runoff that must be managed

Pastures and Grazing

The appropriate management of pasture or grazing-based livestock production can minimize nutrient losses from production areas by eliminating uncontrolled livestock access to streams and drainage ways, maintaining areas that receive heavy use and high traffic, providing shade and watering sources away from streams and waterways, and maintaining healthy grass stands that reduce nutrient runoff.

Feed

Livestock producers can mitigate the potential loss of total phosphorus through manure by reducing the phosphorus content animal feeds. Formulating diet rations consistent with University of Illinois recommendations can, in some cases, reduce the total phosphorus content of the resulting manures.

USDA NRCS standards directly associated with livestock nutrient management include, but are not limited to:

- Nutrient Management (590)
- Feed Management (592)
- Waste Storage Facility (313)
- Heavy Use Area Protection (561)
- Roof Runoff Structure (558)
- Spring Development (574)
- Watering Facility (614)
- Water Well (642)
- Access Control (472)
- Vegetated Treatment Area (635)

Future Regulatory Actions

IDOA, in consultation with the Water Quality Partnership Forum established by this strategy (discussed below), will evaluate the state's existing fertilizer and related nutrient non-point regulatory framework to identify potential gaps and develop possible remedies for future stakeholder consideration.

Future Strategic Actions

Expanded Outreach and Education

Promotion of nutrient loss reduction practices like those identified in this strategy will be expanded by public, private sector, academic, and non-profit entities. Education and outreach efforts will be tailored to the needs of specific watersheds or counties and will focus on the most appropriate nutrient loss reduction practices.

Educational efforts will expand to further target programs for technical assistance providers, including local, state and federal agency staff, and private sector advisors such as certified crop advisors and farm managers.

Agricultural producers as well as non-resident landowners will be provided information on the impacts of nutrient losses on water quality and practices to reduce those losses. State and federal agencies as well as CBMP members and its individual farmer member organizations will actively engage in outreach to educate farmer members on the Illinois NLRS and the tools available to farmers to implement changes in individual watersheds or regions of the state. Educating landlords is particularly important for those practices that do not provide any direct economic return to the producer or tenant in the short run, such as wetlands, buffers, and bioreactors.

The Illinois NLRS will also be discussed in county and watershed meetings. Producers will be given opportunities to voluntarily implement practices that will reduce nutrient losses. Increased incentive-based programs are being developed and implemented by all of the stakeholders involved in developing the strategy. Many of the partners already have developed or are developing such programs (e.g. KIC, MOM, MRBI, NWQI, and others).

Based on the results of the watershed prioritization process (see chapter 4), Illinois EPA will prioritize financial support for groups to develop watershed plans that lead to voluntary and incentive-based implementation of the strategy and encourage partners to provide additional funding or other resources where possible.

Non-traditional approaches and means of reaching target audiences should also be pursued. For example, soil testing labs may be able to highlight soil test values above optimal. Developing and implementing new approaches for the delivery of nutrient management information to absentee landowners should also be pursued to ensure that both the farm operator or manager and the land owner are adequately informed about these issues and the importance of appropriate nutrient management on the lands they control.

Agricultural Water Quality Partnership Forum

An Agricultural Water Quality Partnership Forum will be formed to steer, coordinate, and assign responsibilities for delivering outreach and education required to involve individual farmers in addressing nutrient losses. The partnership will include high-level officials from relevant agencies and organizations. Tasks for this group will include:

- Strengthening connections between industry initiatives, continuing education requirements for certified crop advisors, state programs, and other technical service providers
- Identifying necessary education initiatives and assigning their development to the appropriate organization
- Selecting members for a subgroup to develop products and programs that help producers evaluate and select the most appropriate BMPs

- Working with the Nutrient Monitoring Council to track and report BMPs necessary for adaptive management
- Coordinating and aligning priorities for funding BMP implementation
- Reaching a consensus on whether Illinois should pursue an Agricultural Water Quality Certification program, either statewide or in pilot areas, that would encourage voluntary adoption of BMPs

If a certificate program were to be established, the partnership would be responsible for developing a timeline and program implementation plan. The partnership would also identify the training requirements and authorization necessary for technical advisors and certified crop advisors to provide water quality certifications for producers, if such a program is developed, and would be required to develop a timeline and implementation plan.

Supporting Watershed-Specific Practices

Although even small reductions in nitrate-nitrogen and total phosphorus losses from agricultural lands will move us closer to the overall reduction goals, limited public and private resources require that efforts be targeted to areas with the greatest nutrient losses and make use of the most cost-effective practices. Prioritization of financial assistance to support the adoption of the most effective and efficient nutrient loss reduction practices will be critical to the success of existing programs. Management mechanisms such as the NRCS State Technical Committee must be used to help target support programs that can help reduce nutrient losses while still addressing traditional program goals. State and federal agencies should provide incentives or financial assistance for the adoption of nutrient loss reduction practices that have been shown to effectively reduce nitrate-nitrogen and total phosphorus in the peer-reviewed literature.

Continued Research

Continued research is needed to ensure that that BMPs supported by this strategy are the most effective and cost-efficient. Future research should focus on three broad topics: management techniques, obstacles to adoption, and improved practice targeting. At the county or small watershed level, additional tools are also needed to make it possible to target local efforts to specific sub-watersheds and fields with high-risk conditions. For example, soil survey information could be used to identify soils that are likely to be tile-drained and thus likely sources of nitrate-nitrogen losses. The BMPs recommended in this strategy will be updated in response to continued research on the effectiveness of these practices and as new practices emerge.

Assuring Adequate Funding

In the absence of new funding, the state must initially rely on existing government financial assistance programs to continue to support grower adoption of nutrient loss reduction management practices. The limited resources available through NRCS, IDOA, and Illinois EPA will be augmented with resources available through NREC.

These funds will not be adequate to support the type of actions that may be needed to meet the nutrient loss reduction target levels identified by the U.S. EPA Science Advisory Board (U.S. EPA, 2007). The state may need to consider the identification of additional funding sources. IDOA and Illinois EPA have begun to rigorously explore other new initiatives to further support BMP adoption. Expansion of the conservation practice property tax modifications, creation of a state revolving fund loan program to support producer practice adoption, creation of a “certainty” program for progressive producers, and the development of a tradable conservation certificate program should also be considered and further developed as ways to make nutrient loss reduction practices more profitable for land owners and managers.

There may also be opportunities to collaborate with other state and federal agencies and non-governmental organizations to identify where nutrient loss reduction practices such as wetlands and buffers also achieve compatible goals, such as improved wildlife and waterfowl habitat. Additional funding from these sources would augment the limited state and federal dollars available. Moreover, this approach may provide an additional incentive for some landowners to participate in sponsored programs and adopt new practices designed to result in nutrient loss reductions.

Photo by Marilyn Sanders

Chapter 7
Nutrient Loss Reduction Strategy for Urban Non-Point Sources

Urban Stormwater Contributions

Urban runoff due to increased impervious surfaces is a much smaller contributor of nutrients to Illinois waterways than either point source discharge or agricultural non-point source runoff. Current loading from urban stormwater represents about 4 percent of the statewide total phosphorus loading into the Mississippi River and 2 percent of the nitrate-nitrogen loading.

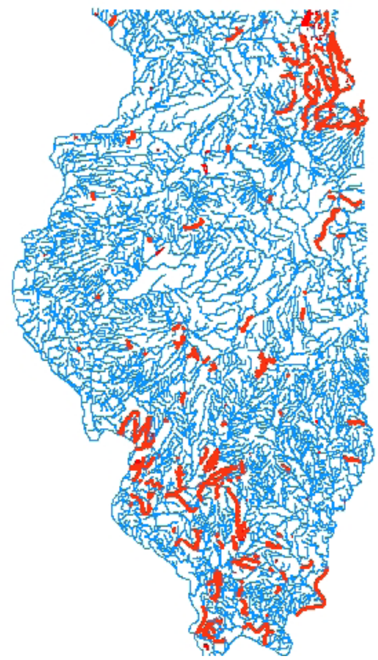


Figure 7.1. Illinois streams impaired due to urban runoff.

The 2014 Illinois Integrated Water Quality Report identified 1,262 miles of streams and 40,037 acres of lakes as impaired due to urban runoff and storm sewer impacts (Illinois Environmental Protection Agency, 2014). As little as 10 percent impervious cover in a watershed can result in stream degradation, and impervious cover in the six-county northeastern Illinois region is estimated at approximately 18 percent. Cook County has the largest amount at almost 50 percent, while Will County and McHenry County are closer to 5 percent each (Illinois Environmental Protection Agency, 2013).

Current Programs and Projects Supporting Nutrient Reduction Goals

Section 319

Section 319 is a grant program under the Clean Water Act (33 U.S.C. 1329) that provides funding for states with approved non-point source management plans. States in turn can competitively award grants to qualified applicants for non-point source pollution control projects.

Through technical and financial assistance, The Illinois Environmental Protection Agency (Illinois EPA) encourages the development of watershed-based plans consistent with current watershed planning principles. Plans are tracked through the Research Management Mapping Service, whether they are being developed or are complete. Visit www.rmms.illinois.edu for more information.

By implementing urban best management practices (BMPs), the Section 319 program alone has reduced annual loads of nitrate-nitrogen by 138,000 lbs/yr, total phosphorus loads by 65,000 lbs/yr, and sediment loads by 73,000 tons/yr. Examples of urban BMPs completed through Section 319 funding include 229 grade stabilization structures, which are estimated to have reduced nitrate-nitrogen loads by 98,000 lbs/yr, total phosphorus by 49,000 lbs/yr and sediment by 49,000 tons/yr. Fifteen sediment detention basin BMPs also account for annual reductions of 3,000 lbs/yr of nitrate-nitrogen, 1,000 lbs/yr of total phosphorus, and 8,000 tons/yr of sediment.

Municipal Separate Storm Sewer System Permits

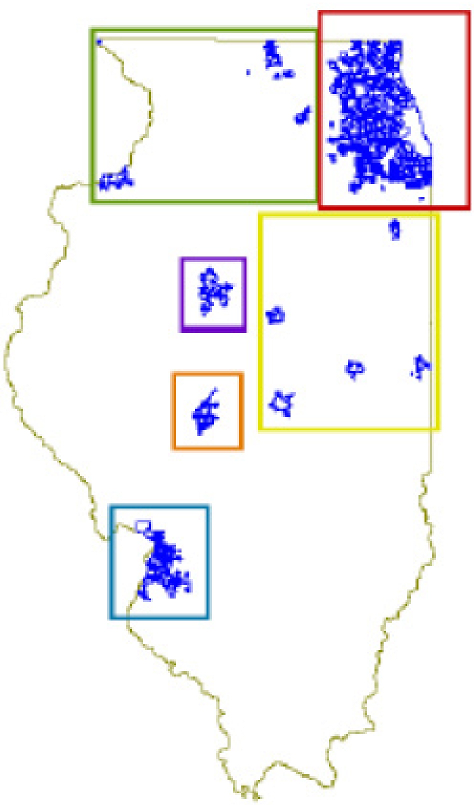


Figure 7.2. MS4 Communities.

Under the Clean Water Act (33 U.S.C. 1342), states must issue National Pollution Discharge Elimination System (NPDES) permits for stormwater discharges from industrial, construction, and municipal activities. The permit for municipalities is known as the municipal separate storm sewer system (MS4) permit and is managed by Illinois EPA. Approximately 440 Illinois municipalities, townships, and state agencies, concentrated in six regions, are subject to the permit.

The MS4 general permit requires permittees to adopt green infrastructure stormwater management strategies and techniques as part of their programs. This includes providing information on green infrastructure practices through public education and outreach programs, training municipal employees and contractors on green infrastructure practices, and incorporating green infrastructure techniques into stormwater management practices used during construction, including the construction and reconstruction of municipally-owned impervious surfaces. Post-construction stormwater management should also incorporate green infrastructure strategies of infiltration, evapo-transpiration, and harvesting for reuse and must favor these strategies over conventional ones.

The proposed 2014 MS4 permit would further address stormwater by requiring permittees to consider green infrastructure and plan for a ninetieth percentile storm event while designing onsite retention for all new and redeveloped building sites.

Clean Water Initiative and State Revolving Fund

Illinois EPA is working to update rules to develop a new schematic that will prioritize the funding of green infrastructure as well as traditional water pollution control projects. The change comes in response to a recent loan program eligibility expansion under the Clean Water Initiative (Public Act 98-0782), which allows funds to be used to implement green infrastructure and stormwater treatment projects.

Illinois Green Infrastructure Grant

Illinois Green Infrastructure Grant is a state-funded grant program targeted to local government units and other organizations that supports the implementation of green infrastructure BMPs to improve water quality by controlling stormwater runoff. Information on green infrastructure costs is provided in the following resources:

- Illinois Green Infrastructure Study, available at www.epa.state.il.us/green-infrastructure/docs/draft-final-report.pdf
- The Stormwater Performance Standards Recommendation, available at www.aiswcd.org/wp-content/uploads/2013/07/Stormwater-Performance-Standard-Recommendations_FINAL0628131.pdf
- Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices, available at water.epa.gov/polwaste/green/costs07_index.cfm
- The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits, available at www.cnt.org/resources/the-value-of-green-infrastructure-a-guide-to-recognizing-its-economic-environmental-and-social-benefits/
- The Green Build-out Model: Quantifying the Stormwater Management Benefits of Trees and Green Roofs in Washington, DC, available at www.capitolgreenroofs.com/pdfs/Green_Infrastructure_Report.pdf

Rain Barrel Programs

Metropolitan Water Reclamation District of Greater Chicago communities are eligible to participate in a program that provides homeowners with low-cost rain barrels. Chicago residents may also receive a 50 percent rebate through the city. For more information, visit www.mwrd.org/irj/portal/anonymous/rainbarrel.

Streambank Stabilization and Restoration Program

In an effort to stabilize and restore severely eroding stream banks that would otherwise contribute sediment to the state's rivers and tributaries, the Illinois Department of Agriculture (IDOA), with assistance from soil and water conservation districts, administers the Streambank Stabilization and Restoration Program (SSRP). Severely eroding stream banks can contribute as much as 30-50 percent of the sediment entering waterways from all sources. SSRP, funded under the Partners for Conservation Program, provides funds to implement low-cost techniques for stabilizing eroding stream banks. Examples of these practices include rock riffles, stone toe protection, and bendway weirs. In 2004-2012, 58 miles of eroding stream banks were stabilized, resulting in about a 61,000-ton reduction in sediment delivery. Total phosphorus loading was reduced by approximately 57,000 pounds.

Total Maximum Daily Load

In accordance with the Clean Water Act (33 U.S.C. 1313) Illinois EPA uses Total Maximum Daily Loads (TMDLs) to set pollution reduction goals necessary to improve the quality of impaired streams. When establishing TMDLs, Illinois EPA considers all point and non-point sources of a pollutant, existing scientific uncertainty, potential community growth, and the effects of seasonal variation. Illinois EPA also creates implementation plans for every TMDL developed.

Calumet Stormwater Collaborative

This collaborative, facilitated by the Metropolitan Planning Council and comprised of key stakeholders, was developed to foster awareness of the many ongoing stormwater management initiatives in the Calumet region, forge a shared understanding of terms, establish common goals, identify opportunities to align existing projects with those goals, and develop new projects to achieve these goals. Early tasks for the Calumet Stormwater Collaborative include aiding Illinois EPA and Cook County in prioritizing a range of stormwater investments along the Calumet River, providing guidance to the Cook County Land Bank Authority on its role in stormwater management, and scoping out a role for the Chicago Metropolitan Agency for Planning's Local Technical Assistance Program.

Future Regulatory Actions

Monitoring Program

Illinois EPA will consider developing a monitoring program that would help municipalities monitor stormwater discharge into impaired streams. Illinois EPA will also consider revising future MS4 general permits to require municipalities to monitor discharge.

Technical Assistance for Municipalities

Illinois EPA will work to develop a stronger stormwater program that provides technical assistance to permittees seeking to implement low-impact development and green infrastructure BMPs. Additionally, the state will explore options for providing technical and financial assistance for municipalities interested in developing stormwater plans.

> Nutrient loss reduction strategies for urban stormwater focus on volume. While this approach does not directly address stormwater, volume reductions could result in water quality improvements since much of the excess nutrient load carried by stormwater will decrease with greater stormwater retention measures. Additional data and research are needed to set specific nutrient load reduction goals for urban stormwater sources.
>
> Because watersheds do not follow municipal boundaries, this portion of the strategy also targets all urban areas rather than the most urban watersheds, which offers a greater impact to water quality.

Post-Development Stormwater Performance Standard

Illinois EPA is moving forward with the adoption of rules that set onsite performance standards, as recommended by the Post-Development Stormwater Runoff Standard Workgroup, which comprised representatives from state and federal agencies, non-profit organizations, community groups, and consulting firms. These rules will include all new and developed sites over 1 acre and would be implemented through NPDES General Permit ILR10. Visit www.aiswcd.org/wp-content/uploads/2013/07/Stormwater-Performance-Standard-Recommendations_FINAL0628131.pdf for the complete recommendations.

Future Strategic Actions

Urban Stormwater Working Group

Municipalities, non-governmental organizations, and agencies involved in urban stormwater management will meet annually to explore funding, identify legislative initiatives, and develop plans. The Urban Stormwater Working Group will also coordinate outreach and orchestrate statewide efforts related to green infrastructure expansion and retrofitting, MS4 program training, and urban stream, lake, and stormwater monitoring.

Planning

Illinois EPA will encourage the development of comprehensive, science-based stormwater plans at the municipal and county level to reduce stormwater volume and, as a result, nutrient loading. Existing plans created by watershed planning groups and municipalities are often driven by flood events and lack the details needed for the implementation of stormwater management.

Storm Sewer System Mapping

Illinois EPA will encourage municipalities to fully map storm sewer systems. Few communities currently have system maps, with the exception of combined sewer overflow communities that are required to develop a long-term control plan as part of their NPDES permits. These plans allow for permitted overflows.

Training

Illinois EPA will consider developing a more formalized approach for helping communities meet employee training requirements in the MS4 permit. This may take the form of developing a framework municipalities could follow to conduct and document training efforts or of increased collaboration to provide county-level training opportunities.

Assuring Adequate Funding

The adoption of stormwater management strategies is largely constrained by funding availability. Expanding current resources and identifying additional funding sources will be necessary to meet the nutrient loss reduction target levels identified by the U.S. EPA Science Advisory Board (U.S. EPA, 2007).

Illinois EPA supports legislative actions that would expand opportunities for counties to set stormwater utility fees. A dedicated revenue source for stormwater management programs is essential for successful implementation. Some counties have been given the authority to implement stormwater management programs; expanding this authority could ensure local stormwater management programs have the dedicated revenue source needed to be successful.

Chapter 8
Numeric Nutrient Criteria

Introduction

The Clean Water Act (33 U.S.C. 1313(c)) and the Gulf Hypoxia Action Plan require that states adopt water quality standards for their navigable waters. Adopted standards must include the designated uses of each waterbody and water quality criteria that protect those uses. Under U.S. Environmental Protection Agency (U.S. EPA) regulation (40 CFR 131.11), these criteria may be either numerical values, or, where numerical criteria cannot be established, narrative criteria or criteria based on biomonitoring methods.

Current Nutrient Standards

Nutrient-related standards for surface water have been in place in Illinois since the early 1970s. Table 8.1 shows the adopted water quality standards for total phosphorus by waterbody type or discharging facility.

Table 8.1. Current nutrient standards under 35 Ill. Adm. Code 302-304.

Regulated waterbody or facility	Total phosphorus (mg/L)
Lake Michigan open waters (302.504(c))	.007
Lakes of 20 acres or more (302.205)	.05
Streams at the point of entry into a lake (302.205)	.05
302.205 dischargers to the lake (304.123(b))	1
New or expanding facilities with an average flow of 1 million gallons per day* (304.123(g))	1

**Industrial facilities under this effluent standard receive a permit limit of 1 mg/L if they discharge 25 lb total P/day or more.*

A 10 mg/L nitrate-nitrogen standard also applies at designated public water supply intakes and in the open waters of Lake Michigan (302.304 and 302.504(c)).

The Illinois Environmental Protection Agency (Illinois EPA) has also drafted a regulatory update that would identify low-phosphorus streams and establish a 0.04 mg/L total phosphorus water quality standard to ensure those streams are protected from increases.

In addition to these numeric standards, Illinois has narrative water quality standards for general use waters (302.203) and Lake Michigan (302.515) that prohibit unnatural algae or plant growth. Drafted updates would also prohibit excess plant and algae growth that is offensive to the senses, physically harmful to aquatic life, and that may be shown to cause eutrophication when, in any 24-hour period, the minimum dissolved oxygen standard is exceed and dissolved oxygen exceeds 100 percent air saturation.

Research Supporting Numeric Criteria

Over more than a decade, Illinois EPA has supported a variety of research projects designed to understand the relationships between nutrients and Illinois stream quality in an attempt to identify numeric water quality standards. Four of these projects, conducted between 2003 and 2007, were funded by the Council on Food and Agricultural Research:

- Spatial and Temporal Relationships Between Biotic Integrity of Illinois Streams, Dissolved Oxygen, and Nutrients (see Royer et al., 2008)
- Effects of Phosphorus Mediated Through Algal Biomass in Illinois Streams (see Hill et al., 2009)
- Nutrient and Periphyton Dynamics in Agriculturally Dominated Headwater Streams (Bill Perry, Illinois State University, publication not available)
- The Impacts of Sediments on the Potential Bioavailability of Phosphorus in Illinois Streams (see Machesky et al., 2010)

Two additional U.S. EPA-sponsored projects were conducted in 2008 and 2013, respectively:

- Data Analysis Report for Analysis of Illinois Stream and River Nutrient and Biological Data for the Nutrient Specific Technical Exchange Partnership Support (N STEPS) (Tetra Tech, 2008)
- An Exploratory Analysis of Indiana and Illinois Biotic Assemblage Data in Support of Nutrient Criteria Development (Angradi, 2013)

Although specific findings varied, the results of these projects suggest that attempts to set overarching numeric criteria for streams, rivers, and lakes would result in statistically non-significant numbers for any specific waterbody. The primary regulator of biotic integrity throughout Illinois (and the most common reason streams do not meet water quality standards) is physical habitat, including sediment. The importance of nutrients to water quality would likely increase if sediment was reduced, but, under current conditions, nutrients almost never limit algal biomass. The complex relationship between nutrients and water quality, coupled with the degraded conditions of Illinois waterbodies, makes it difficult to determine the direct cause-and-effect relationship between nutrient levels in water and impairments. This "scientific understanding of the relationship between nutrient loadings and water quality impairment" (Stoner, 2011) is fundamental to the development of scientifically-defensible numeric nutrient criteria.

Future Directions

Illinois EPA will convene a Nutrient Science Advisory Committee using a selection process modelled after the U.S. EPA Science Advisory Board Hypoxia Advisory Board to guide the development of nutrient criteria that help protect aquatic life in Illinois streams and rivers. It will be comprised of scientific experts nominated by the stakeholder sectors represented in the Illinois Nutrient Loss Reduction Strategy Policy Working Group. The Nutrient Science Advisory Committee will examine technical issues concerning nutrients and their effects in flowing waters. Their review will include an analysis of the available data, research results, and statistical analyses referenced above, similar data and research results from other states, the technical basis for numeric nutrient criteria established in other states, the basis for nutrient-related water quality goals developed by watershed groups, U.S. EPA guidance, and any other relevant information. Stakeholder input will follow U.S. EPA Science Advisory Board guidelines. The committee will compare the value of establishing scientifically-defensible numeric nutrient criteria on a watershed basis versus standards with statewide applicability. Following its reviews and evaluations, the committee will determine the appropriate numeric nutrient criteria for Illinois. Illinois EPA will propose numeric nutrient criteria to the Illinois Pollution Control Board in a rulemaking process based on the findings and determinations of the committee. Illinois EPA will work with stakeholders to develop a plan for implementing the numeric nutrient criteria before filing the rulemaking with the Board.

Table 8.2. Timeline for the Nutrient Science Advisory Committee*.

Dates	Action
April- June 2015	Nomination and selection of members
July 2015-December 2016	Committee convenes and conducts review
January 2017	Committee presents determination(s)
February –June 2017	Outreach and discussion among stakeholders
July-November 2017	Illinois EPA develops rulemaking packagevv
December 2017	Illinois EPA files rule(s) with the Illinois Pollution Control Board

**This timeline will be adjusted if the committee determines that additional studies are needed.*

Chapter 9

Measurement, Management, and Implementation

Introduction

The actions needed to reduce nutrient losses to water are diverse, with multiple parties responsible for implementation. To demonstrate that action is being taken and progress is being made, a system of tracking both environmental outcomes and implementation of program activities is needed. Illinois has a suite of programs that together form the toolbox for implementing strategic actions that reduce nutrient losses. Illinois will take advantage of existing tracking programs and methods as much as possible, adding new efforts as appropriate, to reach the Gulf of Mexico hypoxia and local water quality goals and milestones outlined in chapter 2. The fundamental measurements of progress are nutrient load reductions and improved water quality.

The Illinois Environmental Protection Agency (Illinois EPA) recommends that 2011 be used as the baseline year for tracking implementation activities to coincide with the last year of load estimation outlined in chapter 3.

Expected Results

Many factors influence the environmental outcomes of management programs. As with all complex systems, the management efforts outlined in the Illinois Nutrient Loss Reduction Strategy (Illinois NLRS) will not result in linear impacts. We expect rapid reductions in stream nitrate-nitrogen loads in tile-drained areas as a result of the adoption of loss-reduction practices. However, in areas where groundwater discharge to streams is the largest source of nitrate-nitrogen loadings, the lag time may be as much as several decades. Annual and long-term weather variations, such as winter temperatures and precipitation rates, also affect nutrient losses. Statewide load data outlined in chapter 3 shows that the average nitrate-nitrogen load in 2007-2011 was 60 percent greater than the 2003-2007 average, largely because the average river discharge was 75 percent greater.

We also expect a long lag time between efforts to reduce total phosphorus loading from both point and non-point sources and water quality improvements. Stream beds and banks will be a continuous source of total phosphorus subject to entrainment by erosion processes and desorption from sediments. The science assessment (chapter 3) notes "there has been no decline in total P loads despite the large reductions in Universal Soil Loss Equation (USLE) soil erosion estimates of the 1980s and early 1990s."

Measuring Environmental Impacts

Current Monitoring Programs

To track local and regional water quality and evaluate the efficacy of nutrient loss reduction implementation, Illinois EPA will use surface water monitoring programs in place since 1970 and a groundwater monitoring program in place since 1984. These programs have been continuously refined to keep pace with technological advances, broadening environmental concerns, and increasing opportunities to collaborate with other agencies and partners. Nutrient data typically collected for surface water include total phosphorus, dissolved phosphorus, nitrate-nitrogen, ammonia nitrogen, and total Kjeldahl nitrogen, depending on the specific program and waterbody type. Nutrient data collected in groundwater monitoring includes nitrate-nitrogen.

The Illinois Nutrient Monitoring Council (NMC) subsequently discussed in this chapter, will bring together member organizations to work collaboratively to determine how currently-available datasets, including those outlined below, and datasets collected under future initiatives will be used for the primary goals of estimating nitrogen and phosphorus losses, determining nutrient export trends over time, and measuring the impact of management action on water chemistry and biological health.

National Pollutant Discharge Elimination System

Nutrient data is collected from site-specific point source locations per requirements of the National Pollutant Discharge Elimination System (NPDES) permit program and municipal or industrial point source effluent monitoring conducted by Illinois EPA field operations staff. Changes in phosphorus and nitrate-nitrogen effluent levels from point sources are documented and tracked so loading changes can be calculated.

Ambient Surface Water Monitoring Network

Illinois has a statewide network of 146 fixed monitoring stations collecting primarily water chemistry data. Each station is monitored nine times a year to provide baseline water quality information that can be used to define trends, determine water quality problems, and develop water quality standards. Chlorophyll *a* is collected at 50 of the stations, while total phosphorus, dissolved phosphorus, nitrate nitrogen, amonia, and total Kjeldahl nitrogen are collected at all stations. The nutrient data collected through this network were used in conjunction with stream flow data collected by USGS and others to generate the nutrient loading estimates discussed in the science assessment (chapter 3). Future load calculations will rely on the data collected through this network.

Intensive Basin Survey Program

This survey is a cooperative program between the Illinois Department of Natural Resources (IDNR) and Illinois EPA that annually monitors 130-140 stations for biological (fish and macroinvertebrates), chemical, and physical indicators to determine stream aquatic resource conditions. Chlorophyll *a* collections and continuous dissolved oxygen monitoring have been initiated at all Intensive Basin Survey stations. Changes in water chemistry and biological health due to management actions will be detected through this program.

Facility-Related Stream Survey Program

This annual program collects macroinvertebrates, water chemistry, stream flow, and habitat data upstream and, incrementally, downstream of municipal and industrial wastewater treatment facility discharges to evaluate potential water resource impacts and the need for additional treatment controls.

Ambient Lake Monitoring Program

The Ambient Lake Monitoring Program collects physical, chemical, and biological data at approximately 45 public lakes annually to diagnose lake problems and provide data for the development of lake management plans. Lakes are typically monitored five times a year at three to four sites. Changes in water chemistry and biological health due to management actions will be detected through this program.

Watershed-Based Monitoring

This program provides targeted, site-specific monitoring at lake or stream locations where watershed plans are being implemented or Total Maximum Daily Loads are being developed or are underway to determine needed pollutant loading reductions and water quality improvements. Changes in water chemistry and biological health due to management actions will be detected through this program.

Ambient Groundwater Monitoring

Illinois EPA has a statewide, probabilistic fixed station network of 354 randomly selected community water supply (CWS) wells. This random selection is further stratified by depth, aquifer type, and the presence of aquifer material within 50 feet of land surface to improve precision and accuracy. The network is used for collecting water chemistry data and has established baseline water quality information on the population of CWS wells using principle aquifers that can be used to define trends, determine groundwater quality problems, and develop groundwater water quality standards.

Illinois EPA monitoring rotates every two years from this network to special intensive trend or regional studies. Intensive studies examine characteristics such as herbicide transformation products and Chromium 6. A trend network of 43 CWS wells with historical nitrate-nitrogen concentration levels are sampled eight times a year. Chloride and bromide are also being collected to evaluate the ratio of chloride/bromide vs. chloride concentrations to help determine the source of the nitrate-nitrogen. One of these trend network wells is also being piloted under a U.S. Geological Survey (USGS) effort to assess the feasibility of continuous, automated monitoring of nitrate plus nitrite concentrations and physical field parameters at a CWS well.

Shallow Aquifer Monitoring

The Illinois Department of Agriculture (IDOA) operates a monitoring well network designed to provide statistically reliable estimates on the occurrence of nitrate and selected pesticides in shallow aquifers in areas with corn and soybean production. The network is a tool mandated by the U.S. Environmental Protection Agency for the management of pesticides in Illinois. The network currently consists of 133 shallow groundwater-monitoring wells located throughout the state. Each well in is sampled once during a two-year period. Well depths vary from 10 to 81.5 feet. Each well is located in public rights-of-way adjacent to row-crop fields. All wells are installed in areas where aquifer materials occur within 50 feet of land surface.

Additional Monitoring Efforts

Other existing permit or monitoring programs that could be used to gauge progress towards the goals and milestones identified in chapter 2 include:

- Consistent evaluation of the offensive conditions narrative standard (35 Ill. Adm. Code 302.203) for unnatural plant or algae growth.

- The Harmful Algal Bloom Program, designed to safeguard public health, secure the safety of drinking water, and protect recreational uses from toxic microcystin blooms that may appear in nutrient-rich lakes or streams.

- Continuous monitoring for nitrate, phosphate, turbidity, and dissolved oxygen on the Illinois River at Florence. Conducted by the USGS Illinois Water Science Center with funding from Illinois EPA, the data collected by this project has been used to estimate baseline, seasonal, and storm-event loadings, assess instrument performance and deployment issues, and determine the efficacy of using turbidity data to identify suspended sediment concentrations and loads.

- Specialized nutrient monitoring at a number of high-priority watersheds (e.g., Indian Creek and Kickapoo Creek) to monitor water quality before, during, and after the implementation of watershed management plans.

- Designated use attainment reports.

Suggested Future Efforts

Agricultural Non-Point Practice Adoption

Monitoring the progress of management practice adoption by producers will be key to determining whether the voluntary, incentive-based approach laid out in this strategy can successfully be used to meet Illinois NLRS goals and objectives. Tools such as the Soil Conservation Transect Survey and other special producer surveys will serve important roles in practice adoption measurement.

Statewide Nutrient Export Loadings Network

Monitoring the changes in loadings exported from large rivers can help determine which management strategies will work best within a basin statewide. Real-time nutrient monitoring at the following Illinois EPA water quality and USGS gage sites would provide nutrient export estimates from approximately 74 percent of Illinois:

- Rock River near Joslin
- Green River near Geneseo
- Illinois River at Florence
- Kaskaskia River at New Athens
- Big Muddy River at Murphysboro
- Vermilion River near Danville

- Embarras River at Ste. Marie
- Little Wabash River at Carmi

HUC 8 Watershed Pollutant Export Loadings Network or Export Modeling Efforts

Continuous real-time monitoring of nutrients or nutrient export modeling could be conducted at a select group of high-priority eight-digit Hydrologic Unit Code (HUC) watersheds to evaluate the implementation and environmental successes of this strategy.

Low Phosphorus Stream Identification and Assessment

As part of Illinois EPA's effort to develop nutrient standards, streams low in total phosphorus (<0.04 mg/L) are being identified and targeted for special protection. While some low phosphorus streams have been identified already, particularly near southern Illinois' Shawnee National Forest, a concerted monitoring effort is needed to identify if and where other low phosphorus streams exist.

Implementation Benchmarks

To effectively track progress towards the 45 percent reduction goal, the Policy Working Group charged with implementation (see pg. 9.9) will consider potential benchmarks for strategy best management practices (BMPs).

Current Programs and Management Tools to Support Implementation

Current Point Source Programs

National Pollutant Discharge Elimination System Permits

Requirements for nutrient loss reduction from point sources are placed in NPDES permits in the form of permit limits or special conditions. The load reduction from an individual source can be calculated using required discharge monitoring reports submitted by permittees to Illinois EPA. These reports can also be used to determine the collective load reduction from sources within a watershed or statewide. Measures of progress include the:

- Annual loading of total phosphorus in the millions of pounds (and the percent reduction from the baseline)

- Annual loading of nitrate-nitrogen in the millions of pounds (and the percent reduction from the baseline)
- Annual loading of total phosphorus and nitrate-nitrogen (and the percent reduction from the base line) in watersheds where TMDLs or other watershed plans have been developed to address nutrient pollution
- Number of permits with total phosphorus or nitrate-nitrogen limits or other special conditions relevant to nutrient loss reduction

Illinois EPA currently tracks the information needed to calculate these measures through its Integrated Compliance Information System database. Information is based on required reports and the coding of new permits into the system. This information will be documented in a biannual report on nutrient strategy implementation.

Additional programs are listed in chapter 5.

Current Agricultural Programs

Section 319 Non-point Source Pollution Grants

Illinois EPA verifies and tracks the implementation of projects funded through Section 319 of the Clean Water Act (33 U.S.C. 1329). Through this grant program, Illinois EPA works with local governments and other organizations to protect water quality through the control of non-point source pollution. Illinois EPA also estimates the annual load reduction of nutrients and sediment resulting from these projects. Projects are geo-located through the Research Management Mapping Service so the number of projects within particular watersheds can be visualized (see www.rmms.illinois.edu). Results are reported as annual phosphorus and nitrate-nitrogen load reductions in the thousands of pounds (and the percent reduction from the respective baseline).

Partners for Conservation

IDOA administers the Partners for Conservation program in cooperation with Illinois Soil and Water Conservation Districts (SWCDs). The program provides technical and financial incentives to Illinois landowners for the construction or adoption of conservation practices that reduce soil erosion and nutrient loading from non-point agricultural sources and improve water quality.

> Regulatory and voluntary programs that result in point and non-point source nutrient loss reductions are key to meeting loss reduction goals and improving local water quality. The regulatory tools identified in this section will be managed and monitored through the permit process. Additional voluntary agricultural programs will also be used to encourage nutrient loss reduction through implementation of best management practices.

Streambank Stabilization and Restoration Program

IDOA's Streambank Stabilization and Restoration Program addresses sediment and nutrient delivery from eroding stream banks by providing technical and financial resources to help landowners install effective, low-cost stabilization techniques. Summary data regarding the various practices adopted via this program and the resulting reductions in soil loss and nutrient loading are compiled annually by department staff.

Soil Conservation Transect Survey

This survey, first conducted in 1994, tracks sheet/rill and ephemeral soil erosion, as well as the tillage systems used, on about 50,000 cropland fields. The survey is conducted biennially by SWCDs with coordination and assistance from IDOA. Surveyors conducting the windshield survey return twice to the same fields along a dedicated route that transects each township in a county.

> The lack of a comprehensive baseline at the watershed scales presents a challenge to measuring the implementation and environmental impact of this strategy. Baselines are available only for some programs, and the implementation practices that are neither funded by a government agency nor tracked by organizations or businesses may not be detected. As a result, records tracking implementation efforts and estimated load reductions may be incomplete.

The survey has the potential to be expanded to collect data more directly applicable to tracking the implementation of nutrient loss reduction practices, such as the use of cover crops and other erosion control practices. Information on conservation practices needed on surveyed fields can be added as well.

Natural Resources Inventory

This inventory is a statistical survey of natural resource conditions and trends on non-federal land conducted by the Natural Resources Conservation Service (NRCS). The Natural Resource Inventory (NRI) provides nationally-consistent statistical data on land use patterns and the conditions of soil, water, and related resources. Data are currently available on a state and county basis only. Additional staff resources will be needed to provide data on a watershed basis.

NRI information can be used to analyze conservation practices and achievements in the state. Available summary information includes the acres/number/feet (depending on the practice reporting unit) for practices implemented by a funding program, a conservation practice, and a state or county.

Natural Resources Conservation Service Reports

NRCS provides summary Financial Information Reports detailing fiscal year financial obligations in Illinois. These obligations include three categories: technical assistance, financial assistance, and reimbursable funds. Conservation Practice Information Reports are also available. These summarize land unit acres that have received conservation, including a practice count, by fiscal year for the following categories: cropland soil quality, fish and wildlife, forest land conservation, grazing land conservation, irrigation efficiency, water quality, and wetlands. Both reports currently summarize information from fiscal years 2005-2012. Information is presented on a statewide basis, and information on implementation activities on a watershed basis is not currently available.

Voluntary Industry-Based Programs

Several agriculture groups, discussed in chapter 6, are designing and participating in a series of voluntary reporting systems and surveys to track the adoption of nutrient stewardship practices that may reduce nutrient losses. These systems will track:

- The number of acres in a watersheds where nitrogen management systems such as split nitrogen applications and Maximum Return to Nitrogen rates are used
- Trends in the use of nitrogen stabilizers and urease inhibitors in both fall and spring nitrogen applications
- The number of sites in priority watersheds participating in the N-WATCH soil nitrate testing and tracking system
- Increases in cover crop seed sales and cover crop plantings in priority watersheds
- Increases in post-application nitrogen and strip-till equipment sales
- IDOA fertilizer sales reports compared to crop nutrient uptake (NuGIS reports)
- Application practices (source, rate, time, and place) for both nitrate-nitrogen and total phosphorus by watershed

Additional programs are listed in chapter 6.

Current Urban Non-Point Source Programs

Non-Point Source Pollution Grants

Funding for green infrastructure projects is available through three grant programs administered by Illinois EPA: the Clean Water Act 319 Non-point Source Pollution Control grant program (33 U.S.C. 1329), the Illinois Green Infrastructure Grant program, and the Clean Water Initiative (Public Act 98-0782). These programs provide a mechanism to track the number and coverage of projects, including information on the total phosphorous and nitrate-nitrogen reduction in pounds and as a percent reduction from the baseline.

Local Stormwater Management Ordinances

Illinois EPA, the Chicago Metropolitan Agency for Planning, and other entities track the existence of local stormwater management ordinances. Measuring increases in the number of effective, high-quality ordinances enacted annually is a straight forward way to measure progress implementing this strategy.

Municipal Separate Storm Sewer Systems Stormwater Management Plans

Medium and large municipal systems are required to have separate storm sewer systems (MS4) and obtain NPDES coverage through this program. Illinois EPA receives and does limited audits of the implementation of MS4 stormwater management plans. Improved oversight of the quality, scope, and implementation of activities to comply with individual plans would lead to better ability to track implementation.

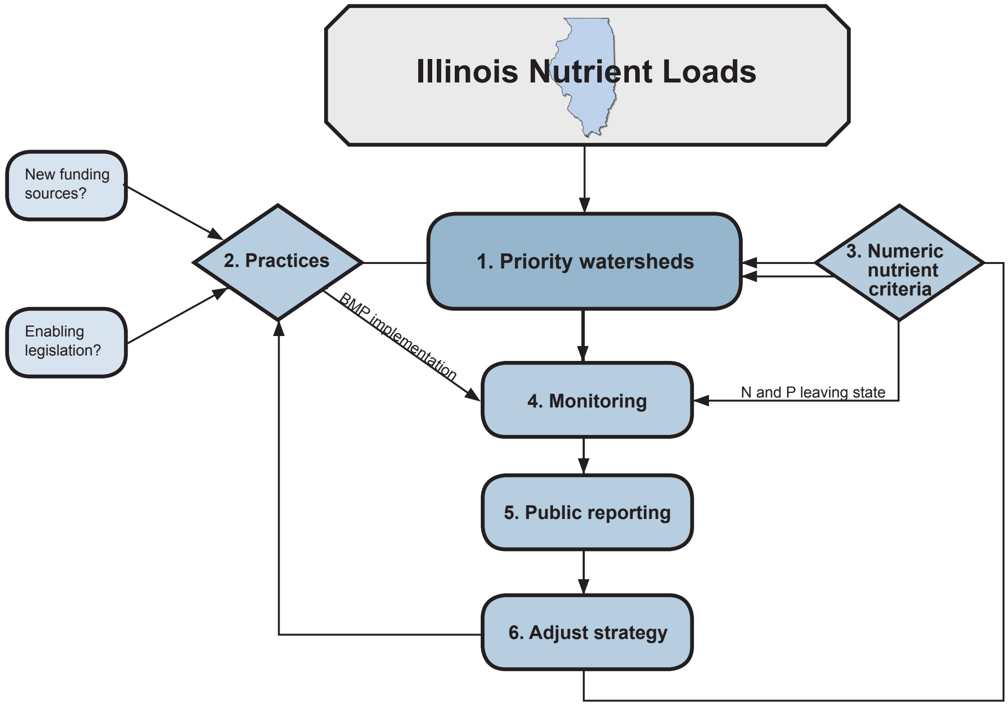
Product Bans

The Illinois General Assembly has restricted the sale of dishwashing detergents (415 ILCS 92/5) and the use of commercially-applied lawn fertilizers containing phosphorus (415 ILCS 65). Any expansion of these product bans, or any relevant new bans, could be tracked to help measure progress toward nutrient reduction goals. Monitoring product ban legislation would be required.

Additional programs are listed in chapter 7.

Implementation of the Nutrient Loss Reduction Strategy

Five working groups will be convened over the next two years to answer questions raised in this strategy and monitor progress. Illinois EPA has contracted with the Illinois Water Resources Center (IWRC) at the University of Illinois to facilitate the implementation and communication phase of the strategy. Figure 9.1 illustrates the implementation process.



Responsible party:

1. Policy Working Group and Illinois EPA
2. Agriculture Water Quality Partnership Forum, Urban Stormwater Working Group, and point source permits—Illinois EPA
3. Nutrient Science Advisory Committee
4. Nutrient Monitoring Council
5. Public reporting—Illinois EPA and IDOA
    - Biennial meeting
    - Biennial report
6. Adjust strategy/adaptive management—based on annual reports, determined by Policy Working Group

Figure 9.1. Implementation of the Illinois NLRS.

Policy Working Group

Convened in March of 2013 by the Illinois EPA and IDOA, the Policy Working Group is made up of representatives from state and federal agencies, industry, universities, agriculture, wastewater treatment agencies, and non-governmental organizations (see chapter 1 for a complete list of members). Upon adoption of this strategy, this group will meet at least twice a year to guide implementation of the strategy, consider policy issues raised in public comments, explore funding opportunities, identify needed legislative initiatives, and network with the appropriate people and groups. In the second year of the strategy, after the biennial report is complete, the Policy Working Group will identify adaptive management adjustments and update this strategy. Policy-related comments from the public that the Policy Working Group will immediately consider include:

- Implementation benchmarks: Whether the course of action should be more clearly laid out, with implementation benchmarks, to achieve the needed reductions; whether this should include out lining a target schedule for achieving reduction goals laid out in a particular scenario from the science assessment (chapter 3) and identifying the BMP adoption rate needed to achieve that scenario; and what a plan for measuring progress of any established benchmarks would be.

- Target date: A goal date for achieving the 45 percent reduction in nitrate-nitrogen and phosphorus. Working group members will begin by evaluating the feasibility of the 2040 date recommended by commenters.

- Watershed protection utility: A watershed protection utility to fill current funding gaps inhibiting successful implementation of the strategy. The strategies and mechanisms utilized in the past for nutrient loss reductions fall far short of the resources needed to close this funding gap. A new concept born out of the U.S. Water Alliance Mississippi River Nutrient Dialogues final report (2014) that warrants further investigation and development is the creation of a state-wide watershed protection utility (WPU). An Illinois WPU would address funding issues through a fully collaborative approach that engages all nutrient stakeholders and the public. It would be designed as a new finance and governance entity to advance state nutrient loss reduction strategies. It would integrate watershed-based leadership to facilitate decision-making and engage market mechanisms, along with research, data, monitoring, and modeling to improve water quality and watershed health. A WPU would provide for ecosystem protection by financing and integrating priority projects that effectively protect water quality and watershed health at the lowest possible cost. For more information on the report, visit www.uswateralliance.org/?attachment_id=4862.

- Technical advisory team: An Agronomic Technical Advisory Team of approximately five experts to advise the working groups charged with implementation.

Urban Stormwater Working Group

Municipalities, non-governmental organizations, and agencies involved in urban stormwater management will meet annually to explore funding, identify legislative initiatives, and develop plans. The group will also coordinate outreach and orchestrate statewide efforts related to green infrastructure expansion and retrofitting, MS4 program training, and urban stream, lake, and stormwater monitoring.

Nutrient Science Advisory Committee

A group of science experts nominated by stakeholder sectors represented in the Policy Working Group will convene in 2015-2016 to help guide Illinois EPA on the development of numeric nutrient criteria. The group will determine the numeric criteria most appropriate for Illinois streams and rivers based on the best available science. They will also consider whether standards should be statewide or watershed-specific. The Nutrient Science Advisory Committee will formally report out to stakeholder groups at public meetings in 2016-2017 as per the timeline established in chapter 8.

Nutrient Monitoring Council

This group will be comprised of representatives from agencies and organizations involved in monitoring nutrients, including Illinois EPA, the Illinois State Water Survey, USGS, IDNR, sewage treatment plants, and agricultural groups that perform monitoring with input from the Policy Working Group. The council will meet 2-3 times a year to identify monitoring locations and data needed to calculate annual loads and assess improvements to or declines in water quality. The group will identify the data needed to track best management practices (BMPs) implemented according to this strategy, make recommendations for updating the transect survey, and develop and execute data acquisition and sharing plans needed to calculate a baseline.

Agriculture Water Quality Partnership Forum

The Agriculture Water Quality Partnership Forum will be comprised of high-level officials from agencies and non-governmental organizations, including the Council on Best Management Practices, NRCS, IDOA, SWCDs, Illinois EPA, IDNR, and environmental organizations. The group will meet regularly, and facilitated work group meetings will be held quarterly to develop implementation plans.

This group will steer outreach and education efforts to help farmers address nutrient loss and select the most appropriate BMPs. Efforts may include identifying needed education initiatives or training requirements for famers and technical advisors as well as strengthening connections between industry initiatives, certified crop advisor continuing education requirements, state initiatives, and other technical services. The group may also consider an agriculture water quality certification program that would give farmers who adopt approved BMPs priority in cost-share programs, regulatory certainty, or public recognition. A timeline and implementation plan for trainings and certification programs will be established.

The Agriculture Water Quality Partnership Forum will also create a subgroup responsible for working with the Nutrient Monitoring Council to track and report BMPs and developing products and programs to help producers evaluate and select the most appropriate BMPs.

Public Reporting

A biennial report that compiles the implementation of strategic actions for the previous 24 months will be developed by September 1 every other year. The outcomes of the current programs and new workgroups described above will be summarized statewide and by watershed. The report will be presented at an Illinois EPA annual public meeting, facilitated by IWRC, as well as posted on the Illinois EPA, IDOA, and

Policy Working Group member websites in November of 2016. Public comments and feedback will be solicited to improve implementation, strengthen collaborative partnerships, and identify additional opportunities for accelerating cost-effective nitrate-nitrogen and total phosphorus load reductions. Illinois EPA will also include a nutrient update in the Integrated Water Quality Report published every two years. This will ensure that the public receives nutrient loss reduction updates through numerous venues.

Adaptive Management

The Illinois NLRS is a living document. Through implementation, monitoring, and public feedback, new and revised approaches will be considered by Illinois EPA, IDOA, and the Policy Working Group. As load reductions or water quality improvements are achieved, priorities will be adjusted. Statewide and basin-level load reductions (compared to the baseline, as noted in chapter 3) will be documented every two years in the Integrated Water Quality Report. When needed load reductions are observed in priority watersheds, a new tier of watersheds will become the focus of management actions. Similarly, progress implementing point source controls and non-point source practices will be tracked as discussed above and compared to the 2011 baseline. To do so, a non-point source implementation baseline will need to be established as soon as possible, and the Policy Working Group will need to identify implementation benchmarks. As success is achieved in implementing certain controls or practices, priority for funding, incentives, outreach, and education may be shifted towards additional effective controls or practices.

If load reductions or other water quality improvements are not observed, or if implementation of management actions does not meet expectations, the Policy Working Group will evaluate whether new strategic actions must be considered.

The strategy will be reviewed every five years by Policy Working Group members (or their successors) to determine needed revisions, which will be made by Illinois EPA and IDOA.

Table 9.2. Summary of future activities.

Committee	Meeting Timeline (through 2017)	Charge
Policy Working Group	1-2 times per year	Explore funding opportunities, identify needed legislative initiatives, and network with the appropriate people and groups. Identify adaptive management adjustments and update the strategy.
Agriculture Water Quality Partnership Forum—full and subcommittee(s)	1-3 times per year	Steer and coordinate outreach and education efforts to help farmers address nutrient loss and select the most appropriate (BMPs). Coordinate cost sharing and targeting. Identify needed education initiatives or training requirements for farmers and technical advisors. Strengthen connections between industry initiatives, certified crop advisor continuing education requirements, state initiatives, and other technical services. Consider an agriculture water quality certification program that would give farmers who adopt approved BMPs priority in cost-share programs, regulatory certainty, or public recognition. Establish a timeline and implementation plan for trainings and certifications. Develop other tools as needed.
Nutrient Monitoring Council	2-3 times per year	Develop a nutrient monitoring program outlining elements such as program design, data collection and methods, data analysis and assessment, quality assurance, reporting, and evaluation. Develop a prioritized list of nutrient monitoring program activities and associated funding needed to accomplish the charges and goals.
Nutrient Science Advisory Committee	6 times total	Determine the numeric nutrient criteria most appropriate for Illinois rivers and lakes based on the best available science. Consider whether standards should be statewide or watershed-specific.
Urban Stormwater Working Group	Once a year	Explore funding, identify legislative initiatives, and develop plans. Coordinate outreach and orchestrate statewide efforts related to green infrastructure expansion and retrofitting, MS4 program training, and urban stream, lake, and stormwater monitoring.

Glossary

Effluent – The liquid or gas discharged from a process or chemical reactor, usually containing residues from that process.

Non-point source – A diffused source of chemical or nutrient inputs not attributable to any single discharge (e.g., agricultural surface runoff, agricultural subsurface drainage by tile systems, urban runoff, and atmospheric deposition).

Nutrients – Inorganic chemicals (particularly nitrogen, phosphorus, and silicon) required for the growth of plants, including crops and phytoplankton.

Point source – Readily identifiable inputs where treated wastes are discharged from municipal, industrial, and agricultural facilities.

Watershed – The drainage basin contributing water, organic matter, dissolved nutrients, and sediments to a stream or lake.

Watershed load – The total mass or amount of a nutrient or chemical that leaves the watershed in stream flow during a given amount of time, typically measured in tons or pounds per year. Nutrient loads from larger watersheds are often greater than loads from smaller watersheds.

Watershed yield – The load of a nutrient or chemical for a given time period divided by the drainage area of the watershed, which is measured in square kilometers, hectares, square miles, or acres. Because nutrient loads usually increase with watershed size, the yield indicator facilitates comparisons between watersheds of different sizes. Units are typically kg ha^{-1} yr^{-1} or lb/acre/yr.

Photo by Diane Shasteen

Appendix A:

Watershed Prioritization Lists

Prioritization Glossary

Name: Generally accepted name for each of the 33 eight-digit Hydrological Unit Code watersheds in Illinois.

HUC8: U.S. Geological Survey defined Hydrologic Unit Code for each of the 33 watersheds.

M lbs/yr: Million pounds of nutrient (phosphorus or nitrates) lost from specific watershed per year by both point and non-point sources.

Non-point source M lbs/yr: Million pounds of nutrient (phosphorus or nitrates) lost from specific watershed per year by non-point sources. This column is only found on non-point source prioritization tables.

Point source M lbs/yr: Million pounds of nutrient (phosphorus or nitrates) lost from specific watershed per year by point sources. This column is only found on point source prioritization tables.

Load rank: Points given to each watershed based on the non-point or point source load by nutrient contributions.

WQ: Water quality ranking based on the number of water bodies identified as not meeting designated uses based on the potential for nutrient impacts.

% meeting: Percent of waters meeting designated uses in the watershed.

***# of WBPs:** Number of known watershed-based plans in the watersheds, including active U.S. Department of Agriculture Natural Resource Conservation Service watershed groups.

Total: Total of all points for each of the 33 watersheds. Those with the highest points are the highest priority for each nutrient, non-point and point source.

For additional information on the prioritization process, see chapter 4.

Table A.1. Watershed prioritization for nitrates from non-point source inputs.

			Non-point source	Load Rank	WQ		*# of WBPs	TOTAL
Name	HUC8	M lbs/yr	M lbs/yr			% meeting		
Lower Illinois-Senachwine Lake	7130001	23.600	22.970	8	5	52%	6	19
Lower Rock River	7090005	21.200	19.210	8	5	57%	4	17
Mississippi North Central - Flint/ Henderson	7080104	27.300	26.760	8	5	41%	0	13
Spoon River	7130005	21.300	20.970	8	4	66%	1	13
Vermilion (Illinois River)	7130002	19.300	18.950	8	5	58%	0	13
Vermilion (Wabash)	5120109	18.100	16.730	6	5	50%	2	13
Upper Sangamon River	7130006	14.400	12.390	4	5	43%	4	13
Kishwaukee River	7090006	11.000	9.990	2	5	48%	6	13
Embarras River (Lawrenceville)	5120112	17.900	17.380	6	5	51%	1	12
Salt Creek	7130009	18.900	17.670	6	4	66%	1	11
Mackinaw River	7130004	14.800	14.650	4	4	64%	3	11
Upper Fox River	7120006	3.600	0.010	0	2	12%	8	10
Des Plaines/DuPage Rivers	7120004	34.240	0.000	0	2	0.11	8	10
La Moine River	7130010	8.300	7.940	2	5	54%	3	10
Mississippi N./Copperas-Duck	7080101	6.200	5.570	2	5	60%	3	10
Big Muddy River	7140106	2.200	1.120	0	3	28%	7	10
Iroquois River	7120002	18.000	17.910	6	3	30%	0	9
Upper Illinois	7120005	15.300	15.090	6	3	80%	0	9
Lower Illinois River	7130011	11.800	11.330	4	4	61%	1	9
Lower Fox River	7120007	9.900	7.170	2	5	59%	2	9
Shoal Creek	7140203	2.000	1.770	0	5	50%	4	9
Upper Kaskaskia River	7140201	11.700	11.380	4	4	35%	0	8
Green River	7090007	9.100	9.000	2	5	41%	1	8
Pecatonica River	7090003	7.100	6.750	2	5	50%	1	8
Middle Wabash Tribs	5120111	6.500	6.330	2	4	38%	2	8
Little Wabash	5120114	4.800	4.360	2	2	19%	4	8
Middle Illinois River	7130003	15.500	14.580	4	3	28%	0	7
South Fork Sangamon	7130007	10.600	10.000	4	2	17%	1	7
Lower Sangamon River	7130008	10.200	9.510	2	5	53%	0	7
Kankakee River	7120001	7.100	6.890	2	5	55%	0	7
Lower Kaskaskia River	7140204	6.600	5.450	2	3	24%	2	7
Macoupin Creek	7130012	4.500	4.340	2	2	19%	3	7
Middle Kaskaskia River	7140202	3.900	3.650	2	2	17%	3	7

Table A.2. Watershed prioritization for nitrates from point source inputs.

			Point source	Load Rank	WQ		*# of WBPs	TOTAL
Name	**HUC8**	**M lbs/yr**	**M lbs/yr**			**% meeting**		
Upper Fox River	7120006	3.600	3.590	8	2	12%	8	18
Des Plaines/DuPage Rivers	7120004	34.240	34.240	8	2	11%	8	18
Upper Sangamon River	7130006	14.400	2.010	8	5	43%	4	17
Big Muddy River	7140106	2.200	1.080	6	3	28%	7	16
Lower Fox River	7120007	9.900	2.730	8	5	59%	2	15
Lower Rock River	7090005	21.200	1.990	6	5	57%	4	15
Kishwaukee River	7090006	11.000	1.010	4	5	48%	6	15
Lower Illinois-Senachwine Lake	7130001	23.600	0.630	4	5	52%	6	15
Vermilion (Wabash)	5120109	18.100	1.370	6	5	50%	2	13
Chicago/Little Calumet	7120003	15.800	14.530	8	1	4%	3	12
Mississippi N./Copperas-Duck	7080101	6.200	0.630	4	5	60%	3	12
Salt Creek	7130009	18.900	1.230	6	4	66%	1	11
Lower Kaskaskia River	7140204	6.600	1.150	6	3	24%	2	11
Shoal Creek	7140203	2.000	0.230	2	5	50%	4	11
Miss. S. Cen./Cahokia-Joachim	7140101	1.400	0.870	4	4	37%	2	10
La Moine River	7130010	8.300	0.360	2	5	54%	3	10
Lower Sangamon River	7130008	10.200	0.690	4	5	53%	0	9
Embarras River (Lawrenceville)	5120112	17.900	0.520	2	5	51%	1	8
Little Wabash	5120114	4.800	0.440	2	2	19%	4	8
Bear-Wyaconda	7110001	2.700	0.350	2	5	57%	1	8
Pecatonica River	7090003	7.100	0.350	2	5	50%	1	8
Spoon River	7130005	21.300	0.330	2	4	66%	2	8
Middle Kaskaskia River	7140202	3.900	0.250	2	2	17%	4	8
Middle Wabash Tribs	5120111	6.500	0.170	2	4	38%	2	8
Middle Illinois River	7130003	15.500	0.920	4	3	28%	0	7
Mississippi North Central Flint/ Henderson	7080104	27.300	0.540	2	5	41%	0	7
Lower Illinois River	7130011	11.800	0.470	2	4	61%	1	7
Vermilion (Illinois River)	7130002	19.300	0.350	2	5	58%	0	7
Kankakee River	7120001	7.100	0.210	2	5	55%	0	7
Mackinaw River	7130004	14.800	0.150	0	4	64%	3	7
Upper Kaskaskia River	7140201	11.700	0.320	2	4	35%	0	6
Cache River - Ohio Drainage	5140206	0.500	0.130	0	4	33%	2	6

Table A.3. Watershed prioritization for phosphorus from non-point source inputs.

Name	HUC8	M lbs/yr	Non-point source M lbs/yr	Load Rank	WQ	% meeting	*# of WBPs	TOTAL
Big Muddy River	7140106	1.081	0.867	6	3	28%	7	16
Embarras River (Lawrenceville)	5120112	2.347	2.247	8	5	51%	1	14
Little Wabash	5120114	1.659	1.497	8	2	19%	4	14
Lower Kaskaskia River	7140204	1.929	1.651	8	3	24%	2	13
Mississippi North Central - Flint/ Henderson	7080104	1.658	1.519	8	5	41%	0	13
Spoon River	7130005	1.315	1.212	8	4	66%	1	13
Upper Sangamon River	7130006	2.383	0.793	4	5	43%	4	13
Middle Wabash Tribs	5120111	0.870	0.818	6	4	38%	2	12
La Moine River	7130010	0.840	0.787	4	5	54%	3	12
Middle Kaskaskia River	7140202	1.230	1.160	6	2	17%	3	11
Lower Sangamon River	7130008	1.035	0.830	6	5	53%	0	11
Shoal Creek	7140203	0.737	0.609	2	5	50%	4	11
Kishwaukee River	7090006	0.607	0.377	0	5	48%	6	11
Lower Illinois-Senachwine Lake	7130001	0.601	0.361	0	5	52%	6	11
Upper Fox River	7120006	0.588	0.000	0	2	12%	8	10
Des Plaines/DuPage Rivers	7120004	5.571	0.000	0	2	11%	8	10
Macoupin Creek	7130012	1.086	1.063	6	1	19%	3	10
Miss. S. Cen./Cahokia-Joachim	7140101	1.148	0.743	4	4	37%	2	10
Lower Rock River	7090005	1.303	0.649	2	5	57%	3	10
Lower Illinois River	7130011	0.865	0.738	4	4	61%	1	9
Vermilion (Wabash)	5120109	0.827	0.604	2	5	50%	2	9
Mackinaw River	7130004	0.436	0.396	2	4	64%	3	9
Bear-Wyaconda	7110001	0.740	0.614	2	5	57%	1	8
Mississippi South	7140105	0.493	0.433	2	5	47%	1	8
Mississippi N./Copperas-Duck	7080101	0.619	0.277	0	5	60%	3	8
Saline River	5140204	0.693	0.633	2	2	15%	3	7
Vermilion (Illinois River)	7130002	0.692	0.629	2	5	58%	0	7
Salt Creek	7130009	0.809	0.495	2	4	66%	1	7
Lower Fox River	7120007	0.740	0.256	0	5	59%	2	7
Mississippi Central	7110004	0.664	0.664	4	2	88%	0	6
Upper Kaskaskia River	7140201	0.598	0.584	2	4	35%	0	6
Green River	7090007	0.356	0.326	0	5	41%	1	6
Cache River - Ohio Drainage	5140206	0.322	0.295	0	4	33%	2	6
Cache River - Mississippi Drainage	7140108	0.227	0.223	0	4	39%	2	6
Pecatonica River	7090003	0.289	0.195	0	5	50%	1	6
Little Vermilion (Wabash)	5120108	0.150	0.143	0	5	57%	1	6
Skillet Fork	5120115	0.803	0.799	4	1	0%	0	5
Iroquois River	7120002	0.606	0.585	2	3	30%	0	5

Table A.4. Watershed prioritization for phosphorus from point source inputs.

			Point source	Load Rank	WQ		*# of WBPs	TOTAL
Name	**HUC8**	**M lbs/yr**	**M lbs/yr**			**% meeting**		
Upper Fox River	7120006	0.59	0.59	8	2	12%	8	18
Des Plaines/DuPage Rivers	7120004	5.57	5.57	8	2	11%	8	18
Upper Sangamon River	7130006	2.38	1.59	8	5	43%	4	17
Lower Rock River	7090005	1.30	0.65	8	5	57%	4	17
Lower Illinois-Senachwine Lake	7130001	0.60	0.24	4	5	52%	6	15
Kishwaukee River	7090006	0.61	0.23	4	5	48%	6	15
Mississippi N./Copperas-Duck	7080101	0.62	0.34	6	5	60%	3	14
Lower Fox River	7120007	0.74	0.48	6	5	59%	2	13
Chicago/Little Calumet	7120003	3.69	3.69	8	1	4%	3	12
Miss. S. Cen./Cahokia-Joachim	7140101	1.15	0.41	6	4	37%	2	12
Big Muddy River	7140106	1.08	0.21	2	3	28%	7	12
Salt Creek	7130009	0.81	0.31	6	4	66%	1	11
Vermilion (Wabash)	5120109	0.83	0.22	4	5	50%	2	11
Shoal Creek	7140203	0.74	0.13	2	5	50%	4	11
Middle Illinois River	7130003	1.00	0.44	6	3	28%	0	9
Lower Kaskaskia River	7140204	1.93	0.28	4	3	24%	2	9
Little Wabash	5120114	1.66	0.16	2	2	19%	4	8
Bear-Wyaconda	7110001	0.74	0.13	2	5	57%	1	8
Embarras River (Lawrenceville)	5120112	2.35	0.10	2	5	51%	1	8
Pecatonica River	7090003	0.29	0.09	2	5	50%	1	8
Mississippi South	7140105	0.49	0.06	2	5	47%	1	8
La Moine River	7130010	0.84	0.05	0	5	54%	3	8
Upper Illinois	7120005	0.43	0.29	4	3	80%	0	7
Lower Sangamon River	7130008	1.04	0.21	2	5	53%	0	7
Kankakee River	7120001	0.39	0.20	2	5	55%	0	7
Mississippi North Central Flint/ Henderson	7080104	1.66	0.14	2	5	41%	0	7
Lower Illinois River	7130011	0.87	0.13	2	4	61%	1	7
Spoon River	7130005	1.32	0.10	2	4	66%	1	7
Middle Kaskaskia River	7140202	1.23	0.07	2	2	17%	3	7
Saline River	5140204	0.69	0.06	2	2	15%	3	7
Vermilion (Illinois River)	7130002	0.69	0.06	2	5	58%	0	7
Mackinaw River	7130004	0.44	0.04	0	4	64%	3	7
Wood River/Piasa Creek	7110009	0.48	0.23	4	2	17%	0	6
Middle Wabash Tribs	5120111	0.87	0.05	0	4	38%	2	6
Green River	7090007	0.36	0.03	0	5	41%	1	6

Appendix B:

Non-Point Source Cost Estimates

This section provides cost estimates for each practice to reduce nitrate-nitrogen and total phosphorus losses from agricultural fields introduced in chapter 3. Cost estimates are provided in annual dollars per acre.

The following subsections provide detail on methods used to estimate the cost of each practice. Before proceeding, however, there are five issues to consider.

First, the method used in generating cost estimates is a partial budgeting approach. In this approach, a base case representing general agricultural practices is specified. Then, a nutrient reduction practice is specified. Changes in costs from the current practice and the reduction practice are then estimated. Hence, cost estimates represent a change from the current general practice.

Second, some of the following practices have initial investments. These investments are made in the first year, with the benefits of the investment accruing over many years. In these cases, the initial investment cost is amortized over the life of the investment using an annualized equivalence approach. A discount factor of 6 percent is used in calculating annualized investment costs. A 20-year life was assumed for most practices.

Third, some practice changes may impact yields. For example, some of the proposed changes would shift nitrogen applications from fall to spring, while others split applications of nitrogen over more than one application period. Research on these practices is ongoing, with some results indicating they increase yields or reduce nutrient applications. In determining whether to include a yield change for a practice, we consulted the Illinois Agronomy Handbook (University of Illinois, 2012a), particularly the Managing Nitrogen chapter. The Illinois Agronomy Handbook is treated as a guide to standard agronomic practices in Illinois. We included a yield change for a practice if the handbook indicated one was warranted. Some of the newer timing and split application strategies may prove beneficial. As of yet, however, they are not standard, most likely for economic and agronomic reasons. In addition, research-based results do not necessarily translate to general situations, as general practices differ from those in the research setting.

Fourth, costs need to be viewed in context of the earning potential of farmland. This can be determined by looking at per acre net returns to farmers where the farmland is rented at average cash rent (University of Illinois, 2014b). Net returns to central Illinois farmers in 2000-2006 averaged $56/acre. Returns for 2007-2013 were higher, averaging $195/acre. Because returns were above historical averages, 2007-2013 will likely be remembered as a high-profit period. Current projections place estimated returns over the next five years around $55/acre, with the potential for 2014 and 2015 to be much lower. Using this number as a guideline, a practice that costs $10 represents an 18 percent reduction in returns to the farmer. On a percentage basis, many of the following strategies represent a significant reduction in agricultural returns.

Fifth, whether to adopt these practices will depend on more than cost alone. Two additional factors are particularly critical: high investment costs and timing. The incentive to implement some practices may be reduced by initial investment costs, which may require debt capital and increase a farmer's risk exposure. Additionally, many of the strategies would move field operations to the spring and after the planting period. There are a limited number of days suitable for field work during these periods. Placing more field operations in the spring has the potential to reduce profits. These concerns are listed below as caveats to each practice.

Table B1 includes the costs of each practice as well as the concerns that may impede adoption. The following subsections describe each of the practices in more detail.

Reducing Tillage

The base practice includes a heavy tillage pass. The alternative is to eliminate that tillage pass. However, this alternative would still include tillage and is not a no-till system. The cost of this strategy is the reduction of one tillage pass. The cost of the tillage pass was taken from Machine Cost Estimates: Field Operations (University of Illinois, 2012b). The particular implement included in the cost is a horizontal disk, drag, rolling basket. The cost is -$17/acre, indicating a savings.

Caveats: Many farmers undertake a tillage pass when they grow corn several years in a row. There is reason to believe that breaking up residue aids in stalk decomposition, potentially leading to higher corn yields the following year. A yield reduction would reduce the expected savings of this practice.

Eliminating Phosphorus Applications

The base strategy assumes the soil has high levels of phosphorus obtained through a combination of naturally high phosphorus levels, commercial application of fertilizers, and manure applications. Not all soils meet these conditions. The nutrient reduction scenario eliminates phosphorus applications for six years to bring down the soil test levels.

In pricing this scenario, we assumed that 170 lb of diammonium phosphate (DAP), a fertilizer with 18 percent nitrogen, 46 percent phosphorus, and 0 percent potassium, will sustain adequate phosphorus levels for several rotations. The 170 lb application rate represents a maintenance level of fertilizer application and is equal to 34 lb P/acre/yr. It is typically applied at this rate every other year. This compares well to the 11-13 lb/yr application previously estimated for the state (Table 3.9). A DAP fertilizer price of $540/ton was used to calculate the cost. A credit was given for nitrogen in DAP as the nitrogen will likely have to be replaced by some other commercial source. The credit was based on a $680/ton anhydrous ammonia price. Given the credit, the elimination of phosphorus fertilizers in one year will result in a cost savings of $34/yr.

Given this savings, we calculated the present value of eliminating three applications of phosphorus fertilizer, which would typically be applied over a six-year period. The annualized yearly value during a 20-year period was then calculated. A 6 percent discount factor was used in calculating both the present value and the annualized cost. The annual yearly cost for reducing phosphorus fertilizer is -$7.50/yr, indicating that this practice reduces costs.

Installing Stream Buffers

This practice takes acres out of production to provide a buffer near streams and other waterbodies. The base practice is an acre in production. The nutrient reduction practice takes the acre out of production and plants grass on that acre.

The buffer eliminates all income potential from the acre. The cost of this will be represented by the cash rent from the acre. Implementing the practice will require farmers to plant grass, a one-time investment cost. In addition, the buffer acre will require maintenance. The total cost of the buffer includes:

- The cash rent value of the farmland given up. The average cash rent in central Illinois, a likely target area for buffers, is $280/acre. This number could be adjusted for other areas of the state. For example in southern Illinois, the cash rent value would be much less (University of Illinois, 2013).

- The cost of planting grass. This is a cost of $50/acre, including seed and tillage. Amortized over a 20-year life using a 6 percent interest rate, the cost is $4.36/acre.

- Annual maintenance costs, which is $10/acre/yr.

The total cost is $294/acre.

Caveats: Taking farmland out of production may have negative impacts on farmland prices as tillable acres typically sell at higher values than non-tillable acres. These costs were not included in the estimates.

Reducing Nitrogen Rates

The base case assumes that 10 percent of producers over-apply nitrogen. The nutrient reduction practice would reduce nitrogen applications by 20 lb/acre (to the Maximum Return to Nitrogen rate), resulting in an $8/yr savings.

Adding Nitrification Inhibitors

This practice adds a nitrification inhibitor to all fall-applied fertilizer. The cost of this practice was conservatively estimated at $7/acre because it is likely that the use of a nitrogen inhibitor will result in a reduction in nitrogen applications. The use of a nitrogen inhibitor is a relatively standard practice for fall-applied nitrogen in Illinois.

Splitting Nitrogen Fertilizer Applications

The base case for this practice is fall-applied nitrogen. The nitrogen reduction strategy is to split nitrogen application in half between fall and spring. Under both the base and nutrient reduction practices, a total of 160 lb of actual nitrogen is applied and the nitrogen application in the fall is applied as anhydrous ammonia. Under the reduction practice, however, the spring application is divided, with one-half anhydrous ammonia and the other a 28 percent nitrogen solution. The nitrogen solution is used to speed up application. Under the nitrogen reduction practice, the following costs are incurred:

- $6.10/acre for an additional anhydrous ammonia pass on half the acres. An anhydrous ammonia pass costs $12.20/acre (University of Illinois, 2012b). Since this pass is on half the acres, this cost equals $6.10/acre.

- $4.55/acre for an additional nitrogen solution pass on half the acres. A nitrogen solution pass costs $9.10/acre (University of Illinois, 2012b). Since this is on half the acres, this cost equals $4.55/acre.

- $6.40/acre for nitrogen solutions. These solutions averaged $.16/lb higher in active nitrogen in 2010-2012. The cost is $.16 per acre multiplied by 40 lb of active nitrogen.

The total cost of this practice is $17/acre.

Caveats: This practice adds another operation pass in the spring, when there are a limited number of available days. Slightly less than half of all days during this time are typically suitable for field work. Adding a field operation could potentially delay planting, which could lower yields. The costs and additional risks associated with delayed planting were not included in our estimate. The risk of delayed planting could limit adoption of this practice.

Moving Nitrogen Fertilizer Applications

The base practice is fall application of nitrogen. The reduction practice moves this application to the spring. In both cases, we assumed that 160 lb of nitrogen will be applied. This will have two impacts on costs. First, due to timing concerns, half of the spring application will be switched from anhydrous ammonia to nitrogen solutions. Second, switching all tile-drained soils to a spring application will result in the need for an additional nitrogen application and storage infrastructure to ensure fertilizers are applied in a timely manner. This will increase costs, which will be reflected in higher nitrogen and application costs. This reduction practice will result in the following cost changes:

- A $12.80/acre increase due to the shift towards nitrogen solutions. We assumed that half of appli cations will be 28 percent nitrogen solutions. The additional cost of liquid nitrogen over anhydrous ammonia averaged out at $.16/lb of actual nitrogen in 2010-2013.

- A $1.60/acre increase due to the higher price of anhydrous ammonia in the spring. Prices are on average $.02 higher in spring.

- A $2.70/acre increase due to the need for more nitrogen infrastructure. We estimate that this will increase the cost of nitrogen by $20/ton, or about $.017/lb of actual nitrogen.

- A $.80/acre increase due to additional equipment needs. Based on work-day probability analysis, this practice would reduce the number of acres a machine can cover by 20 percent.

The total cost of this practice is $18/acre.

Caveats: Moving fertilizer applications will result in timing concerns, particularly ones related to late planting. The additional costs associated with late planting were not included in the above analysis. Timing concerns could prove to be a hindrance to the adoption of this practice.

Planting Cover Crops

The base case is no cover crops, and the reduction practice would add cover crops. Pricing was based on the aerial application of rye seeds onto fields with standing corn. The cover crop is then chemically killed in the spring. However, the cost of the herbicide application was not included as an herbicide application or tillage pass would also occur under the base case. However, a $5/acre partial spray was included to cover any additional problems. Costs for this strategy are:

- $16/acre for aerial seed vvapplication
- $8/acre for seeds ($16/bushel at half a bushel per acre)
- $5/acre for partial spray

The total cost for this practice is $29/acre.

Caveats: Cover crops may introduce additional management problems, particularly in adverse years. Establishing cover crops may be difficult in years with dry summers and falls and may lead to a reduction in crop yields. Cover crop planting operations may also introduce logistical issues on farms. As indicated earlier, these impacts were not included in our cost estimates.

Building Bioreactors

This base practice is no bioreactor. The reduction practice is the construction of a bioreactor at the end of the tile line. Cost estimates for the practice were taken from Christianson et al. (2013). The costs for this strategy are:

- $133/acre in investment costs. This is the cost on an annual basis using a 6 percent discounted rate and a 20-year life. The annualized cost is $12/acre.
- $5/acre in annual maintenance costs.

The total cost for this practice is $17/acre.

Caveats: A bioreactor is a significant investment that likely requires debt capital, thereby increasing the risk to farmers. In addition, there are no cash flows from bioreactors to provide funds for payback on capital. And the large-scale construction of bioreactors could increase investment costs by creating more demand pressure.

Constructing Wetlands

The base practice is no wetlands. The reduction practice is the construction of 5 acres of wetland for every 100 acres of production. Wetland designs were taken from Christianson et al. (2013). The primary cost of wetlands is farmland taken out of production. Costs are:

- $1,095.04/acre of wetland, or $57.63/yr. A farmland value of $12,500/acre was used in pricing. In addition, $60/acre for designing the wetland was included. The 5 percent of farmland taken out of production is charged against the 95 percent of farmland remaining in production. The $12,560 investment cost was amortized over a 20-year period at a 6 percent interest rate.

- $3/acre in maintenance costs.

The total cost of this practice is $60.63/acre

Caveats: This practice represents a large decrease in income-generating potential. Adoption of this practice will be slow due to the costs of wetlands. Also, there may be property value reductions beyond those included here.

Moving to Perennial Crops

This base practice is corn and soybean production in a 50 percent corn/50 percent soybean rotation. The reduction practice is moving to a perennial crop, in this case alfalfa. This cost change equals returns from corn and soybean production minus returns from alfalfa production.

Corn and soybean returns were taken from 2014 Illinois Crop Budgets (University of Illinois, 2014a) for high-productivity farmland. Operator and farmland returns equal $309 for corn and $265 for soybeans. These were averaged to arrive at a $287/acre return. Returns for alfalfa production were modeled from the 2013 Iowa budgets. The following changes were made:

- Land charges were taken out of the Iowa budgets to be consistent with Illinois budgets.
- The hay stand life was increased from 4 to 5 years, which increases alfalfa profitability.
- Alfalfa yield was increased to 5 tons/acre, which increases alfalfa profitability.

These changes result in $201/acre in alfalfa production. The total cost of this practice is $86/acre (a $287/acre return from corn/soybean rotation minus a $201/acre return for hay).

Caveat: Large scale movement to perennial crop production would require dramatic changes in agricultural structure. In particular, alfalfa and most other forages are fed to ruminant livestock (predominately in beef or dairy production). Increases in alfalfa acres would require an increase in ruminant livestock. Without this change, hay prices likely would decline, leading to a higher cost for this practice.

Table B1. Costs of agricultural practices and other economic concerns.

Practice	Cost ($/acre)	Other economic concerns
Reduced tillage	-17	Potential yield reductions
P rate reduction	-7.50	
Stream buffer	294	Cost is per acre of buffer; negative impacts on farmland
N rates reduced from background to MRTN	-8	
N inhibitor with fall-only fertilizer application	7	
Split N fertilizer application on tile-drained soils (50 percent fall and 50 percent spring)	17	
Spring-only N fertilizer application on tile-drained acres	18	Timeliness
Cover crops		Planting difficulty; potential impact on yields
Bioreactors	17	Large investment costs; increasing costs with large adoption
Wetlands	61	Large investment costs
Perennial crops	86	Lower forage prices due to large shifts

Appendix C:

Ground Water Contributions to Nitrate in Streams

Dennis P. McKenna, Illinois Department of Agriculture, modified from McKenna and Keefer (1991)

> This appendix presents a discussion of the processes and conditions affecting groundwater movement to streams, summarizes research in Illinois and the Midwest on nitrate in groundwater, and reviews research using geologic mapping to identify areas that may be sources of groundwater discharge of nitrate-nitrogen to streams.

The science assessment estimated non-point source nitrate-nitrogen yields by eight-digit Hydrologic Unit Codes (HUC8s) (Figure 3.13) and nitrate-nitrogen yield per row crop acre by combined Major Land Resources Area (MLRA) (Table 3.8). In most cases, the areas with the highest yields are extensively tile-drained. However, in some areas, such as northwestern Illinois (combined MLRA 3), nitrate-nitrogen yields are high but there is minimal tile drainage. The alternate way for nitrate-nitrogen to reach streams is in groundwater, which discharges to streams as base flow.

The primary pathway by which nitrate-nitrogen is transported to surface water involves water percolating through the root zone of cultivated crops to shallow groundwater, some of which is then discharged to nearby streams. The highest nitrate-nitrogen loads usually occur in regions with tile drains or highly permeable soils, such as sands and karst, because there tends to be relatively more percolation of water through the root zone and movement of the groundwater to the stream is relatively rapid, with little opportunity for biological transformation of the nitrate-nitrogen. In regions without tile drains or with less permeable soil, there is less percolation of water through the root zone and more surface runoff, which generally has low nitrate-nitrogen concentrations. Furthermore, slower movement of groundwater to streams in these areas provides more opportunities for nitrate-nitrogen transformation or uptake. Thus, the potential for loss depends on soil and hydrogeologic conditions.

Several groundwater monitoring studies in Illinois in the last 25 years have confirmed that aquifers are subject to contamination where the top of the aquifer occurs within 20 feet of the land surface. Goetsch et al. (1992) and Schock et al. (1992) found that private water supply wells in areas with aquifer materials (permeable deposits) within 20 feet of land surface were likely to contain high concentrations of nitrate-nitrogen.

The distinction between aquifer materials and aquifers is that aquifer materials have the hydrogeologic characteristics to be classified as aquifers, but only when they are saturated with water. In Illinois, the water table generally occurs within 20 feet of ground surface. Below this depth, aquifer materials are generally saturated and capable of yielding water to a well. In areas mapped as having aquifer materials within 20 feet of the surface (about 25 percent of cropland acres in Illinois), the materials may not be saturated. However, these highly permeable materials readily transport agricultural chemicals to the underlying saturated permeable materials (aquifers).

Since October 2000, the Illinois Department of Agriculture (IDOA) has sampled a network of dedicated monitoring wells located adjacent to cropland in areas of the state where aquifer materials are within 50 feet of land surface. Results from this ongoing program confirm that wells in areas with aquifer materials within 20 feet of land surface are much more likely to contain nitrate-nitrogen at high concentrations (and detectable levels of pesticides) than wells in areas where the tops of aquifer materials are found between 20 and 50 feet of land surface (Table C.1). About 60 percent of the state aquifers are more than 50 feet deep and probably not vulnerable to contamination.

Table C.1. Summary of nitrate-nitrogen concentrations in IDOA groundwater monitoring network wells in 2012-2014.

Depth interval (ft)/number of samples	NO_3-N median concentration	*NO_3-N <0.15 mg/L*		*NO_3-N 0.15 - 3 mg/L*		*NO_3-N >3 -10 mg/L*		*NO_3-N >10 mg/L*		*NO_3-N >3 mg/L*	
		n	%	n	%	n	%	n	%	n	%
0–20 (n=96)	4.0	27	28.1	16	16.7	23	24.0	30	31.3	53	55.2
>20 – 50 (n=33)	<0.15	22	66.7	7	21.2	3	9.1	1	3.0	4	12.1

The source of groundwater in Illinois is precipitation that infiltrates the soil and percolates downward to the groundwater system. About 10 percent of precipitation enters the groundwater system (Berg et al. 1984). Recharge, the replenishment of groundwater, depends upon soil moisture conditions, soil permeability and water retention capacity, type and distribution of vegetation, precipitation duration and intensity, and location within the groundwater flow system. Regionally, the interrelationship between soils, underlying geologic materials, and configuration of the landscape determines the rate and amount of recharge and the direction of shallow groundwater flow. In agricultural areas, tile drainage systems have considerably altered natural drainage and recharge characteristics. Recharge does not occur at specific points or even in small local areas; some recharge occurs in all unpaved areas except the discharge areas themselves. In Illinois, as in most humid areas, streams that flow for all or most of the year are groundwater discharge areas. Water will infiltrate to the water table over the entire inter-stream area. Some of this water will move back upward in response to evapotranspiration. The remainder will continue to move downward into the saturated zone. Some of this water will discharge into nearby streams; the remainder will move deeper and become part of the regional groundwater flow system.

The rate of groundwater movement is directly related to the permeability of geologic materials and the hydraulic gradient. Relatively rapid infiltration and groundwater movement will occur in areas directly underlain by permeable bedrock or sand and gravel. Conversely, surface runoff may be greater and groundwater movement generally slower in areas directly underlain by silty or clayey materials, which have a considerably lower permeability. Thus, over a given period of time, these areas provide considerably less recharge to aquifers than areas composed of sand and gravel or permeable bedrock at or near land surface.

The vulnerability of aquifers to agricultural chemical contamination is a function of soil properties and hydrogeologic conditions. The thickness and character of the geologic materials between the base of the soil and the top of the underlying aquifer greatly affect the potential contamination of the aquifer. Once contaminants such as nitrate-nitrogen reach the water table, their rate of movement to an aquifer is dependent on the hydraulic gradient and conductivity, effective porosity, and attenuating capacity of materials overlying the aquifer. In general, the rate of movement of the contaminant is controlled by the average linear velocity of the groundwater. However, dispersion causes some contaminant molecules to move faster and others to move slower than the groundwater. These processes can also cause the contaminant to spread in directions transverse to the groundwater flow path. The net effect of these processes is dilution, a reduction of the concentration (but not the mass) of the dissolved contaminant in the groundwater system.

Dilution is apparently the only significant process affecting the fate of nitrate-nitrogen in deeper aquifers. Although it is clear that denitrification occurs in soils and relatively shallow groundwater, the role of denitrification in removing nitrate from groundwater in deeper aquifers is uncertain. In the IDOA monitoring well network, 20 of 62 wells (32.3 percent) with a pesticide or pesticide metabolite detected had nitrate-nitrogen concentrations less than 3.0 mg/L. Denitrification is a biologically mediated reaction; the appropriate microbes and organic substrate (necessary as an energy source) must be present. The environmental conditions required for denitrification may not exist in deeper aquifers.

Research on groundwater contributions to stream nitrate

The Minnesota Pollution Control Agency (2013) has summarized research findings on groundwater discharge (baseflow) as a pathway for nitrate-nitrogen to streams. The following is excerpted from that report.

Similar to the findings of the UMN/MCPA Minnesota N source assessment, other studies have shown that groundwater baseflow is an important pathway for N entering surface waters, particularly in areas with minimal agricultural tile drainage. Groundwater baseflow is generally considered to be the portion of stream flow that represents longer term groundwater discharge from underground watershed storages, which typically moves slowly and continuously into streams, even during periods of reduced precipitation. Some use the term "baseflow" to refer to all portions of the streamflow that are not partitioned or separated from surface runoff and quick-flow groundwater in the stream hydrograph (Spahr 2010). Under this second definition, a portion of tile drainage flows can show up in the "baseflow" part of the stream hydrograph, due to the lag time between the storm event and when infiltrating waters reach tile lines and surface waters. In a study of stream nutrients from around the United States, baseflow was found to contribute a substantial amount of nitrate to many streams (Dubrovsky et al., 2010). In two-thirds of the 148 studied streams, baseflow contributed more than a third of the total annual nitrate load. These findings are based on data from streams that drain watersheds less than 500 square miles. The researchers found less baseflow influence in areas of the Midwest that are heavily tile-drained, similar to the source/pathway assessment findings by the UMN/MPCA in Chapters D1 and D4 of this report. Tesoriero et al. (2009) examined nitrate flow pathways in five aquifer and stream environments across the United States., including one Minnesota stream (Valley Creek). As the proportion of stream flow derived from baseflow increased, nitrate concentrations also increased. They concluded that the major source of nitrate in baseflow dominated streams was groundwater; and rapid flow pathways (i.e. tile lines) were the major source of N in streams not dominated by baseflow. Another finding of the study was that baseflow does not enter the stream uniformly, but rather through preferential flow paths in high conductivity stream-bed sediments (i.e. sands) or as bankside seeps or springs.

In eastern Washington County, Minnesota, two studied creeks had over 90% of the nitrate load delivered during non-storm event periods (SCWRS, 2003). Groundwater was determined to be the major source of N to the creeks, and the difference in N yields between the two creeks was attributed to differing groundwater nitrate concentrations. While groundwater baseflow often contributes a substantial part of N loads to streams, not all of the nitrate entering groundwater ends up in streams. Recharge rates of nitrate to groundwater beneath the land are commonly greater than discharge rates of nitrate in nearby streams (Böhlke et al., 2002). Part of the reason is that it can take months to years before the nitrate that leaches to groundwater is transported into streams; and therefore groundwater can continue to contribute nitrate to streams long after all nitrate sources are removed (Goolsby, Battaglin et al. 1999; Tesoriero et al. 2013). Additionally, nitrate can be reduced through denitrification as it flows within groundwater toward streams. Dubrovsky et al. (2010) concluded that the amount of N in baseflow depends, in part, on how much of the baseflow is coming from deep aquifers and how much is coming from shallow ground waters. Deep aquifers usually contain water with lower concentrations of N than shallow aquifers because of several reasons: (1) it takes a long time—decades or more, in most cases—for water to move from the land surface to deep aquifers (resulting in long residence times for groundwater and any solutes, like nitrate, it may contain); (2) long travel distances increase the likelihood that nutrients will be lost through denitrification; (3) protective low-permeability deposits (which inhibit flow and transport) may be present between the land surface and deep aquifers; and (4) mixing of water from complex flow paths over long distances and time periods tends to result in a mixture of land-use influences on the chemical character of deep groundwater, including contributions of nutrients from areas of undeveloped lands where concentrations are generally lower than those from developed lands.

Groundwater baseflow was found to be an important contributing pathway in several additional studies, especially in areas not dominated by tile line flow. Using data collected between 1984 and 1993, the USGS conducted an in-depth study of stream nutrients in large parts of Minnesota, including the southern half of the Mississippi River Basin; the Canon and Vermillion River watersheds, and the St. Croix River Basin in Minnesota and Wisconsin (Kroening and Andrews, 1997). Nitrate concentrations in the Minnesota River near Jordan, and the Straight and Cannon Rivers in southeastern Minnesota, were found to be greatest in the spring and summer months, when precipitation, runoff, and tile-line flows are typically highest. However, for much of the rest of the study area, nitrate concentrations were greatest in the winter months when stream flow is dominated by groundwater baseflow. Burkhart (2001) found an association between base flow contributions of nitrate to streams and the permeability of soils and underlying bedrock. The USGS report stated "nitrate loads from base flow were significantly lower (contributing about 27% of total stream nitrate load) in streams draining landscapes with less permeable soils and bedrock than in those draining landscapes with permeable soils and (or) bedrock (contributing 44% to 47% of the total stream nitrate load)." Other studies have also shown that soil and bedrock permeability affects nitrate levels in water. In a small Wisconsin karst landscape watershed largely under row crop land uses, 80% of nitrate loadings to streams came from groundwater baseflow (Masarik, 2007). Nitrate-N ranged from 4.7 to 23.5 mg/l in the Fever River watershed. In this highly permeable setting of loess soils over fractured carbonate bedrock, baseflow was found to be the dominant pathway of N to surface waters. The nitrate loading due to baseflow into two south-central Iowa streams in a non-karst watershed with relatively shallow soils were also found to be high, and accounted for 61% to 68% of nitrate loads in Walnut Creek and Squaw Creek watersheds, respectively (Schilling, 2002). Bedrock in the Iowa study is overlain by 20 to 100 feet of soil, in a rolling naturally well-drained landscape. Schilling et al. (2000) also found that karst watersheds showed higher nitrate than would be expected based on land use influences only. They postulated that this was due to less surface runoff, and alternatively more water going down through the soils into groundwater and coming out as baseflow and springs. Baseflow typically has higher nitrate concentrations than the surface runoff. Sauer (2001) noted that low soil and bedrock permeabilities do not necessarily translate to low nitrate in streams, particularly in areas where tile drainage occurs. In tiled lands, nitrate concentrations in streams are typically elevated, even though the natural permeability of the soil is low.

Mapping the potential for agricultural chemical contamination of aquifers

Geologic mapping has been used in Illinois since the early 1960s to identify areas where aquifers are vulnerable to contamination from landfills and other waste disposal practices. Berg et al. (1984) mapped the statewide potential for contamination of shallow aquifers by surface and near-surface waste disposal activities. Ratings were made by comparing capacities of 18 generalized sequences of geologic materials to transmit contaminants. Highly permeable materials (sands, gravels, fractured carbonate rocks, and sandstones) generally allow rapid migration of contaminants. Materials of relatively low permeability (loess, glacial till, shale, cemented sandstone, and non-fractured carbonate rocks) generally restrict contaminant migration. The thickness of the fine-grained materials controls the susceptibility of the underlying aquifers to contamination. As the thickness of these fine-grained materials increases, the potential increases for the attenuation of the contaminant due to dilution, denitrification degradation, or sorption before it reaches an underlying aquifer.

Mapping conventions

Geologic information used to map the potential for contamination of aquifers by agricultural chemicals was compiled from the stack-unit map of Illinois (Berg and Kempton 1988). The map units depict the distribution of geologic deposits vertically from the surface to a depth of 50 feet, as well as horizontally over a specified area. The minimum thickness of continuous map units is 5 feet, except where a unit less than 5 feet was mapped over at least 0.4 square miles (Berg and Kempton 1988). Where a unit is mapped as laterally discontinuous within the specified area, the unit is frequently less than 5 feet thick.

The stack-unit map was published at a scale of 1:250,000 (1 inch equals approximately 4 miles). The availability of subsurface data varies across the state. Consequently, the accuracy of the map will vary. In areas such as Mason County, the map is probably 95 percent accurate. In areas with complex geology and limited data, map accuracy may be significantly less. The maps are most accurate in describing geologic conditions within the upper 20 feet. McKenna and Keefer (1991) combined the 18 sequences of Berg et al. (1984) into four groups of depth to aquifer materials: less than 5 feet, between 5 and 20 feet, between 20 and 50 feet, and greater than 50 feet. Figure C.1 shows only areas where aquifer materials occur within 20 feet of land surface.

Sand and gravel greater than 5 feet thick, sandstone greater than 10 feet thick, and fractured carbonates greater than 20 feet thick are considered to be aquifer materials. Loess, glacial till, shale, and non- fractured carbonate rocks have relatively low hydraulic conductivities and generally will not provide a sufficient volume of water to a drilled well and are not considered aquifer materials. Discontinuous sand and gravel deposits were not mapped as aquifers. Continuous surficial sand and gravel deposits less than 20 feet thick under overlying fine-grained, non-aquifer materials are also not considered to be aquifers, because of seasonal fluctuations in the depth of the water table. These surface deposits are probably not reliable sources of water to wells.

Use of the map

The scale and accuracy of the map showing the potential for aquifer contamination by agricultural chemicals are appropriate for use in targeting educational and technical assistance programs and for designing regional groundwater monitoring programs, but are not adequate for regulating agrichemical usage on specific fields. This map, which was modified from McKenna and Keefer (1991) and Keefer (1995), should be helpful in targeting efforts to reduce nitrate-nitrogen losses. Additional research is needed to provide estimates of nitrate-nitrogen yields to streams from these areas.

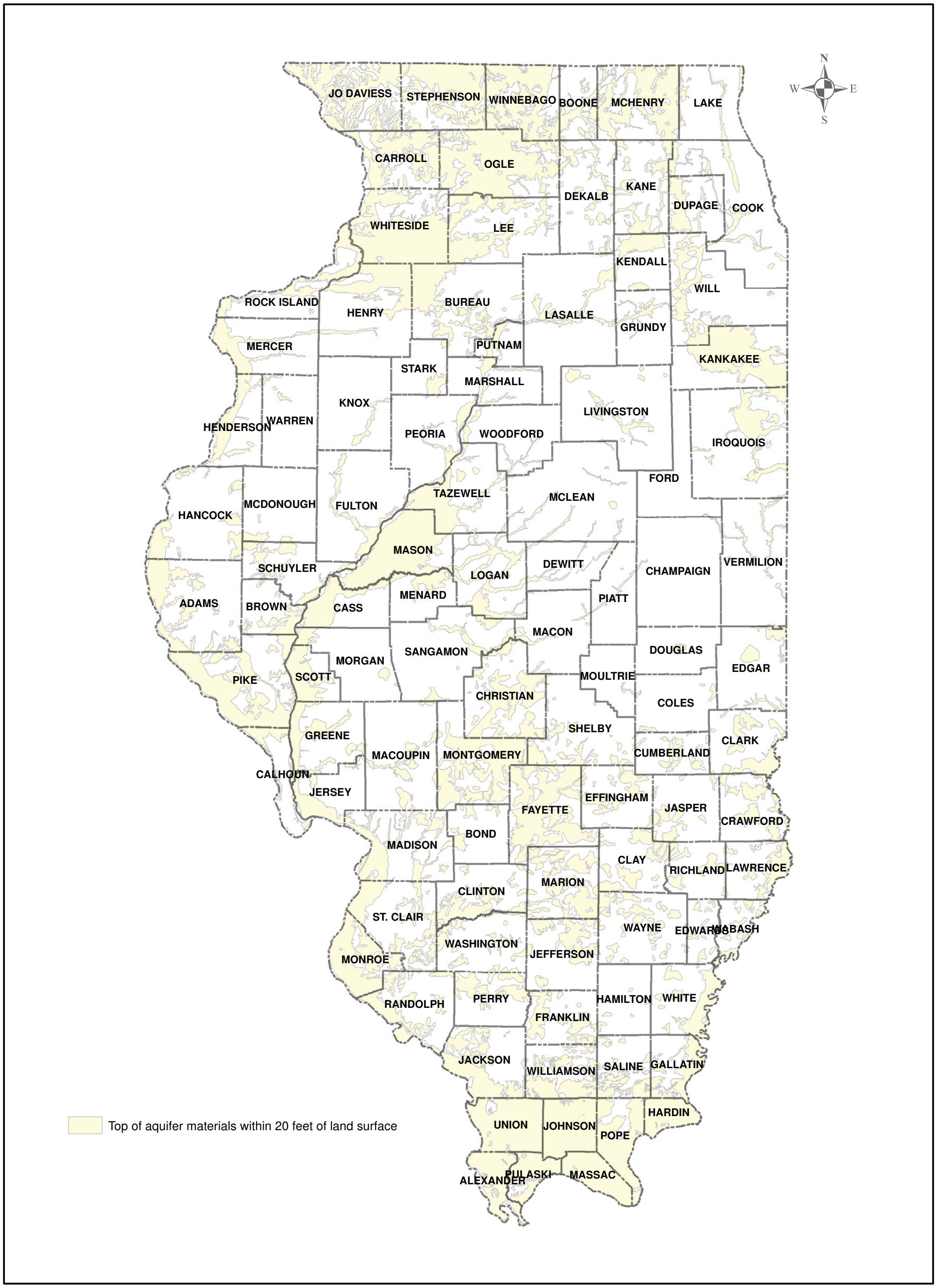


Figure C. 1. Areas where aquifer materials occur within 20 feet of land surface. Modified from McKenna and Keefer (1991) and Keefer (1995).

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