

Livestock Agriculture and Water Resources in Wisconsin

by Steve Oberle, Ph.D.

Ecological Context

Agricultural productivity gains since the 1950s have resulted from the development of farming systems that rely heavily on external inputs of energy and chemicals to replace management and on-farm resources. The intensity to which the natural environment has been modified to attain this productive capacity has directly resulted in degradation of natural resources; notably land, water, and the biodiversity, that sustain these systems (Figs. 1-4).

Over the past 70 years, the structure of the livestock industry in America has changed dramatically, especially in terms of animal numbers and densities, crop/livestock diversity, and scale (ie. land area) of operations. Livestock production in the U.S. has generally favored substituting land and animals (larger farms) and associated inputs (eg. machinery, fuel, irrigation, fertilizers, pesticides, waste storage) for management, public health/safety, and ecological considerations. Animals in large-scale operations are now raised in confinement, where feed is brought to the animal rather than the animals seeking feed in pastures, or on rangeland. Consequently, livestock production has transitioned towards larger operations further separated over time from the land base that produces their feed, and in turn, the land base that is required for spreading (in most cases) excessive amounts of manure and process wastewater.

Large-scale livestock operations in the U.S. now typically specialize in production of one animal type, often at one stage of its life cycle (more highly-specialized). In swine production, hogs may be transferred from a farrow-to-feeder farm during the initial life stages, to a feeder-to-finish farm and finally to a slaughter plant, rather than being raised at one farm.

Across all agricultural sectors, farms have gotten larger and fewer in number, with the shift from “family farm” perhaps most pronounced in livestock production. Since the 1950s, the production of livestock and poultry in the U.S. has more than doubled, however the number of operations has decreased by 80%. Under most modern livestock production systems, many farmers are trapped and find that the only way to expand their net farm income is to farm more land (or add more animals) – but expansion only goes so far, since the need for outside capital and productive inputs (eg. fuel, land, water), moves the farm beyond the size of a single family unit, and toward on-going consolidation and concentration of production within the industry (Fig. 5).

Livestock production has evolved to fewer and larger operations and increasingly more regionally concentrated facilities and animal densities within impacted watersheds (Figs. 6 and 7). Over many years in the U.S. and Wisconsin, livestock production has transformed from small and medium-sized farms, to much larger operations that concentrate many animals and their land spread manure and process wastewater in relatively small land areas. These operations are often referred to as concentrated animal feeding operations (CAFOs). The largest CAFOs are defined as having 1,000+ animal units (au); defined here as a 1,000 pound steer (beef). Note graphic for a comparison across livestock types (Figs. 8 and 9).

Because of the shift in livestock farming towards larger (in size and scale) production systems, excessive volumes of manure and process wastewater are oftentimes generated relative to the cropland base (fields/spreadable acres) available for application of the associated excessive amounts of manure-derived nutrients. Increased animal densities in a given watershed/region ultimately leads to concentrations of manure and process wastewater that exceed the beneficial (nutrient) needs of the cropland used for land spreading.

And this, in turn, ultimately leads to increased capital costs (diseconomies of scale) associated with land rents, water access, machinery/fuel for manure (nutrient) transfer/application, among others. In many cases and watersheds with high densities of larger-scale livestock operations and CAFOs, there is likely more than one facility land spreading on the same field(s) (Fig. 10).

Manure and process wastewater generated by many modern, large-scale livestock farms are often stored and utilized in a manner that can pollute air, surface water, and groundwater; posing acute and chronic environmental and public health/safety risks, particularly for CAFO workers and nearby residents, private wells, communities, and public water supplies. These operations also disproportionately affect low-income, disadvantaged communities, raising serious social and environmental justice concerns. And despite growing evidence that CAFOs pose serious health and environmental risks and negatively impact workers and communities, CAFO regulations and their enforcement have failed to adequately protect public health, safety, and the environment (APHA, 2019).

Livestock Agriculture and Water Resources

Agriculture contributes to pollution of the nation's water resources through leaching and runoff of crop nutrients, pesticides, and animal wastes, and through soil erosion from croplands. Livestock agriculture has likely impacted our water resources and watersheds in one way or another, since animals were first raised on farms in Wisconsin (Figs. 11-13).

In Wisconsin and throughout the country, examples of water resource challenges and associated public health and safety issues connected with CAFOs and other concentrated, large-scale livestock operations include, but are not limited to, nutrient (eg. nitrate, phosphorus) and raw manure contamination of groundwater, surface water, and local/regional drinking water supplies; excessive soil erosion and nutrient runoff from cropland and the associated contamination/sedimentation of waterways and aquatic ecosystems; e-coli and algae blooms in lakes and streams; and dead zones (hypoxia) in the Great Lakes (ie. Lakes Erie and Michigan), Estuaries (eg. Chesapeake), and the Gulf of Mexico (Figs. 14-22).

Contamination of groundwater is particularly troublesome with respect to long-term water treatment costs to communities with public water systems and private well owners to ensure safe drinking water for citizens, families, and businesses. Additionally, from a longer-term perspective and on a larger-scale, we must never forget that once pollutants (eg. nitrates, pesticides) enter an aquifer and contaminate groundwater, in most cases, these pollutants (and potentially harmful public health/safety hazards) travel unnoticed in the aquifer and watershed, until they are detected in public and/or private drinking water supply wells. And by then of course, it's too late. Groundwater contaminants like nitrate are also used as environmental indicators showing pathways exist for other (potentially more harmful) chemicals to enter groundwater and contaminate local/regional drinking water supplies (Fig. 23).

Key Factors

A primary factor in understanding current and longer-term (future) implications of CAFOs on Wisconsin's ecology and water resources - based on the number of animal units (au) in the operation - is a simple comparison of the number of spreadable acres (ac) used by currently permitted CAFOs for land spreading their manure and process wastewater vs. Wisconsin's more traditional (and sustainable) animal unit densities, also known as stocking rates (3 to 4+ ac/au). Review of Nutrient Management Plans (NMPs) from many CAFOs around the State reveals that, on average, the number of spreadable acres WI CAFOs are using for land spreading is less than 1.0 ac/au, and in many cases, less than 0.5 ac/au. There is also evidence (in some cases) these numbers have decreased over the length of time the CAFO has been permitted, based on fields (over time) being excluded from further spreading due to excessively high phosphorus (P) levels, and on the availability, suitability, and affordability of fields nearest the production area for land spreading purposes.

Modern livestock production systems in Wisconsin have not only increased in size (animal numbers) and scale (associated land area), representing serious challenges to local watersheds and drinking water supplies; there has been an associated transition from land spreading solid/semi-solid manure to entirely liquid manure/process wastewater storage, transfer, transportation, and land application systems. And this likely represents the greatest challenge and most serious threat to our aquifers and watersheds; especially in karst and sand/gravel regions of the State, and especially in areas and watersheds with high concentrations of CAFOs competing for (and land spreading on) the same fields.

We have seen on-going livestock expansions, consolidations, and CAFO-sized operations in WI for many years now. And we have known for quite some time that these larger-scale operations (in some cases) have been sited improperly (including capacity/location) and permitted to operate in very vulnerable and inappropriate places. The evidence for this includes well-documented issues involving surface water problems (eg. harmful algae blooms, fish kills) and severe and long-term (chronic) cases of groundwater (drinking water) contamination; especially in karst areas of Wisconsin where (on an annual basis) raw manure makes its way into Wisconsin citizens' wells, kitchen sinks, bathtubs, washing machines, etc. (Figs. 24-29).

Livestock manure and process wastewater often contain pathogens (many of which can be infectious to humans), heavy metals, anti-microbials, and hormones that can enter surface water and ground water through runoff and infiltration potentially impacting aquatic life, recreational waters, and drinking water systems. Over especially the last 20 years, and especially in counties and watersheds with high densities of large-scale livestock farms and CAFOs, excessive amounts of plant nutrients (eg. N, P) are added to farm fields with consecutive (eg. annual, biannual) manure and wastewater applications, especially on fields adjacent and nearest to the production area(s). Use of livestock manure to enhance soil fertility and to promote plant health and proper plant nutrition are sustainable agricultural practices. Use of the land as a means of livestock waste disposal is not only unsustainable; it is a direct threat to the groundwater, surface water, and the health/safety of everyone downstream.

Excessive plant nutrient applications (loading) to farm fields (soils) from livestock manure, process wastewater, and synthetic fertilizers makes no agronomic, economic, or environmental sense. Put another way, in the words of the University of Wisconsin's nutrient recommendation program, the

“optimum” level of plant nutrients in soils (fields) is “economically and environmentally the most desirable soil test category,” and “yields are optimized at nutrient additions approximately equal to amounts removed in the harvested portion of the crop. There is no profit in applying nutrients that will not be used.”

Now the only explanation one is left with for these excessive nutrient applications to farm fields is, (in general) many CAFOs and large-scale livestock producers choose to treat their animal manure as a waste, and the land (soil) as their means of waste disposal. And undoubtedly there are several reasons for this including the massive quantities of manure and process wastewater produced; the associated excessive amounts of plant nutrients generated relative to actual plant (crop) needs; limited (and in some cases) decreasing spreadable acres available and/or used for land spreading purposes; and increased storage, transportation, and spreading costs over time (diseconomies of scale) as operations consolidate and expand.

Where livestock operations in WI (regardless of size) are rapidly building excessively high P levels (> 35 ppm P) in agricultural fields and soils, these fields represent significant short- and longer-term threats to surface water and groundwater quality in the impacted watersheds and well recharge areas. Excessive P loading (over time) to fields from manure and fertilizer sources (especially on already excessively high P testing soils), increases the likelihood of significant P delivery to surface waters (for many years), when runoff occurs (even without additional manure/fertilizer applications) from these fields.

Phosphorus runoff is the main factor in nutrient over-enrichment of waterways resulting in eutrophication and hypoxia in Lake Michigan and other inland lakes, streams, and impoundments. Agricultural practices are the number one source of sediment and P in Wisconsin due to high erosion rates and high P levels in agricultural soils, and P losses from crop fields are a major source of P entering lakes and streams. Phosphorus and sediment are present at dangerous levels in many Wisconsin waterways, and are primary reasons why many of WI waters are listed as Impaired (Figs. 30-36).

Phosphorus behavior in soil and management effects on P losses are complex (note P cycle graphic). Since excessive amounts of P have been applied and accumulated in many fields/soils in Wisconsin, small amounts of P in runoff can cause surface water problems. For fields with soil test phosphorus levels of 200 ppm and greater, applications of P from manure and process wastewater are prohibited unless the permittee receives DNR approval.

Although the excessively high P level for most agronomic crops is 20 to 35 parts per million, the average soil P test for field samples analyzed by UW testing labs was 52 ppm during the 1995-99 timeframe. And drawdown of soil test P is a very slow process in Wisconsin. Given Wisconsin's soil P buffering capacity, with continuous corn grain production, it would take 24 years (without any additional P) to go from an “excessively high” level of 100 parts per million P to an “optimum” level of 20 ppm P.

There is ample evidence around the State showing many fields/acres under CAFO-sized (and even smaller) operations with soil P levels grossly exceeding 200 ppm and even 300 ppm P on some fields, especially those directly adjacent and near the production areas. Based on Wisconsin conditions, it would take nearly 100 years to drawdown P levels exceeding 300 ppm to the UWEX suggested “optimum” level for crop production.

And this ultimately means that any runoff or erosion from these fields will ultimately result in increased and excessive P loading to surface water quality for the next 100 years, even without additional land spreading (as required over 200 ppm P). It is important to also note, and reasonable to assume, that since both P and nitrogen (N) are macro-nutrients in crop production, where we find excessively high P build-up in agricultural fields/soils, we are also most likely to find excessive applications of N on these same fields (over time), resulting in increased potential and risk of nitrate leaching (under these fields) to groundwater and public/private drinking water supplies (Figs. 37-55). And in response, I'd like to pose this question: Where does the right to farm automatically infer the concomitant right to pollute (and endanger public health and safety, in the process)?

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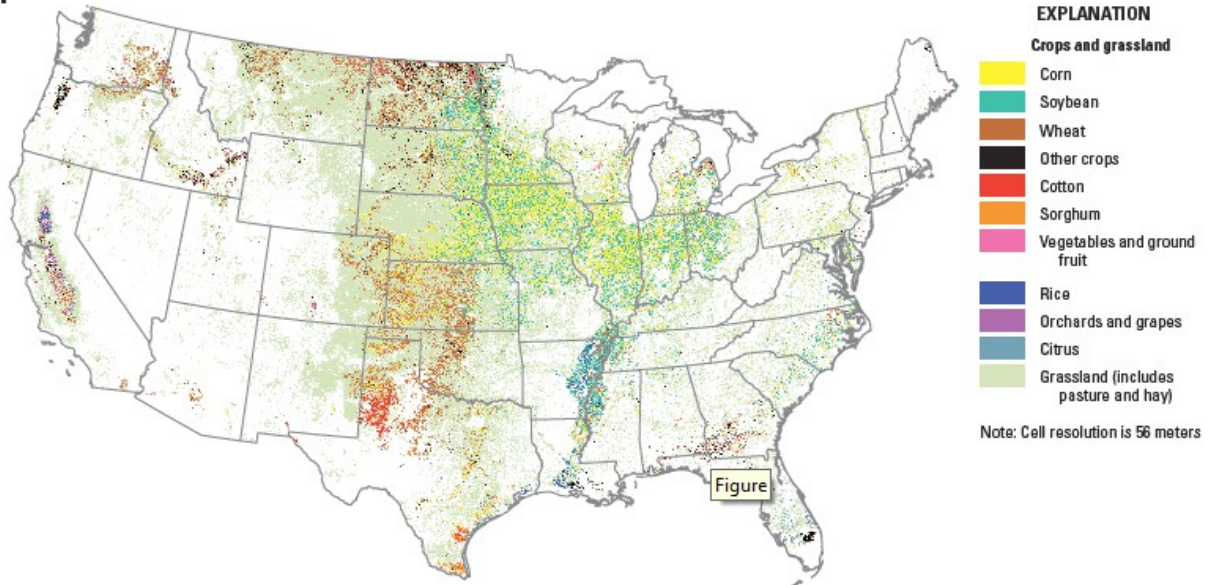
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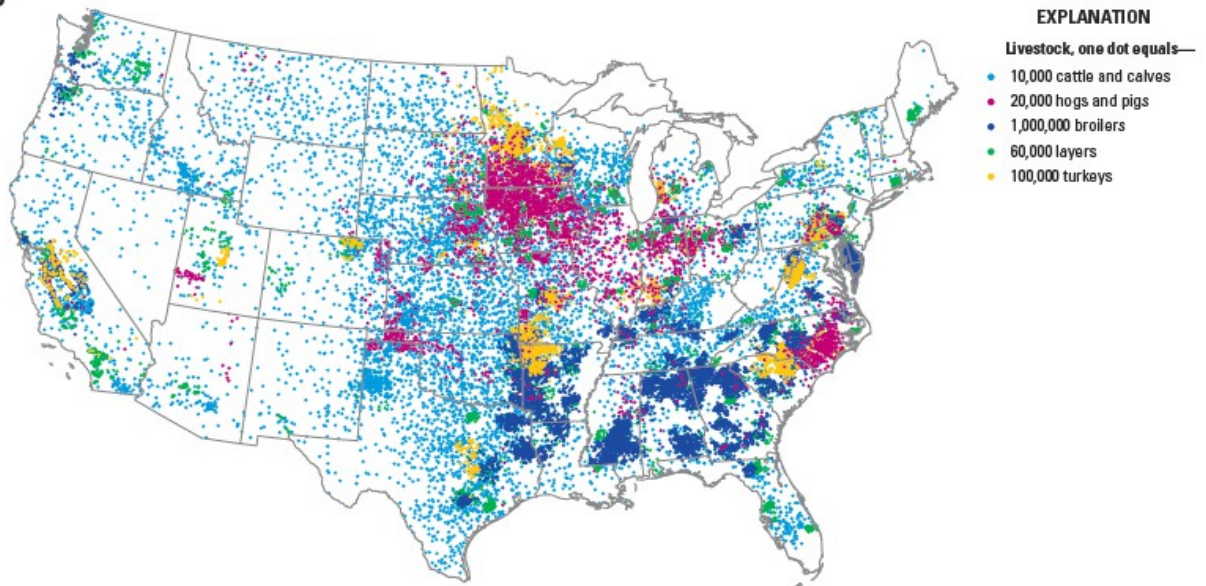
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A



B



Figures 1 and 2.

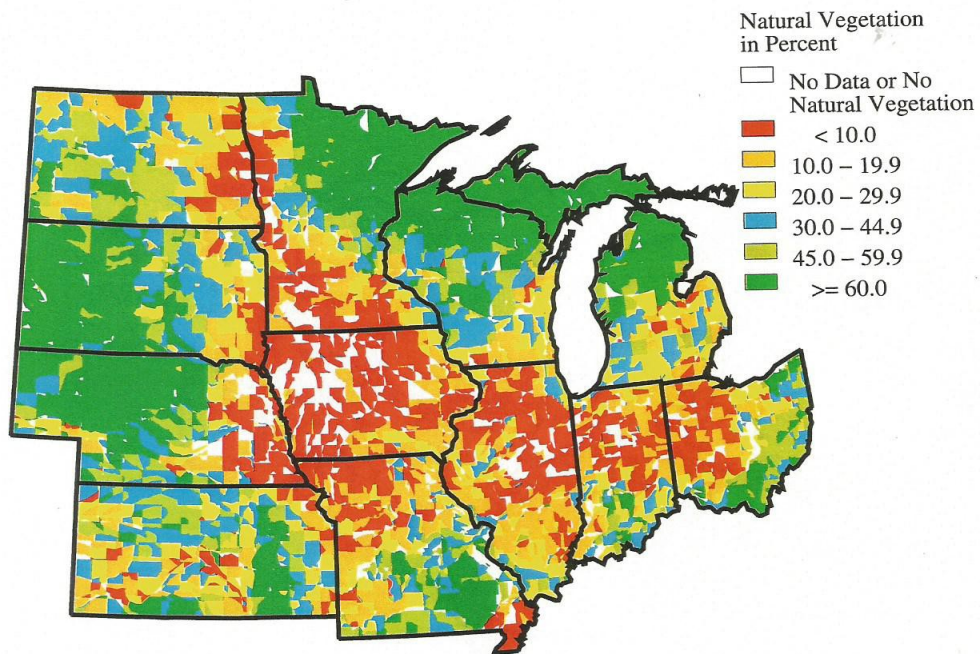


Fig. 1. Frequency of occurrence of one or more natural vegetation assemblages including wetland systems, riparian areas, forests, and rangeland.

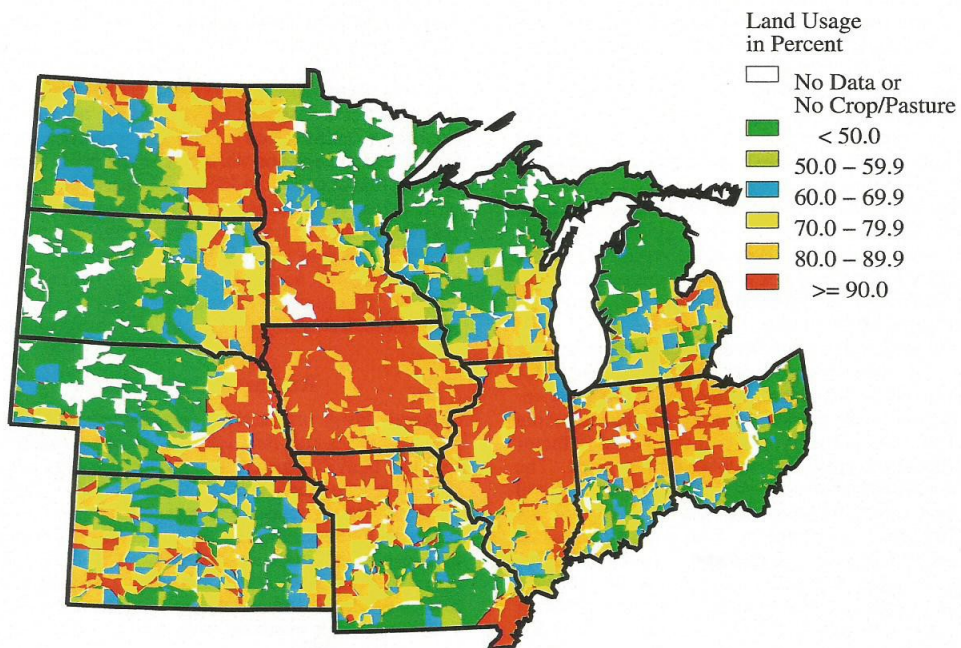


Fig. 2. Frequency of land used for crops and pasture.

The nation's top dairy counties — based on cows per square mile

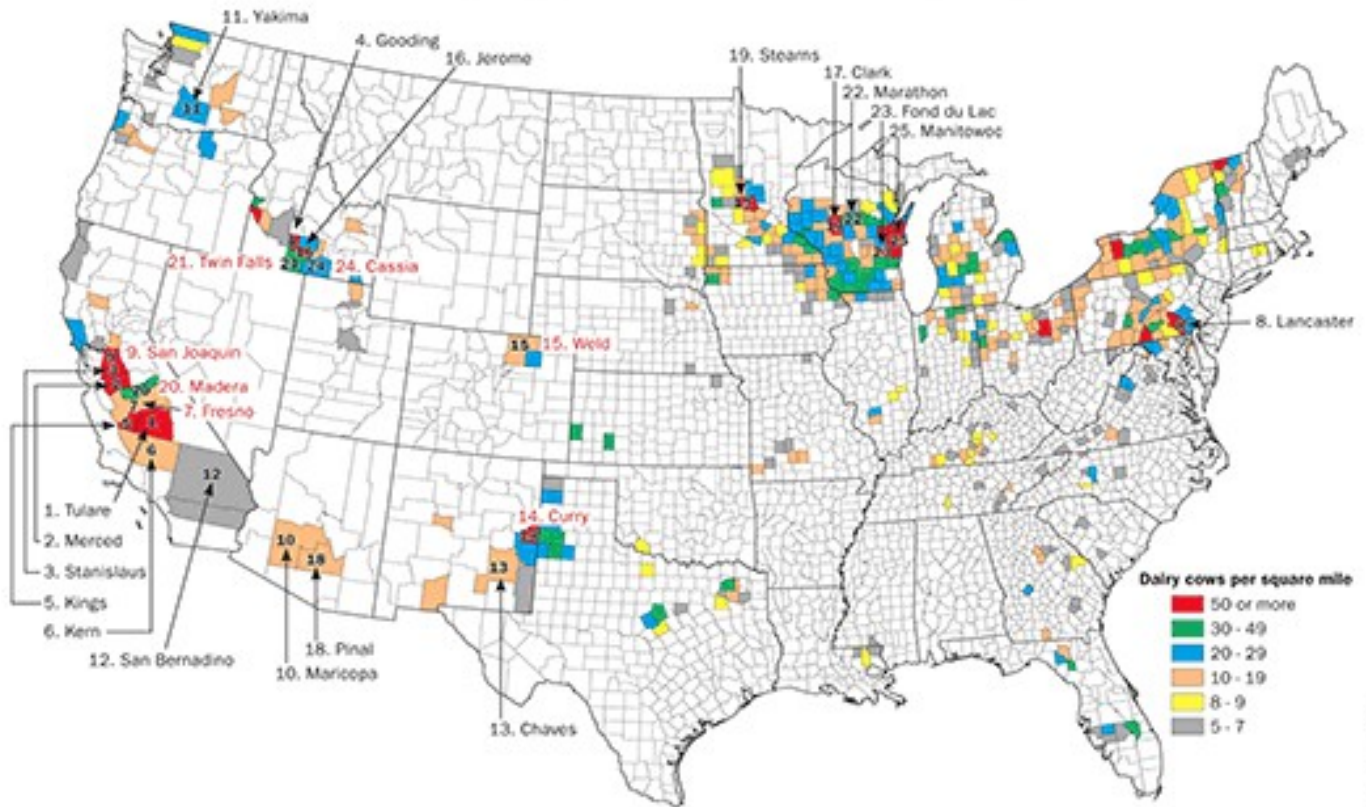
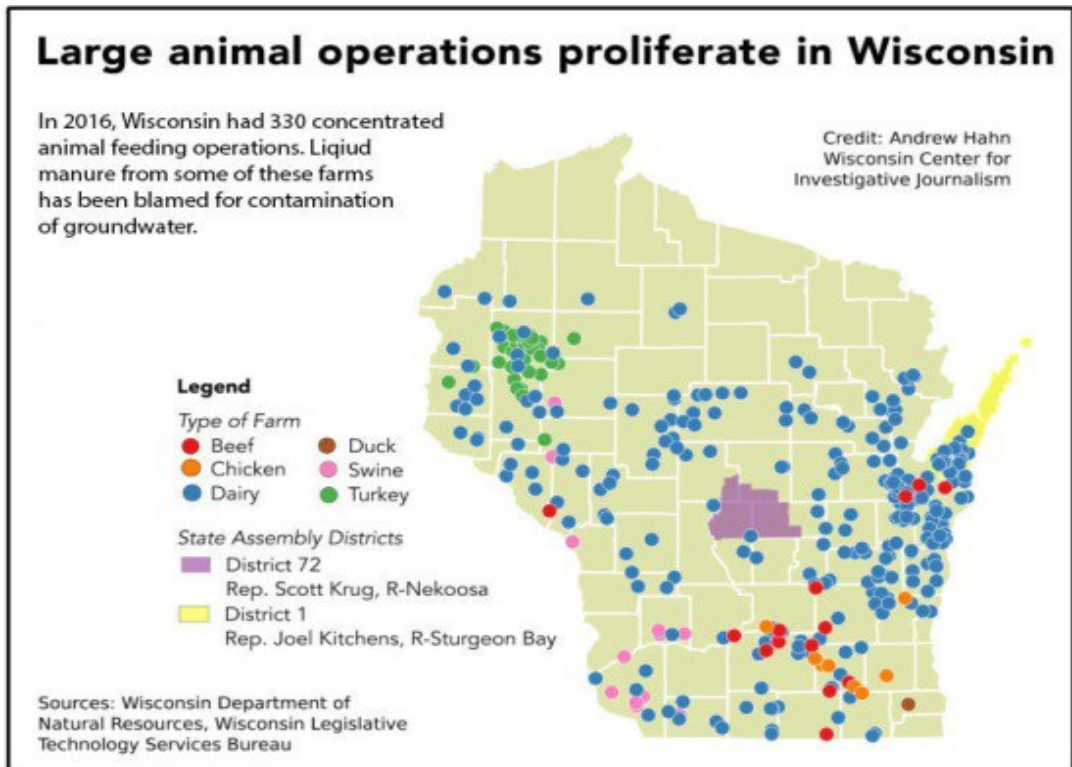
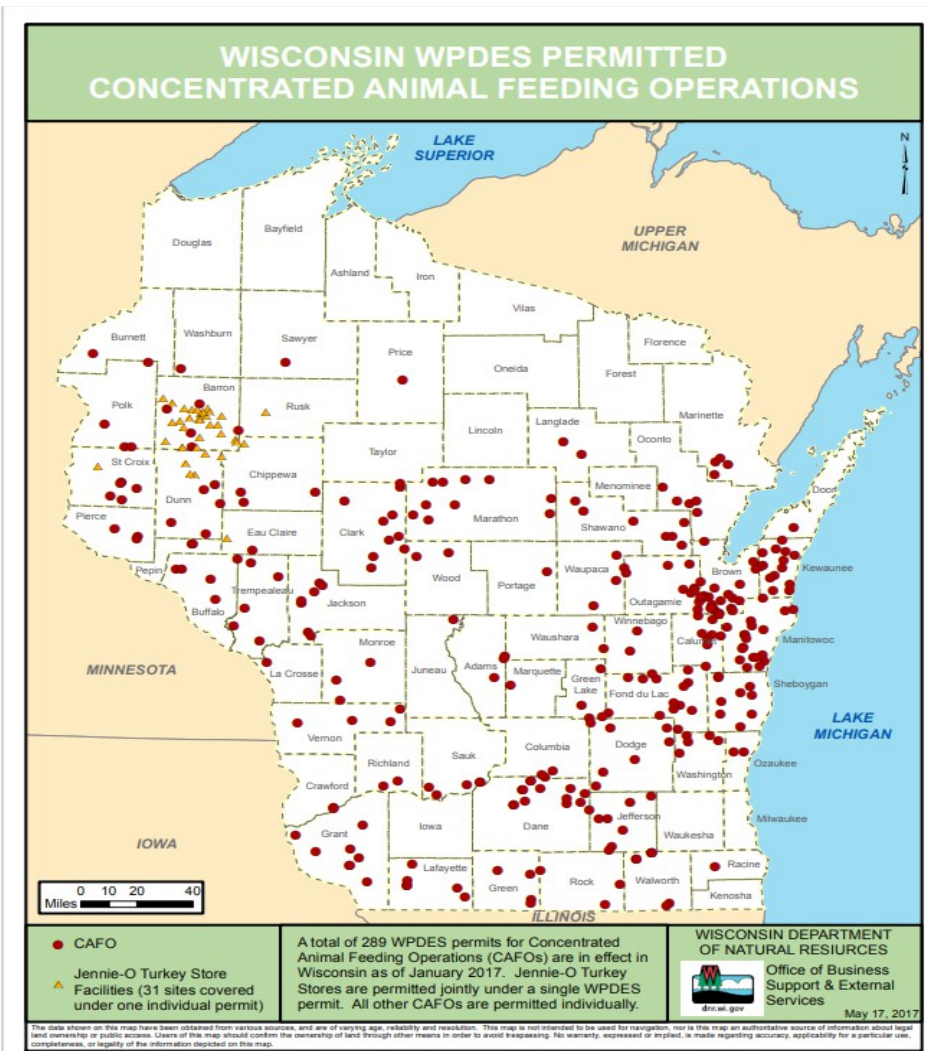


Figure 5.



Figures 6 and 7.

WISCONSIN'S CAFOs, KARST TOPOGRAPHY, AND GROUNDWATER RESOURCES

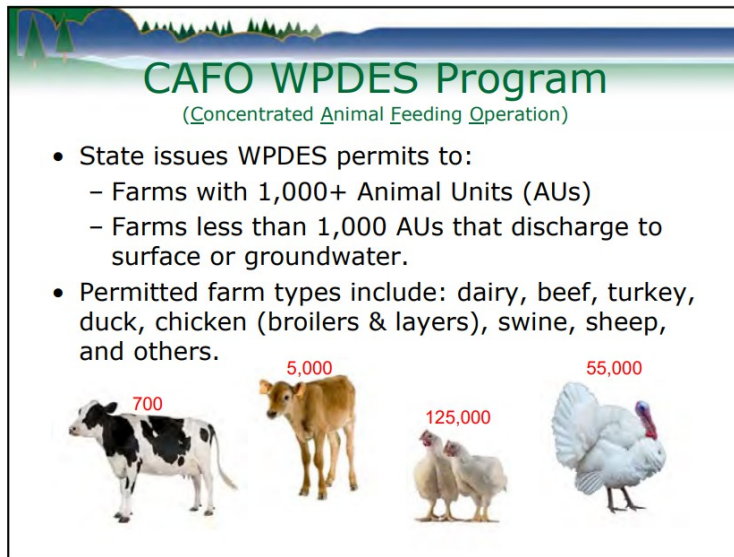
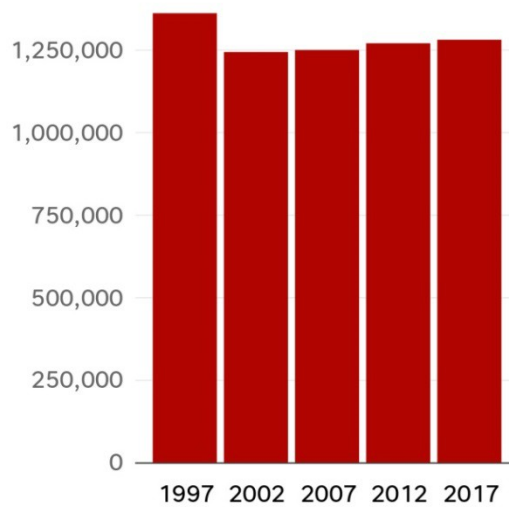
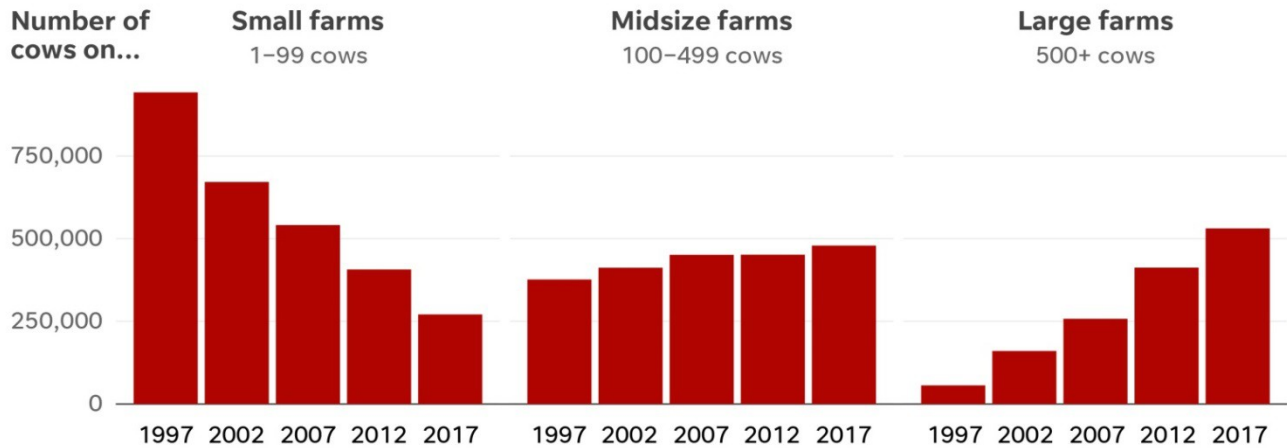


Figure 8.

In Wisconsin, the number of milk cows has remained steady ...



... though more and more are part of larger dairy operations.

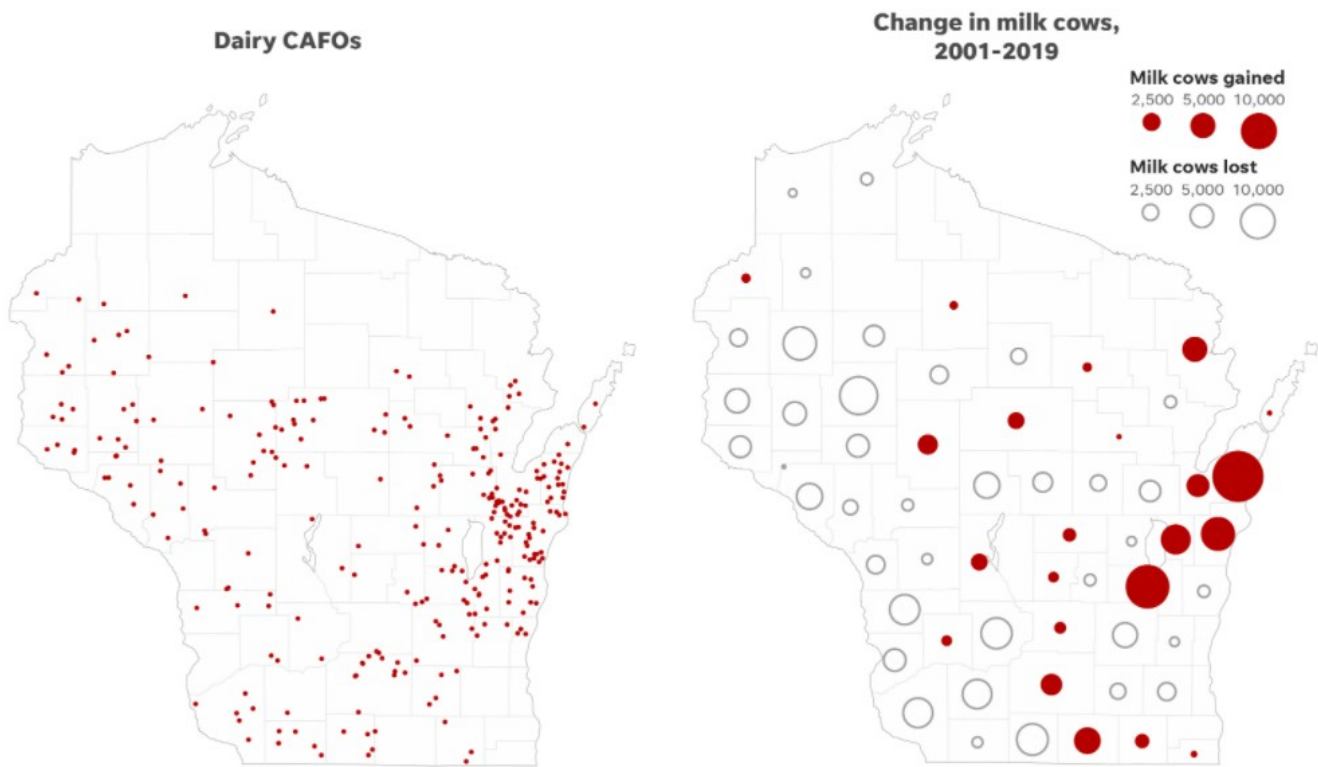


Source: U.S. Department of Agriculture

Figure 9.

Growth of large dairy farms means shift in cows

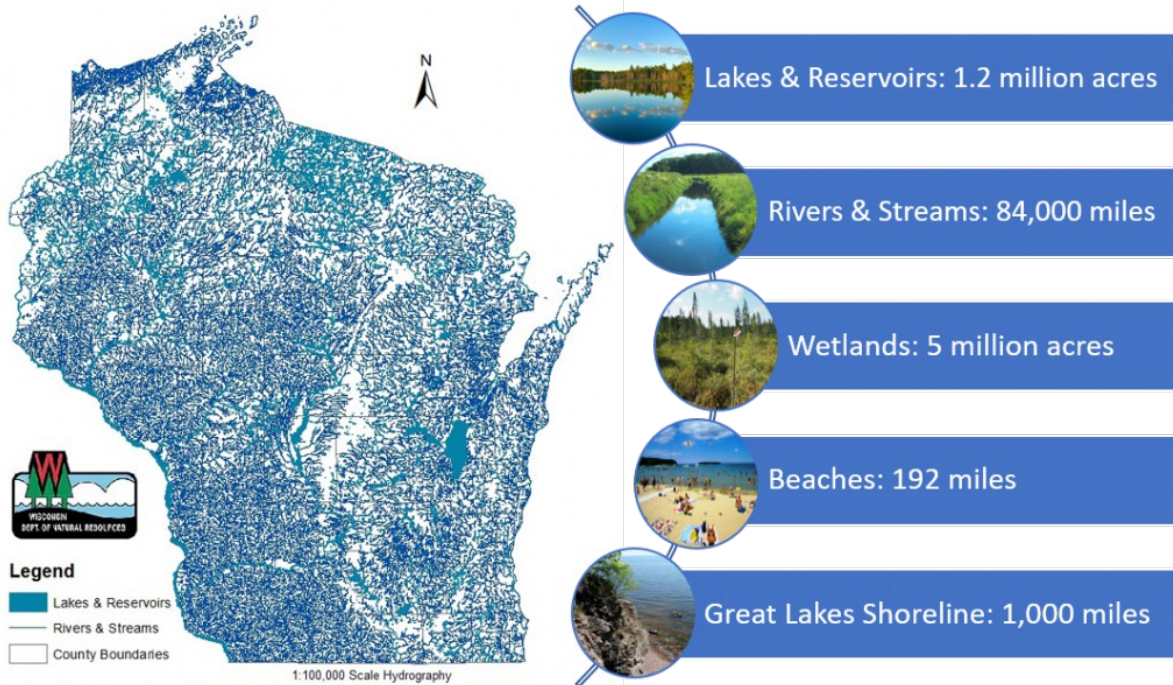
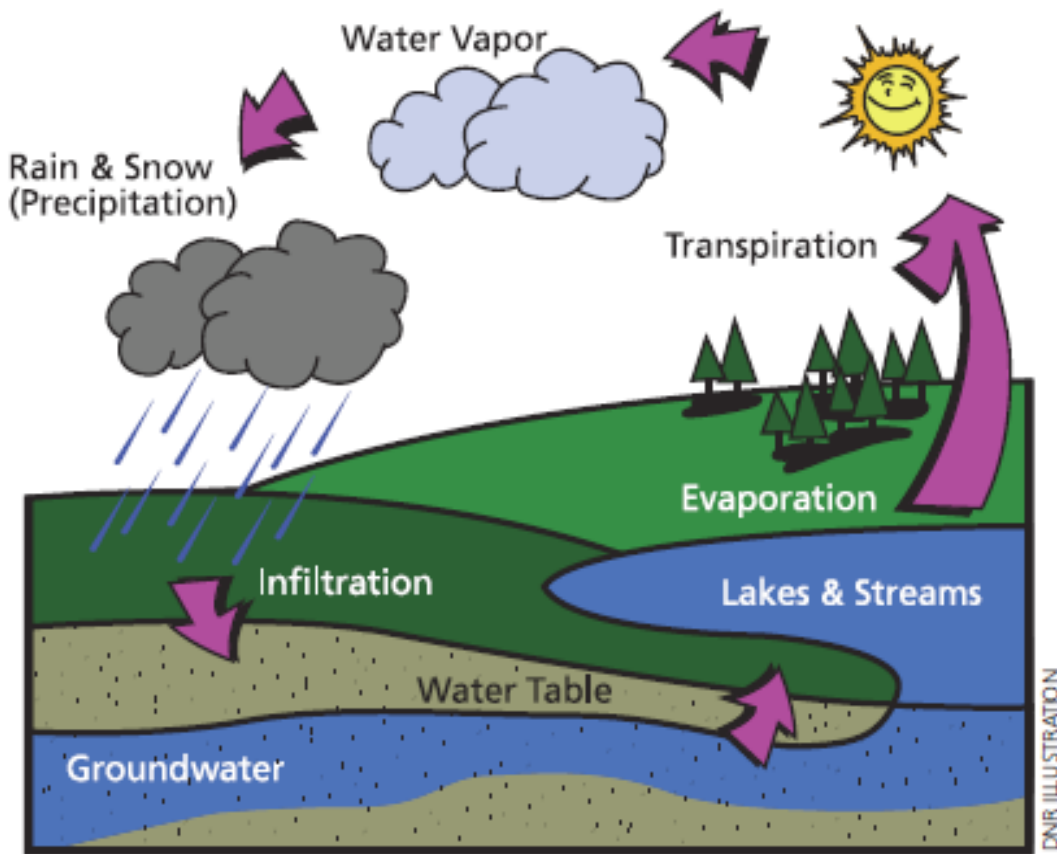
In recent years, Wisconsin has seen an increase in the number of large farms, known as concentrated animal feeding operations, or CAFOs, as small, family-owned farms close. The first map shows where the CAFOs are located. The second map shows a corresponding growth — or loss — in the number of cows in each county.



Source: Wisconsin Department of Natural Resources; U.S. Department of Agriculture; Milwaukee Journal Sentinel analysis

Figure 10.

THE WATER CYCLE



Figures 11 and 12.

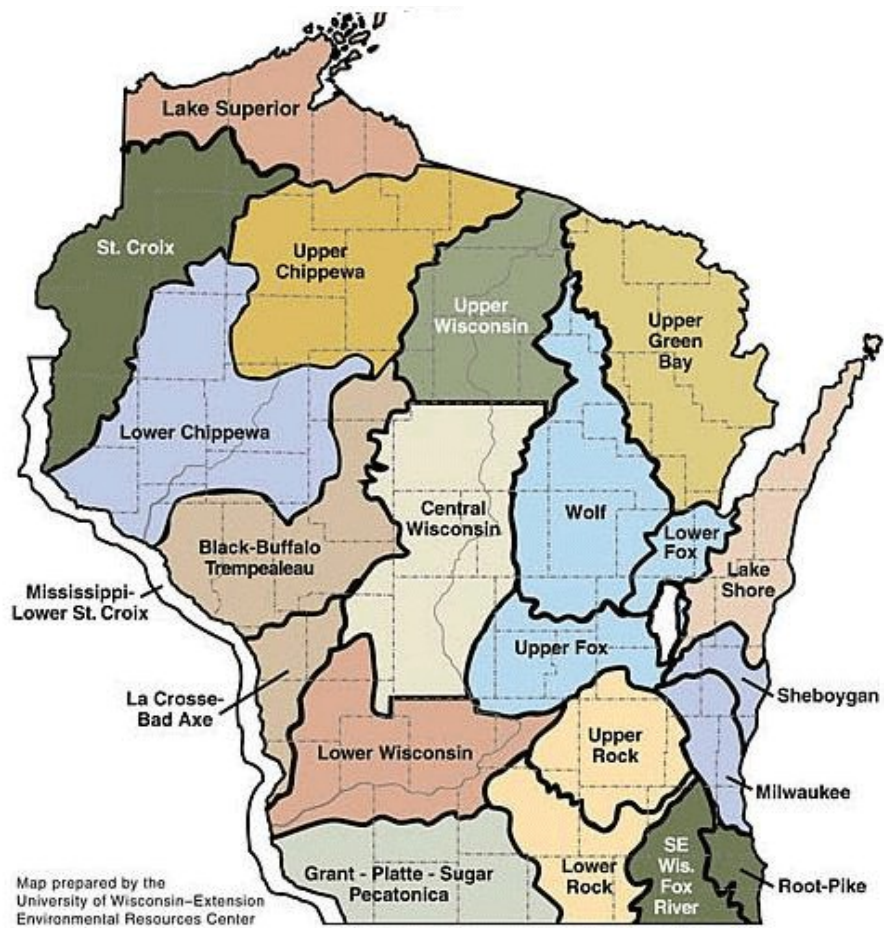


Figure 13.

Green Bay is developing a large 'dead zone'

By MICHIGAN RADIO NEWSROOM • AUG 16, 2013



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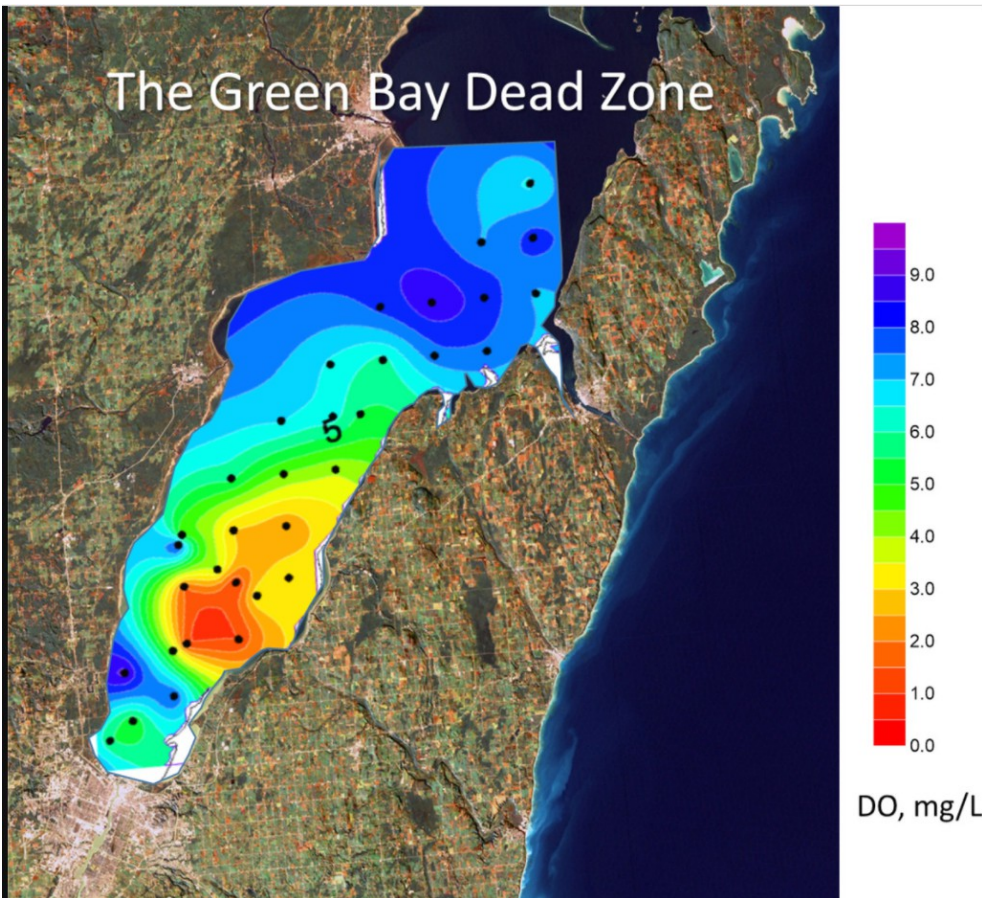
Email



Algae like this is a leading cause of dead zones

NOAA GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY / FLICKR

Figure 14.



Figures 15 and 16.

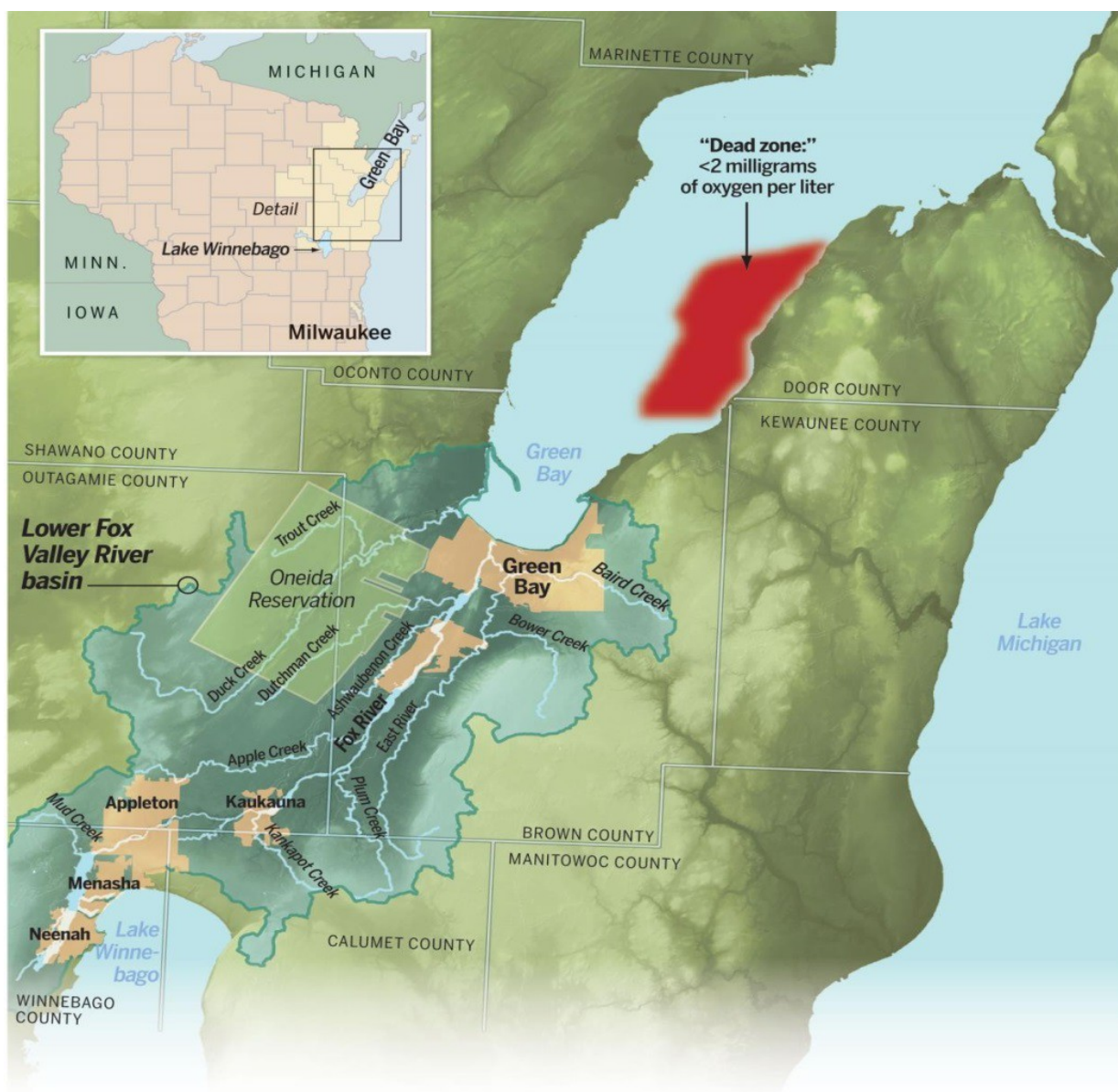


Figure 17.

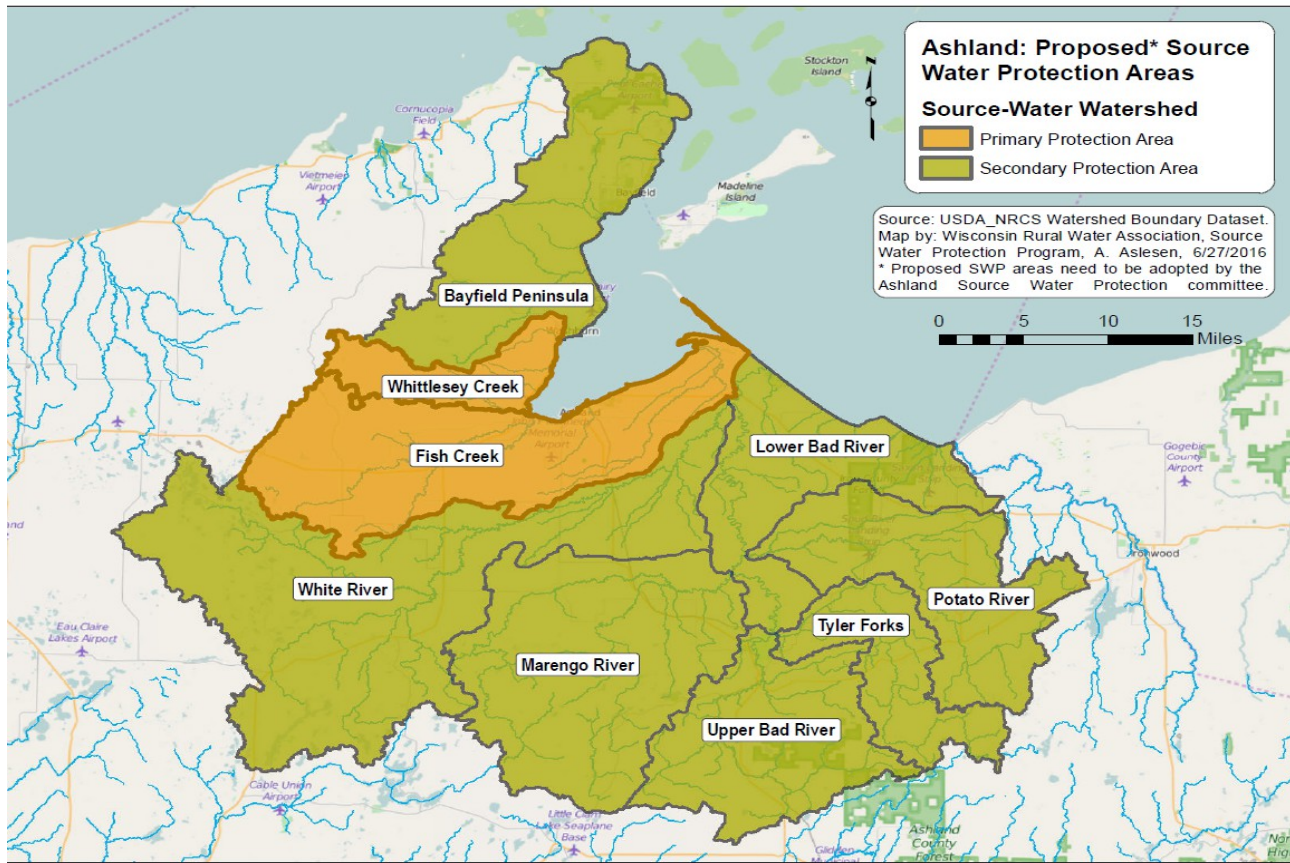
don't know, but he don't know how to make you feel no.



In August 2018, a combination of manure spreading and heavy rains damaged miles of the Sheboygan River, killing fish.

BEN UVAAS / WISCONSIN DNR

Figure 18.



Figures 19 and 20.



Figures 21 and 22.

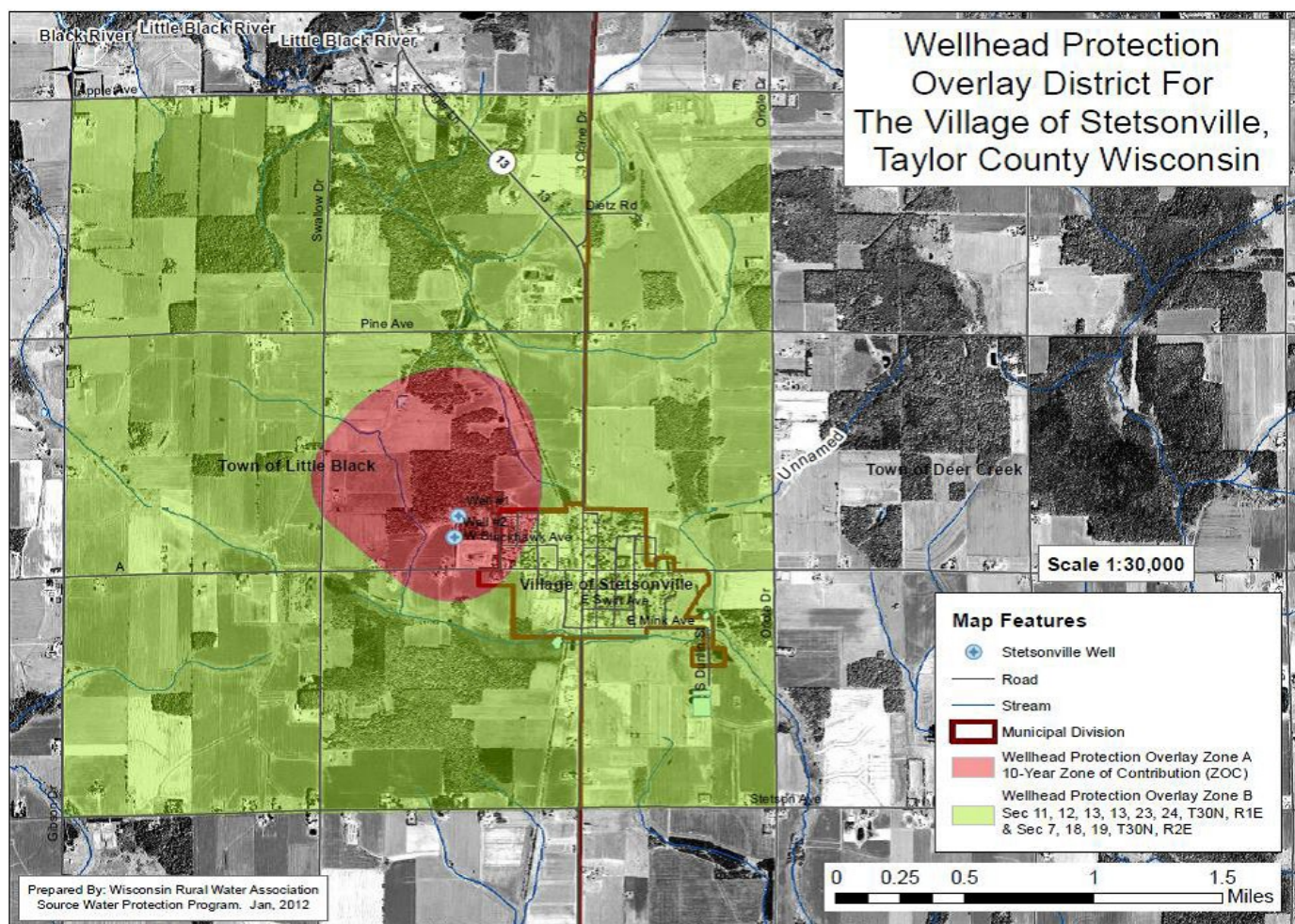
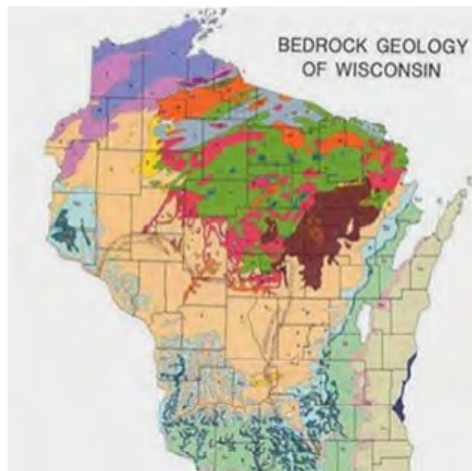


Figure 23.

Karst Topography

- Karst is a type of landscape where water dissolves the underlying bedrock.
 - Soluble bedrock
 - Dolomite
 - $\text{CaMg}(\text{CO}_3)_2$
 - Limestone
 - CaCO_3



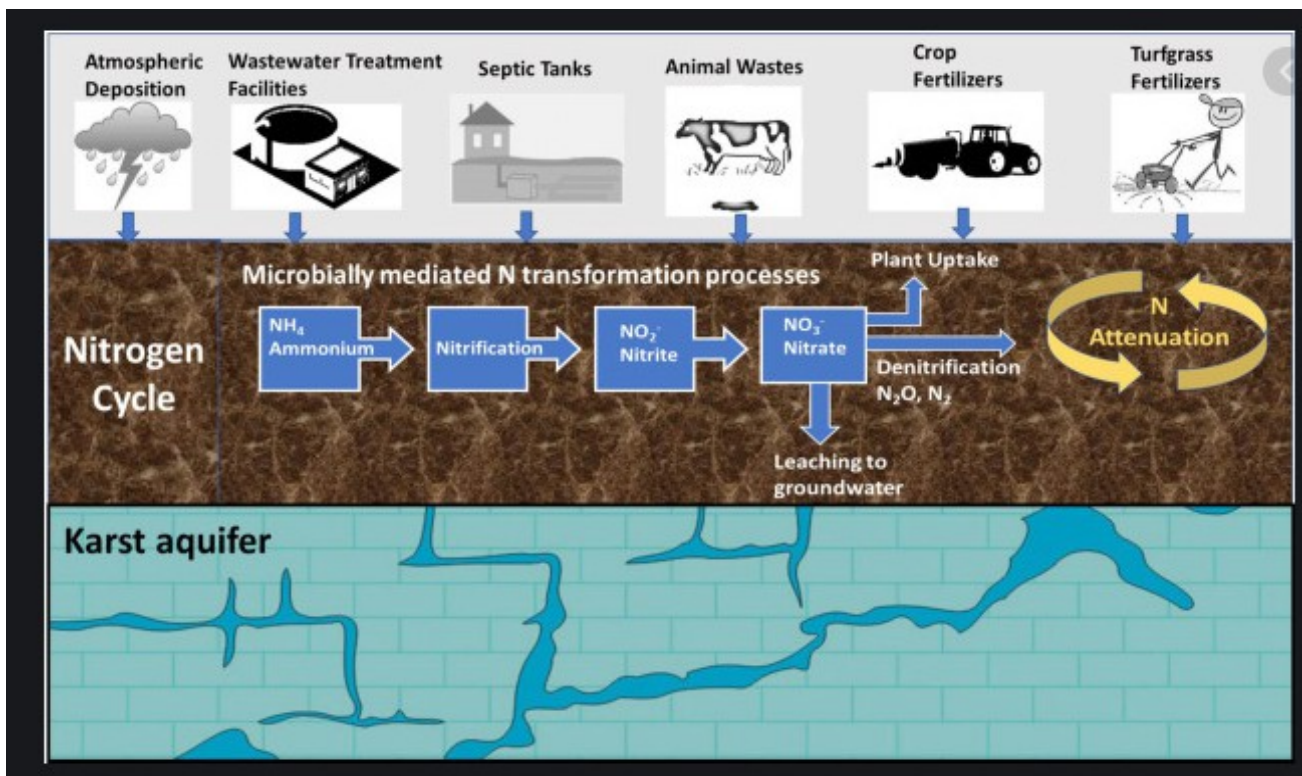
Joe Baeten

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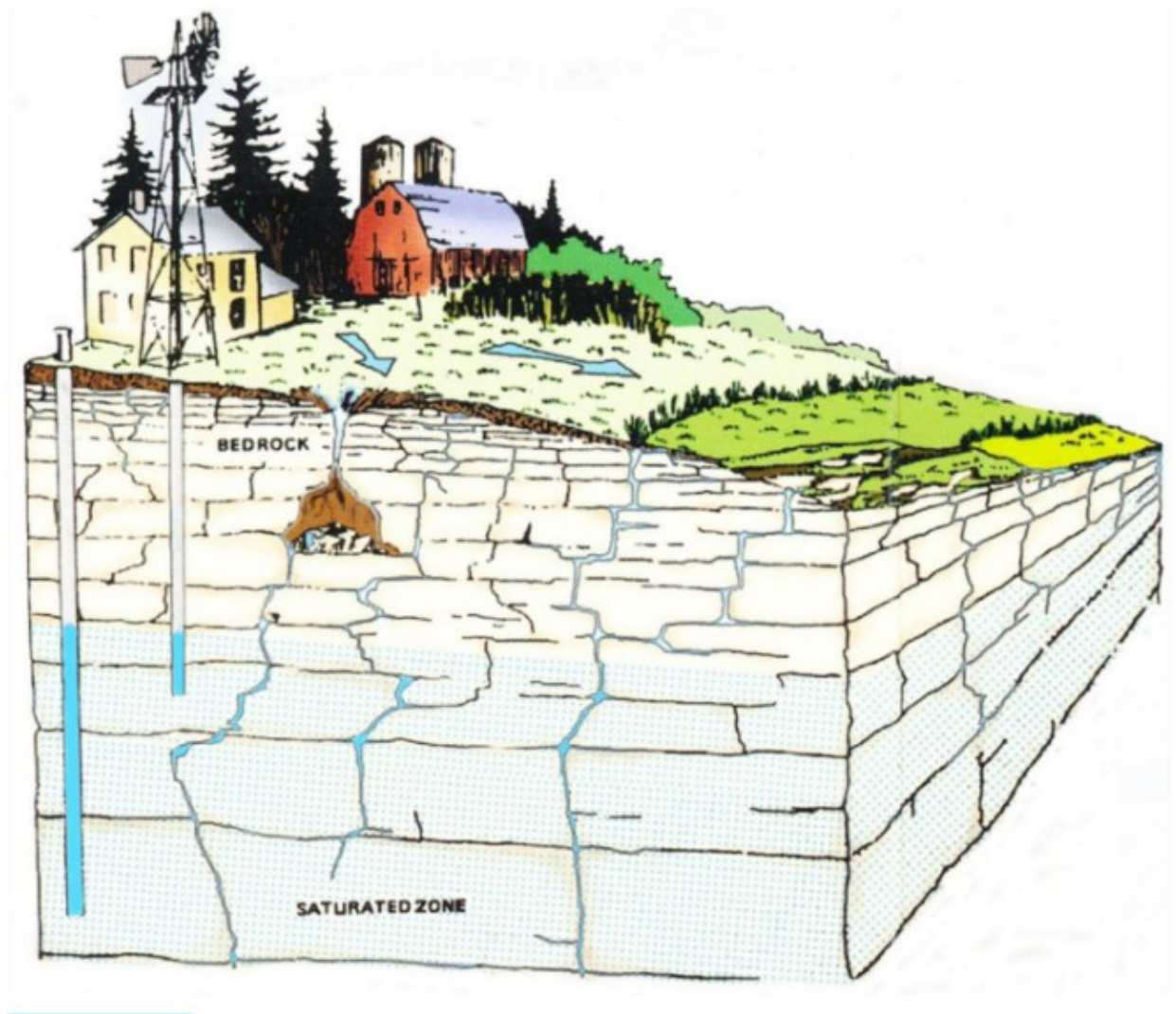
Figure 24.



A karst cliff face is exposed at the George K. Pinney Park in southern Door County. The fractured bedrock is common in Door and Kewaunee counties, allowing contaminants on the surface to move rapidly through the fractures into the groundwater.
Coburn Dukehart/Wisconsin Center for Investigative Journalism



Figures 25 and 26.



The fractured nature of the bedrock in Kewaunee County allows for water to easily infiltrate to the subsurface, especially after rain or or snowmelt. The researchers placed autosamplers in three homes to continuously test water quality during periods of recharge.

Figure 27.

THE WALL STREET JOURNAL.

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Farms, More Productive Than Ever, Are Poisoning Drinking Water in Rural America

One in seven Americans drink from private wells, which are being polluted by contaminants from manure and fertilizer

'I was pretty naive,' says Chuck Wagner, whose wells became contaminated. 'I thought you drilled a well and had good water.'

LAUREN JUSTICE FOR THE WALL STREET JOURNAL



These jars contain brown water taken from a tap in Kewaunee County that researchers tied to the recent spreading of manure on a nearby field. The soil from the field and water from the home shared the same signatures for fecal contaminants. *Courtesy Of Kewaunee County Land And Water Conservation Department*

Figures 28 and 29.

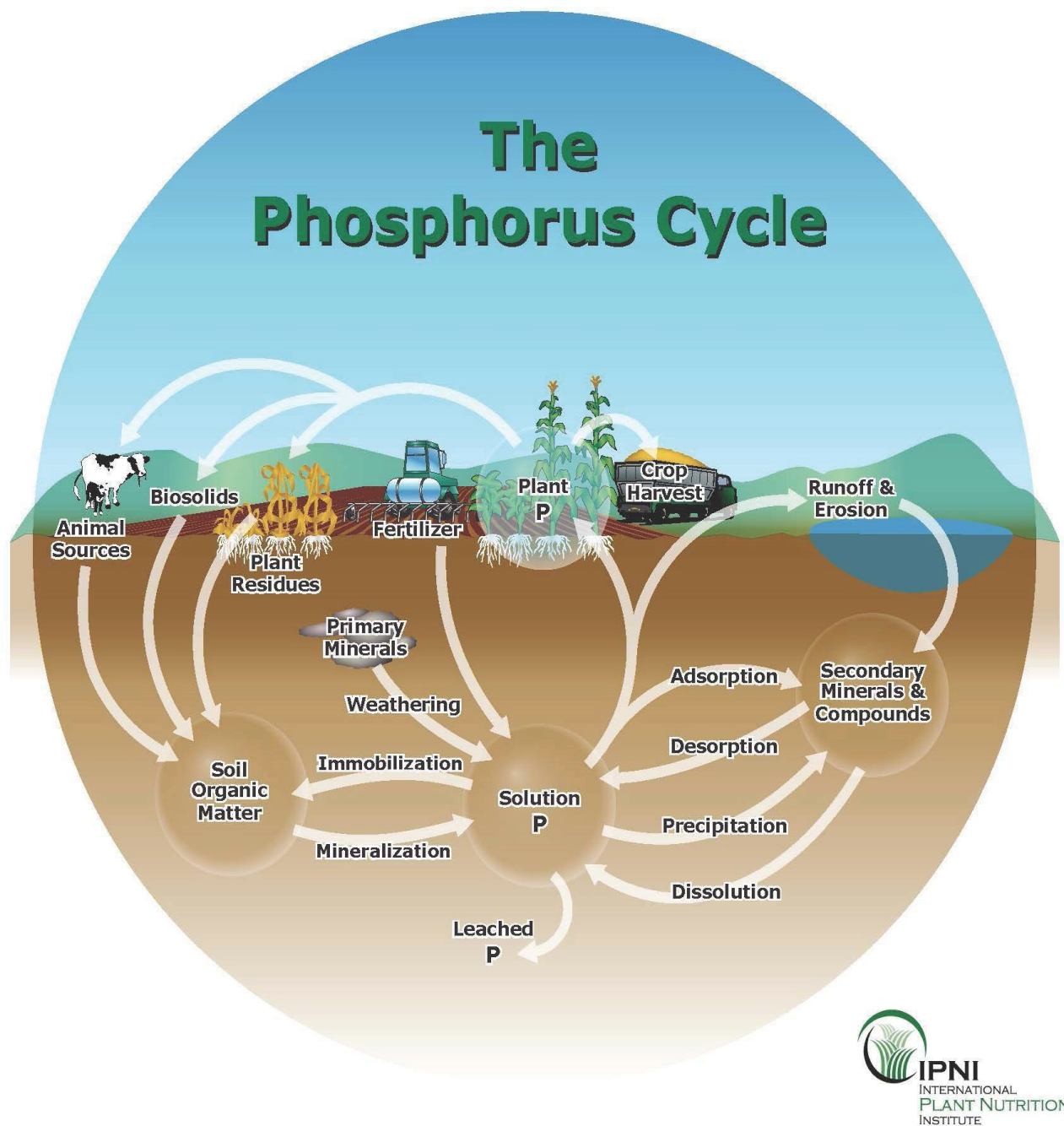


Figure 30.

economic yield and provides flexibility in nutrient management planning.

For soils that test greater than optimum, the objective of the nutrient application guidelines is to rely on the soil to supply the bulk of the nutrients needed for crop growth and to reduce the soil test level to optimum.

For soils that test less than optimum, the objective is to build-up soil test levels to the optimum category.

This publication is available from the Nutrient and Pest Management (NPM) program.

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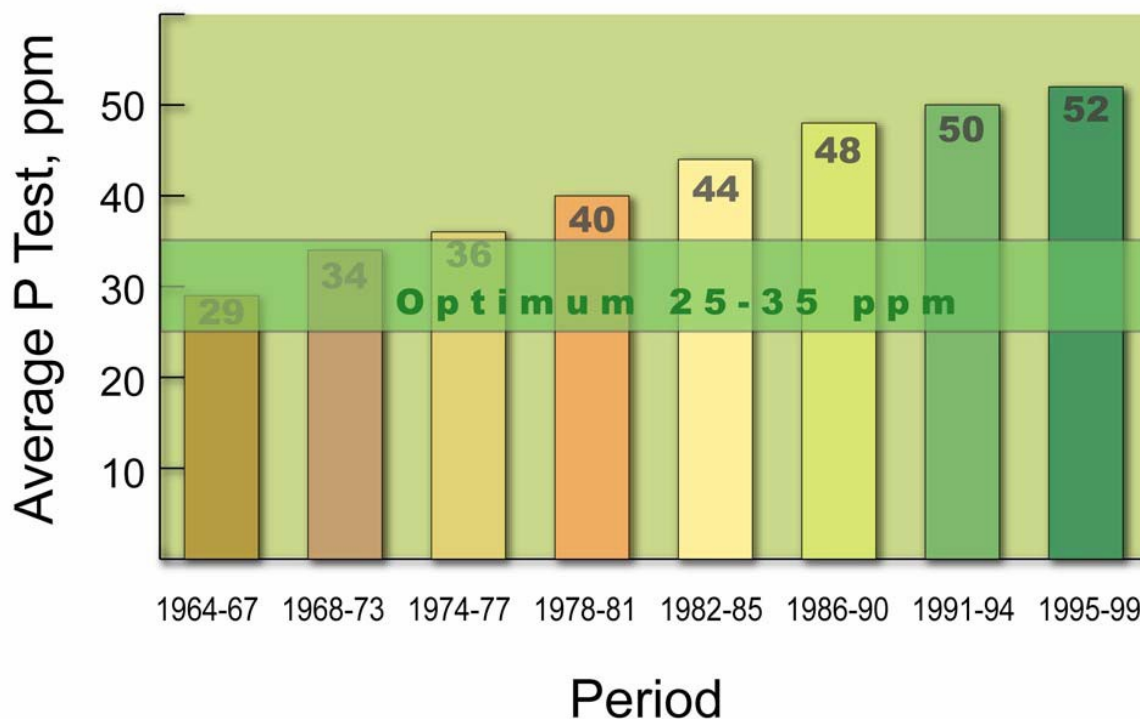


To determine your soil test phosphorus (P) category:

- 1) Choose the highest demanding crop in your rotation.
- 2) Choose the soil group for the predominant soil in the field.
- 3) Find your soil test category by using the analysis number for phosphorus from your soil test results.

Soil group	Soil test category				
	Very low (VL)	Low (L)	Optimum (O)	High (H)	Excessively high (EH)
demand level 1: Corn grain, Soybean, Clover, Small grains (but not wheat), Grasses, Oilseed crops, Pasture					
Loamy	< 10	10–15	16–20	21–30	> 30
Sandy, Organic	< 12	12–22	23–32	33–42	> 42
demand level 2: Alfalfa, Corn silage, Wheat, Beans, Sweet Corn, Peas, Fruits					
Loamy	< 12	12–17	18–25	26–35	> 35
Sandy, Organic	< 18	18–25	26–37	38–55	> 55
demand level 3: Tomato, Pepper, Brassicas, Leafy greens, Root, Vine, and Truck crops					
Loamy	< 15	15–30	31–45	46–75	> 75
Sandy, Organic	< 18	18–35	36–50	51–80	> 80
demand level 4: Potato					
Loamy	< 100	100–160	161–200	> 200	
Sandy, Organic	< 30	30–60	61–90	91–120	> 120

If the desired crop is not listed on the table or you are unsure of your soil group, consult UWEX publication A2809 Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin's tables 4.1 and 4.2.



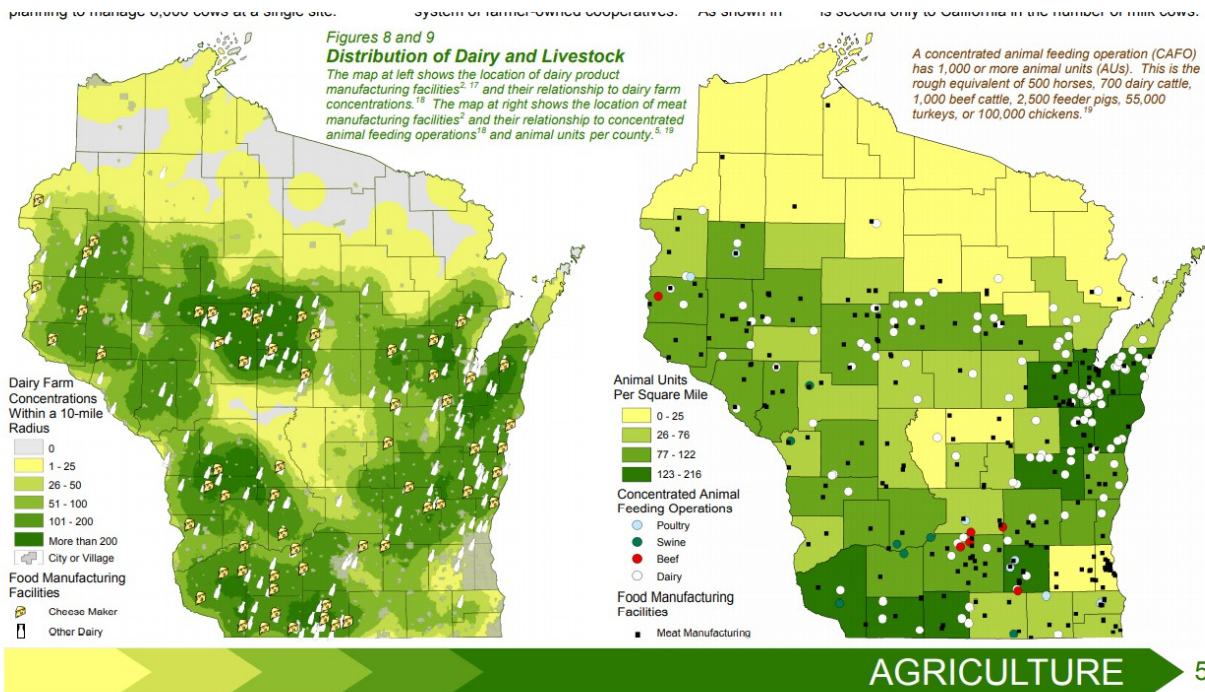
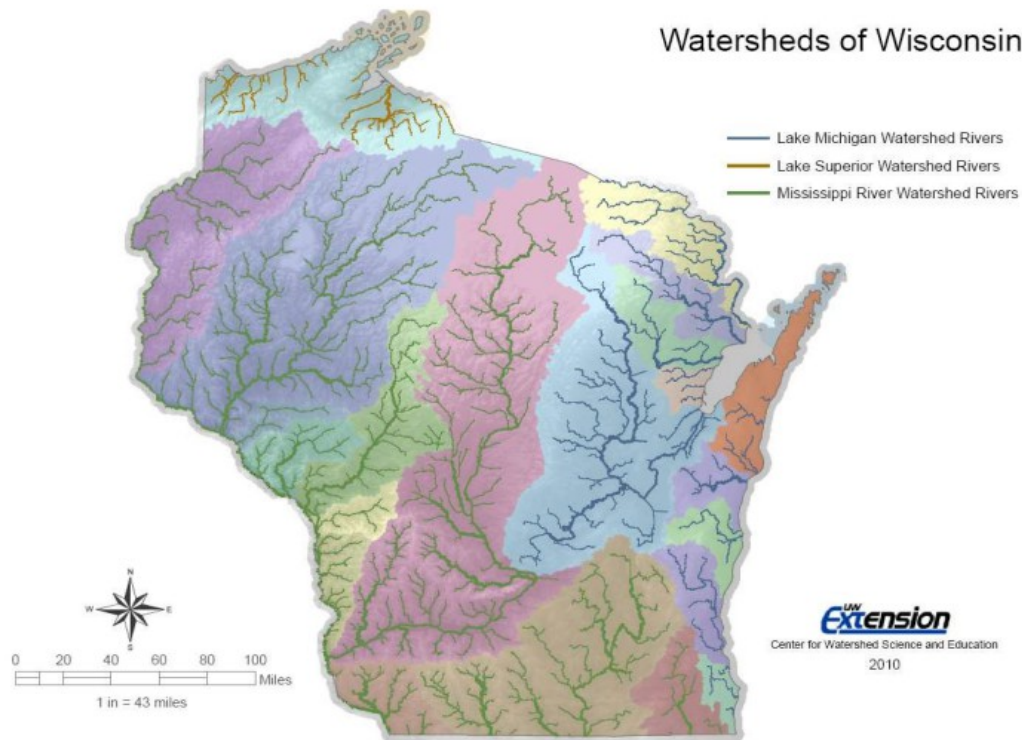
Nutrient and Pest Management Program 2002

Figures 31 and 32.



Figure 35. (need clearer and more current graphic here)

The basins can be divided into regional watersheds....



Figures 36 and 37.

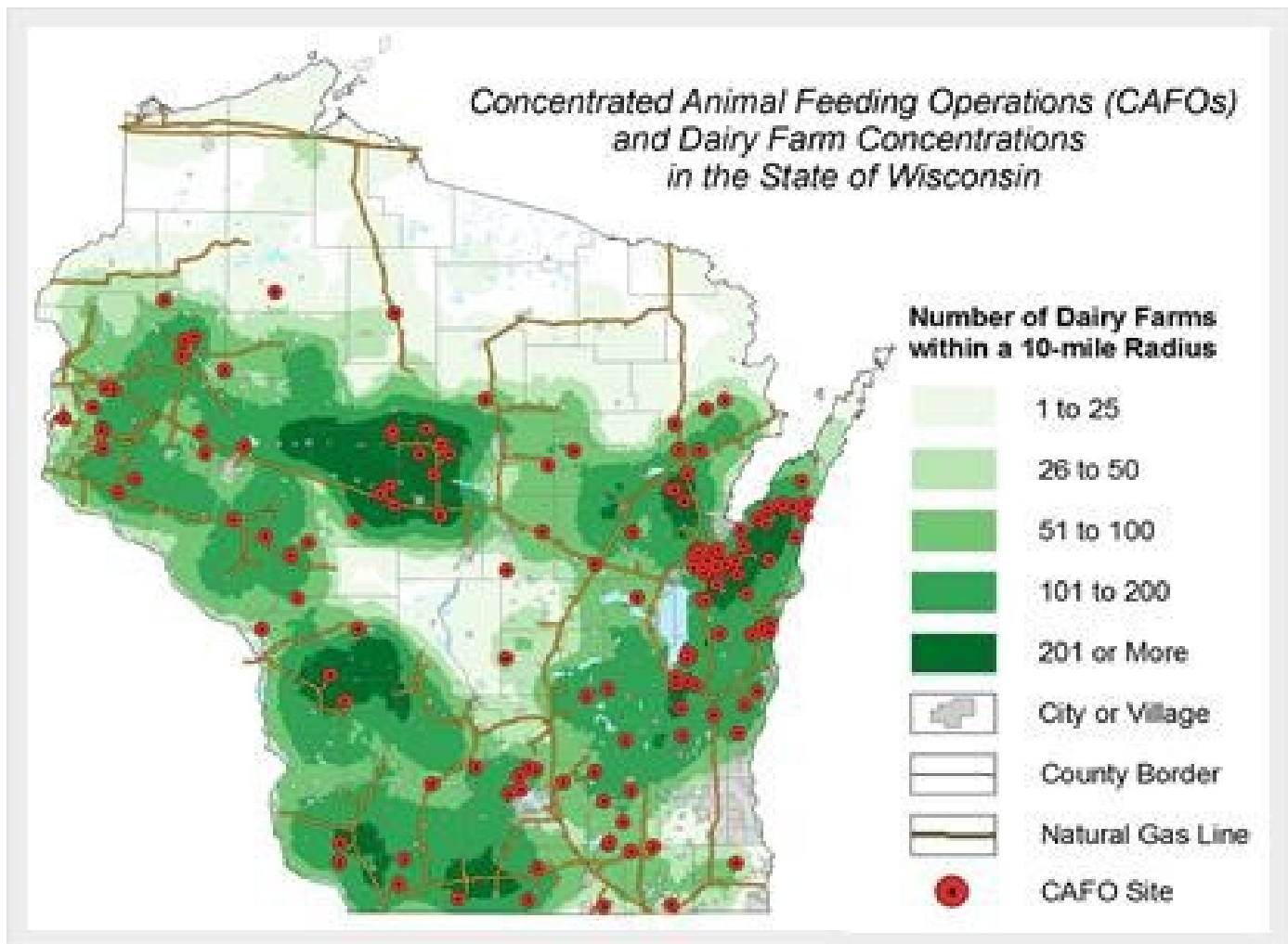
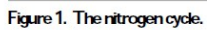


Figure 38. Since both P and nitrogen (N) are macro-nutrients in crop production, where we find excessively high P build-up in agricultural fields/soils, we are also most likely to find excessive applications of N on these same fields (over time), resulting in increased potential and risk of nitrate leaching (under these fields) to groundwater and public/private drinking water supplies.

The diagram illustrates the water cycle with the following components and processes:

- Atmosphere:** Includes a smiling sun, white clouds labeled "Water Vapor", and grey clouds labeled "Rain & Snow (Precipitation)".
- Land:** A green hillside with trees. A pink arrow labeled "Transpiration" points from the trees to the clouds. Another pink arrow labeled "Evaporation" points from a body of water to the clouds.
- Water Bodies:** A blue area labeled "Lakes & Streams".
- Ground:** A brown layer labeled "Groundwater". A pink arrow labeled "Infiltration" points from the rain/snow down into the ground. Another pink arrow labeled "Water Table" points from the groundwater back up towards the lakes and streams.

Vertical text on the right side: "NIR ILLUSTRATION"



Figures 39 and 40.

Groundwater: Wisconsin's Buried Treasure

- 95% of Wisconsin Communities
- 850,000 private residential wells
- Supplies almost all water for agriculture – livestock, irrigation, dairy operations
- 1/3 of industrial water use
- 1/2 of commercial water use
- Supplies the majority of the water for Wisconsin's lakes and streams

75% of Wisconsin residents



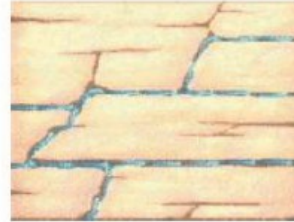
Figure 41.

Aquifers: Our groundwater storage units

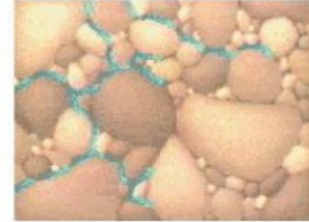
Aquifers are geologic formations that store and transmit groundwater.

The aquifer properties determine how quickly groundwater flows, how much water an aquifer can hold and how easily groundwater can become contaminated. Some aquifers may also contain naturally occurring elements that make water unsafe.

Wisconsin's geology is like a layered cake. Underneath all of Wisconsin lies the Crystalline bedrock which does not hold much water. Think of this layer like the foundation of your house. All groundwater sits on top of this foundation. Groundwater is stored in the various **sandstone**, **dolomite** and **sand/gravel** aquifers above the **crystalline bedrock** layer. The layers are arranged in the order which they formed, oldest on the bottom and youngest on top.



Water and contaminants can move quickly through cracks and fractures.



Water moving through tiny spaces in between sand particles or sandstone moves slower and allows for filtration of some contaminants.

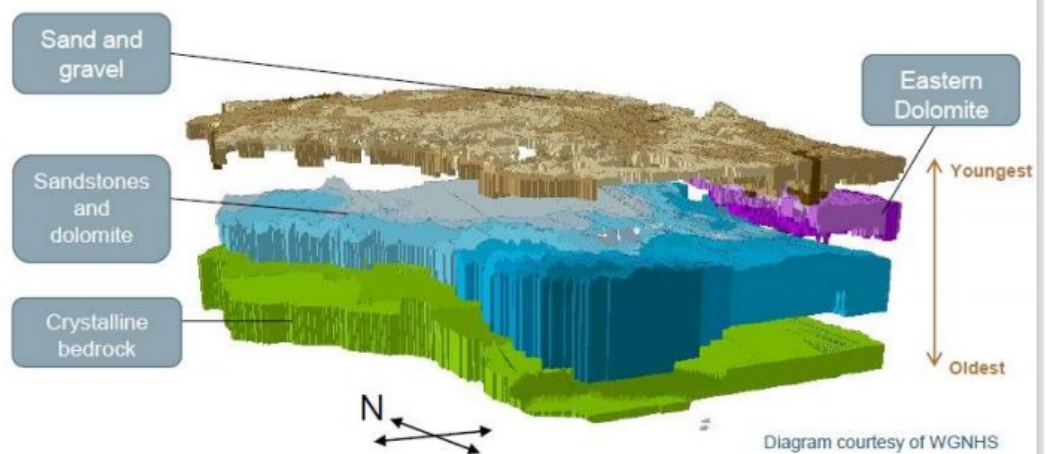


Figure 42.

Groundwater Movement

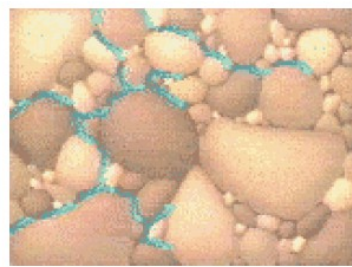
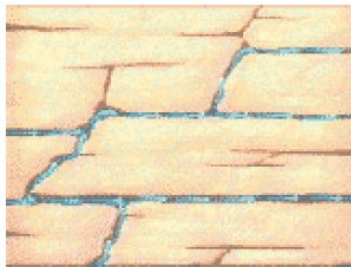
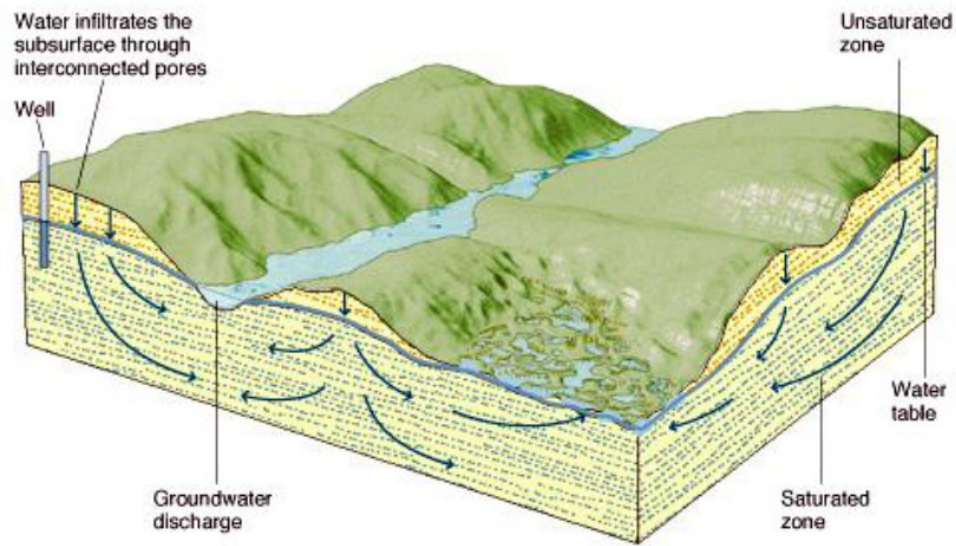
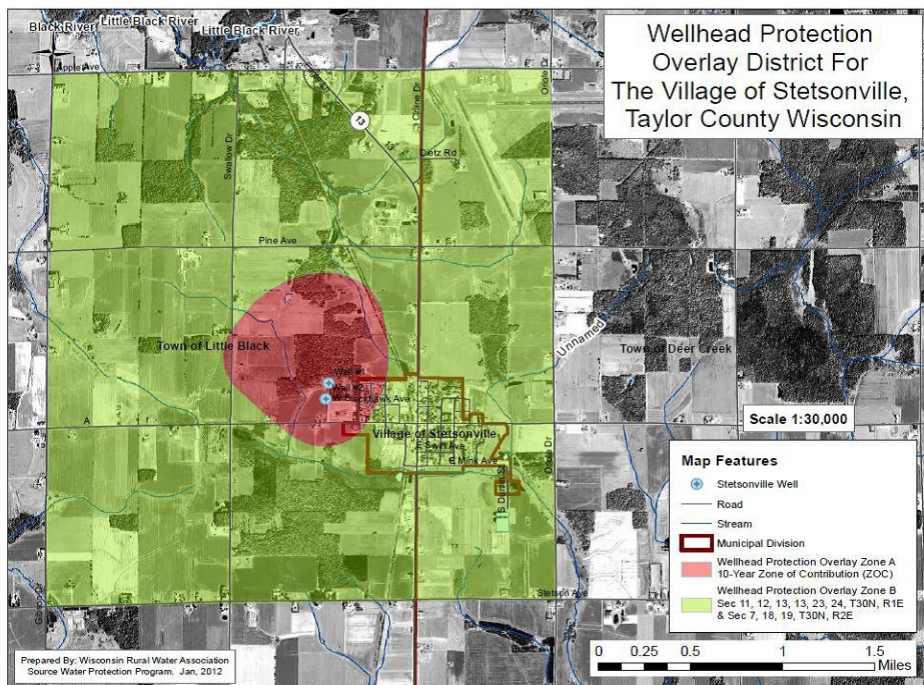
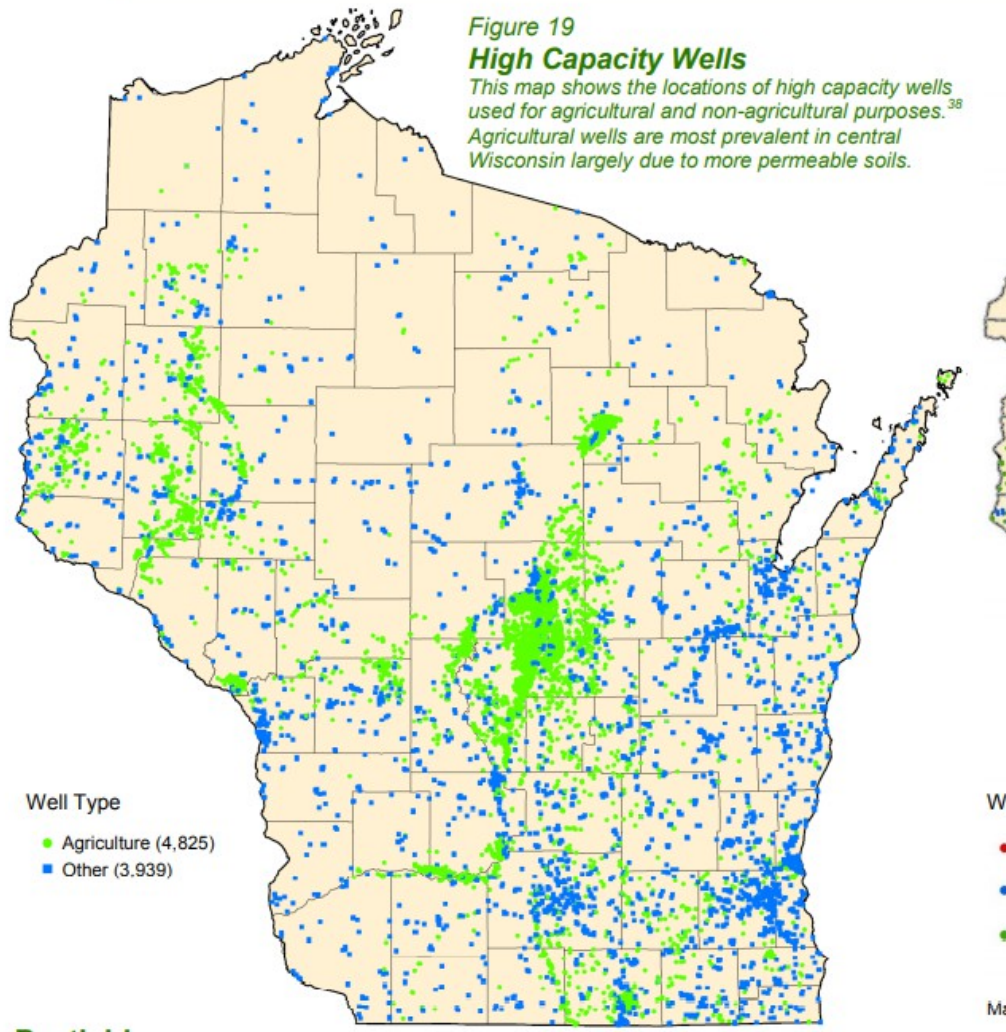


Figure 43.

Figure 19
High Capacity Wells

This map shows the locations of high capacity wells used for agricultural and non-agricultural purposes.³⁸ Agricultural wells are most prevalent in central Wisconsin largely due to more permeable soils.



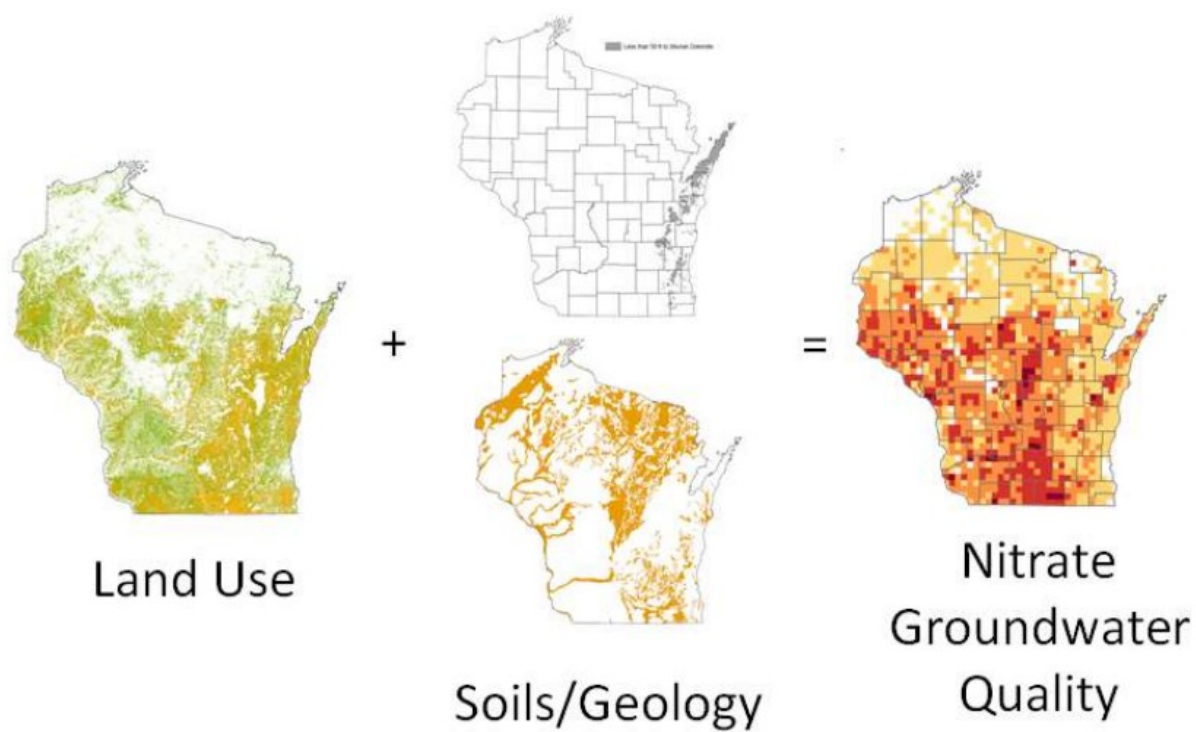
Nitrate in Wisconsin Groundwater: Sources and Concerns

Larry G. Bundy, Lynda Knobeloch, Bruce Webendorfer, Gary W. Jackson and Byron H. Shaw



Little nitrate moves into groundwater from well-managed, non-irrigated farmland.

Figure 46.



Kevin Masarik, Center for Watershed Science and Education

kmasarik@uwsp.edu

<http://www.uwsp.edu/cnr-ap/watershed>

Figure 47.

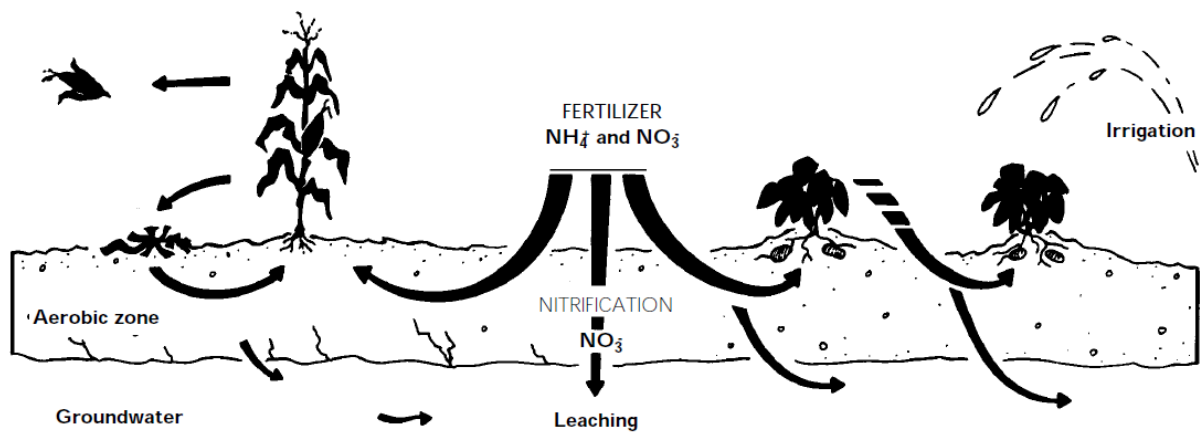
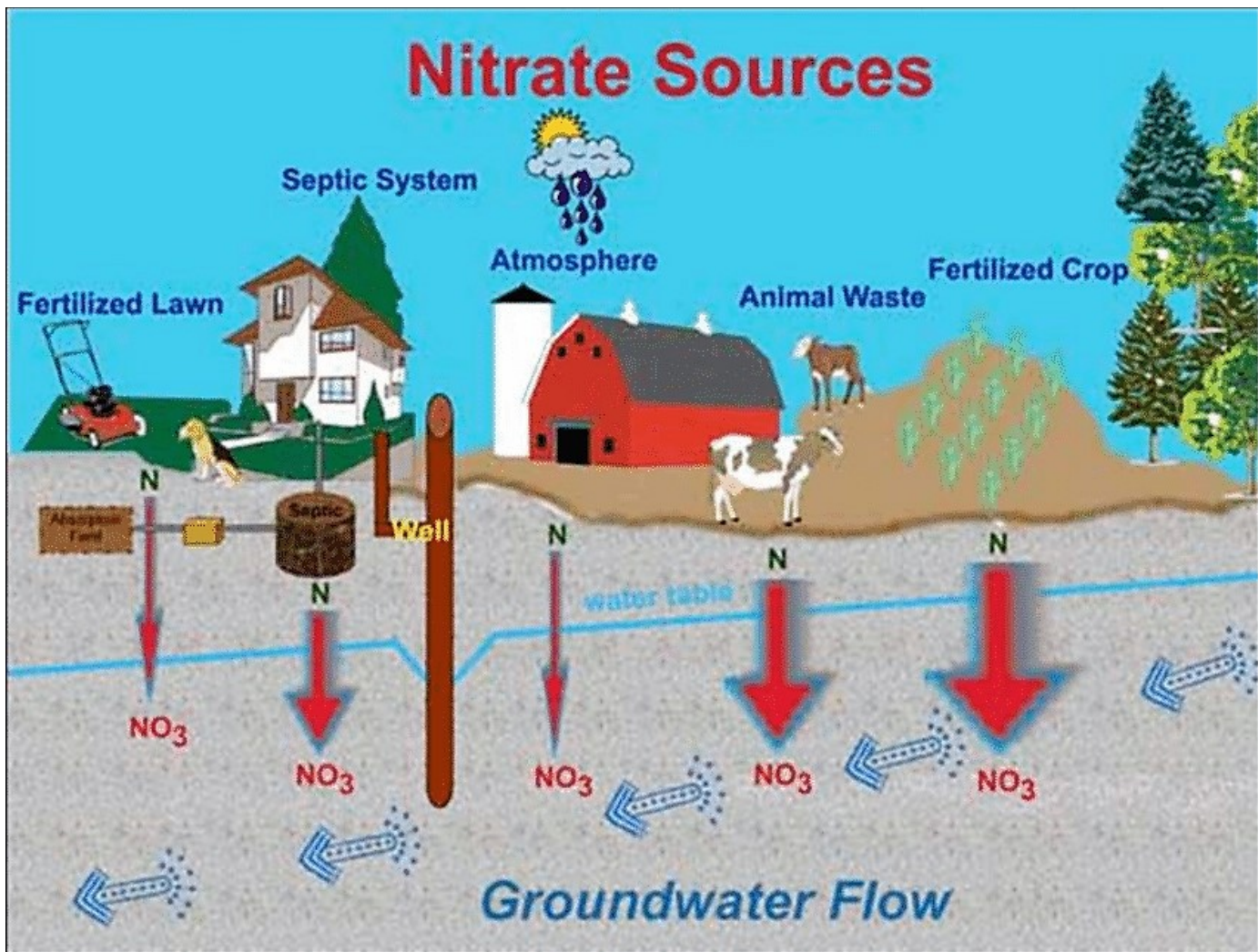


Figure 2. Unused nitrate can leach out of the soil under rain-fed agriculture (left) or irrigated agriculture (right).

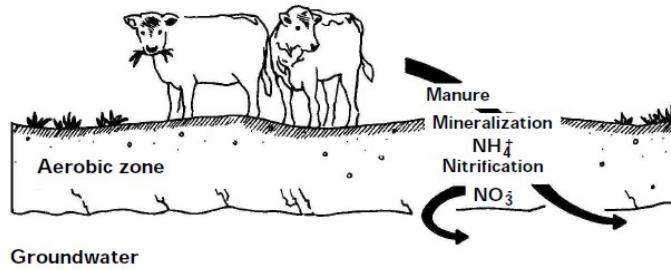


Figure 3. In some areas, animal manures are an important nitrate source.

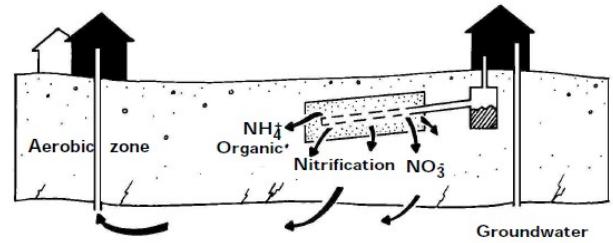
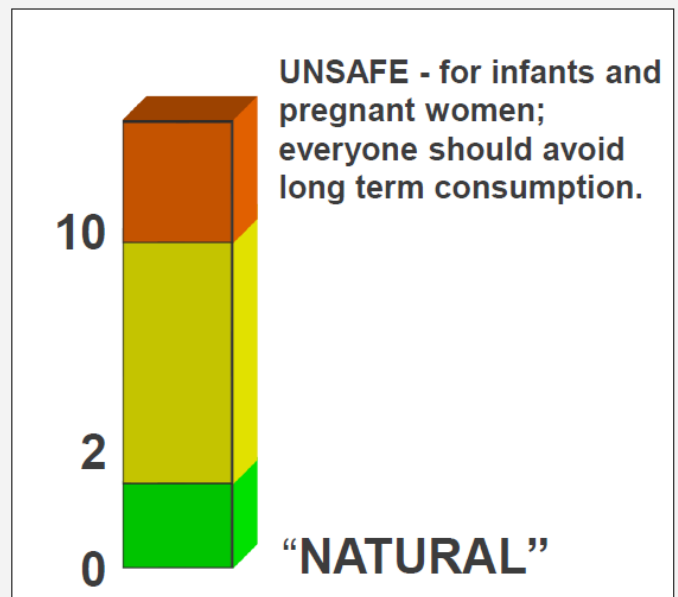


Figure 4. Septic tank systems can be a source of nitrate.

Test Important to Health

Nitrate Nitrogen

- **Greater than 10 mg/L**
Exceeds State and Federal Limits for Drinking Water
- **Between 2 and 10 mg/L**
Some Human Impact
- **Less than 2.0 mg/L**
"Transitional"
- **Less than 0.2 mg/L**
"Natural"



Nitrate and Human Health

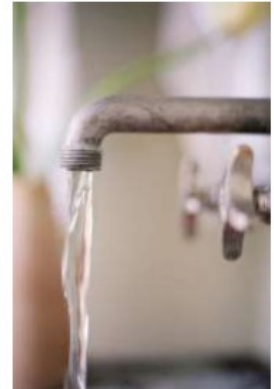
Infants and pregnant women

- Methemoglobinemia or “blue-baby syndrome”
- Possible correlation to central nervous system malformations

Adults

Possible correlations to:

- Non-Hodgkin’s lymphoma
- Various cancers (ex. gastric, bladder)
- Thyroid function
- Diabetes in children



*Many are statistical studies that provide correlation between nitrate and health problems

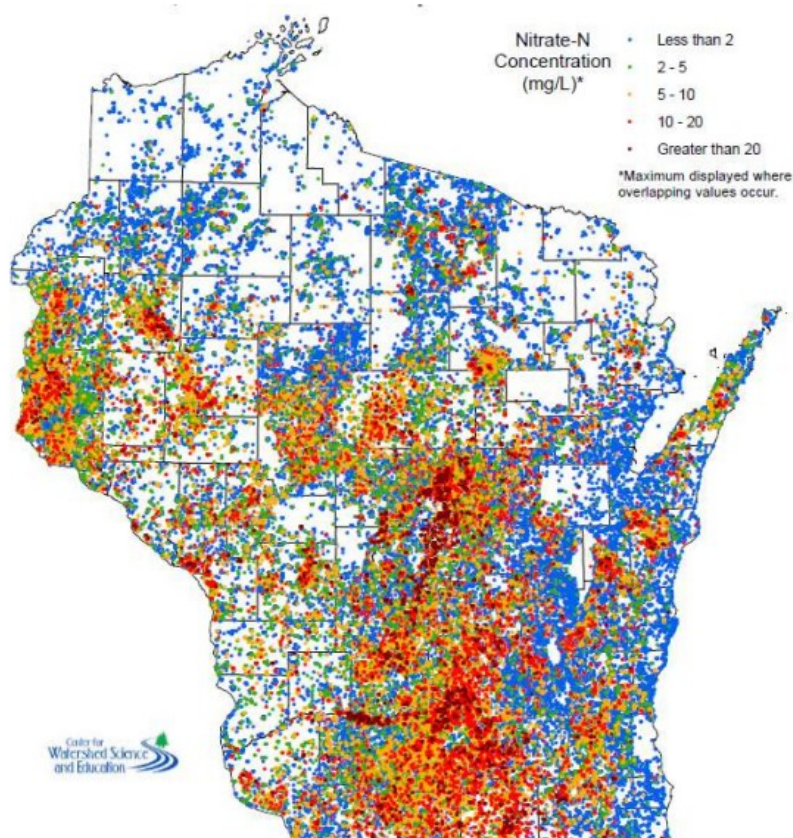
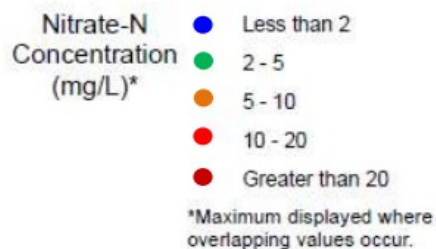
*Studies don’t always agree, but cannot say with certainty that nitrate poses no health risk.

Nitrate often indicator of other possible contaminants
(ex. other agricultural contaminants, septic effluent, etc.)

[Wisconsin Groundwater Coordinating Council, 2015](#); [Weyer, 1999](#)

Figure 52.

Private Well Nitrate Concentrations



Disclaimer: This map represents well water data in the Center for Watershed Science and Education database, WI DNR Groundwater Retrieval Network. It does not represent all known private wells.

Figure 53.

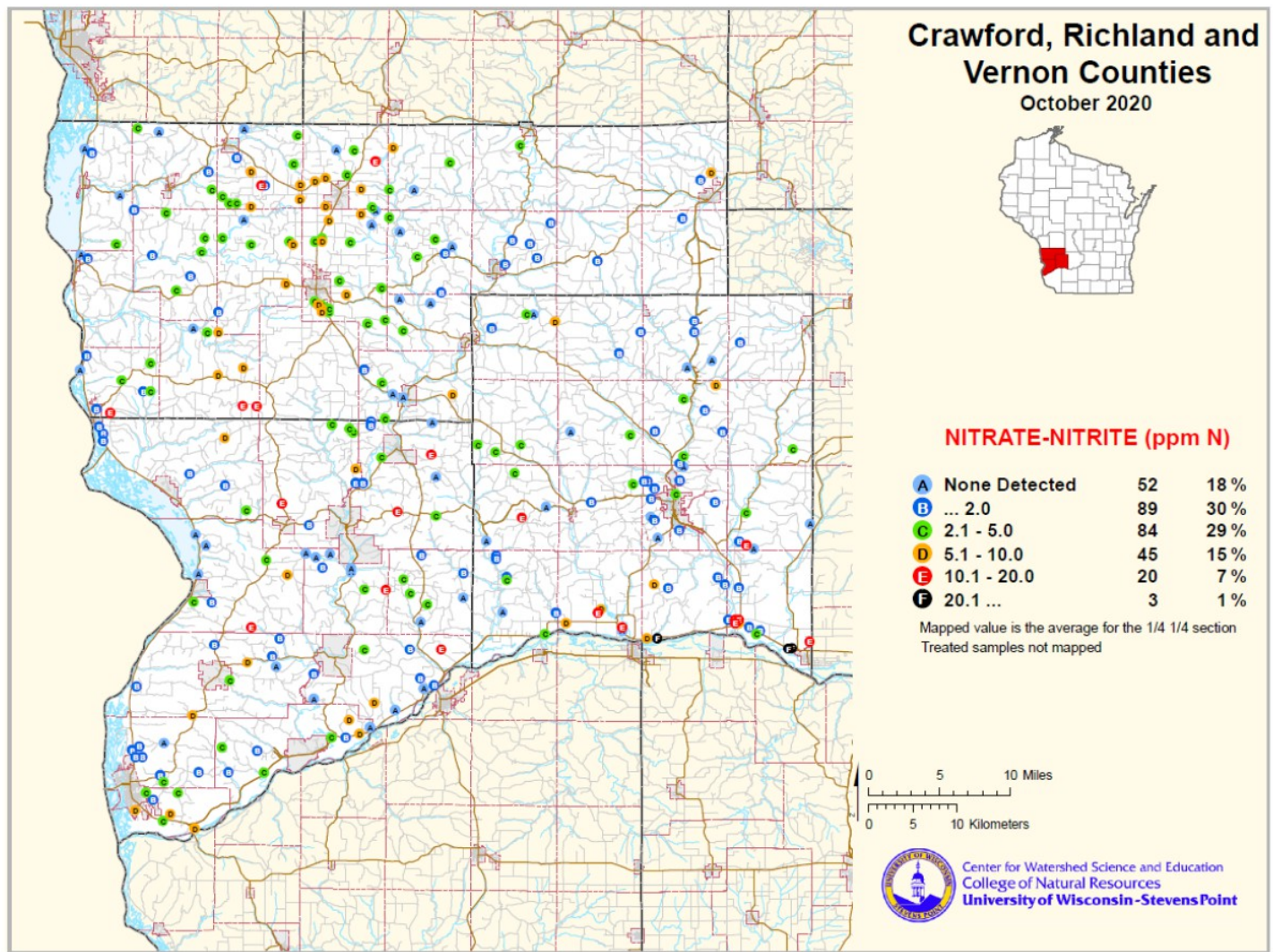


Figure 54.

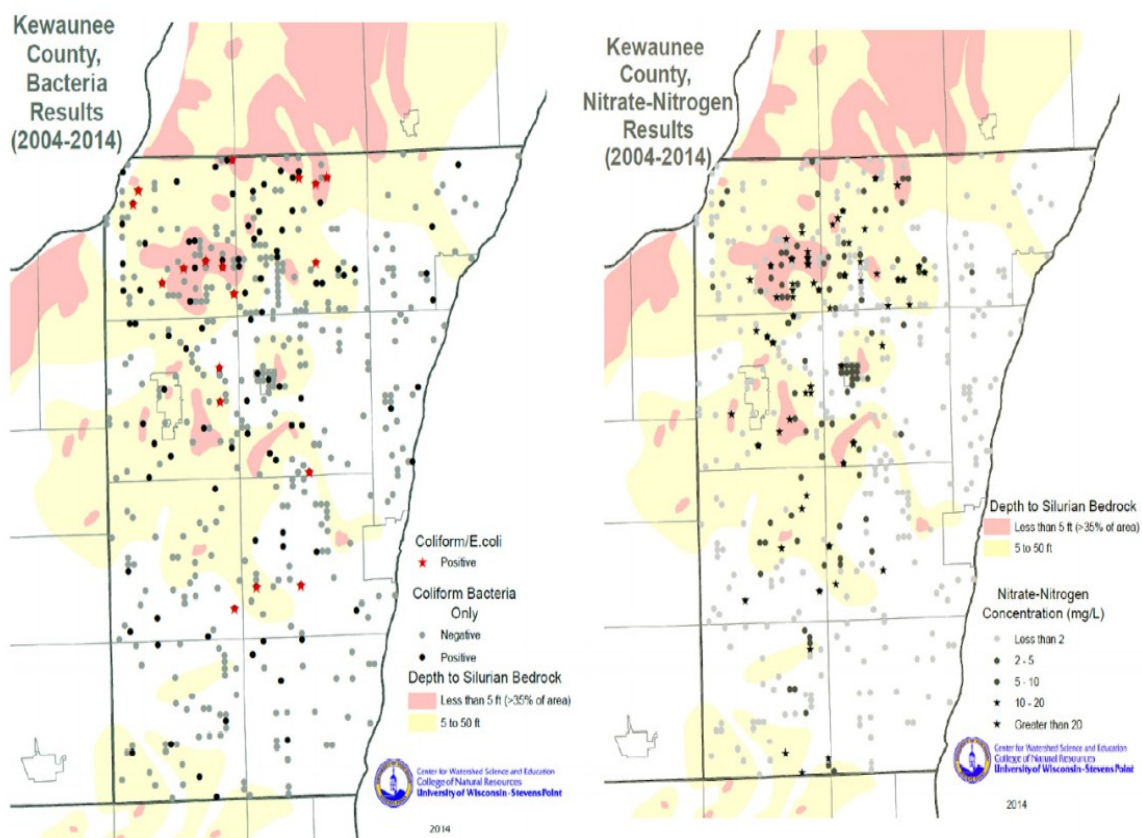


Figure 1. Existing water-quality data for Kewaunee County (Bonness and Masarik, 2014)

Figure 55.