Water Quality

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Water quality can be evaluated in many ways including color, odor, temperature, turbidity and the presence or absence of bacteria. Pharmaceuticals and personal care products (PPCPs) have also been identified in many of the lakes, rivers, and streams in the United States. Current water quality issues in Illinois generally relate to drinking water safety and the need to reduce nutrient loss from agricultural fields. This chapter is organized around those two themes.

Agriculture has long been identified as a primary source of water quality impairment. Pesticides and fertilizers are often cited as examples of agricultural contaminants, but soil erosion continues to cause water quality concerns in local waters and downstream water bodies. As a result, appropriate chemical selection and crop management decisions are needed to ensure good water quality.

Drinking Water and Rural Well Protection

Drinking-Water Standards and Reporting

All public water supplies must sample quarterly for regulated contaminants, including a number of agricultural chemicals. Maximum Contaminant Levels (MCLs) have been established for many pesticides, herbicides, and other agricultural chemicals (https://bit.ly/2V6O4Tn). For example, the current MCL for atrazine is 3 parts per billion, glyphosate is 700 parts per billion, and nitrate is 10 parts per million (measured as nitrate-nitrogen).

Compliance with the federal standards is based on an average of four quarterly samples. If standards are exceeded, water customers are notified by local media and subsequently on their water bills. If a water source is in violation, no additional water permit extensions can be issued until the problem is addressed. Solutions might include blending with an uncontaminated supply, extensive de- contamination treatment, or finding an alternative supply. The additional water treatment expense can be prohibitive to small communities, underscoring the importance of agriculture management practices that reduce the entry of chemicals and nutrients into the aquatic system.

Since 1999, all public water supplies have been required to provide customers with an annual report on drinking water quality. These “consumer confidence” reports were developed by the U.S. Environmental Protection Agency (USEPA) to provide consumers important information about the quality of their drinking water. Each report includes information about the source of drinking water (for example, lake, river, or aquifer) and whether it meets federal drinking water requirements. They indicate how susceptible this local drinking water source is to contamination and identify potential sources of contamination. Finally, they list the contaminants detected in the water supply and outline the potential health effects of any contaminant found in violation of a USEPA health standard.

In addition, any community water system that serves more than 100,000 people is required to make its consumer confidence report available to customers on a publicly accessible website. A listing by state is available at https://bit.ly/3rAnwpG. More information can be found on the USEPA’s drinking-water website (https://bit.ly/3ryX3cd) or from the Safe Drinking Water hotline (800-426-4791).

Testing Private Wells

Although public water supplies are closely regulated and must meet USEPA standards, private wells are not required to be tested. If the main source of your drinking water is a private well, it is your responsibility to test the water on a regular basis. Water testing can be done by the Illinois Department of Public Health or by private labs. A list of laboratories accredited by the Illinois EPA to test home drinking water is available at https://bit.ly/3eTsBo3. The Illinois Department of Public Health recommends that all new wells and those that have been recently repaired be tested. A basic test analyzes water for two common contaminants: coliform bacteria and nitrate.

Coliform bacteria are an indicator of overall water quality. If they are detected in a water sample, there is some degree of contamination, and other organisms may also be present. Although chemical disinfectants such as chloride tablets or bleach can be used to treat wells, it is important to identify potential sources of contamination. Contamination may come from soil or surface water, or there may be problems with well construction or location. Five minutes of vigorous boiling is an effective way to kill most pathogens if they are suspected to be contaminating well water.

High nitrate levels in water are a concern for pregnant women and infants under 6 months of age. Boiling water does not reduce nitrate levels. If tests show that nitrate-nitrogen levels exceed 10 parts per million, the MCL for nitrate, water should not be consumed by pregnant women or infants under the age of 6 months. Use an alternate water source, such as bottled water.

Reducing Contamination in Private Wells

The highest levels of pesticide contamination are often at wells near chemical handling sites or at wells that are known to have been contaminated directly by an accidental point source introduction of the chemical, such as back-siphoning. Since cleaning up contaminated wells is difficult, the preventative step of protecting groundwater drinking sources is critical. Protection can be accomplished by attention to these four points which are further described in sections below:

- preventing point source contamination of the well
- evaluating groundwater contamination susceptibility, as determined by soil and geologic conditions and the water management system
- selecting appropriate agrichemicals and application strategies
- practicing sound agronomy, which uses integrated pest management principles and appropriate yield goals

Preventing Point Source Contamination

Controlling point source contamination is one of the most important actions for protecting a groundwater supply. A point source is a well-defined and traceable source of contamination, such as a leaking pesticide container, a pesticide spill, or back-siphoning from spray tanks directly into a well. Because point sources involve high concentrations of contaminants or direct movement of contaminants to the water source, the filtering ability of the soil is bypassed. The following handling practices, based largely on common sense, minimize the potential for groundwater contamination:

- Never mix chemicals near (within 200 feet of) wells, ditches, streams, and other water sources.
- Prevent back-siphoning of mixed pesticides and agrichemicals from the spray tank to the well by always keeping the fill hose above the overflow of the spray tank. Irrigators who perform chemigation or fertigation (that is, application of agrichemicals or fertilizer via the irrigation system) must equip their system with devices to prevent backflow.
- Store agrichemicals in a secure location a safe distance from both wells and surface waters.
- Triple-rinse agrichemical containers and put rinsate back into the spray tank to make up the final spray mixture.
- Identify vulnerable areas and avoid applying insecticides, fungicides, herbicides or fertilizers near sinkholes.

Abandoned wells are a special consideration as a point source contamination risk as well as pose a direct and immediate risk to human safety. Every year, many wells are abandoned when they are replaced with new wells or when homes are connected to community water systems. The risk of accidents for humans or domestic animals is greatest with large-diameter or dug wells, but any abandoned or unused well poses a threat to groundwater quality.

The Illinois Water Well Construction Code requires the owner of a well to properly seal it within 30 days after it is abandoned and no longer used to supply water (Figure 7.1). However, old wells that may have been abandoned for some time are not always clearly visible. If you suspect there is an abandoned well on your land, it may be necessary to contact former property owners or neighbors who might remember well locations. In addition, local well drillers often have site records of previous installations. If old photos are available, they may show windmills, houses, barns, or other buildings that have since been torn down where wells might be located.

Fig. 7.1. Sealing an abandoned well in Illinois (Credit: G. Czapar, UIUC)

Sealing an abandoned well must be done by a licensed water well driller. A homeowner may do this themselves but only if a written request is made to the local health department or to the Illinois Department of Public Health describing procedures and materials, all of which must comply with the well code. Additionally, the local health department must be notified at least 48 hours before well sealing activities start. After the sealing is finished, a completed sealing form must be submitted to the local health department or the Department's central office in Springfield. More information is available at: https://bit.ly/3kW419V

Groundwater Vulnerability

Site characteristics, including soil and geologic properties, water-table depth, and depth of the well, determine the potential of nonpoint source contamination of groundwater. Differently from point sources, nonpoint sources of contamination are difficult to pinpoint because nonpoint sources of contamination originate from a variety of sources and are affected by many processes. Contaminants moving into groundwater from routine agricultural use are an example of a nonpoint source.

Soil Characteristics: Water-holding capacity, permeability, and organic matter content are important soil properties that determine a soil's ability to retain agrichemicals in the crop root zone. Fine-textured, dark prairie soils have large water-holding capacities and large organic matter contents, which reduce the likelihood of chemical leaching due to reduced water flow or increased binding of the chemical. The forest soils that dominate the landscape in western and southern Illinois are slightly lower in organic matter and thus may be less effective at binding pesticides and similar chemicals. The most vulnerable soils for groundwater contamination are the sandy soils that lie along the major river valleys. Sandy soils are highly permeable, have low organic matter content, and often are irrigated. All of these factors represent increased risks to groundwater quality. Extra precautions should be taken in these vulnerable soils regarding chemical selection and application methods. Irrigators, in particular, should pay attention to groundwater advisory warnings that restrict the use of some herbicides on sandy soils.

Geology: The geologic strata beneath a farming operation may be important in determining the risk of nonpoint source contamination. The karst, or limestone, geology that occurs along the margins of the Mississippi River and in the northwestern part of the state is particularly hazardous for the risk of groundwater pollution. Sinkholes and fractures that occur in the bedrock in these areas may extend to the soil surface, providing access for runoff directly to the groundwater. Water moving into these access points bypasses the natural treatment provided by percolation through soil. Karst areas should be farmed carefully, with attention to buffer zones around sinkholes to prevent runoff entry to the groundwater. Agronomic practices that minimize runoff reduce the potential for pesticide movement to the groundwater.

Groundwater and Well Depths: Deep aquifers that lie under impermeable geologic formations are the sites most protected from contamination by surface activities. In contrast, shallow water-table aquifers are more vulnerable to contamination because of their proximity to the surface. Shallowly dug wells in sandy soils or areas with shallow aquifers are also more vulnerable, due to typically inadequate wellhead protection.

Pesticide Properties and Selection
The selection of agricultural chemicals is critical for producers on vulnerable soils and geologic sites. Chemical selection is a complex task that must take into account the crop, the tillage system, the target species, and a host of other variables. Chemical properties are important to consider when evaluating their potential to leach to the groundwater. The three most important chemical characteristics that influence leaching potential are solubility in water, ability to bind with the soil (adsorption), and the rate at which the pesticide breaks down in the soil. High solubility (a pesticide that dissolves readily), low binding ability, and slow breakdown all increase a pesticide's ability to move to the groundwater. Always check the label for environmental hazards and mixing and loading instructions. Many herbicides carry a groundwater advisory section with detailed information on protecting groundwater and surface water.

Surface Water Contamination and Nutrient Loss

Although groundwater protection is an important priority, surface water quality is generally at greater risk due to agricultural runoff. Agrichemical losses are often greatest when heavy rainstorms closely follow insecticide or herbicide applications. Moreover, the prevalence of subsurface "tile" drainage in many parts of Illinois creates a short circuit for nutrients to move from fields to streams and downstream waters (Figure 7.2). Addressing the impacts of agriculture on surface water continues to be one of the biggest challenges facing the industry.

Surface water quality impairment
A variety of terms are commonly used when Illinois' waters are discussed in context of water quality and nutrient runoff. A body of water is considered **impaired** if it fails to meet one or more water quality standards. **Water quality standards** are set based on the concept of **designed uses** for a given water body such as the ability of the water body to support aquatic life and recreational activities or be used as a drinking water supply. In other words, common designated uses are for waters to be "fishable, swimmable, and/or drinkable".

Fig. 7.2 Flowing tile drainage outlet (source: G. Czapar/UIUC)

A common way impaired waters in the United States are addressed is through the **total maximum daily load** (TMDL) process. A TMDL is the allowable amount (or, load) of a single pollutant that a water body can receive from all contributing sources and still meet the designated use set for that given water body. Establishment of a TMDL serves as the starting point and as a planning tool to restore the quality of the water to the standards required to achieve the desired designated use(s). The TMDL development process starts with a water body being identified as impaired by the state; impaired water bodies are listed on what is called the "303d list" which refers to Section 303(d) of the federal Clean Water Act. The list of Illinois' impaired waters is available online (https://bit.ly/36YUgzD). Once a water body is listed as impaired, the TMDL process involves collecting local environmental data for use in a computer model that estimates pollutant loads and how those loads can be reduced so the water body can then meet the designated use.

The TMDL process includes inventorying all sources of a contaminant for a given water body including both point and nonpoint sources. **Point source pollution**, which is also described above regarding protection of wells, is water pollution that is emitted from a specific identifiable point like a pipe, whereas **nonpoint source pollution** (also known as diffuse source pollution) does not have a defined, identified point of discharge. Examples of point sources include factories and wastewater treatment plants; examples of nonpoint source pollution include agricultural runoff, urban stormwater, and runoff from lawns. The distinction between these two is legally important because point sources are regulated with a permit system where they cannot exceed a given amount of pollutants based on their specific discharge criteria. Another important nuance is that, as of the date of writing, agricultural tile drainage systems are explicitly excluded from point source permitting and regulation within the Clean Water Act even though tile outlets are defined pipes.

Illinois Nutrient Loss Reduction Strategy

The **Mississippi River/Gulf of Mexico Hypoxia Task Force** ("Hypoxia Task Force") was formed in 1997 to better understand the causes and effects of the hypoxic zone in the Gulf of Mexico and to coordinate action to reduce its size and severity. The Hypoxia Task Force's goal, which was reaffirmed in 2015, is to reduce the five-year average size of the Gulf of Mexico hypoxic zone to less than 5,000 square kilometers (or, less than 1,930 square miles) by the year 2035. This coincides with a 45% reduction in the amount of nitrogen and a 45% reduction in the amount of phosphorus sent downstream in the Mississippi River. The Hypoxia Task Force added an interim goal in 2015 to achieve a 20% reduction in nitrogen and phosphorus loading to the Mississippi River by 2025. The reduction in nutrient loading is relative to the average nutrient loading from 1980-1996.

A key aspect of the Hypoxia Task Force's approach to coordinating activities to reduce the size of the hypoxic zone was the development of a state nutrient reduction strategy by each of the twelve states represented on the Task Force. Each strategy is a state-specific approach detailing nutrient loading from point and nonpoint sources within the state and how the state aims to reduce nutrient pollution sent downstream. This state-oriented approach allowed flexibility between states which was important given the spatial extent and the variety of ecoregions, agricultural practices, and population across the Mississippi River Basin. The USEPA supports these state strategies as "voluntary" approaches. However, actually achieving the goals as defined by the Hypoxia Task Force is not voluntary; the term voluntary refers to the approach that each state selects to achieve the goals.

Illinois is one of the main contributors to the nutrients in the Mississippi River and consequently to the annal hypoxic zone in the Gulf of Mexico. Thus, the **Illinois Nutrient Loss Reduction Strategy**, released in 2015, is very important for waters in our own state as well as for downstream waters. The ultimate goal of the Illinois Nutrient Strategy aligns with the 45% nitrogen and phosphorus loss reduction goals of the Hypoxia Task Force. Illinois' interim goals differs slightly from those set by the Task Force, with our state aiming for a 15% reduction in nitrogen loss and 25% reduction in phosphorus loss by 2025. The science assessment upon which the Illinois Nutrient Loss Reduction Strategy is based credited agricultural nonpoint sources for 80% of the nitrogen sent downstream and 48% of the phosphorus sent downstream.

The Illinois Nutrient Loss Reduction Strategy is fundamentally different from the TMDL process described above. A TMDL can be set for any water pollutant or combination of pollutants (for example, pesticides, nutrients, metals, sediment, temperature) whereas Hypoxia Task Force state nutrient strategies only pertain to nitrogen and phosphorus. Secondly, a TMDL is developed at a watershed-scale for a specific impaired waterbody; the state nutrient strategy approach is based on individual state's boundaries and encompasses the entire state. Finally, a TMDL is the universally accepted formal method to address water impairment in any state within the United States. The state nutrient strategy process applies only to the twelve states that send the most water and nutrients to the Mississippi River and are represented with a seat on the Hypoxia Task Force.

Nutrient Standards

In work related to the Illinois Nutrient Loss Reduction Strategy process, the state of Illinois developed nutrient criteria for total phosphorus and total nitrogen (Table 1). Both the processes of determining and then achieving robust and meaningful water quality standards for nutrients is a challenge for Illinois and many other states. Factors such as physical habitat, sediment, light availability, temperature, and hydrology are part of a complex relationship affecting biotic responses in rivers and streams. Cause-and-effect relationships for nutrients

Table 7.1. Total nitrogen and total phosphorus water quality standards and criteria from the Illinois Nutrient Loss Reduction Strategy Nutrient Science Advisory Committee. The Illinois Science Advisory Committee report is available online (https://bit.ly/36YUh6F).

Reference	Water body type	Total phosphorus		Total nitrogen	
		------------ µg TP/L ------------		------------ µg TN/L ------------	
		North Ecoregion	South Ecoregion	North Ecoregion	South Ecoregion
Illinois Nutrient Loss Reduction Strategy Nutrient Science Advisory Committee (2018)	Wadeable streams	133	110	3,979	901

in water and their impacts are sometimes difficult to establish because Illinois lacks a wide range of nutrient conditions, and nutrients may not be the primary limiting factor for algal production in some cases. For example, some streams in Illinois exceed the recommended nutrient criteria for wadeable streams, including some waters that support a rich diversity of aquatic species.

Conservation Practices for Water Quality-
Conservation practices are designed to minimize adverse effects of agricultural chemicals and nutrients on surface water and groundwater quality. In most cases, a combination of conservation practices is required to achieve water quality goals, and the suggested practices may vary depending on the resource concern, soils, topography, and the individual farm operation.

Best practices to reduce losses of agrichemicals
Integrated pest management (IPM) plays a vital role in protecting water resources. Regular monitoring of crop conditions and pest populations helps a producer make the most informed production decision about pesticide applications. Applications based on economic thresholds optimize grower profits while reducing environmental hazards. When possible, select the pesticide that is least likely to run off into surface water or leach to groundwater.

Proper handling and disposal of pesticides can reduce the potential for point-source contamination of water resources. Spills or improper disposal of excess spray can overload the soil's ability to hold and degrade pesticides, with resulting water contamination. If sprayers are dumped or washed out in the same place over the years, concentrated sources of herbicides may be created.

Consider a split application of soil-applied products to reduce the risk that heavy rainfall will cause extensive runoff. Select postemergence herbicides with physical and chemical characteristics that have less potential for surface runoff. Band-apply herbicides and use mechanical control when appropriate. Rotate crops and use a combination of weed management practices. In addition to helping achieve water-quality goals, these practices will reduce the chance for developing herbicide-resistant weeds.

Consider delaying herbicide application if heavy rains are forecast for the next few days. Research has shown that heavy rainfall shortly after herbicide application can cause significant chemical loss. Finally, some individual practices may not be appropriate as part of an overall cropping system. Incorporation of herbicides, for example, has been shown to decrease the amount of chemical runoff in surface water. Obviously, this practice is not compatible with a no-till system, and the balance between controlling soil erosion and reducing pesticide movement must be considered.

Practices to reduce nutrient and sediment losses
In terms of the Illinois Nutrient Loss Reduction Strategy, the challenge for those working in agriculture is to adopt appropriate practices to demonstrate that strategy goals can be met with voluntary action without regulation. While the Illinois Nutrient Strategy focuses on reducing the amount of nitrogen and phosphorus

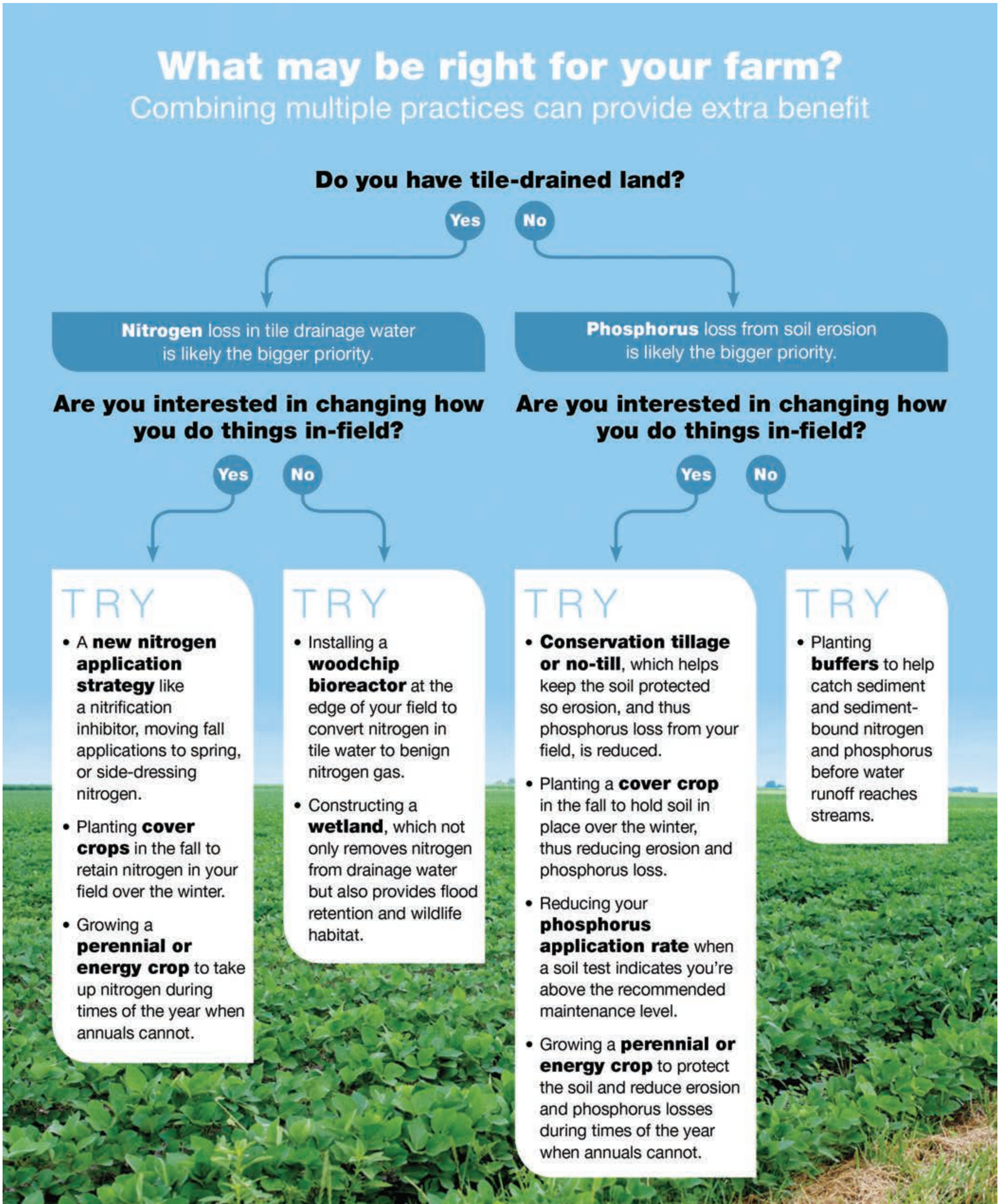

Fig. 7.3. A decision tree to help compare suitability of practices recommended in the Illinois Nutrient Loss Reduction Strategy. See the link for more information: go.illinois.edu/UseScience.

sent downstream, many phosphorus loss reduction practices are also effective ways to reduce sediment loss. The options for conservation practice selection are numerous, but there are resources to help make management decisions. An example using several of the conservation practices recommended in the Illinois Nutrient Strategy is shown in in Figure 7.3. More related information about conservation practices in context of the Illinois Nutrient Loss Reduction Strategy is available at: Go.Illinois.edu/UseScience.

The Illinois Nutrient Strategy recommends following the university-backed approach of the Maximum Return to Nitrogen (MRTN) to determine nitrogen application rates. Reducing the application rate to the MRTN-recommended rate reduces nitrogen loss by 10%. Splitting nitrogen applications between the fall and the spring (that is, not applying 100% of the nitrogen in the fall) reduces nitrogen loss from 7.5% to 20% and use of a nitrification inhibitor with fall-applied nitrogen fertilizer reduces nitrogen loss by 10%. In terms of phosphorus application and losses, reducing the phosphorus application rate on soils that have soil test phosphorus levels above the maintenance level reduces P losses by 7%. For either nutrient, soil testing is a basic foundation for fertilizer recommendations and ensuring nutrient applications balance agronomic and environmental goals.

Conservation tillage practices reduce sediment and phosphorus losses and also reduce or slow water runoff. Converting from conventional tillage to conservation tillage or a no-till system reduces phosphorus losses by 50% according to the Illinois Nutrient Loss Reduction Strategy. Because many agrichemicals can move from treated fields dissolved in runoff water, conservation tillage practices that increase water infiltration into the soil profile should help control herbicide runoff as well. Grass waterways should be established in areas of concentrated water flow. In addition to protecting these soils from erosion, waterways trap sediment and reduce the velocity of runoff flow, allowing greater infiltration of dissolved agrichemicals as well as allowing phosphorus and sediment to filter out of the runoff.

Winter cover crops hold some of the most promise for reducing nutrient losses in both surface runoff and tile drainage. The effectiveness of cover crops in controlling erosion is well documented, and controlling erosion is an important component of protecting the quality of surface water. Any kind of cover crop can reduce sediment and nutrient losses due to surface runoff, given hearty establishment. The Illinois Nutrient Loss Reduction Strategy credits cover crops at 30% phosphorus loss reduction on tile-drained acres and 50% phosphorus loss reduction on acres that are eroding. Grass-based cover crops that overwinter like cereal rye reduce nitrogen loss in tile drainage by 30%.

Other conservation practices are at the edge of the field such as vegetated buffers, bioreactors, and constructed wetlands. Edge of field conservation practices specifically for reducing the amount of nitrogen in tile drainage water are considered “conservation drainage” practices and are described in Chapter 11: Water Management.