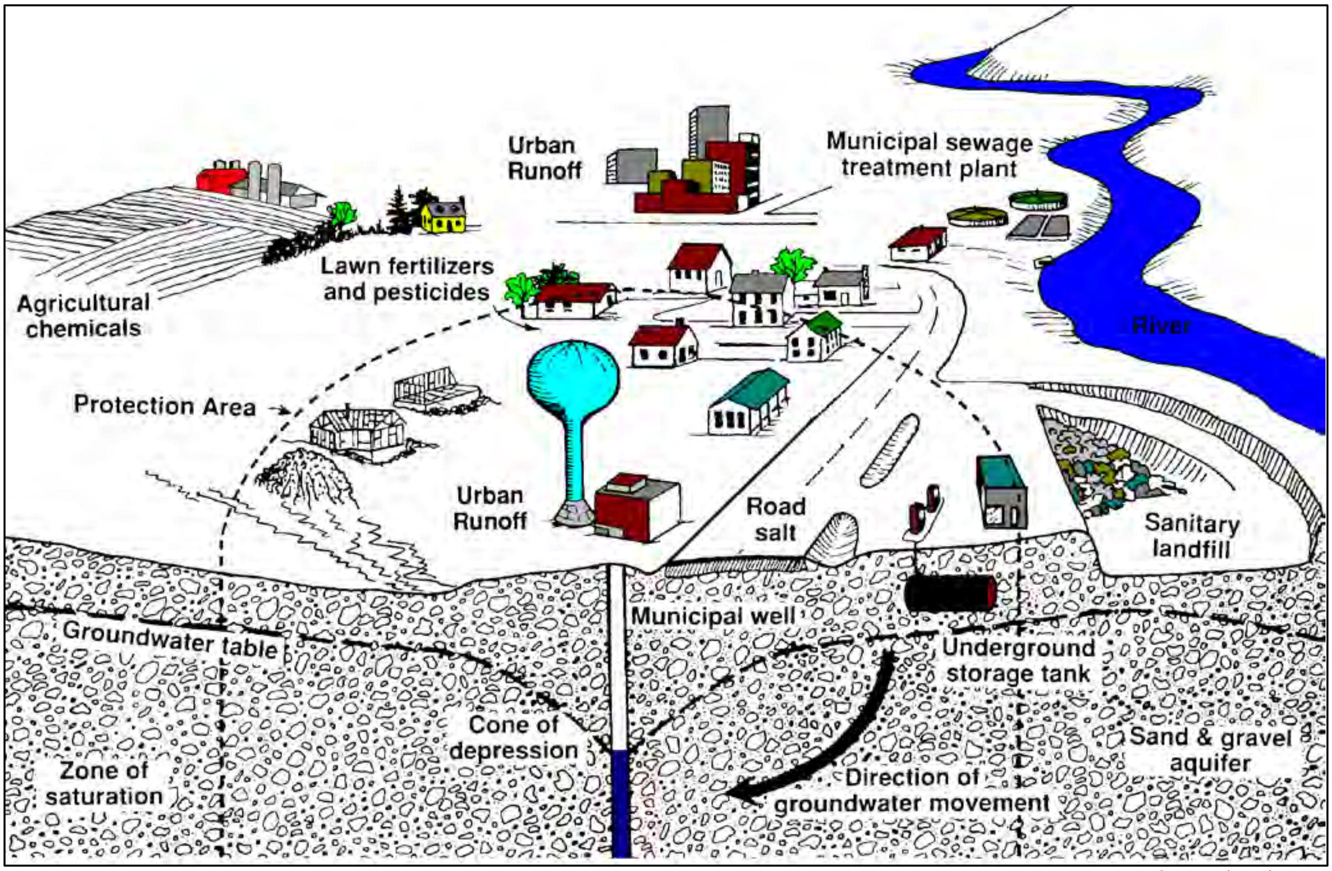
Dane County Groundwater Protection Planning Framework



Source: Wisconsin DNR

Appendix G: Groundwater Element of the Dane County Water Quality Plan

March 2017

Capital Area Regional Planning Commission

State of Wisconsin
DEPARTMENT OF NATURAL RESOURCES
101 S. Webster Street
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WISCONSIN DEPT. OF NATURAL RESOURCES

March 30, 2017

DNR File No. DC-0182

Mr. Steve Steinhoff, Deputy Director
Capital Area Regional Planning Commission
City County Building, Room 362
210 Martin Luther King Jr. Blvd.
Madison, WI 53703

Subject: Dane County Water Quality Management Plan - Appendix G
Groundwater Element - 2017 Update

Dear Mr. Steinhoff:

We have completed our review of the Dane County Water Quality Plan Groundwater Element (Appendix G) which was submitted to the Department by the Capital Area Regional Planning Commission in January 2017. The Department hereby approves of this update to the Dane County Plan and the Wisconsin Areawide Water Quality Management Plan (see Resolution CARPC No. 2017-02).

The DNR recognizes the **Groundwater Element of the Dane County Water Quality Plan, January 2017** as a long-term, significant undertaking, as it compiles a vast amount of data on this critical resource. This report provides volumes of data and information for public consumption and lays out a procedure/framework for future work regarding groundwater management for the county. We value that you worked closely with WGNHS, USGS, Dane County, DNR, and other highly respected hydrogeologists and hydrologists, as well as stakeholders from multiple perspectives to prepare this document.

A public hearing was held on January 12, 2017. The CARPC Commission passed a resolution recommending approval of the amendment on the same date.

This amendment becomes a part of the *Dane County Water Quality Management Plan* and will be forwarded to the US Environmental Protection Agency to meet the requirements of the Clean Water Act of 1987 (Public Law 92-500 as amended by Public Law 95-217), and outlined in the federal regulations 40 CFR, Part 35.

This review is an integrated analysis action under s. NR 150.20 (2) (a) 3, Wis. Adm. Code. By means of this review, the Department has complied with ch. NR 150, Wis. Adm. Code, and with s. 1.11, Stats.

The approval of this plan update does not constitute approval of any other local, state, or federal permit that may be required for sewer construction or associated land development activities.

Appeal Rights:

Wisconsin statutes and administrative rules establish time periods within which requests to review Department decisions must be filed. For judicial review of a decision pursuant to sections 227.52 and

227.53, Wis. Stats., a party has 30 days after the decision is mailed, or otherwise served by the Department, to file a petition with the appropriate circuit court and serve the petition on the Department. Such a petition for judicial review must name the Department of Natural Resources as the respondent.

To request a contested case hearing pursuant to section 227.42, Wis. Stats., a party has 30 days after the decision is mailed, or otherwise served by the Department, to serve a petition for hearing on the Secretary of the Department of Natural Resources. All requests for contested case hearings must be made in accordance with section NR 2.05(5), Wis. Adm. Code, and served on the Secretary in accordance with section NR 2.03, Wis. Adm. Code. The filing of a request for a contested case hearing does not extend the 30 day period for filing a petition for judicial review.

Sincerely,

Timothy R. Asplund
Monitoring Section Chief
Bureau of Water Quality

cc:
Greg Searle - WDNR – SCR – Fitchburg
Lisa Helmuth – WDNR, WQ/3
Adam Friehoefer – WDNR, DG/5
Jeff Helmuth – WDNR, DG/5

CAPITAL AREA REGIONAL PLANNING COMMISSION

210 Martin Luther King Jr. Blvd. Room 362 Madison, WI 53703 Phone: 608-266-4137 Fax: 608-266-9117 www.CapitalAreaRPC.org info@CapitalAreaRPC.org

CARPC Resolution No. 2017-02

Recommending to the WDNR Amendment of the *Dane County Water Quality Plan* by Adopting the Update of Appendix G: *Dane County Groundwater Protection Planning Framework*

WHEREAS, In March 1975, Dane County was designated by the Governor of Wisconsin as an area having substantial and complex water quality control problems, and certified such designation to the federal Environmental Protection Agency; and

WHEREAS, the Capital Area Regional Planning Commission is a duly created regional planning commission under Wis. Stats. § 66.0309; and

WHEREAS, the CARPC has an agreement with the Wisconsin Department of Natural Resources (WDNR) to provide water quality management planning assistance to the WDNR; and

WHEREAS, the *Dane County Water Quality Plan* is the approved areawide water quality management plan for the Dane County region; and

WHEREAS, the Capital Area Regional Planning Commission has adopted, reaffirmed, and recommended amendment of the *Dane County Water Quality Plan*; and

WHEREAS, the Capital Area Regional Planning Commission has prepared an updated Appendix G to the *Dane County Water Quality Plan*, entitled "*Dane County Groundwater Protection Planning Framework*," and has made the document available to all local units of government in Dane County; and

WHEREAS, the public hearing was deferred during the Regional Planning Commission meeting on August 11, 2016, to allow more time for public comment on the Appendix; and

WHEREAS, a public hearing was held during the Regional Planning Commission meeting on January 12, 2017, to take testimony on the Appendix including revisions to the report based on public comments received.

NOW, THEREFORE, BE IT RESOLVED that in accordance with Wis. Stats. § 66.0309, and Sec. 208 of Public Law 92–500, the Capital Area Regional Planning Commission recommends the amendment of the *Dane County Water Quality Plan* by adopting the updated Appendix G: *Dane County Groundwater Protection Planning Framework.*

January 12, 2017
Date Adopted

Larry Palm, Chairperson

Kris Hampton, Secretary

Staff:

Steve Steinhoff, AICP, Deputy Director, and Director of Community and Regional Development Planning

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The preparation of this document has been financially aided by funds from the U.S. Environmental Protection Agency and the Wisconsin Department of Natural Resources.

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* Project staff
† Former Capital Area Regional Planning Commission employee

A special thanks to the following for providing technical review on this report:

- Ken Bradbury, Director – Wisconsin Geological and Natural History Survey
- Kevin Connors, Director – Dane County Land and Water Resources Department
- John Hausbeck, Supervisor – Department of Public Health Madison – Dane County
- Tom Heikkinen, General Manager – Madison Water Utility
- Rob Montgomery, Principal – Montgomery Associates: Resource Solutions, LLC.
- Michael Mucha, Chief Engineer and Director – Madison Metropolitan Sewerage District
- Michael Parsen, Hydrogeologist – Wisconsin Geological and Natural History Survey
- Stan Senger, Environmental Quality Section Chief – DATCP
- Brian Standing, Senior Planner – Dane County
- Sara Walling, Nutrient Management and Water Quality Section Chief – DATCP

Thanks also to WDNR for pre-publication review and comment:

- Tim Asplund, Water Quality Monitoring Section Chief -- WDNR
- Mary Ellen Vollbrecht, Groundwater Section Chief – WDNR
- Lisa Helmuth, Water Resources Specialist/WQM Plan Coordinator – WDNR
- Jeff Helmuth, Water Use Section Hydrologist – WDNR
- Dave Johnson, Hydrogeologist/Wellhead Protection – WDNR

Chapter 1: Introduction

Background

In the 1960s and 1970s, national environmental concerns focused mainly on natural resources and pollutants that could be easily seen and monitored. Generally, government agencies and the public were less concerned with groundwater since, hidden from view, there was little recognition of how seriously this resource was jeopardized. In the 1980s, however, the importance of groundwater emerged as pollution incidents were exposed across the nation. As groundwater contamination has increased in the public eye, there has been a growing concern about the health implications of tainted drinking water. As concerns have increased, so have demands for expanded protection of groundwater. With greater emphasis on groundwater protection at the national and statewide level, funding and technical resources have been directed to promote increased state and local management.

The *Dane County Groundwater Protection Plan* was originally developed and adopted as the "Groundwater Element" of the *Dane County Water Quality Plan* in 1987 and updated in 1999. This 2014 framework incorporates new information and tools developed since 1999. Current information on groundwater location and flow, pollution sources, quality conditions, and management controls are presented. The document also promotes strategies to improve the protection of this critical resource now and into the future. The Dane County Groundwater Protection Planning Framework is intended to provide the basis for more detailed evaluations and strategic planning at the local level.

Purpose

The Dane County Groundwater Protection Planning Framework was developed to identify and recommend management actions to address existing and potential groundwater quality and quantity issues in Dane County. This document is an element (Appendix G) of the *Dane County Water Quality Management (WQM) Plan*, developed under federal and state law since 1987. The WQM Plan and particularly this Groundwater Element are maintained and updated with a consortium of partners and stakeholders to help garner all available information, resources, and management alternatives to help ensure the long-term integrity of aquatic resources in the county.

Objectives

The objectives of this groundwater protection framework mirror the goals and objectives of the larger Dane County WQM Plan and include:

- Identify and characterize the location of groundwater and related physical resources (soils, geology, water table depth, springs, etc.).
- Evaluate, characterize and portray existing groundwater quality and quantity data for the county.
- Inventory and assess existing and potential pollution sources in Dane County.
- Describe and evaluate existing federal, state, and local programs that pertain to groundwater management.
- Recommend groundwater protection strategies to improve groundwater management and prevent groundwater pollution.
- Evaluate alternative management strategies for addressing groundwater quantity issues.

- Provide regional water supply planning information for subsequent water supply planning purposes required under Wis. Stats. 281.348.
- Create and share new products including Zone of Contribution and Groundwater Contamination Risk maps.
- Introduce the use of groundwater budget indices and fish response curves to assess the sustainability of local water supply plans within a regional framework

This Dane County Groundwater Protection Planning Framework provides the basis for more detailed evaluations and strategic planning at the local level.

Summary

Dane County is fortunate to have an adequate supply of high quality groundwater. Groundwater is the source of all public and domestic water supplies. Protection of groundwater resources is critically important. However, groundwater pollution sources and threats are present. Identifying and putting into place better pollution prevention and resource management practices has long been recognized as a need. An inventory and assessment of physical resource conditions, water quality data, pollution sources and existing groundwater management controls provide the core of this plan. Based on the groundwater assessments, specific management actions are proposed to safeguard the groundwater resource of Dane County.

Inventory work for this document raised concerns in several areas, notably:

- High nitrate-nitrogen levels (above the recommended drinking water standard) in a significant percentage (25%) of private wells in the county;

- Increasing salt levels (concentrations) in municipal wells;

- Organic chemical detections in some water supply wells near abandoned landfills and underground storage tanks;

- A general lack of information on, and monitoring of, the possible effects of emerging pollutants (e.g., pharmaceuticals, personal care products, endocrine disrupters);

- Lack of rigorous enforcement in regulating land disposal of septage;

- Reductions in ground and surface water levels due to high-capacity well water withdrawals.

The following management actions are recommended to address groundwater concerns in the region:

- Utilize information, tools, and guidelines identified in this plan for decisions involving site approvals or permits that could impact groundwater in Dane County (e.g., well proposals, WPDES permits, land application of waste, rural subdivisions, among other land use decisions or inquiries);

- Promote effective local wellhead protection programs and source water protection plans for all municipal wells in Dane County;

- Increase monitoring of existing and potential pollution sources, particularly in geologically sensitive areas and in areas most likely to affect municipal water supplies;

- Provide information, guidelines, and sources for more information to rural homeowners regarding household hazardous waste use and disposal, maintaining onsite septic systems, and testing drinking water;

- Increase County and UW-Extension training and education for farmers, landowners, and commercial applicators on pesticide use and fertilizer application by the use of integrated pesticide management and nutrient management planning;

- Consider providing an expanded role for the Department of Health – Madison and Dane County in the approval of septage land disposal sites;

- Reduce the use of road salt by local units of government, homeowners, motorists, and commercial applicators in part through the Wisconsin SaltWise Partnership;

- Support an ongoing proactive and collaborative regional groundwater planning and management framework among Dane County communities to address water availability and sustainability issues.

  More specifically, the Capital Area Regional Planning Commission recommends that its staff:

  a. Support the conduct of water supply service area planning required by Wis. Stats. 281.348 and also comprehensive (master) planning under Wis. Stats. 66.0309(9).

  b. Assist municipalities and resource management agencies incorporate and utilize the information, tools, and guidelines in this planning framework to develop processes and standards to address potential groundwater impacts. Decision areas may include but are not limited to well proposals; WPDES permits discharging to groundwater, biosolids and septage land spreading sites; stormwater infiltration; sanitary landfills; large manure storage lagoons or feedlots; large unsewered subdivisions; prioritization of remediation sites and monitoring.

  c. Assist municipalities and resource management agencies provide public information, education, and technical resources to citizens and landowners concerning groundwater quality protection and management throughout the region.

Literature Review and Data Sources

This plan is based on available data on pollution sources, water quality and physical resource features. Existing data and literature were reviewed from numerous agency sources including the documents, publications and online materials from the Wisconsin Department of Natural Resources (WDNR), the Department of Agriculture, Trade and Consumer Protection (DATCP), and the Wisconsin Geological and Natural History Survey (WGNHS), as well as personal communications with state and local agency staff.

The most comprehensive reference regarding the groundwater resource in Dane County came from reports developed from the Dane County Regional Hydrologic Study. The interagency Dane County Regional Hydrologic Study, started in 1992 and completed in 1997, was conducted to provide information on the impact of urban development, well pumping and wastewater diversion on lakes, streams, wetlands and groundwater in Dane County. This work is part of ongoing collaborative work among the Capital Area Regional Planning Commission (RPC), the Wisconsin Department of Natural Resources (WDNR), the Wisconsin Geological and Natural History Survey (WGNHS), the U.S. Geological Survey (USGS), and other state and local governments. Information from the original model has been augmented with a more sophisticated and improved regional groundwater model coordinated and sponsored by the Capital Area Regional Planning Commission and completed in 2014. This updated model builds on research and studies conducted since the original model was first developed in the 1990s.

Information developed from the Regional Hydrologic Study, including the ground and surface water models, provide modern computer technology output to assist planning activities and management decision-making. As part of the original work, the groundwater flow model was used to simulate: changes in groundwater levels due to pumping and urban development; identify groundwater recharge and discharge areas; provide estimates of the direction and rates of groundwater movement; delineate sources of municipal water; and better define ground and surface water relationships in Dane County.

A Yahara Lakes Reservoir Routing model was also used to simulate and specify lake levels and operating conditions to achieve the desired goal of restoring pre-diversion baseflow conditions through the Yahara River system.[1] Groundwater Contamination Risk Maps were developed to rate the relative susceptibility or risk (extreme, high, moderate, low) of groundwater contamination from surface and subsurface pollution sources. More recently, an Ecological Limits of Hydrologic Alteration (ELOHA) model was developed which correlates reductions in baseflow and increases in runoff due to urban development (specifically high capacity well withdrawals and groundwater recharge loss, respectively) with the biologic health in streams. Groundwater Budget Indices have also been developed to aid in developing and assessing water supply plans in Dane County, as required by state statute.

Findings from the Regional Hydrologic Study, and associated spinoff research projects, provide clear evidence that aggressive management of ground and surface waters is essential to preserve streams, lakes, wetlands, and drinking water supplies in the county. Fortunately, most of Dane County's surface and groundwater originate locally, so resource agencies potentially have the unique ability to maintain and protect these waters. The models, maps and reports described in this plan provide management tools to better understand and evaluate the effects of water and land use decisions and to develop management strategies that avoid and possibly mitigate adverse ground and surface water impacts.

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[1] In 1959, groundwater pumped by municipalities and treated by the Madison Metropolitan Sewerage District (MMSD) was diverted around the Yahara Lakes System from its original location on Nine Springs Creek, to its present discharge point on Badfish Creek. Mean annual flow in the Yahara River was reduced by nearly one-third.

Chapter 2: The Groundwater Resource

Physical Setting

Dane County is an area of geologic and geographic contrasts. The eastern part of the county is a slightly rolling plain of low hills interspersed with wetlands drained by sluggish streams and man-made ditches. The western part of the county has steep valleys and ridges drained by fast flowing, spring-fed streams. In the center of the county is the Yahara River with its large scenic lakes and adjacent marshes. These geographic differences may be explained by the geologic history and physiography of the area, **Map 1**.

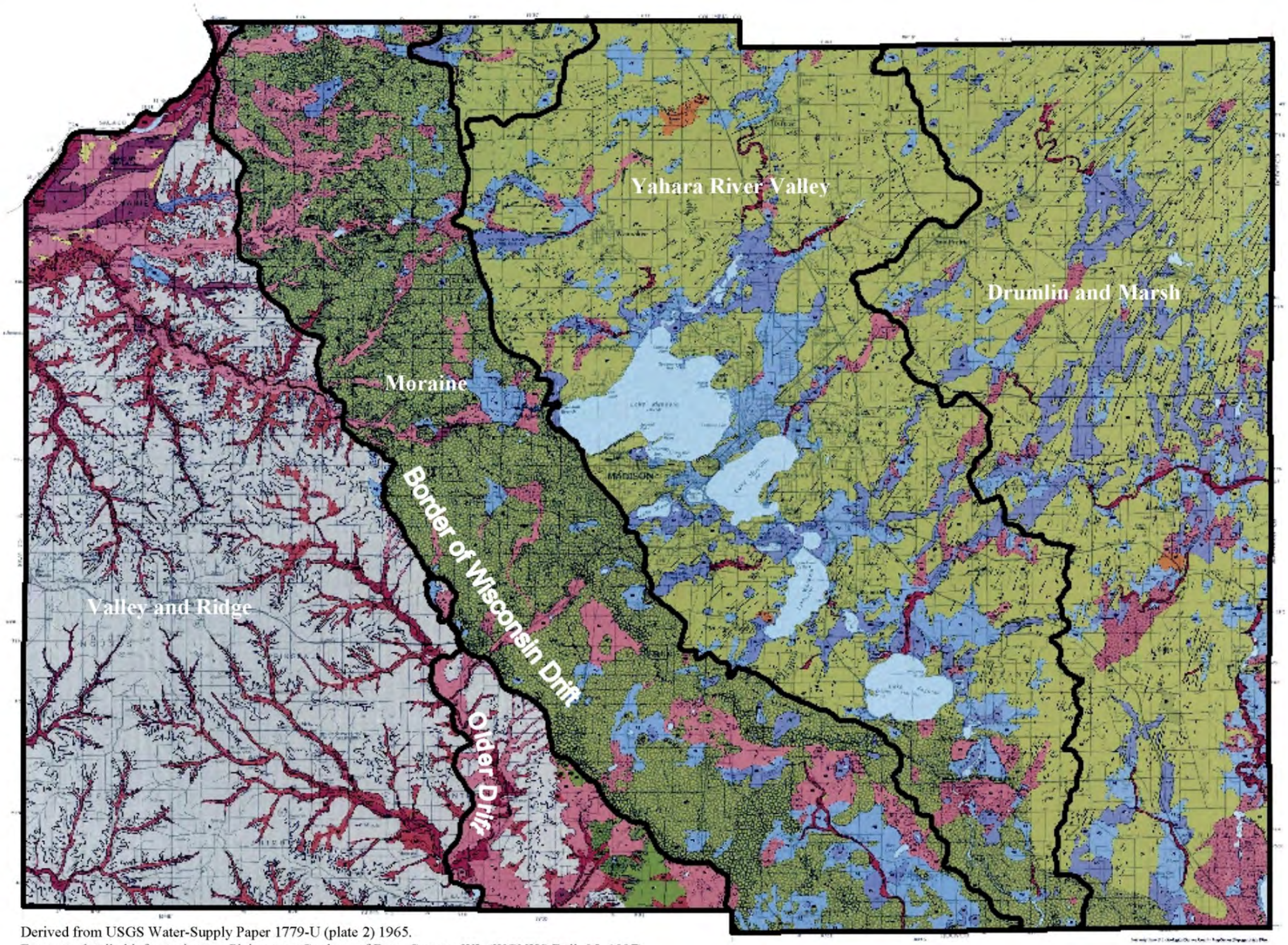
The bedrock in the county is comprised of many layers of sandstone and dolomite (up to 1,700 feet thick) formed from sediments deposited by an ancient sea 420 to 600 million years ago. Under these layers of sedimentary rock is an even older crystalline rock, mostly rhyolite, granite, and basalt. The crystalline rock allows little water penetration, and forms a floor under the water-bearing sedimentary rocks. All the sedimentary rocks can contain water in places where they are below the water table, and all these units form aquifers in some parts of Dane County. The ancient sea that deposited the sedimentary rocks disappeared millions of years ago when geological forces raised the land in Wisconsin above sea level. A well-developed drainage pattern had been cut into the sedimentary rock when the climate changed about 70,000 years ago and glaciers began to be formed in the northern portions of the continent. At least four glaciers moved across what is now Wisconsin. The last glacier reached the Dane County area from 14,000 to 18,000 years ago.

The western third of Dane County is part of the driftless area -- an area that was not covered by the most recent Wisconsin glaciation. The forces of wind and water have eroded the bedrock in this area into steep ridges and valleys drained by fast- flowing streams. Most of the streams are fed by springs and seeps, which flow from water-bearing layers of sandstone or dolomite exposed along the hillsides. An irregular layer of soil formed from the disintegration of the bedrock or blown in from the western plains covers the hills. In many places there is only a thin layer of soil with moderate or moderately slow permeability over fractured dolomite and sandstone.

The large valley of the Wisconsin River and its benches have deep alluvial deposits of sand and gravel with some organic material. The soil along the river valley is mostly poorly-drained sand with organic inclusions. This area is subject to seasonal high water tables and frequent flooding. Poorly-drained silty soils with mineral and organic material are also found in lowlands along some of the smaller streams. The benches and outwash terraces along the streams have well-drained to excessively drained silty or sandy soils underlain by sand and gravel.

On the eastern edge of the driftless area are numerous moraines – a band of hills made up of debris which was scraped up by the glacier and left behind when the ice melted. There are two main moraines in Dane County: the terminal moraine or Johnstown moraine at the far eastern edge of the glaciated area, and the recessional moraine or Milton moraine which formed when the glacier stopped retreating and dumped unstratified and unsorted clay, silt, and boulders with sand lenses. The moraines once included blocks of ice left behind by the glacier. These blocks melted, leaving pot holes or kettles, some of which remain as small ponds, marshes, and bogs. The moraines are a drainage divide where many of the headwater streams of the Yahara River, Sugar River, and Wisconsin River watersheds are located.

Map 1. Physiographic Areas and Deposits of Pleistocene Age in Dane County, WI



Derived from USGS Water-Supply Paper 1779-U (plate 2) 1965.
For more detailed information see Pleistocene Geology of Dane County, WI. (WGNHS Bull. 95, 1997)

East of the moraines, in the center of the county, is the Yahara River Valley. In this area glacial deposits, over 350 feet deep in some places, dammed up large pre-glacial valleys, forming a chain of large lakes and wetlands. The formation of peat in these wetlands seems to have been rapid. Today the peat deposits are extensive and deep, reaching over 90 feet deep in some spots. In many places, an aquifer in the bedrock of adjacent hills supplies springs that maintain high water levels in the peat and assist peat formation. The streams of this area of the county are slower flowing than the streams of the driftless area, and fewer are spring fed.

Farther east, the glacier filled the flatter watersheds of smaller pre-glacial streams, and the resulting lakes and wetlands are much shallower. The wetlands in this part of the county are interspersed by drumlins - long, low, whale-back shaped parallel hills which formed as the glacier advanced and retreated, flowing over piles of material, which it had deposited earlier. In addition to creating drumlins, the glacier deposited a sheet of debris 25 to 100 feet deep over most of the landscape when it retreated. The glacial deposits blocked old drainageways creating an extensive system of interconnected wetlands with a poorly defined drainage pattern. Small streams wind slowly through the lowlands. Since the groundwater contribution from the glacial deposits is minimal, there are few springs in this part of the county, and stream flow is primarily very dependent on overland runoff. During the summer months, the water level in these streams may be very low. The only lakes in this part of the county are small stream impoundments and shallow marshy lakes.

Climate

The climate of Dane County is typical of the Great Lakes states. Winters tend to be cold and snowy, while summers are sometimes humid. Average annual precipitation is about 34.5 inches, with 67% falling from April through September. Average groundwater recharge in Dane County is estimated to be 9 to 10 in/yr; however, this varies by location from 5 to 15 in/yr, with the highest rates in the southeast part of the county. Most recharge occurs in late fall, and early spring when vegetation is dormant and evapotranspiration is minimal. Runoff and evapotranspiration vary widely due to seasonal conditions and land use. June is the wettest month with 4.5 inches of precipitation (1981-2010[2]), and January is the driest with about 1.2 inches. About 83% of the precipitation events are half an inch or less. Snowfall averages 51 inches per year. The ground usually begins to freeze at the end of November and thaws in mid-April. The potential for runoff and severe erosion is often highest in March and early April when heavy rainstorms and snowmelt occur on ground sparsely covered by dead vegetation. Climate change studies and historical data suggest changes in intensity and timing of precipitation have already occurred in our region, and additional changes are expected.

Hydrogeology

Groundwater, compared to other physical resources, is not easy to comprehend because it is not readily seen. To dispel popular myths (such as groundwater existing as underground streams) a better public understanding of groundwater is necessary. Groundwater is just one component of the full water cycle, which provides fresh water to our planet (**Figure 1**).

[2] Source: National Centers for Environmental Information, http://www.aos.wisc.edu/~sco/clim-history/sta-data/msn/MSN-monthly/GHCND_USW00014837_2010-1-1.pdf

Figure 1

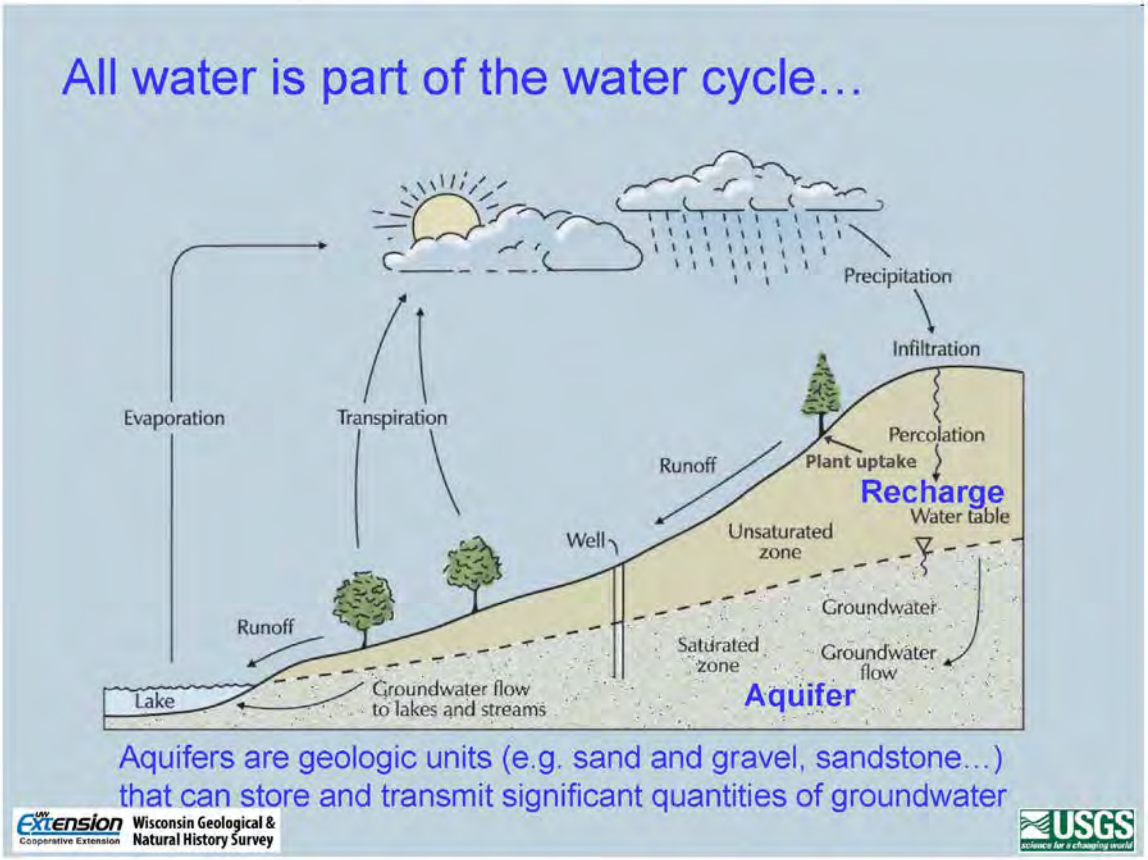
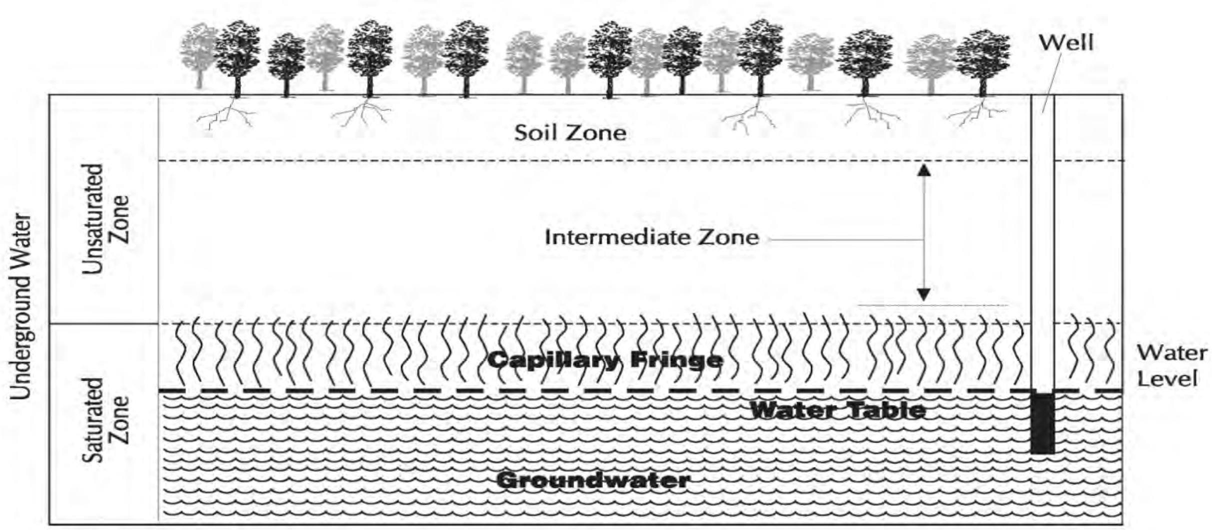


Figure 2

Shallow Groundwater Zones



Source: Heath, 1983.

Water beneath the land surface may be classified into two major zones – the unsaturated and saturated zones (**Figure 2**). The unsaturated zone consists of small openings partially filled with water and partially filled with air. In the soil layer of the unsaturated zone plant roots are present and the greatest amount of biological activity takes place. Many introduced chemicals may be broken down (or *attenuated*) by chemical, physical and biological processes. The soil zone is only three to six feet deep, but it is often the most important layer in determining the fate of pollutants spread on the land surface and resulting groundwater quality. An intermediate layer lies below the soil layer, which varies in thickness from place to place. Although less biological activity takes place there, pollutants may be further attenuated by physical and chemical processes.
Groundwater is found in saturated rock and soil formations below the unsaturated area. Aquifers occur where such saturated formations will yield usable amounts of water to a well. These formation may be *consolidated* bedrock, often limestone or sandstone, or *unconsolidated* deposits of sand, silt, and gravel. Water is stored in void spaces between the rock or soil particles.

Groundwater is comprised of the portion of rainfall that does not run off to streams and rivers and that does not evaporate or transpire from plants. This water percolates down through the soil until it reaches the saturated zone of an aquifer. This process is called *aquifer recharge.*

Unconfined or surficial aquifers occur where only unsaturated porous material overlies the saturated formation. In such cases, the upper surface of the saturated zone is called the *water table*. The water table generally follows the contours of the overlying terrain and can be determined by mapping the water levels in wells tapping the surficial aquifer. Because pollutants move with the groundwater as it flows, the important aspects of this zone are the direction and rate of groundwater flow.

Aquifers may also be bounded at the top and bottom by relatively impermeable formations called *confining beds* (or *aquitards*), typically of clay or shale. These are called *confined* aquifers. Water in these aquifers may be under greater-than-atmospheric pressure, raising water levels in wells above the top of the aquifer, thus creating an *artesian aquifer*. Wells in these aquifers may flow without pumping, like artesian springs.

When an aquifer is confined, the concept of a "water table" is not used to define its hydrology. Instead a concept called *potentiometric* (or *piezometric*) *surface* is used. It describes the heights (or pressure) that the groundwater reaches in wells tapping the confined aquifer.

Both the water table and the potentiometric surface gradients help define the characteristics of the hydrologic system and the rate and direction of groundwater flow. Under natural conditions, the regional flow of water in aquifers is generally a subdued reflection of the surface topography above. Groundwater recharges all across the landscape, flowing from upland areas to low-lying areas where water discharges to springs, streams, and wetlands. Groundwater discharge is important because it nourishes springs, streams and wetlands, especially during dry summer conditions but also during cold winter months in the case of trout streams.

A summary and analysis of the hydrogeology of Dane County was conducted based on work associated with the Dane County Hydrologic Study, which provides a framework for understanding the groundwater resources in the county.[3] **Figure 3** shows the general arrangement and approximate relative thicknesses of bedrock geologic units across Dane County.[4]

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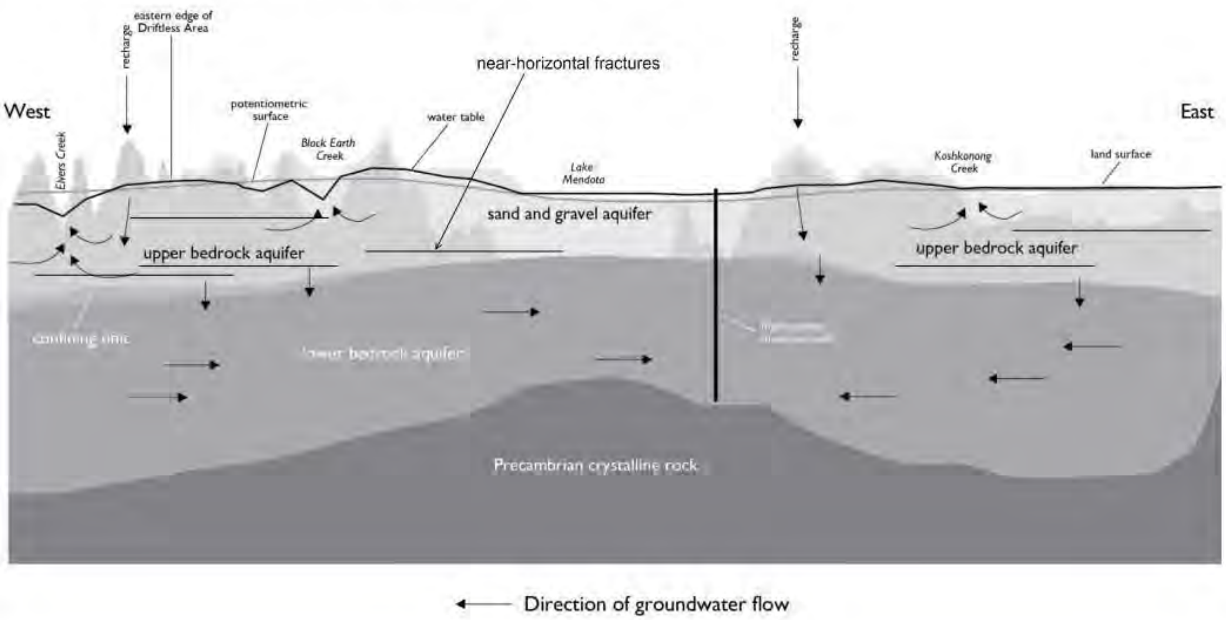
[3] Bradbury, et al. 1999. *Hydrogeology of Dane County, Wisconsin*. WGNHS Open File Report 1999-2004,
[4] Wisconsin Geological and Natural History Survey. 2016. *The 2016 Groundwater Flow Model for Dane County, WI.*

Figure 3. Conceptualized Model of the Groundwater Flow System, Dane County, WI.



GENERAL BEDROCK STRATIGRAPHY — GROUNDWATER FLOW MODEL

Age		Stratigraphic name		Model layers, names				
Era	Period	Group	Formation	1996 model		2016 model		Type
				1	Sand and gravel	1	Unlithified I (fine-grained lacustrine deposits within the glacial Lake Yahara area)	
						2	Unlithified II (till and meltwater stream deposits)	
Paleozoic	Ordovician		Maquoketa	2	Upper bedrock	3	Upper bedrock	aquifers
		Sinnipee	Galena					
			Decorah					
			Platteville					
		Ancell	Glenwood					
			St. Peter					
		Prairie du Chien						
	Cambrian	Trempealeau	Jordan			4	Jordan	
			St. Lawrence			5	St. Lawrence	
		Tunnel City	Lone Rock, Mazomanie			6	Tunnel City—Upper	
						7	Tunnel City—Mid *(fracture layer)*	
						8	Tunnel City—Lower	
		Elk Mound	Wonewoc			9	Wonewoc—Upper	
						10	Wonewoc—Lower *(fracture layer)*	
			Eau Claire	3	Eau Claire	11	Eau Claire	aquitard
			Mount Simon	4	Mount Simon	12	Mount Simon	aquifer
Precambrian		Various unnamed units		No-flow boundary				

Hydrostratigraphic columns showing the relation of model layers to the general bedrock geology of Dane County, and also showing the differences between the 1996 and 2016 regional groundwater models.

Source: Wisconsin Geologic and Natural History Survey, 2016.

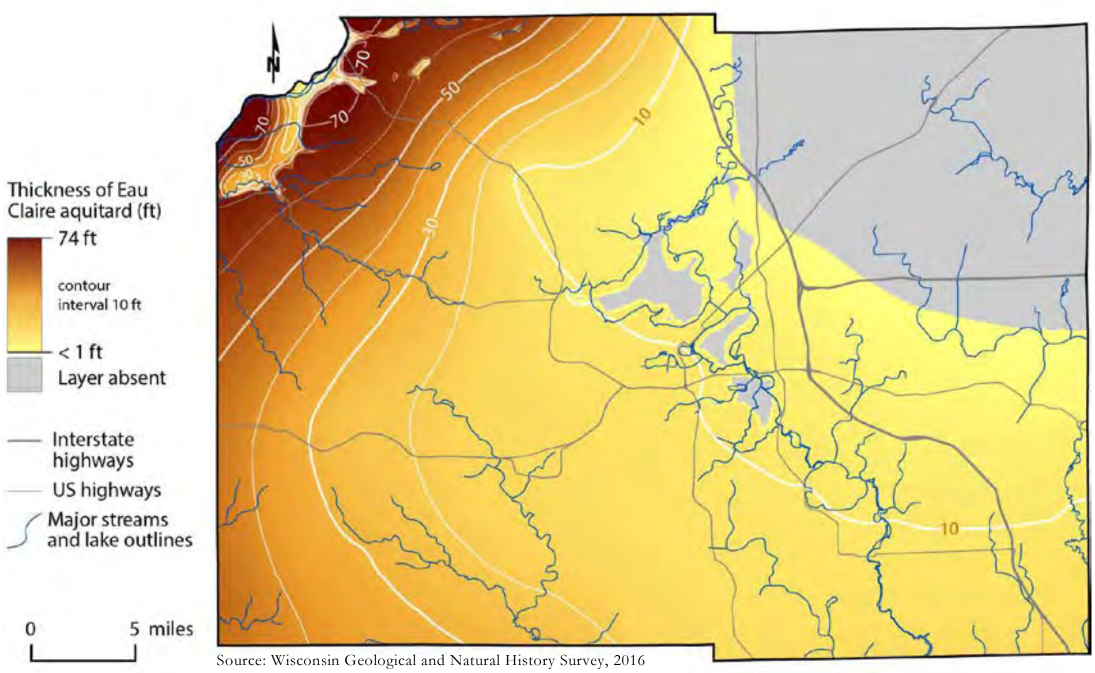
The Mt. Simon aquifer is the most important aquifer in Dane County for the purposes of water supply to high-capacity wells. This aquifer consists of sandstones of the Mt. Simon and lower Eau Claire Formations. The lower boundary of the aquifer is the Precambrian granite surface. The upper boundary is the bottom of the shaley facies of the Eau Claire formation. The aquifer ranges in thickness from about 100 feet to over 700 feet. It is thickest in southern Dane County and thinnest in the northwest and northeast as it approaches the Baraboo Quartzite and Waterloo Quartzite, respectively. The average thickness of the aquifer is about 500 feet.

The shaley facies of the Eau Claire Formation forms an important aquitard over much of Dane County, limiting the movement of groundwater between the lower Cambrian sandstones and the upper Paleozoic sandstones and dolomites. The Eau Claire shale formation is up to 70 feet thick in western Dane County, but thins to the east, and is probably absent in the northeastern parts of the county (**Map 2**).

The Eau Claire aquitard appears to be patchy and partially absent in the central Yahara Lakes area, where the preglacial bedrock surface is believed to have been eroded deeply into the underlying Mt. Simon Formation. Where it occurs, the Eau Claire formation helps limit the movement of water between the upper and lower bedrock units.

The Upper Bedrock aquifer consists of all saturated Paleozoic rocks between the top of the Eau Claire aquitard and the bedrock surface. Although the Upper Bedrock aquifer contains a variety of materials ranging in lithology from sandstone to siltstone to dolomite and the hydraulic properties of these materials may be somewhat dissimilar, on a regional scale all these units appear to be hydraulically interconnected. The thickness of the Upper Bedrock aquifer ranges from zero, where it is absent beneath the Yahara Lakes, to over 200 feet in the western part of the county.

Map 2. Lateral Extent of the Eau Claire Aquitard in Dane County.



Source: Wisconsin Geological and Natural History Survey, 2016

The uppermost aquifer is a shallow unlithified aquifer, consisting of saturated unlithified materials primarily of Quaternary age. These materials range in lithology from clayey lake sediment to sand and gravel. The bottom of this aquifer unit is the bedrock surface, and the top of the aquifer unit is the water table. The saturated thickness of these materials ranges from zero to over 300 feet. Due to the heterogeneity of these materials in Dane County, the materials have been further divided into several aquifer types.[5] The most permeable parts of this aquifer occur in river valleys, such as lower Black Earth Creek, and along the Wisconsin and Yahara Rivers. This aquifer is unconfined in some places and in others is confined by clayey lake sediment.

Groundwater Recharge

All groundwater in Dane County originates as precipitation (rainfall and snowmelt) in or just outside of the county. Groundwater recharge is the addition of water to the water table. Knowledge of the location of groundwater recharge areas and the rates of groundwater recharge is essential for groundwater flow models and for water resources planning.

For example, impervious urban development in Dane County can have an adverse effect on groundwater resources. The problem is caused by the replacement of farmland or open space with impervious areas such as rooftops, parking lots, streets and sidewalks. These impervious areas prevent the infiltration of rainfall and snowmelt so that groundwater recharge is decreased. Generally, decreases in groundwater recharge (without mitigation) would range from 30 to 70 percent, with increases in flood peaks exceeding 300 percent.[6] To address this issue, stormwater management standards have been implemented to maintain natural recharge rates and minimize dramatic alteration of the hydrologic cycle.

Swanson (1996) attempted an improved delineation of groundwater recharge rates and locations in Dane County based on a combination of mass-balance and water-balance models. The results of this procedure suggest that recharge areas occur over about 48 percent of the total land area of the county. Recharge usually occurs in the higher parts of the landscape, along the crests and flanks of broad ridges. Lower areas of the landscape, including broad floodplains, wetlands, and stream val-leys, are more often areas of groundwater discharge. Controls on groundwater recharge include precipitation timing and intensity, topography, vegetative cover, surface roughness, and soil properties, and these parameters are rarely known in detail over large areas.

In 2012, the Wisconsin Geological and Natural History Survey published a report estimating the existing groundwater recharge rates in Dane County based on the soil water balance method. The study found that the groundwater recharge rates generally ranged from 5 to 15 inches per year in Dane County, with the majority of the county being 9 to 10 inches per year as shown in **Map 3.** The Capital Area Regional Planning Commission has generally recommended that pre-development groundwater recharge rates be maintained based on the WGNHS report (and updates) or by a site specific analysis. Experience has shown that this criterion is generally met when a municipality's stormwater volume control standard is achieved by infiltration practices. Enhanced recharge is also recommended, where circumstances and opportunities permit, to help make up for municipal well withdrawals.

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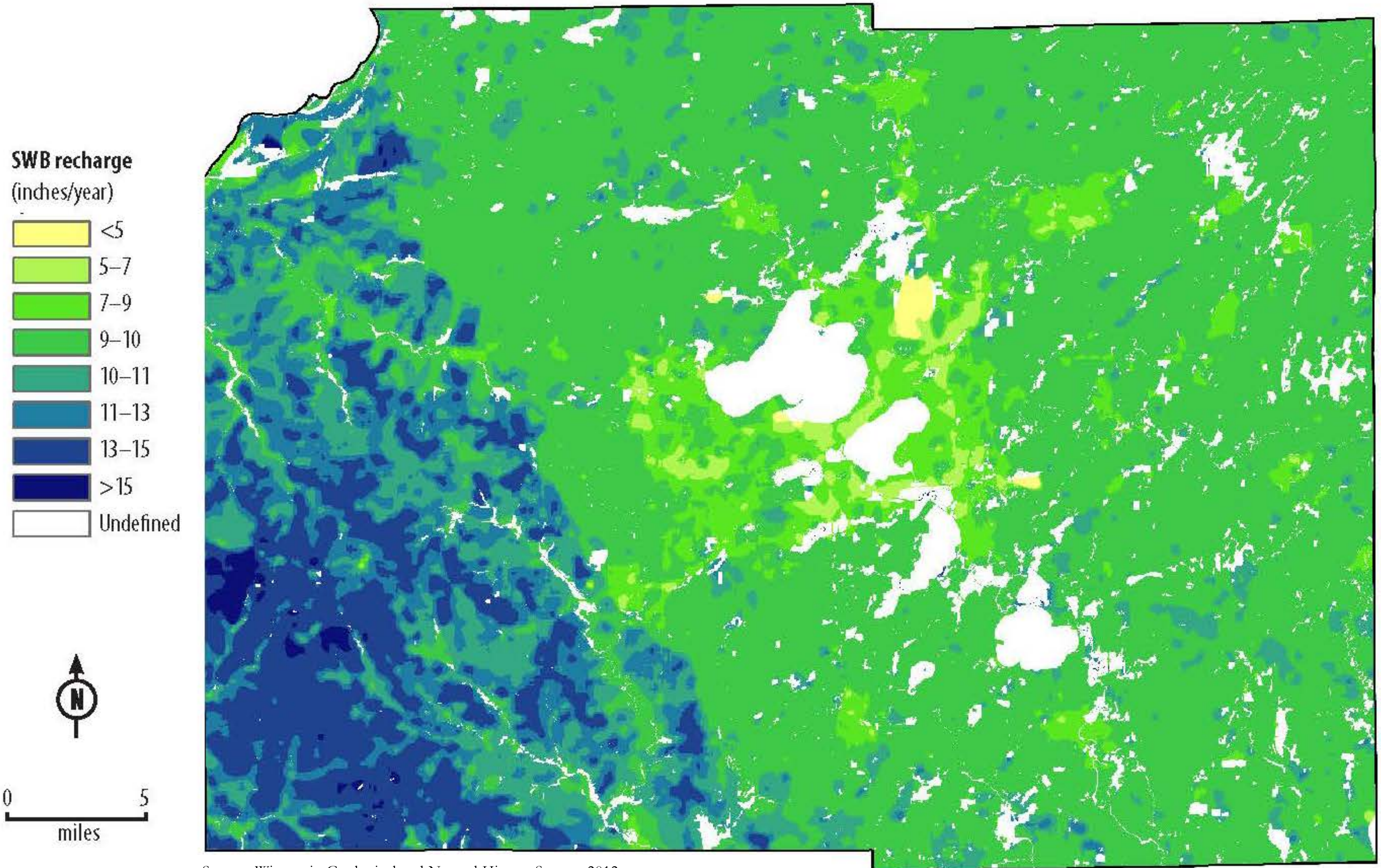
[5] Fritz, A. 1996. *Aquifer Contamination Susceptibility of Dane County, Wisconsin.* Master's thesis. University of Wisconsin, Madison.

[6] Shaver, et al. 2007. *Fundamentals of Urban Runoff Management: Technical and Institutional Issues.*

Map 3. Groundwater Recharge Map for Dane County.



Source: Wisconsin Geological and Natural History Survey, 2012.

In 2006 the Capital Area Regional Planning Commission developed relative infiltration maps for Dane County. **Maps 20, 21, and 22** (**see Chapter 3**) show various opportunities or strategies that can help minimize the impacts of future development as well as retrofit previously developed areas. The maps are available on the Capital Area Regional Planning Commission's web site.[6] They are meant to be used as a screening tool to identify relatively high infiltration areas as well as areas that might be enhanced through engineering techniques, such as engineered soils.

Maintaining baseflow discharge to streams and the water supply to springs and wetlands is an important resource objective. The maps promote various opportunities and strategies that can be used to help minimize the impacts of future development and possibly retrofit previously developed areas. Areas with naturally high infiltration potential should be used to recharge the groundwater to the greatest extent possible. They may also be prime locations for regional stormwater facilities that could be used to infiltrate stormwater generated in other parts of the watershed. Other areas, such as clay soils with low permeability, are less suitable for infiltration. Stormwater generated in these areas could be reduced on site to some extent, such as through rain gardens, but the majority will likely need to be routed to facilities down-gradient. These facilities would need to be adequately sized to accommodate the rates and volumes of stormwater generated by the proposed development.

Groundwater Flow Systems

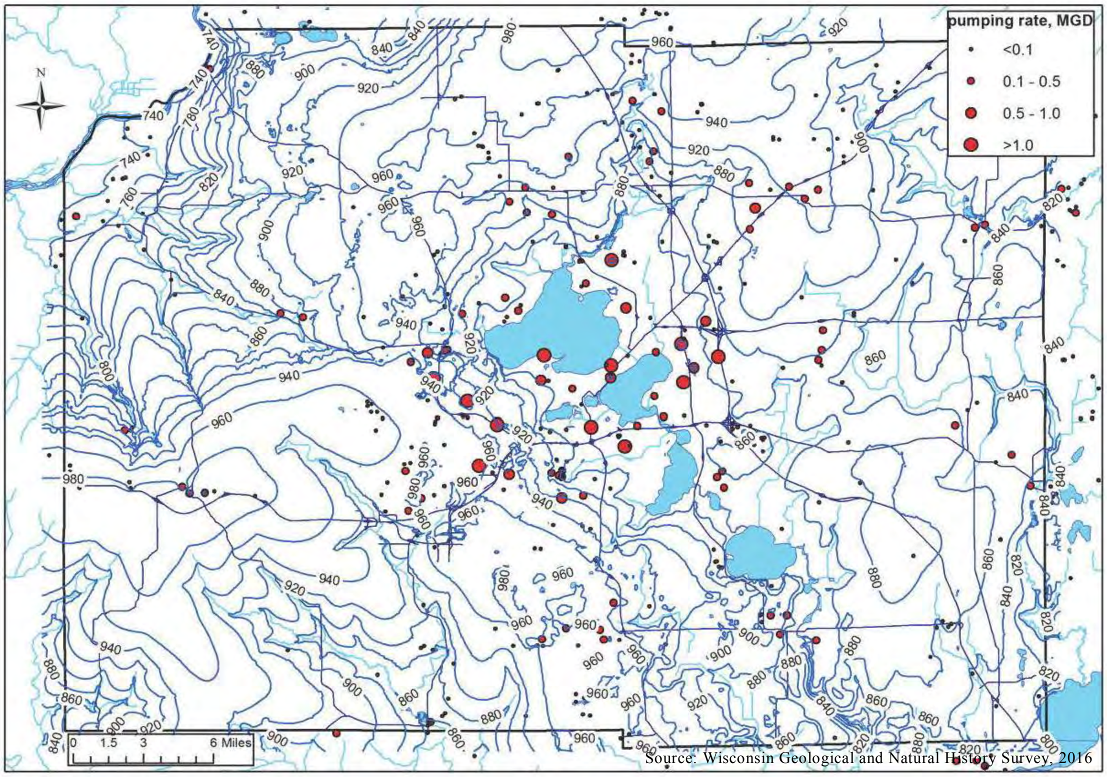
Surface water, shallow groundwater, and deep groundwater are intimately connected in Dane County. Almost all groundwater in Dane County originates as recharge occurring within the County. Most lakes and streams in the county are discharge points for groundwater where the water table intersects the land's surface.

In general, the water table is a reflection of the county's topography. The depth to groundwater in the county ranges from zero at the fringes of lakes and wetlands to over 200 feet beneath the ridges in the southwest. **Map 4** shows the configuration of the water table in Dane County. The water table is highest (nearly 1,000 feet above sea level) in the western part of the county near Mt. Horeb and Blue Mounds, and is lowest (less than 840 feet) along the Yahara River in the southeast.

The shallow water table in Dane County forms several naturally occurring basins, analogous to but not entirely coincident with surface water basins (**Map 5**). Shallow groundwater moves radially away from, and does not cross groundwater divides. Near major lakes, streams and wetlands shallow groundwater flows toward the surface water bodies. Note that groundwater and surface water divides in Dane County are not wholly coincident. There are places in the county where shallow groundwater can move horizontally beneath topographic divides, sometimes in an opposite direction to surface water flow.

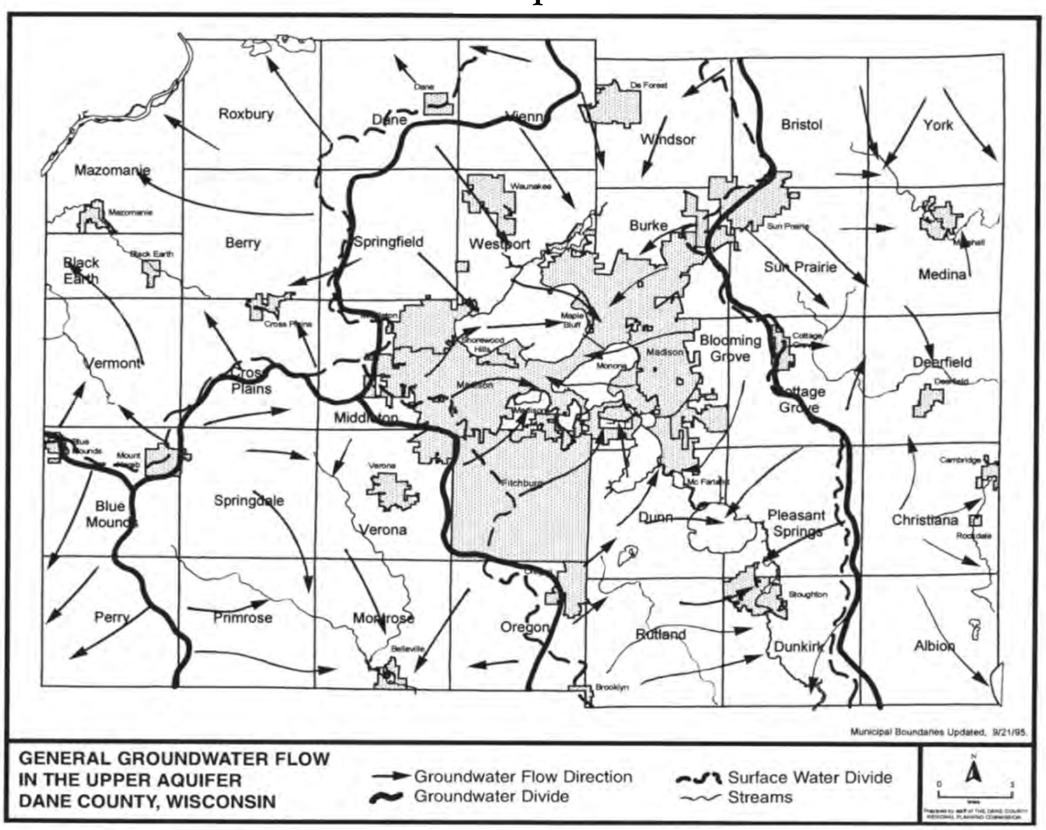
Map 5 superimposes the two types of divides, and shows that they differ significantly in several areas, notably between Madison and Verona and just west of Middleton. In these areas, groundwater passes beneath surface topographic divides. For example, just east of Verona surface water drains to the southwest toward the Sugar River while groundwater moves northeast toward the Yahara River. West of Middleton, surface water drains south toward the Sugar River, but groundwater moves north toward Black Earth Creek.

[6] http://www.capitalarearpc.org/infiltration.html



Map 4. Calibrated simulated steady-state water table (2010 conditions). Dots show locations of wells active in 2010; diameter proportional to pumping rates.

Map 5

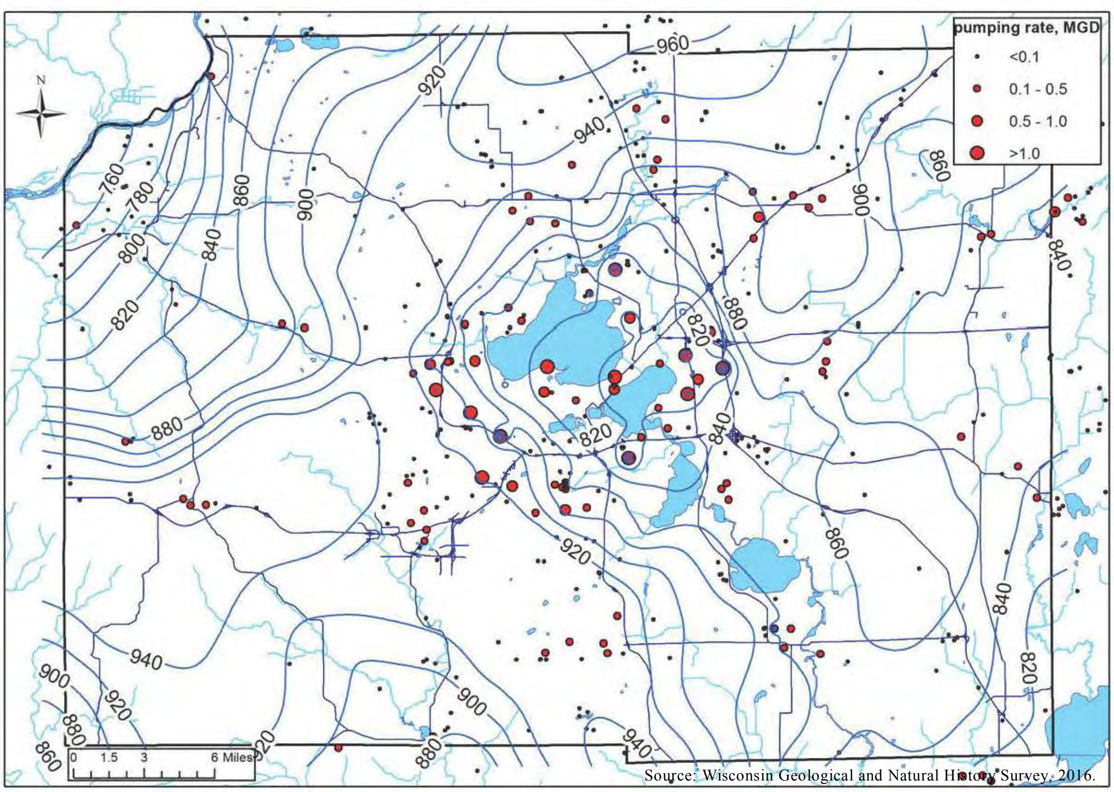


Source: Wisconsin Geological and Natural History Survey, 1995.

The deeper potentiometric surface, representing hydraulic head in the sandstone aquifer, also forms basins roughly but not exactly coincident to surface topography. The elevation of the potentiometric surface of the Mt. Simon aquifer ranges from about 800 feet above sea level in central Madison to over 900 feet near Verona and in western Dane County near Blue Mounds (**Map 6**). A significant low in the potentiometric surface beneath Madison results from long-term pumping of municipal wells there. In this area the potentiometric surface has been lowered until it is below the level of the Yahara Lakes in some places.

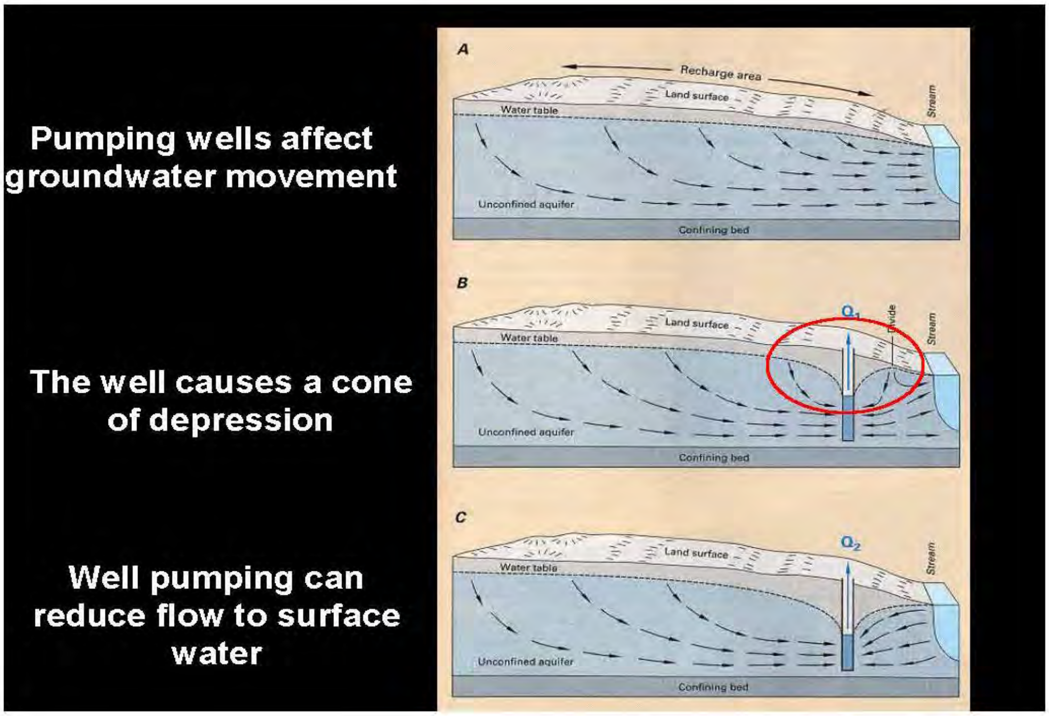
Figure 4 shows these ground-surface water relationships. Groundwater withdrawals by pumping from high-capacity wells in the Madison metropolitan area since the turn of the century have lowered hydraulic heads in the deep sandstone aquifer. These head declines have propagated upward to the surface and have reduced groundwater discharge to lakes, streams, and wetlands in the Madison Metropolitan area. In fact, in the isthmus area of central Madison the historic direction of groundwater flow from the aquifers to the lakes has been reversed so that now parts of Lakes Mendota and Monona are losing water to the groundwater system. Wells located near the Yahara lakes draw significant quantities of water from downward leakage out of the lakes.

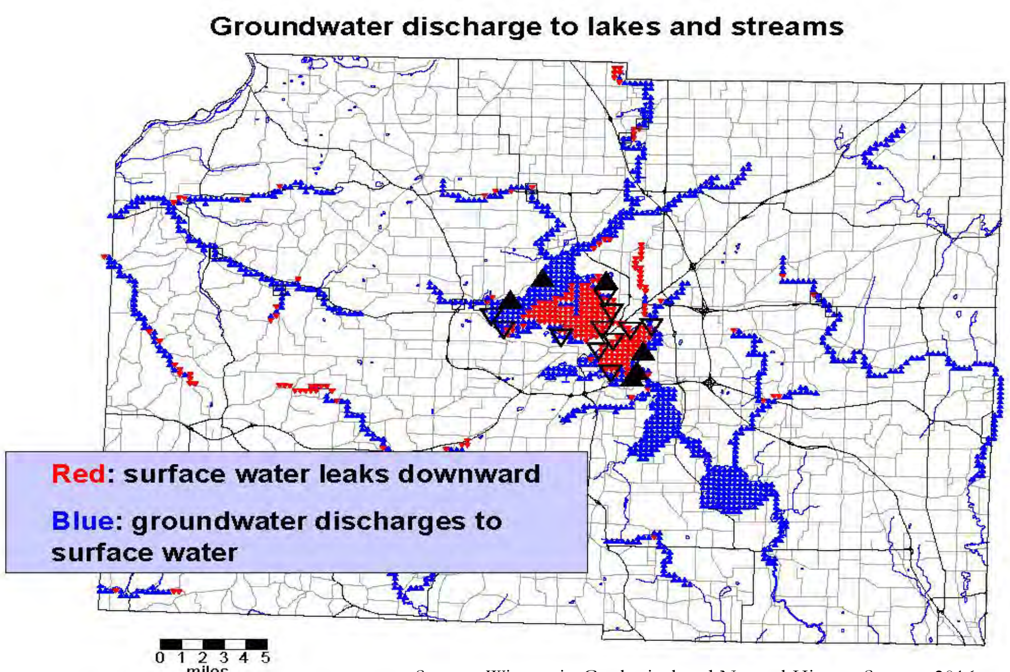
Conversely, the presence of the Eau Claire aquitard can help mitigate the localized impact of high capacity well water withdrawals on surface water features. The presence or absence of the Eau Claire aquitard is an important control on vertical groundwater movement between shallow and deep bedrock aquifers in Dane County. The absence of the aquitard in central Dane County, where pumping stresses are greatest (see Lakes Mendota and Monona, **Map 2**), allows pumping to have much more effect on shallow ground and surface water resources than might otherwise occur.



Map 6. Calibrated simulated steady-state potentiometric surface for the Mount Simon aquifer (2010 conditions). Dots show locations of wells active in 2010; diameter proportional to pumping rates.

Figure 4. The Effect of Well Withdrawals on Area Waters





Source: Wisconsin Geological and Natural History Survey, 2016.

Preferential groundwater flow to springs

Numerous springs occur in Dane County and serve as natural points of groundwater discharge (**Map 7**). The largest springs occur at low topographic elevations near major surface water bodies. Many small springs also occur at higher elevations, particularly in the driftless part of the county, and probably receive local flow from the upper Paleozoic aquifer. Certainly many more springs occur in the county than have been mapped in spring surveys.

Springs can be adversely affected by groundwater withdrawals. The U.S. Geological Survey has investigated several springs in the Madison area and documented relationships between pumping of deep municipal wells and reductions in spring flows and water levels. They have shown that pumping of Madison well 14 (715 feet deep; cased to 117 feet) influences the level of Merrill spring, located on the southwest shore of Lake Mendota. They have also documented a direct correlation between the pumping of Madison city well #1 (since abandoned) and shallow groundwater levels near Council Ring springs, located on the western shore of Lake Wingra. It should be noted that the Eau Claire formation is relatively thin or absent in these areas indicating, where the shallow and deep groundwater systems are fairly well connected. Where the Eau Claire formation is more significant, shallow springs may be better protected from high capacity wells drawing from the deeper (and confined) Mt Simon aquifer.

As a case study, springs in the Nine Springs watershed have been found to contribute a consistent source of water to remnant, but locally-diverse, sedge meadows and fens located there. The springs discharge water at rates of up to 2 cfs (~900 gpm) and typically show little or no response to precipitation and/or seasonal groundwater recharge events – suggesting (initially) deep groundwater sources.[7] Recent work, however, suggests that shallow sandstone aquifers can generate springs with steady flow even in areas where seasonal or higher frequency recharge occurs.[8] Steady flow in such a system can result from diffuse recharge through unlithified deposits or sandstone, followed by focused flow through thin, laterally extensive, high-permeability zones in sedimentary bedrock.

Research was conducted in the Nine Springs watershed to test conceptual models of the hydrogeology that contributes to the abundance of springs in the region and their unique flow characteristics using geochemistry, field-based hydrologic measurements, and numerical modeling approaches.[9,10,11] Results of the research suggests that springs may develop in the area where laterally–extensive, high-permeability zones in the Tunnel City geologic group intersects buried bedrock valleys (**Figure 5**). The Yahara Chain of Lakes and the surrounding wetlands were once part of a large river valley before glaciers filled them with sediment. Many springs in the area tend to occur at the edge of the bedrock, next to the sediment-filled valley.

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[7] Swanson, S. 2001b. *Hydrogeologic Controls on Spring Flow Near Madison, WI.*. UW-Madison Ph.D. Dissertation.

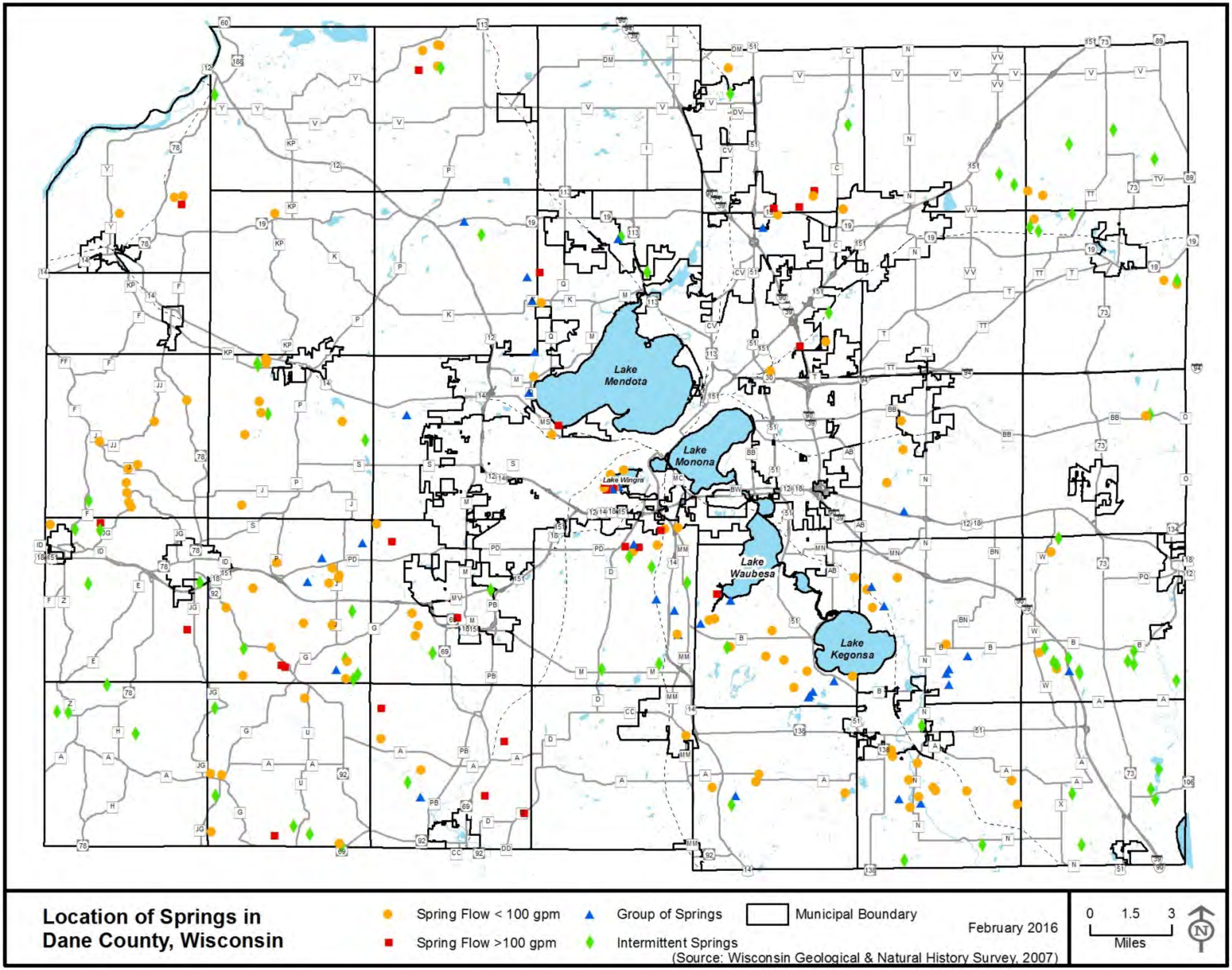
[8] Swanson, S. 2004. *Analytical and Numerical Models to Explain Steady Rates of Spring Flow.* Groundwater Vol. 42, No. 5: 747-759.

[9] Swanson, S. et al. 2001a *Two-Way Cluster Analysis of Geochemical Data to Constrain Spring Source Waters.* Chemical Geology 179: 73-91.

[10] Swanson, S. et al. 2004. *Analytical and Numerical Models to Explain Steady Rates of Spring Flow.* Groundwater Vol. 42, No. 5: 747-759.

[11] Swanson, S. et al. 2006. *Evidence for Preferential Flow Through Sandstone Aquifers in Southern Wisconsin.* Sedimentary Geology 184: 331-342.

Map 7


Lake Mendota
Lake Monona
Lake Wingra
Lake Waubesa
Lake Kegonsa
Location of Springs in Dane County, Wisconsin
Spring Flow < 100 gpm
Spring Flow >100 gpm
Group of Springs
Intermittent Springs
Municipal Boundary
February 2016
(Source: Wisconsin Geological & Natural History Survey, 2007)
0 1.5 3
Miles

Using a refined conceptual model that includes the high-permeability features, a three-dimensional groundwater flow model was developed for the Nine Springs area. Simulation results indicate that spring flow is potentially vulnerable to the loss of groundwater recharge if future urban development is not mitigated for adverse groundwater impact. In addition, spring flow and water quality could be affected by land use changes as far as 2 to 3 miles west of the topographic watershed for Nine Springs Creek, because the groundwater basin does not coincide with the surface watershed. According to the study, groundwater pumping has reduced spring flow by approximately 10 percent over pre-development conditions. Projected increases in municipal pumping over the next 20 years, however, are not likely to result in dramatic changes in spring flow as long as groundwater is withdrawn from the well-confined lower bedrock aquifer (Mt. Simon sandstone).

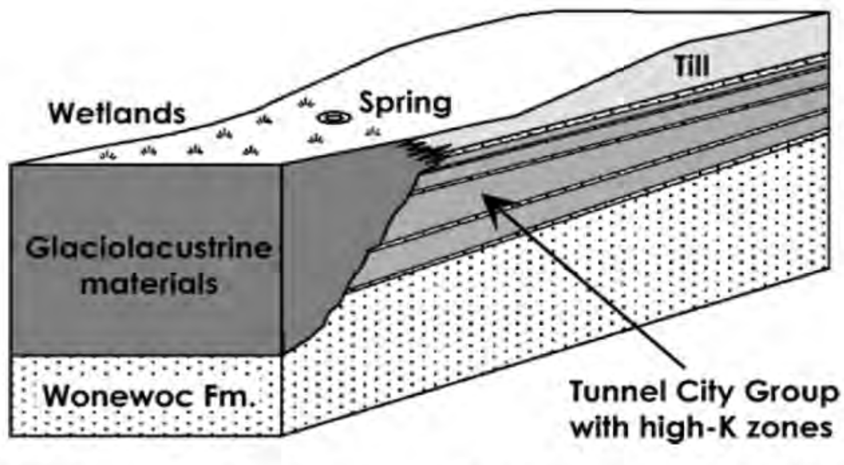


Figure 5. Conceptual model used in the design of the Nine Springs Inset Model. Springs form where high permeability zones in a shallow sandstone aquifer are truncated by a bedrock valley (the Yahara River in this case).

Source: Swanson 2006

Borehole monitoring of wells located near the margin of the buried bedrock valley and several large spring complexes in Nine Springs Creek shows that a head drop of ~18 m occurs across the Eau Claire shale layer. The lower heads in the lower bedrock aquifer are the result of municipal pumping in central Dane County. The large difference in head implies that the Eau Claire aquitard effectively restricts flow between the upper bedrock aquifer and the lower bedrock aquifer in the Nine Springs Creek region. It is believed this situation may exist in other areas having similar hydrogeologic conditions. The existence of high-permeability zones suggest that sandstones should be subjected to detailed hydrogeologic characterization in, for example, aquifer contamination and/or wellhead protection studies, where preferential groundwater flow can have major implications. Similar studies should also be conducted in other critical spring areas taking preferential groundwater flows into account.

According to Professor Jean Bahr, a hydrologist and chair of the UW-Madison Department of Geology and Geophysics, most springs in the Nine Springs area are largely replenished by relatively shallow groundwater sources and would probably not be appreciably affected by another deep well in the area. In part, that is because of the relatively impermeable layer (the Eau Claire shale formation) separates the two aquifers. Although several springs have dried up in the area, the situation reflected previous land use practices and wells that breached the aquifers, not the removal of water from the deep aquifer. Stormwater standards have also improved in recent years and new techniques have been employed, including enhanced infiltration from developed areas. These actions are expected to help mitigate the impacts on these biologically important groundwater features.

Chapter 3: Groundwater Quantity Management

Dane County occupies 1,230 square miles in south-central Wisconsin (**Map 8**), and is the second most populous county in the state with an estimated 2010 population of 488,073. Most of the land in the county is very productive farmland. At the geographic center of the county is the City of Madison, the state capital and the main campus of the state university system. Most of the work force is employed in trade or service industries.

As the county population has grown, the City of Madison and other cities and villages have expanded into neighboring agricultural land. In addition, many individual houses and subdivisions with on-site wastewater systems have been built outside of these urban areas. Both the pressures of urbanization and changes in the farm economy have pushed farmers to convert more land to cash crops such as corn and soybeans. Pastureland has been converted to hay, and drainage in wet areas has been conducted to provide more land for corn or pasture.

Population Trends and Forecasts

Dane County is currently the second largest metropolitan area in Wisconsin. **Figure 6** illustrates the changes in Dane County population from 1930 to 2010. Dane County experienced rapid growth (around 30 percent per decade) in the 1940s through the 1960s. More moderate growth rates, ranging from 11 to 16 percent per decade, have prevailed since the 1970s. Dane County is expected to reach a total population of nearly 606,620 people by the year 2040 –an increase of about 24 percent over the 2010 population.

The population growth in Dane County's cities and villages has essentially mirrored that of the county as a whole. Cities and villages experienced rapid growth rates (around 39 percent per decade) in the 1940s through the 1960s, followed by a slow growth rate of 9 percent per decade in the 1970s and more moderate growth rates, ranging from 15 to 17 percent per decade, since the 1980s. The population growth in Dane County's towns exhibits a different pattern. Towns experienced slow growth rates (around 10 percent per decade) in the 1940s through the 1950s, followed by almost no growth (1 percent per decade) in the 1960s. In the 1970s the town growth rate increased dramatically to 24 percent per decade. Slow to moderate growth rates, ranging from 6 to 12 percent per decade, have prevailed in the towns since the 1980s. The trend since the 1980s of a greater growth rate in cities and villages compared to towns is expected to continue into the future.

In 2010, almost two-thirds of the population of the county resided in the central urban area, one-quarter of the population was located in the smaller cities and villages surrounding the central urban area, and 12 percent was scattered throughout the rural areas of the county. **Tables 1 and 2** summarize population trends in the county. Urban Service Areas in the county are displayed in **Map 9.** A growth and development trend which is expected to continue into the future is a slightly greater proportion of new growth occurring in outlying urban communities compared to the central urban area, with rural areas maintaining the present percentage of total population.

Figure 6. Dane County Population Trends

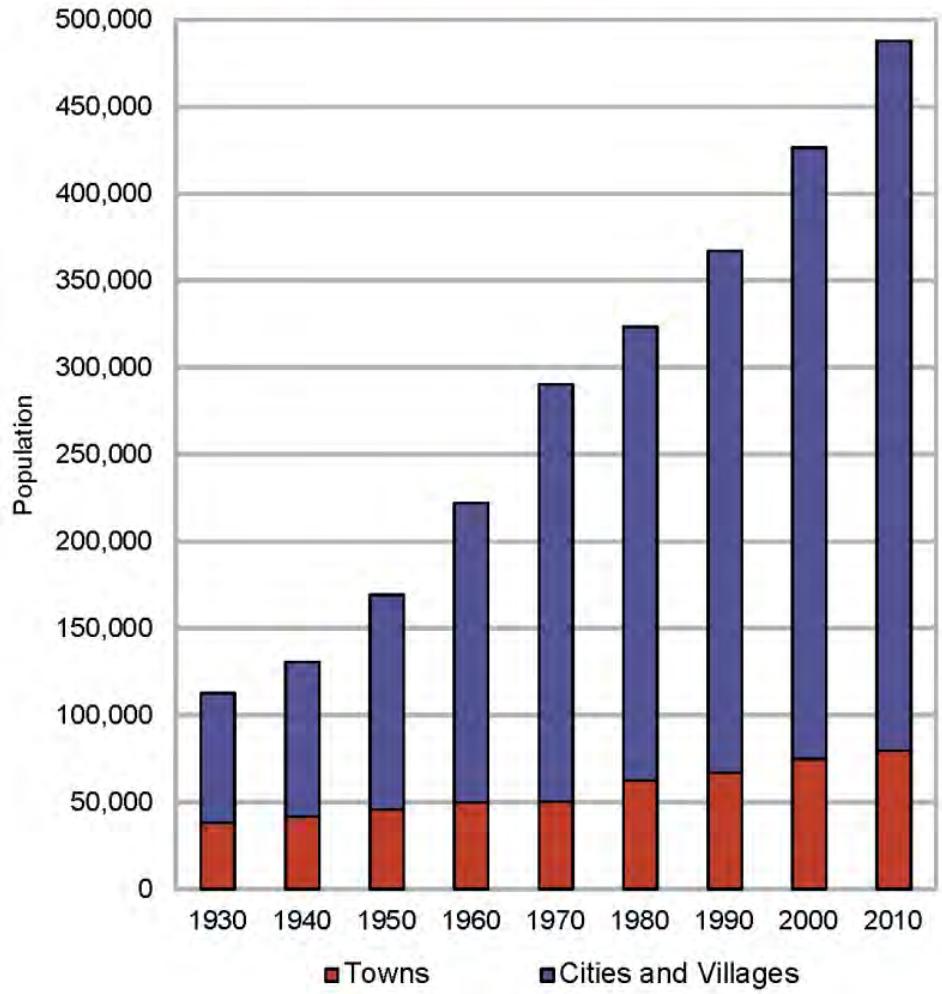


Table 1: Dane County Population Growth

Category	1980		1990		2000		2010	
	Pop.	Percent County	Pop.	Percent County	Pop.	Percent County	Pop.	Percent County
Towns	74,473	23.0%	66,989	18.2%	74,740	17.5%	78,882	16.2%
Villages	33,940	10.5%	41,748	11.4%	59,626	14.0%	73,056	15.0%
3rd & 4th Class Cities	44,516	13.8%	67,582	18.4%	84,106	19.7%	102,926	21.1%
City of Madison	170,616	52.7%	190,766	52.0%	208,054	48.8%	233,209	47.8%
Dane County	323,545	100.0%	367,085	100.0%	426,526	100.0%	488,073	100.0%

*Fitchburg (pop.11,973) included in Town Total in 1980. Fitchburg changed from a town to a 4th class city in 1983.

Source: U.S. Bureau of the Census (April of 1980, 1990, 2000, and 2010)

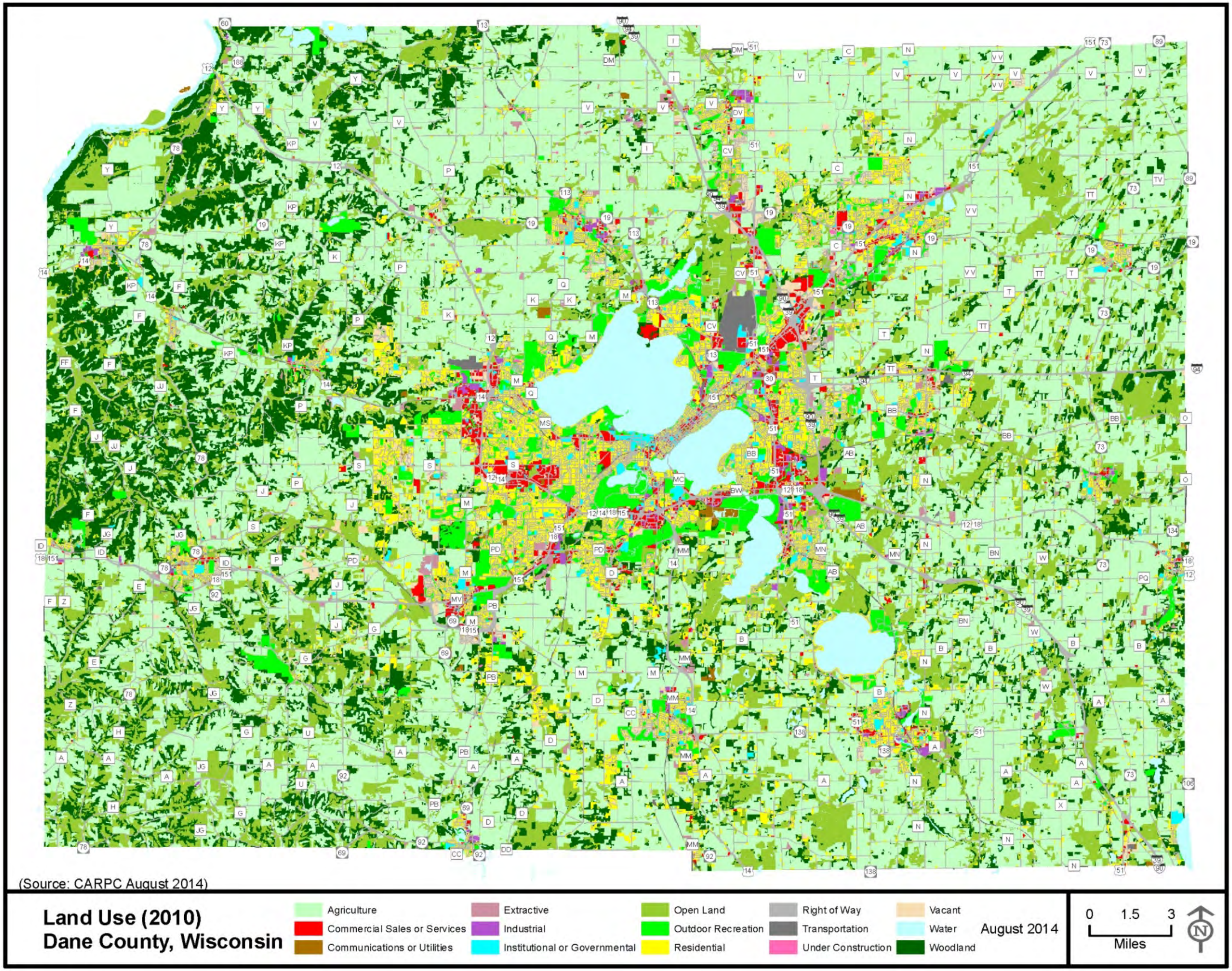
Table 2. Population Forecasts for Urban Service Areas (USAs) Dane County, WI.

USA	Census 2010	Urban Service Area Forecasts 2020	2030	2040	Change 2010-2040
Belleville*	1,885	2,041	2,255	2,369	484
Black Earth	1,346	1,378	1,409	1,404	58
Blue Mounds	855	965	1,090	1,185	330
Brooklyn*	936	1,120	1,350	1,510	574
Cambridge*	1,348	1,476	1,651	1,771	423
Central	302,935	327,042	352,548	367,749	64,814
Cottage Grove	6,230	7,228	8,504	9,509	3,279
Cross Plains	3,541	3,798	4,128	4,323	782
Dane	995	1,135	1,285	1,400	405
Deerfield	2,397	2,642	2,917	3,103	706
Edgerton*	97	294	519	640	543
Koshkonong	620	657	695	732	112
Marshall	3,862	4,100	4,440	4,635	773
Mazomanie	1,657	1,735	1,830	1,870	213
Mount Horeb	7,023	7,640	8,431	8,962	1,939
Northern	13,022	14,922	17,139	18,892	5,870
Oregon	9,234	10,303	11,623	12,583	3,349
Stoughton	12,921	13,434	14,098	14,364	1,443
Sun Prairie	29,403	34,812	40,876	45,629	16,226
Verona	10,645	12,827	15,098	16,878	6,233
Waunakee	12,159	13,916	16,011	17,604	5,445
Urban Total	423,111	463,465	507,897	537,112	114,001
Rural Total	64,962	67,155	69,403	69,508	4,546
Dane County	488,073	530,620	577,300	606,620	118,547

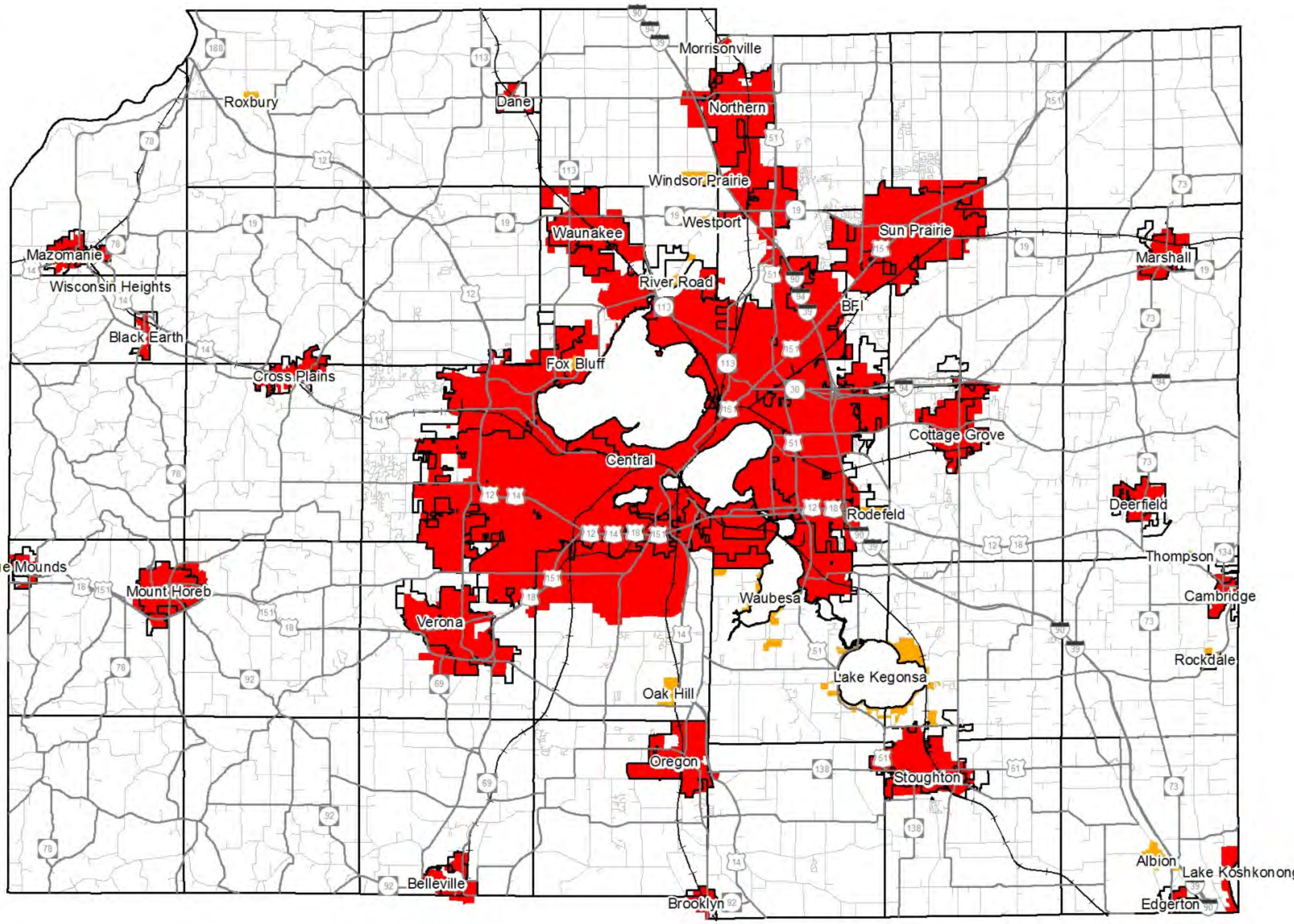
*Dane County portion

Source: Capital Area Regional Planning Commission 12/16

Map 8


(Source: CARPC August 2014)
Land Use (2010)
Dane County, Wisconsin
Agriculture
Commercial Sales or Services
Communications or Utilities
Extractive
Industrial
Institutional or Governmental
Open Land
Outdoor Recreation
Residential
Right of Way
Transportation
Under Construction
Vacant
Water
Woodland
August 2014
0 1.5 3
Miles
N

Map 9



Urban Service Areas of Dane County, Wisconsin

Urban Service Area
Limited Service Area
Municipal Boundary

November 2015

(Source: Capital Area Regional Planning Commission)

0 1.5 3
Miles

Groundwater Sources and Uses

Groundwater supplies nearly all of the water for our domestic, commercial, and industrial uses in Dane County. Although there is a relatively unlimited groundwater supply in the county for these purposes, it is critically important that the quality of groundwater be protected for its continued use by future generations. Groundwater is also very important in providing baseflow discharges to wetlands and streams, which supports and nourishes these resources and the biological communities that live there.

Groundwater that is withdrawn and used in Dane County is for the most part recharged locally from infiltration of precipitation. Water supplies are drawn from the upper sandstone and unconsolidated aquifers, which provide water for shallow domestic wells in rural areas; and the deep sandstone (Mt. Simon) aquifer, which is a source of water for nearly all of the deep municipal wells in the county.

Approximately 50 million gallons per day (gpd) of groundwater is withdrawn from high-capacity wells and used in Dane County – about 100 gallons per capita per day (gpcd). Public water supplies account for about 83 percent of total groundwater use (**Fig. 7**). This includes water withdrawn by public water systems and distributed in both municipal and private systems for residential, industrial, and commercial purposes. Private sources of water supply used for activities such as irrigation, stock watering, self-supplied industry, and rural domestic make up the remaining groundwater use.

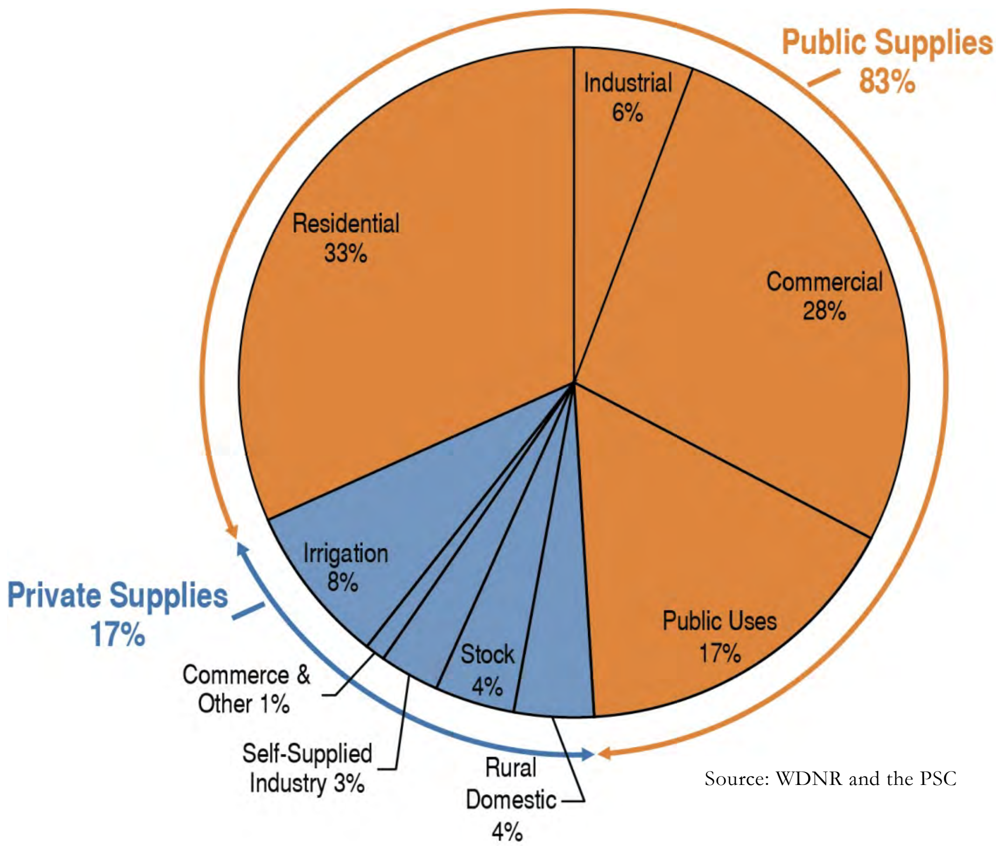
The City of Madison is the largest single consumer, withdrawing over 27 mgd and accounts for over half of the total use in the county (**Table 3 and Map 10**). Most of this water is returned to surface water after use, most often in a location different from where it was withdrawn. In the Madison Metropolitan area wastewater is treated at the Madison Metropolitan Sewerage District (MMSD) and primarily discharged to Badfish Creek – by-passing the Yahara Chain of Lakes entirely.

Trends in Water Use

Growing concern in Dane County over the effects of rapid urban growth and development on ground and surface water resources requires an improved understanding of the effects of urbanization and associated increased groundwater withdrawals on local water resources. Groundwater is the sole drinking water supply for county residents and sustains area lakes, streams and wetlands. Municipalities benefit from a relatively unlimited source of clean, healthy drinking water drawn from the deep Mt. Simon sandstone aquifer. However, local planning officials are faced with decisions that balance the need for increased groundwater withdrawals while maintaining the quantity and quality of groundwater-fed surface water resources.

Historically, the greatest increase in water use and wastewater flows in the Madison metropolitan area occurred between 1970 and 1979 when pumpage increased 6 mgd from 31 to 37 mgd (**Fig. 8**). **Fig. 8** includes public, private and domestic groundwater withdrawals. Even though the population of the area has grown by about the same amount (10-15 percent per decade), an apparent stabilization in water consumption since the 1970s is attributed to reduced industrial use and more efficient household fixtures and appliances.

Fig. 7 Estimated Groundwater Use in Dane County



Source: WDNR and the PSC

Table 3. Classification of Water Use for Dane County Communities (mgd)

7/6/16

	Residential	Commercial	Industrial	Public	Multi-Family	Non-Revenue	2014 Total Gals	2014 Pop. Served	gpcd	Active Wells (inactive)	Projected 2040 Pop.	2040 Water Use	2014-40	2040 Wells
Belleville	0.10 (59%)	0.02 (9%)	0.00 (1%)	0.01 (7%)	0.01 (6%)	0.03 (18%)	0.161	2,393	67	2	2,870	0.193	0.032	2
Black Earth	0.06 (56%)	0.02 (16%)	0.00 (0%)	0.00 (1%)	0.00 (0%)	0.03 (27%)	0.100	1,350	74	2	1,395	0.103	0.003	2
Blue Mounds	0.04 (52%)	0.00 (4%)	0.00 (0%)	0.00 (1%)	0.00 (1%)	0.03 (43%)	0.075	855	87	2	1,185	0.103	0.029	2
Brooklyn	0.06 (73%)	0.00 (3%)	0.00 (0%)	0.00 (4%)	0.00 (0%)	0.02 (21%)	0.081	1,417	57	2	1,975	0.113	0.032	2
Cambridge	0.07 (36%)	0.02 (11%)	0.00 (1%)	0.03 (15%)	0.00 (0%)	0.07 (37%)	0.181	1,383	131	2	1,880	0.246	0.065	2
Cottage Grove*	0.32 (66%)	0.05 (9%)	0.08 (16%)	0.01 (1%)	0.00 (0%)	0.04 (8%)	0.493	6,324	78	3(1)	9,470	0.738	0.245	3
Cross Plains	0.15 (51%)	0.02 (6%)	0.01 (2%)	0.01 (2%)	0.03 (10%)	0.08 (28%)	0.296	3,503	84	2	4,320	0.365	0.069	4
Dane*	0.04 (63%)	0.00 (3%)	0.00 (5%)	0.00 (0%)	0.00 (6%)	0.02 (23%)	0.069	1,038	66	2(1)	1,400	0.093	0.024	2
Deerfield	0.11 (65%)	0.01 (7%)	0.02 (10%)	0.01 (7%)	0.00 (0%)	0.02 (11%)	0.166	2,424	68	2(1)	3,015	0.206	0.040	2
DeForest*	0.37 (49%)	0.10 (13%)	0.05 (7%)	0.02 (3%)	0.05 (7%)	0.16 (21%)	0.760	9,240	82	5	12,010	0.988	0.228	6
Edgerton	0.19 (49%)	0.04 (11%)	0.00 (1%)	0.03 (8%)	0.02 (6%)	0.10 (26%)	0.395	6,000	66	3	6,755	0.445	0.050	3
Fitchburg*	0.76 (40%)	0.32 (17%)	0.14 (8%)	0.01 (1%)	0.60 (32%)	0.04 (2%)	1.878	22,000	85	6	32,670	2.789	0.911	6
Madison*	8.67(31%)	5.54 (20%)	1.44 (5%)	2.44 (9%)	5.63 (20%)	3.96 (14%)	27.671	254,797	109	22	292,030	31.714	4.043	29
Marshall	0.12 (54%)	0.01 (6%)	0.00 (0%)	0.01 (4%)	0.06 (26%)	0.02 (9%)	0.227	3,861	59	4	4,635	0.272	0.045	3
Mazomanie	0.09 (55%)	0.01 (3%)	0.03 (16%)	0.00 (2%)	0.00 (2%)	0.03 (21%)	0.159	1,664	96	2	1,865	0.179	0.019	2
McFarland*	0.37 (66%)	0.06 (10%)	0.00 (0%)	0.01 (2%)	0.04 (8%)	0.08 (14%)	0.566	8,045	70	3	9,895	0.696	0.130	4
Middleton*	0.73 (33%)	0.64 (29%)	0.22 (10%)	0.08 (4%)	0.26 (12%)	0.26 (12%)	2.182	17,733	123	6	23,230	2.859	0.676	7
Monona*	0.31 (34%)	0.43 (45%)	0.00 (0%)	0.01 (1%)	0.10 (11%)	0.08 (9%)	0.938	8,000	117	3	6,560	0.769	-0.169	3
Morrisonville*	0.02 (90%)	0.00 (3%)	0.00 (0%)	0.00 (1%)	0.00 (0%)	0.00 (6%)	0.022	390	55	2(1)	457	0.025	0.004	2
Mt Horeb	0.33 (62%)	0.05 (9%)	0.00 (0%)	0.02 (3%)	0.02 (3%)	0.12 (22%)	0.531	7,092	75	4	8,945	0.670	0.139	4
Oregon	0.45 (54%0	0.08 (10%)	0.02 (3%)	0.04 (4%)	0.05 (6%)	0.18 (22%)	0.827	9,420	88	3	12,580	1.104	0.277	4
Stoughton	0.57 (40%)	0.16 (12%)	0.47 (33%)	0.02 (1%)	0.07 (5%)	0.12 (9%)	1.415	12,800	111	4	14,080	1.556	0.141	4
Sun Prairie	1.34 (55%)	0.41 (17%)	0.10 (4%)	0.04 (2%)	0.23 (9%)	0.33 (13%)	2.452	30,871	79	6(1)	45,580	3.620	1.168	7
Verona	0.50 (34%)	0.37 (25%)	0.10 (7%)	0.05 (3%)	0.09 (6%)	0.38 (25%)	1.480	11,105	133	5	16,850	2.246	0.766	4
Waunakee*	0.67 (51%)	0.09 (7%)	0.25 (19%)	0.02 (2%)	0.07 (6%)	0.21 (16%)	1.315	12,840	102	5	17,530	1.796	0.480	5
Westport*	0.05 (47%)	0.02 (16%)	0.00 (0%)	0.00 (0%)	0.03 (27%)	0.01 (10%)	0.110	800	138	2	4,380	0.604	0.494	2
Windsor*	0.15 (56%)	0.07 (25%)	0.02 (7%)	0.00 (1%)	0.00 (0%)	0.03 (12%)	0.276	2,625	105	2	6,917	0.728	0.451	2
Total	**16.647 (37%)**	**8.525 (19%)**	**2.956 (7%)**	**2.873 (6%)**	**7.381 (16%)**	**6.504 (14%)**	**44.887**	**439,970**		**116 (5)**	**544,479**	**55.219**	**10.394**	**118**

*MMSD Urban Service Areas

Source: Public Service Commission and the Capital Area Regional Planning Commission

Map 10

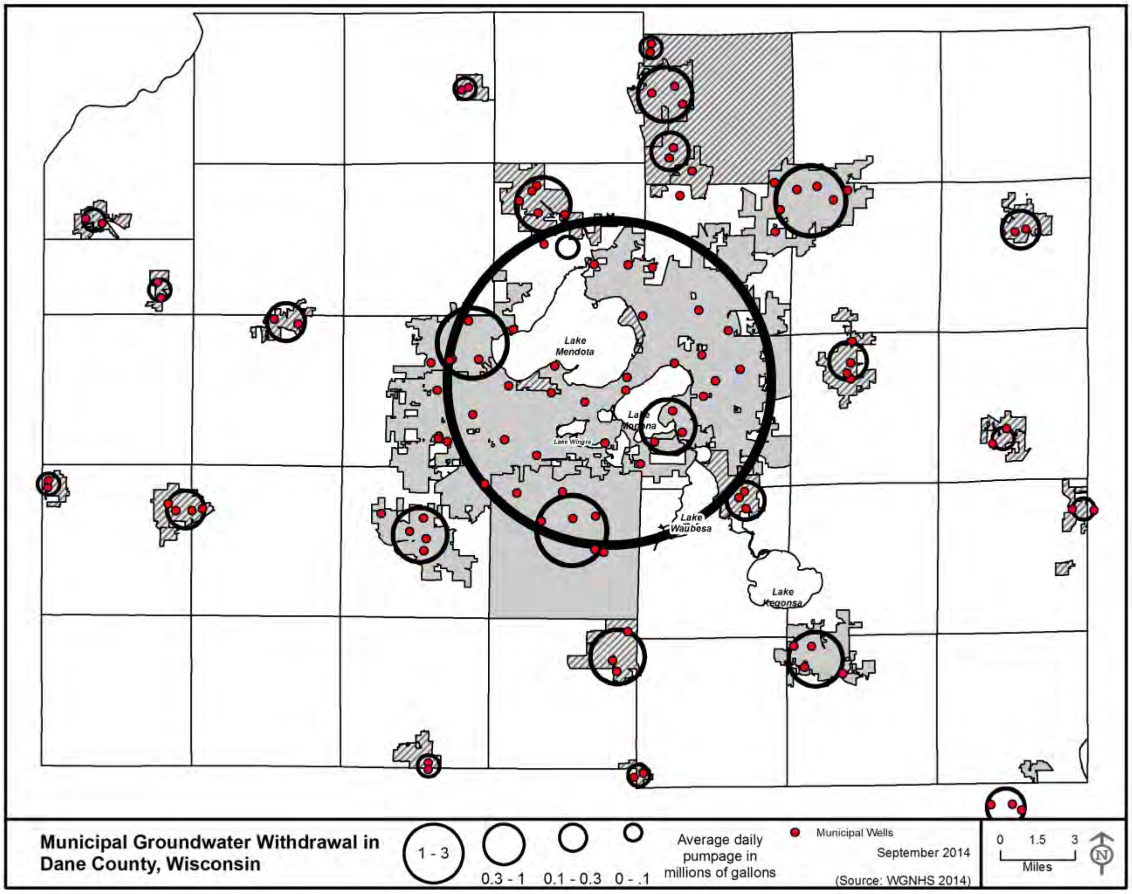
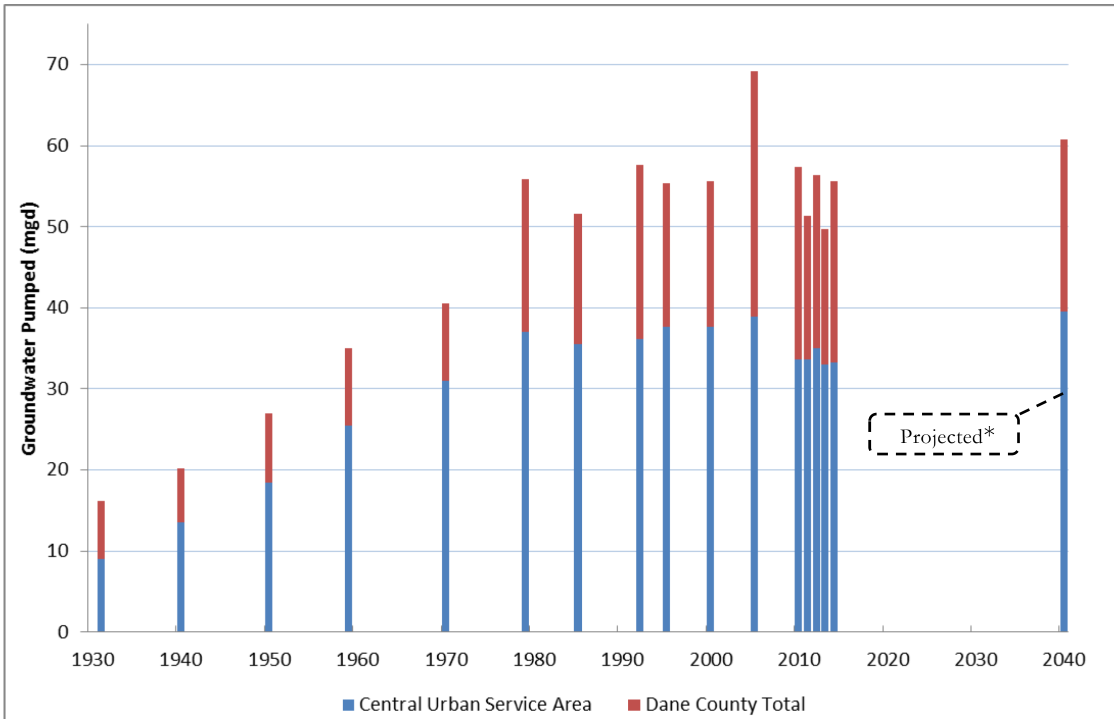


Fig. 8. Reported and Projected Groundwater Withdrawals in Dane County.



* Based on current per capita rate times projected 2040 population. Source: DCRPC, PSC, WDNR, and USGS.

Figure 9 shows Dane County water use by category. Compared to groundwater use, surface water use is a small percentage of the County total (**Table 4**).

Fig. 9

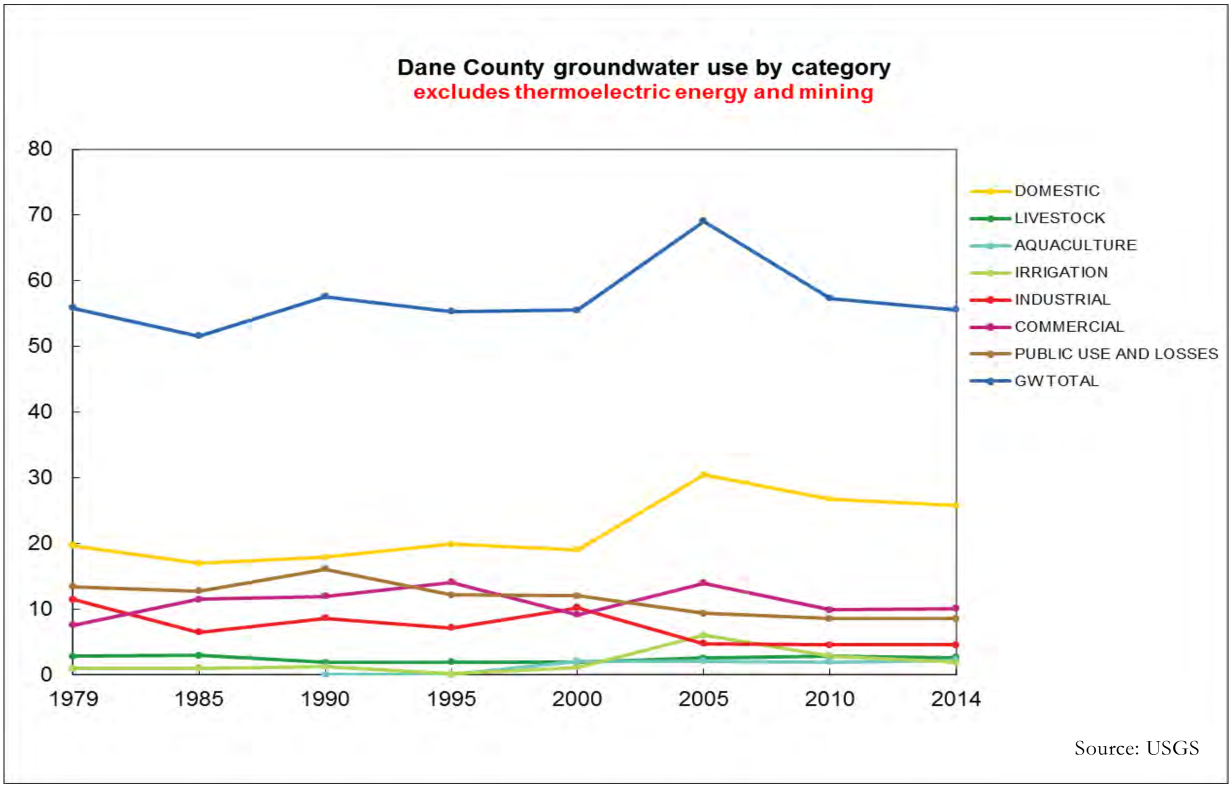


Table 4
Dane County Water Use by Year (mgd)

	1979	1985	1990	1995	2000	2005	2010	2014
Surface Water Use	0.28	1.34	1.41	0.81	0.25	1.05	2.21	2.40
Groundwater Use	55.88	51.57	57.61	55.34	55.56	69.11	57.36	55.60
Total Water Use	56.16	52.91	59.02	56.15	55.81	70.16	59.57	58.00

Source: USGS

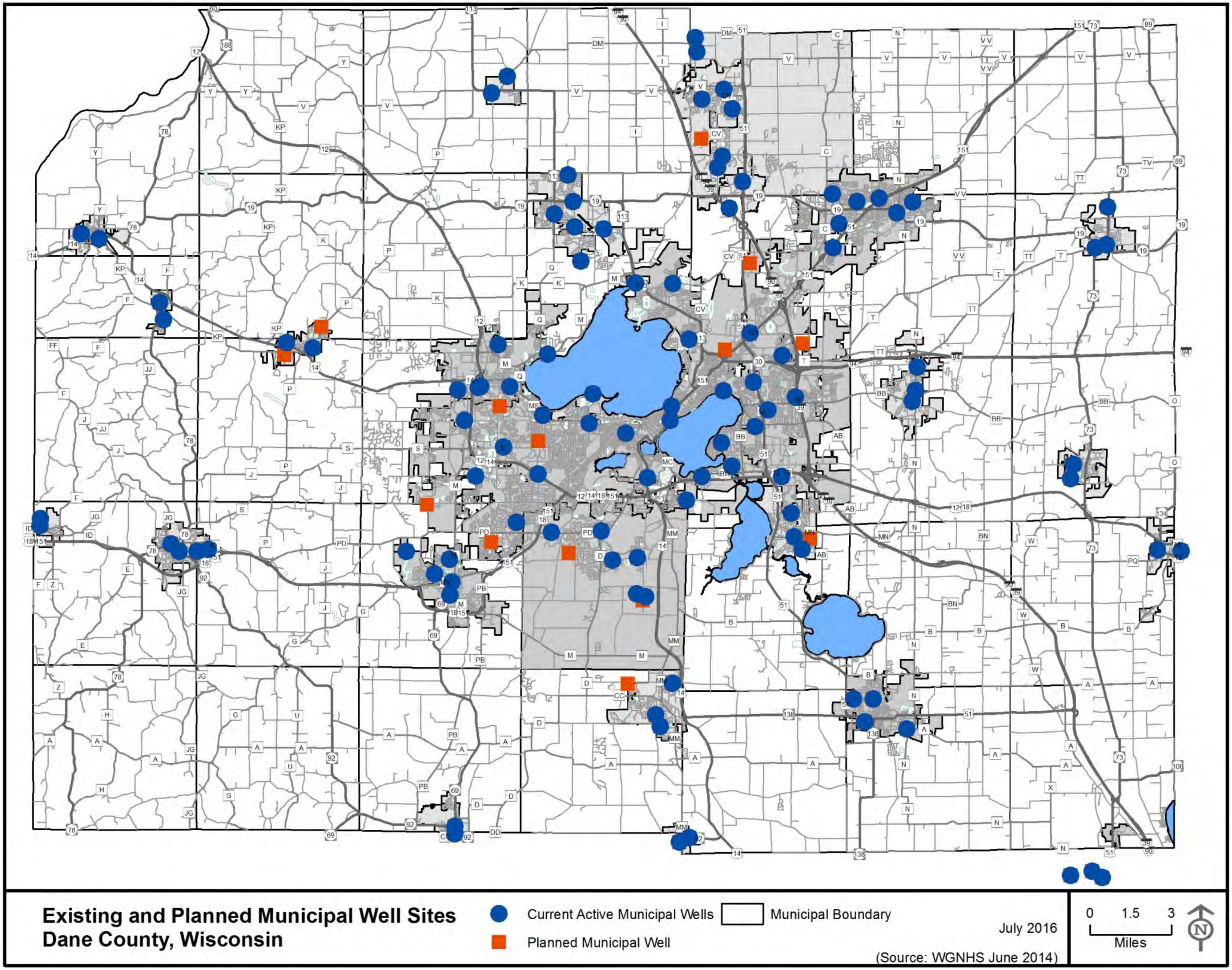
Table 3 summarizes reported 2014 and projected 2040 water use. **Map 11** shows the locations of existing and proposed wells for each community in central Dane County. Note, specific locations of existing and planned wells may change. Municipal water supply agencies can provide more recent and detailed information for a well site. Also note that the 2040 population and water use projections include a somewhat slower pace of growth than earlier projections. This is consistent with the Wisconsin Department of Administration methodology which takes into account the effect of the 2008 recession.

Water use in Dane County is expected to increase by about 23 percent (10.32 mgd) between 2014 and 2040. Projected water use was estimated using current per capita use multiplied by projected 2040 population. In central Dane County, water use by communities served by MMSD is expected to increase by about 21 percent (7.5 mgd or 11.6 cfs). Most of this water will be diverted out of the original basin from which it was withdrawn, further decreasing water table levels and groundwater discharge to local water bodies.

Pumping or withdrawal of groundwater, and its eventual return to surface waters in a different location, can have indirect but serious impacts on local hydrology and water quality conditions. These impacts can be particularly pronounced in urban areas, where concentrated pumping of groundwater lowers the water table, reducing baseflow contributions to streams and lakes. The impacts are also heightened in urban areas as a result of historic paving and impervious areas, which reduces local infiltration of precipitation to recharge groundwater (where mitigation measures have not been implemented).

In Dane County, these effects are most apparent for the central urban area, where most of the groundwater used in the county is withdrawn in a concentrated urban setting, and the water used is subsequently diverted, after treatment, around the natural Yahara River flow system and discharged further downstream at Badfish Creek. As a result, there have been important effects of lowered groundwater levels on wetlands and stream baseflow in the central urban area, including lower base-flows in the Yahara River system downstream from Lake Mendota. In addition, the concentrated withdrawal of groundwater in the central urban area has enlarged the area influenced by ground-water drawdowns to include a larger recharge area, and induces more rapid movement of potential contaminants to groundwater and municipal water supplies. These issues are discussed more fully in the following sections.

Map 11


Existing and Planned Municipal Well Sites
Dane County, Wisconsin
Current Active Municipal Wells
Planned Municipal Well
Municipal Boundary
July 2016
(Source: WGNHS June 2014)
0 1.5 3
Miles
N

Dane County Regional Hydrologic Study

To better identify existing and potential future impacts of urban development, groundwater withdrawals and interbasin water diversions on the county's ground and surface water resources, a Regional Hydrologic Study was completed in 1997. The work was conducted cooperatively by the Dane County Regional Planning Commission (now the Capital Area Regional Planning Commission), the Wisconsin Geological and Natural History Survey, and the U.S. Geological Survey, and sponsored by the Department of Natural Resources, Dane County, the Madison Metropolitan Sewerage District, and the City of Middleton.

As part of the study, a groundwater flow model was developed to simulate changes in groundwater levels due to pumping, identify important recharge and discharge areas, provide estimates of the directions and rates of groundwater movement, and better define ground and surface water relationships. The model was updated by WGNHS and its partners in 2014 to include greater understanding, knowledge, and technology since the original model development in the mid-1990s.

Final products of this investigation include reports and maps describing the hydrogeology of Dane County as well as an evaluation of alternative management strategies to offset future groundwater and streamflow declines. Strategies such as water conservation, concentrated pumping in the City of Madison, maximizing infiltration, and return of highly treated wastewater show promising opportunities to mitigate the impacts resulting from historic and future wastewater diversion around the Yahara Lakes system. An electronic Yahara Lakes reservoir routing model was also developed which demonstrates pre-diversion dry-weather baseflows could be maintained by operating the lakes as surface water reservoirs to store and release more slowly during critical summer periods.

The addition of Verona to the Madison Metropolitan Sewerage District in 1996 has increased the effects of high capacity municipal well withdrawals on baseflows in the Sugar River Basin. In response, MMSD treated effluent generated in the Upper Sugar River is returned to the Sugar River basin at an outfall on Badger Mill Creek. Only the amount of effluent generated in the basin will be returned (maximum 8 mgd or 12.4 cfs). This effort has gained wide public support and has revitalized a stream that had lost most of its baseflow due to the extensive development in the area. The innovation here is treating wastewater as a resource, rather than something simply to be disposed of.

Results of the modeling effort show that most of the groundwater in the county originates within the county boundaries. This highlights the need for water conservation and water supply planning to maintain groundwater supplies and baseflow to county streams. The model serves as an ongoing management tool to evaluate the effects of selected management strategies to mitigate adverse ground and surface water impacts. The model also provides a regional framework for undertaking more detailed local hydrologic studies and spin-off research projects that will still be required to provide refined information for site-specific development and resource management investigations.

Effects of Pumping and Wastewater Diversion

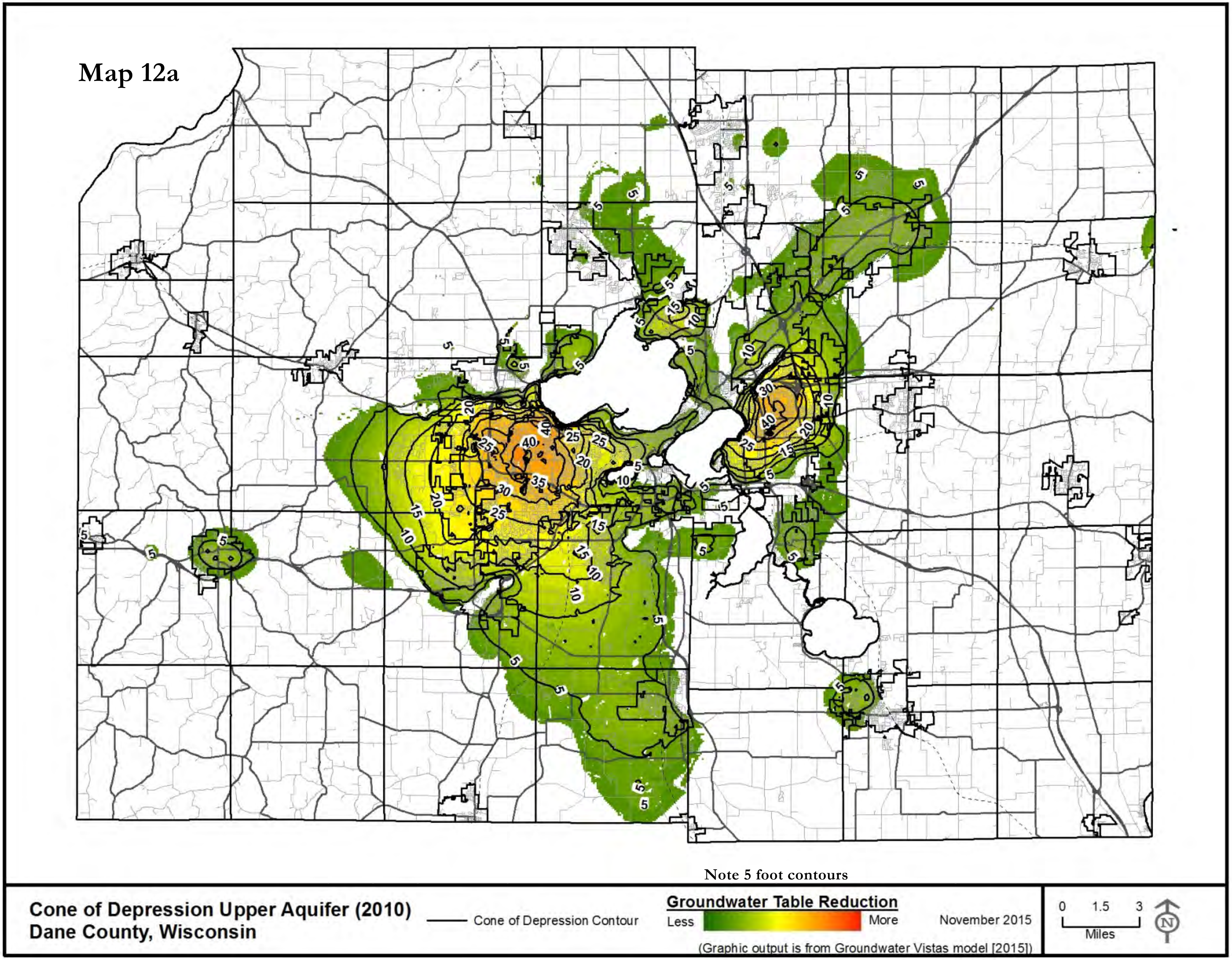
Following use, most of the municipal and industrial well water from central Dane County is conveyed to the Madison Metropolitan Sewerage District's (MMSD) Nine Springs Wastewater Treatment Facility. The treated effluent is then pumped to Badfish Creek and diverted around the Yahara River/Lakes system. As a result, groundwater is removed from the original basin from which it was derived.

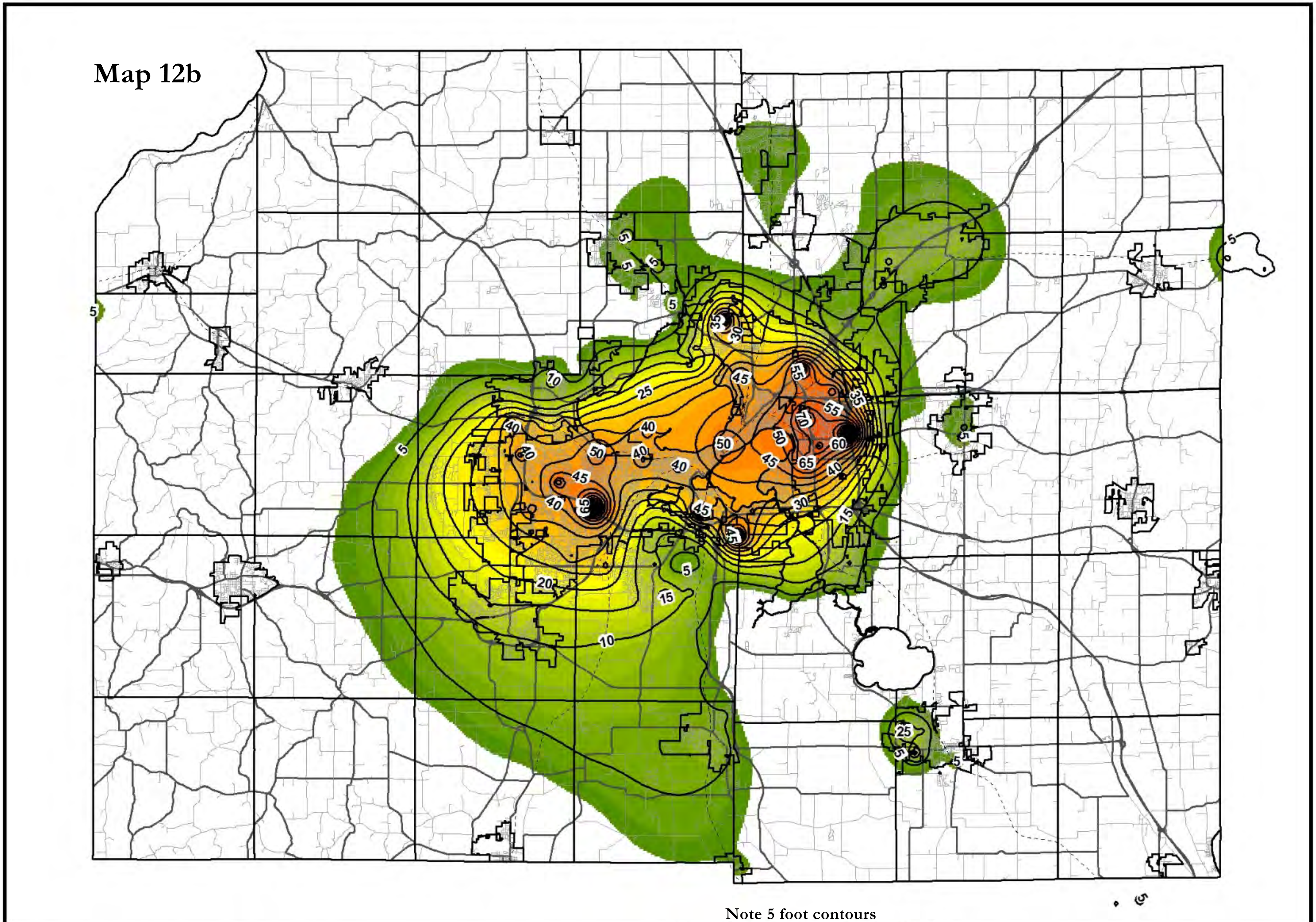
Pumping or withdrawal of groundwater, and its eventual return to surface waters in a different watershed, can have indirect but serious impacts on local hydrology and water quality conditions. The most serious impacts are evident in the urban and urbanizing areas surrounding the Yahara Lakes. Although there is no shortage of groundwater available for future needs, pumping has already lowered groundwater levels, significantly reducing baseflow from groundwater to urban streams and wetlands.

The greatest effect of pumping on groundwater levels occurs in the Madison metropolitan area (**Maps 12a and 12b**). In the vicinity of Madison, the potentiometric level of the Mt. Simon aquifer and the water table level of the shallow aquifer have declined over 50 feet compared to predevelopment conditions. There are also two major cones of depression generally east and west of Lakes Mendota and Monona. This is because the upper sandstone and lower Mt. Simon aquifers are in close hydraulic connection to the lakes, and the semi-confining Eau Claire shale formation is largely absent or very thin in this area. The presence of two distinct cones of depression indicates the lakes are significant water sources that contribute to municipal wells.

The effects of the cone of depression and subsequent drawdown are particularly evident where the water table meets the land surface: at springs, streams, and wetlands. For example, modeling results show pumping from municipal wells has caused noticeable reductions in dry weather baseflow in small Yahara River tributary streams (**Table 5 and Map 13**). Baseflow through the Yahara River system itself at McFarland has been reduced approximately 30 percent (48 cfs) as a result of pumping and wastewater diversion around the Yahara River lakes. This supports earlier studies which find a direct relationship between the reduction in flow through the Yahara River system and the amount of MMSD wastewater diverted around the Yahara Lakes and discharged to Badfish Creek. This is a conservative estimate of the overall impacts since it does not account for the recharge losses resulting from impervious urban development, just well water withdrawals.

Urbanization also changes infiltration and groundwater recharge. This results from impervious surfaces like buildings, roads, and parking lots being constructed over previously undeveloped land. Water then runs off the land surface instead of infiltrating and replenishing groundwater supplies, resulting in additional water table declines. Extensive effort by the Regional Planning Commission and local municipalities since the late 1990s to require stormwater infiltration practices in new development areas, and inclusion of infiltration standards in the Dane County and local stormwater ordinance have addressed this concern in these areas.


Map 12a
Note 5 foot contours
Cone of Depression Upper Aquifer (2010)
Dane County, Wisconsin
Cone of Depression Contour
Groundwater Table Reduction
Less
More
November 2015
(Graphic output is from Groundwater Vistas model [2015])
0 1.5 3
Miles
N



Cone of Depression Mt Simon Aquifer (2010) Dane County, Wisconsin

* Equivalent groundwater level in a confined [i.e. pressurized] aquifer

(Graphic output is from Groundwater Vistas model [2015])

Table 5
Modeled Stream Baseflows for Selected Sites (cfs)

Station	Predevelopment Baseflows[1]	2010 Pumping Conditions[2]	2040 Pumping Conditions[3]
Spring Cr. nr Lodi	22.23	21.70	21.65
Black Earth Cr abv Cross Plains	4.95	3.52	3.50
Black Earth Cr. nr Black Earth	33.33	31.36	31.23
Mt. Vernon Cr	19.19	18.49	18.32
West Br. Sugar R. at Hwy 92*	18.96	19.20	19.13
Badger Mill Cr. south of Verona*	3.65	4.23	3.65
Sugar River abv Confluence	16.58	13.66	13.01
Pheasant Br. at Middleton	2.85	1.19	1.13
Dorn Cr. at CTH M	6.27	5.65	5.50
Sixmile Cr. Waunakee at Mill Rd.	9.07	5.59	7.06
Token Cr. at USH 51	20.35	17.99	16.81
E. Br. Starkweather Cr at Milwaukee St.	3.01	0.73	0.41
W. Br. Starkweather Cr at Milwaukee St.	8.86	4.16	3.27
Murphy (Wingra) Cr. at Beld St.	2.89	1.83	1.64
Nine Springs Cr. at USH 14	11.84	6.69	6.45
Door Cr. nr Cottage Grove	7.69	5.69	5.30
Badfish Cr. at CTH A*	11.59	75.49	75.22
Yahara R. nr Windsor	6.77	6.28	6.13
Yahara R. outlet L. Waubesa	157.12	109.09	102.02
Yahara R. south of Stoughton	207.46	156.65	148.91
Maunesha R. south of USH 151	17.25	16.44	16.16
Koshkonong Cr. nr Sun Prairie*	0.77	5.02	4.76
Koshkonong Cr. nr Deerfield*	27.35	29.79	28.84
Koshkonong Cr. nr Rockdale*	62.84	65.02	63.99

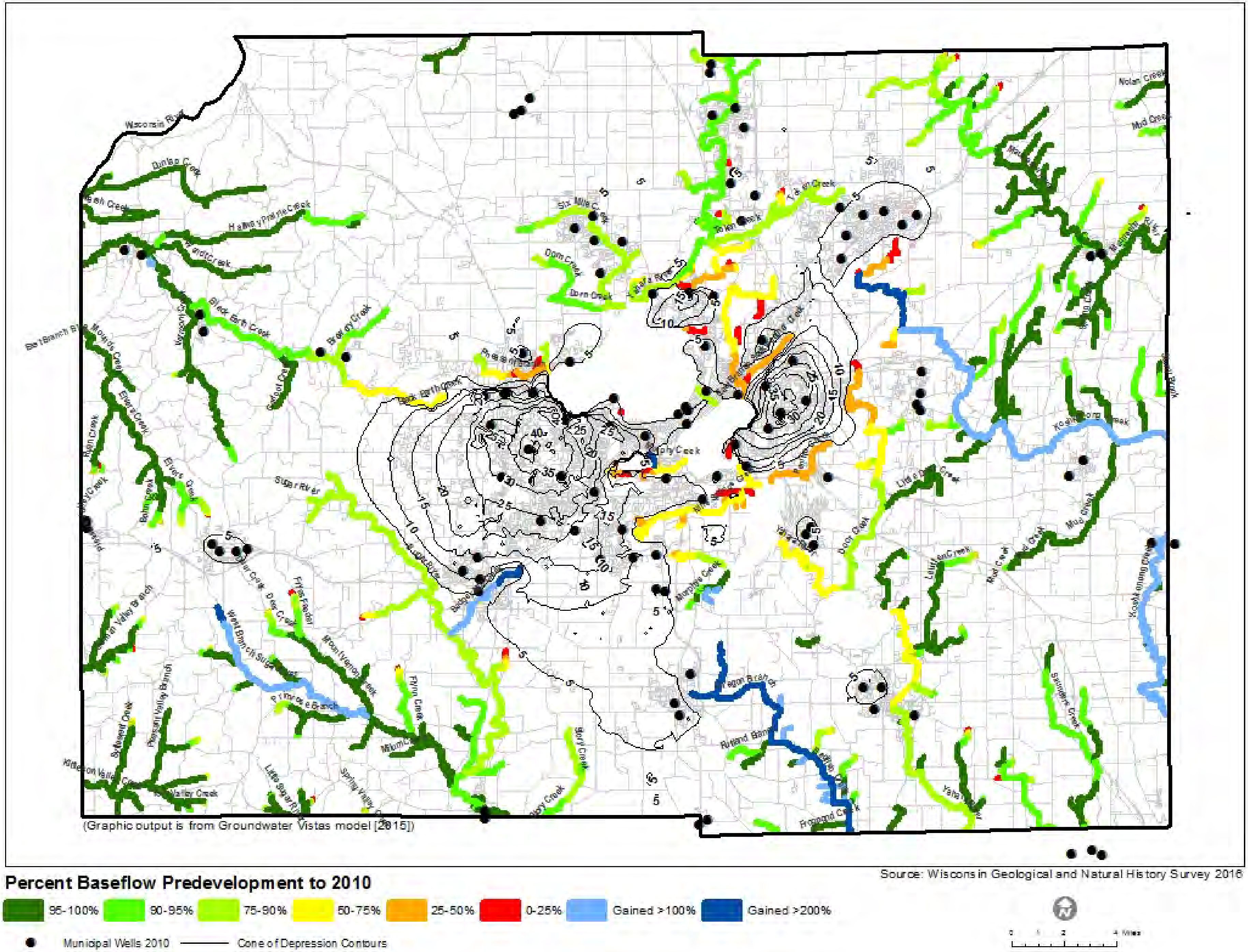
[1] Simulated predevelopment results were estimated by removing all well pumping from the regional groundwater model resulting in a subsequent rebound in water table levels and stream baseflows. Predevelopment flows do not include wastewater treatment plant discharges present in 2010. Asterisks (*) indicate where the 2010 flows include WWTP additions.

[2] 2010 condition streamflow results were estimated using the calibrated regional groundwater model based on measured baseflow results (n=210) from representative streams throughout Dane County and surrounding areas. Estimated wastewater discharges to streams have also been included, where these occur. Note, the modeled differences in streamflows are generally more accurate than the actual values due to regional calibration and seasonal variations. Streamflows are provided for reference purposes.

[3] 2040 baseflow results were estimated using the regional groundwater model and projected 2040 well water withdrawals by municipalities spread equally among both existing and planned wells. Increases in wastewater discharges above current conditions have not been included.

Source: Wisconsin Geological and Natural History Survey and Capital Area Regional Planning Commission.

Map 13. Modeled comparison of changes in streamflow between Predevelopment (no pumping and no WWTP discharges) and 2010 conditions. Streams which actually gained flow receive additional water as discharge from wastewater treatment facilities.



Model runs conducted as part of the Regional Hydrologic Study indicate that well pumping accounts for a significant amount (80 percent) of the baseflow reduction through the Yahara system, while recharge losses from impervious areas (20 percent) causes additional declines.[12] This may vary for individual stream segments based on the degree of development in the sub-watershed and proximity to pumping wells, but overall well water withdrawals are the dominating influence. Also, with improved stormwater volume controls there is no recharge loss resulting from new development (as compared to previous development where these controls have not been put into effect). Modeling conducted by the WGNHS indicates recharge loss due to future development is not expected to be significant because of the adopted stormwater controls (Dane County Chapter 14 and local ordinances), which help maintain pre-development groundwater levels.[13]

It should be noted, in the Madison area near areas of heaviest groundwater pumping, the original direction of groundwater flow towards the lakes and Yahara River has been reversed and instead flows towards the municipal wells in areas of heaviest withdrawals as induced groundwater recharge (**Figure 7**). Heavy municipal pumping can accelerate downward leakage of "shallow" groundwater and surface water, which may increase the flow of associated contaminants to municipal wells.

Finally, the expanding cone of depression appears to have also shifted the regional groundwater divide to the southwest, causing groundwater which previously discharged to the Sugar River, to be diverted to the Yahara River basin (**Map 5**). Groundwater diversion may also be occurring from other adjacent river basins to a lesser extent. In 1998, MMSD began returning treated wastewater to Badger Mill Creek, equal to the amount of water pumped out of the basin. This has helped to restore the water balance between the Upper Sugar River and Yahara River watersheds (resulting from diversion) and remove low flow as a limiting condition. This project has had widespread public support and success. In 2008 Badger Mill Creek was designated a Class II trout stream by the WDNR, largely attributed to the treated effluent return.

2040 Baseline Conditions[14]

As part of the Regional Hydrologic Study a future baseline condition was modeled which incorporated specific assumptions for anticipated future water use and wastewater diversion. This effort was repeated using the updated groundwater model in 2014.

Map 14a shows the additional groundwater declines that can be expected by the year 2040 (from current conditions) due to increased well pumping and continued wastewater diversion. Noticeable additional water table declines would occur northeast and southwest of Madison metro area. Similar potentiometric surface declines would occur in the deeper Mt. Simon aquifer (**Map 14b**), although the effects are more pronounced near new urban well sites.

Note many of the white areas in the urban metropolitan region are the result of an actual water table *rebound* compared to exiting conditions. The area along the west beltline (Madison wells 10, 12, 26, and 20) is a good example. This occurs where current pumping at an individual well site currently exceeds the 2040 pumping assumption where future water use is spread out equally among both existing and planned well sites. Though imprecise, the equal withdrawal scenario provides a useful comparison among communities in the region and represents an average condition or equal

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[12] Dane County Regional Planning Commission. 1997. *Evaluation of Alternative Management Strategies, Dane County Regional Hydrologic Study*.

[13] Professor Ken Brandbury, WGNHS, personal communication 5/13, and Stormwater Performance Standards contained in Dane County Chapter 14.51(2)(e)(3). https://pdf.countyofdane.com/ordinances/ord014.pdf.

[14] Assumes no mitigating actions being taken.

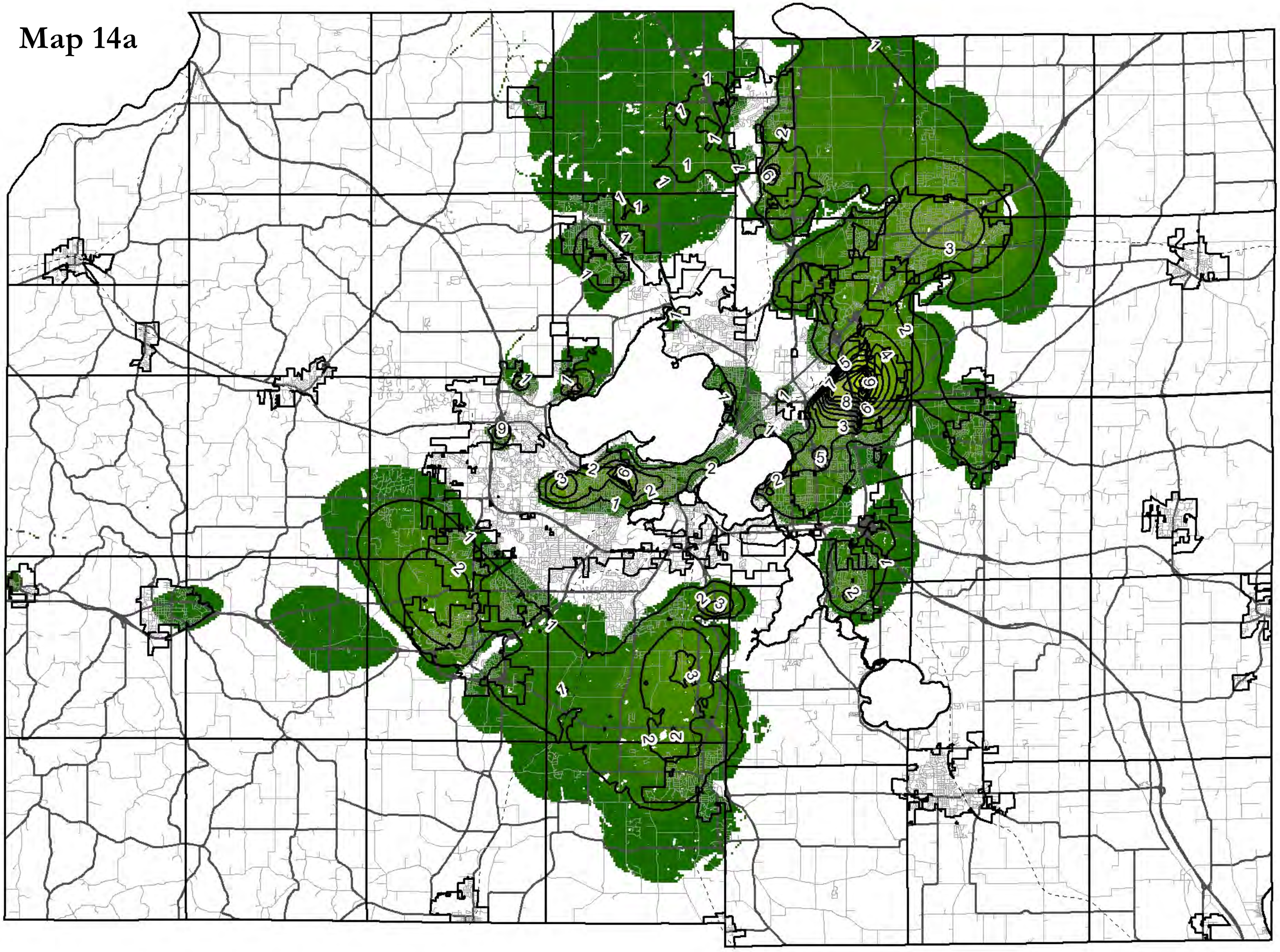
likelihood of withdrawal among existing and planned municipal wells. That is usually not the case under actually conditions, which can change year to year and community to community. The modeling indicates the kinds of analyses that can be conducted for individual communities depending on different well strategies or alternatives based on varying well locations and withdrawal rates. As such, this modeling scenario represents an average future condition.

Baseflows in small tributary streams are also affected, particularly near the Central Urban Area (**Map 13 and Table 5**). Baseflows could decrease 50 percent or greater in Murphy, Nine Springs, Pheasant Branch, and Starkweather Creeks compared to predevelopment conditions. Baseflow through the Yahara River system at McFarland is expected to decline an additional 8 cfs from 2010 to 2040, a total 36 percent reduction compared to predevelopment conditions.

The 2040 baseline condition was modeled in order to determine the most likely impacts to water resources if the region grew as expected, mitigating measures were not employed, and wastewater diversion continued as usual. These impacts would be in addition to those experienced in 2010 (**Maps 12a and 12b**). The 2040 baseline condition also serves as a very useful reference point for evaluating various management alternatives or combination of alternatives that may be undertaken to help mitigate future groundwater level declines and reductions in stream baseflow.

As part of the original study, an evaluation of alternative management strategies was also conducted which could potentially offset groundwater and streamflow declines. Strategies such as aggressive water conservation, maximizing infiltration, selective pumping patterns in the City of Madison, improved lake management, and return of highly treated wastewater showed the most promising opportunities for mitigating the water table level declines and reductions in baseflows (See **Table 7** below).

Map 14a



(Graphic output is from Groundwater Vistas model [2015])

Note 1 foot contours

Upper Aquifer 2040 Cone of Depression (change from 2010) Dane County, Wisconsin

Groundwater Table Reduction

Less — More

Cone of Depression Contours

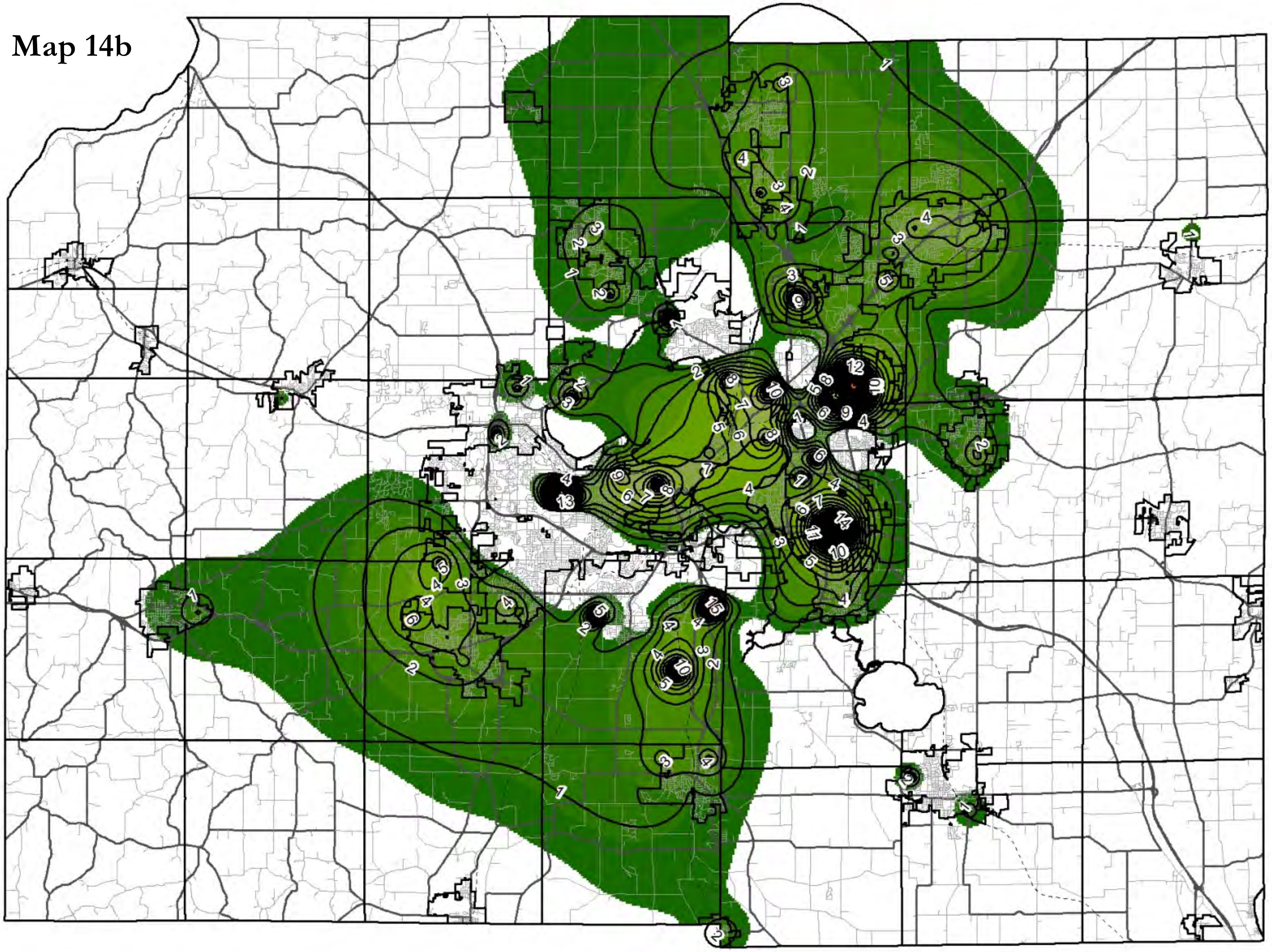
November 2015

(Source: WGNHS 2015)

0 1.5 3
Miles

N

Map 14b



(Graphic output is from Groundwater Vistas model [2015])

Note 1 foot contours

Mt Simon Aquifer 2040 Cone of Depression (change from 2010) Dane County, Wisconsin

* Equivalent groundwater level in a confined [i.e. pressurized] aquifer

Potentiometric Level Reduction*

Less — More

Cone of Depression Contour

November 2015

(Source: WGNHS 2015)

0 1.5 3
Miles

N

Groundwater Budget Indices and Water Supply Plans

Based on work conducted by Douglas S. Cherkauer, Ph.D., UW-Milwaukee, as part of the groundwater modeling conducted by Southeast Wisconsin Regional Planning Commission, groundwater budget indices have been developed to assess water supply plans in southeast Wisconsin. These indices can similarly be used to augment and provide more detailed information than the drawdowns or cones of depression analyzed as part of the earlier Dane County regional hydrologic study. In addition to drawdown, the model can be used to determine the magnitudes of all the individual components of a groundwater budget (**Table 6**).

Table 6. Definition of Flow and Storage Terms.

	Inflows	**Outflows**	**Storage**
	R = recharge		
Shallow Aquifer – upper sand and gravel glacial deposits and underlying sandstone and dolomite bedrock	$\mathbf{SW_{in}}$ = flow from surface waters to groundwater	$\mathbf{SW_{out}}$ = discharge to surface waters from groundwater	Volume of water in the aquifer below the water table and above the Eau Claire shale formation
	$\mathbf{Sh_{in}}$ = lateral inflow through the aquifer	$\mathbf{Sh_{out}}$ = lateral outflow through the aquifer	
	$\mathbf{L_{up}}$ = leakage up from the deep aquifer	$\mathbf{L_{down}}$ = leakage down to the deep aquifer	
	$\mathbf{H_r}$ = human inputs (e.g., artificial or enhanced recharge)	$\mathbf{Well_{sh}}$ = pumpage from the shallow aquifer	
Eau Claire Shale – semi-confining unit			
	Inflows	**Outflows**	**Storage**
Deep Aquifer – lower Mt. Simon sandstone formation	$\mathbf{D_{in}}$ = lateral inflow through the deep aquifer	$\mathbf{D_{out}}$ = lateral outflow through the deep aquifer	Volume of water in the aquifer below the Eau Claire shale formation and the base of the Mt. Simon formation
	$\mathbf{L_{down}}$ = leakage down from the shallow aquifer	$\mathbf{L_{up}}$ = leakage up to the shallow aquifer	
	$\mathbf{H_{dp}}$ = human inputs = 0	$\mathbf{Well_{dp}}$ = pumpage from deep aquifer	

More specifically:

- How does the quantity of water being removed from an aquifer by wells relate to the aquifer's natural supply?
- What effect does human alteration of the groundwater system have on surface waters?

The indices presented, called demand to supply ratio (DSR), and baseflow reduction index (BRI) address the two questions above. They were developed by Weiskel, et al (2007), and Cherkauer (2010), respectively. In terms of cause and effect, it is useful to think of the DSR as being the "cause" (increasing demand compared to supply) and BRI as the "effect" (reduction in baseflows). The results of an analysis conducted for Dane County using these two indices follows.

Demand to Supply Ratio (DSR)

One measure of an aquifer's groundwater budget comes from comparing the net amount of water humans are extracting (volume pumped) to how much water is replenished at any given time. The Demand to Supply Ratio (DSR) is basically the ratio of groundwater demand to the available supply. It can be expressed as:

Demand/Supply = (Well pumping out – Human replacement in)/(Sum of natural inflows).

The net extraction (outflows induced by humans pumping wells minus any human returns to the same aquifer) is used as an indicator of human stress on the aquifer. In terms of scale, it is expressed as a percentage of the natural inflows (i.e., precipitation and groundwater recharge). The natural inflows include groundwater recharge, leakage between aquifers, flow from surface water bodies, and lateral flow through the aquifer shown in **Table 6**. Note that current law requires all new development projects in Dane County to maintain pre-development recharge, meaning no recharge loss.[4] Whereas human water replacement for well withdrawals are assumed to be generally zero at this time (as in the equation above), there are certainly opportunities to mitigate well withdrawals in the future, such as enhanced infiltration of runoff or treated wastewater. Note this would specifically not include projects making up for lost recharge resulting from new development, which is already required under existing law. Therefore, changes in recharge were not included as part of this analysis, focusing primarily on high capacity municipal well withdrawals. A human replacement project (e.g., enhanced infiltration in a particular area to make up for well withdrawals) could certainly be included in the analysis. But this would be the focus of more detailed local water supply modeling and planning conducted for individual communities.

Maps 15a and b show the spatial distribution of the DSR attributed to well withdrawals. DSR values range up from zero. A value of zero indicates that the groundwater budget remains in the same balance as it did before municipal well withdrawals. As ratio values increase, this indicates that pumping is moving the budget out of its natural balance. When a value of 100 percent is reached, net pumping is pulling out the same amount of water as would be naturally replenished. Values greater than 100 percent indicate that pumping has moved the aquifer into groundwater budget deficit; and the further the ratio is above 100 percent, the further it is out of balance.

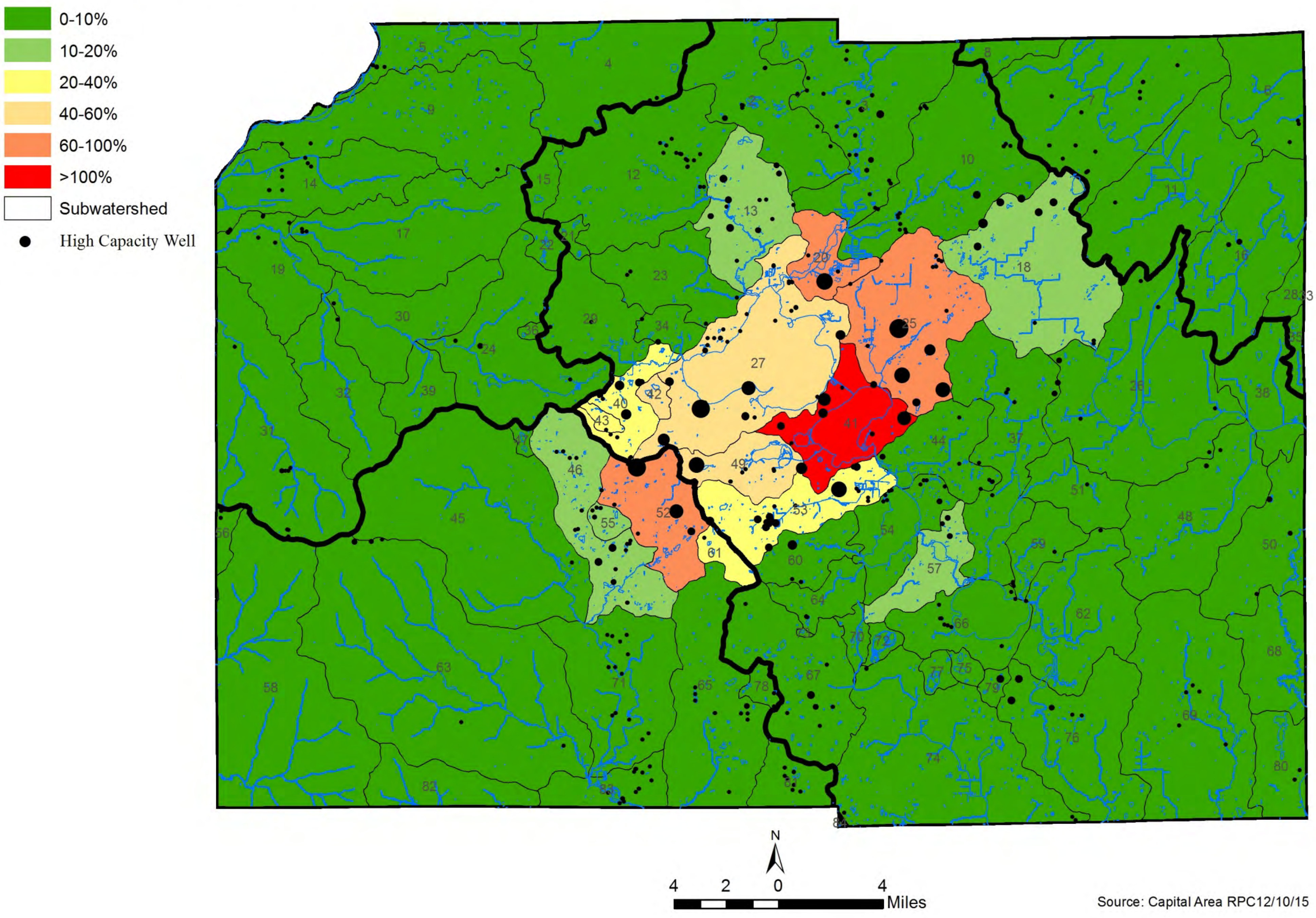
The highest DSRs are in the Madison Metropolitan Area, with the Lake Monona value being in excess of 100 percent (demand greater than supply). The result is that water is being induced from the Yahara Chain of Lakes. Whereas groundwater discharged to Lakes Monona and Mendota during pre-development conditions, this situation has since reversed with surface water now being drawn into and augmenting groundwater supplies as a result of well water withdrawals. This has an accompanying effect on surface water features that depend on groundwater supplies, described in the next section.

Overall, the DSR serves as a good example of the kind of information that could be analyzed as part of a municipality's water supply plans. As such, more detailed modeling of wells and mitigation strategies can and should be conducted in coordination with the Capital Area Regional Planning Commission staff using the tools outlined in this report. For example, note the improvement in the Upper Badger Mill Creek (52) and Cherokee Marsh (20) subwatersheds from 2010 to 2040. This is the result of the 2040 pumping assumption used, where a community's total well withdrawal is drawn equally from both existing and planned wells. This represents an average or equal likelihood

[4] See the Stormwater Performance Standards contained in Dane County Chapter 14.51(2)(e)(3). https://pdf.countyofdane.com/ordinances/ord014.pdf

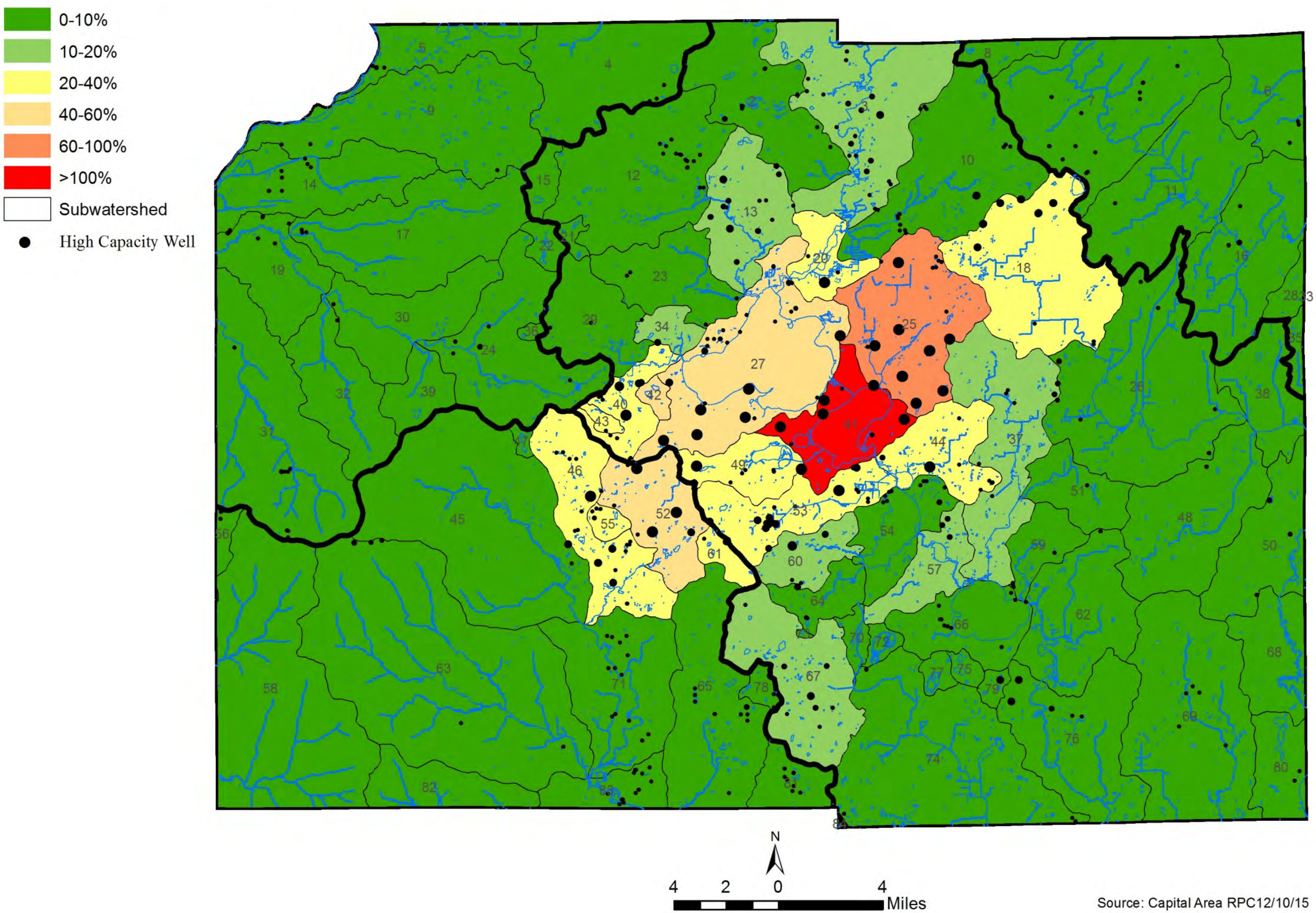
of future wells and withdrawals for a community. Under this configuration (among many other different possibilities or alternatives) a well may indeed be pumping less in 2040 than actually occurred in 2010, particularly if it is being heavily used currently. This could result in an apparent decline in the DSR for a particular subwatershed in the future, as here. This re-enforces the point that the DSR is indeed sensitive to changes in pumping rates and locations. The utility of this index is that it is possible to test different locations of wells and configurations of withdrawals to evaluate alternative pumping patterns and mitigation strategies. More specifically, the index provides useful information and methodology for testing alternative growth scenarios, impacts, and mitigation strategies by varying the different variables (i.e., well withdrawals and locations, human inputs, etc.). While only highlighted here, this could certainly be the focus of more detailed local water supply modeling and planning conducted in coordination and cooperation with and among individual communities.

Map 15a. 2010 Demand to Supply Ratio (DSR)



Source: Capital Area RPC12/10/15

Map 15b. 2040 Demand to Supply Ratio (DSR)



Baseflow Reduction Index (BRI)

Groundwater discharge is the outflow that keeps surface waters flowing during dry periods when there is no runoff. Pumping intercepts groundwater that would have discharged to surface water bodies as baseflow. As pumping increases the baseflow discharge to streams, wetlands, and lakes decreases. The actual amount is the result of a complex exchange among different variables such as the proximity of a well to a waterbody, neighboring wells, the amount(s) of withdrawal, the geologic layers being drawn upon, hydrogeologic variables of transmission and resistance, as well as climatic variations. Similar to DSR, the baseflow reduction index (BRI) has been developed to help quantify that loss in subwatersheds throughout Dane County. It is the ratio of the change in groundwater discharge between a base time period and the time of interest, divided by the base period discharge. Here it is expressed as the change between Pre-Development Conditions (circa 1900) and Current Conditions (2010):

$$BRI = [(\text{Net Baseflow}_{2010} - \text{Net Baseflow}_{1900})/\text{Net Baseflow}_{1900}] * 100,$$

Where Net Baseflow is $SW_{out} - SW_{in}$ (**Table 6**).

In the analysis of Future Conditions, it is expressed as the change in baseflow between 1900 and 2040.

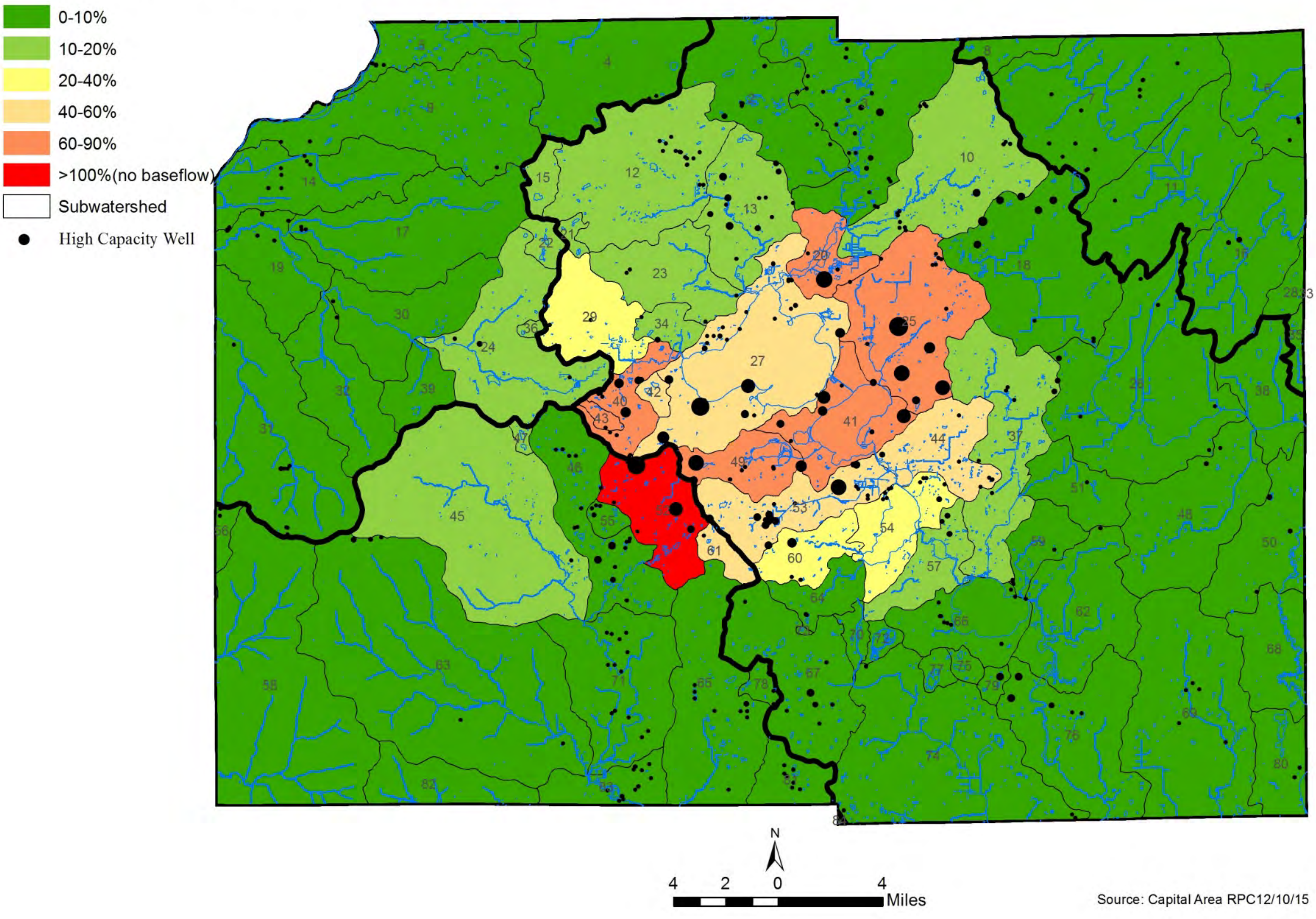
The values, expressed as percent, are presented in **Maps 16a and b.** There has been a baseflow reduction of 20 percent or greater throughout much of the central region (shown in yellow, orange, and red). This shows a strong parallel to DSR, **Maps 15a and b.** Also, BRIs generally increase in developing areas due to future well withdrawals. Madison is by far the largest groundwater user, pumping 29 mgd in 2010 and a projected withdrawal of 33 mgd in 2040 (an 11 percent increase over the period analyzed). The areas where the shallow aquifer is most stressed by human activities have experienced the greatest baseflow reduction.

Maps 16a and b show the effect of pumping on baseflows for individual subwatersheds. In dry periods, virtually all of the flow in a river is groundwater discharge (baseflow), so the effects will be most apparent in the summer, fall, and early winter. These periods are particularly critical for biologic life and the health of stream communities. Baseflow reductions due to pumping will also be greatest on a percentage basis on smaller waterbodies, such as springs, headwater streams, small lakes, wetlands, and ponds. During wet periods flow in surface water bodies is dominated by surface runoff of rain or snowmelt. During these periods the effects of the pumping would probably not be discernible.

Similar to the DSR above, the utility of this index is that it is possible to test different configurations of wells and withdrawals to evaluate alternative pumping patterns and management strategies. More specifically, the index provides useful information and methodology for testing alternative growth scenarios, impacts, and mitigation strategies by varying the different variables (i.e., well withdrawals and locations, human inputs, etc.). While only highlighted here, this could certainly be the focus of more detailed local water supply modeling and planning conducted in coordination and cooperation with and among individual communities.

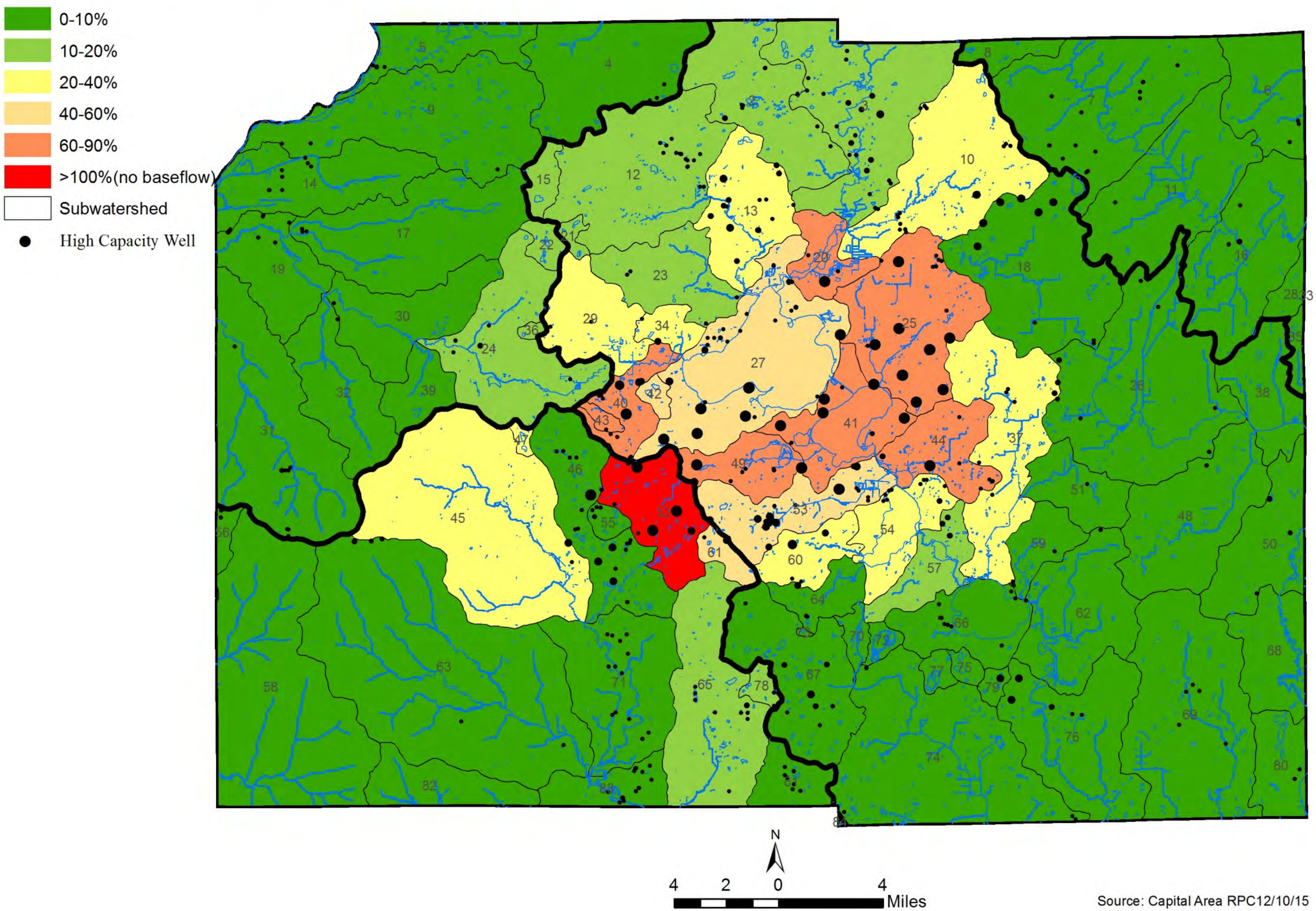
For example, note in **Map 13** that the treated effluent discharge from wastewater treatment plants has resulted in a *gain* in baseflow in some streams. While perhaps not as pristine as groundwater discharge, treated wastewater is a reliable source of water during dry periods and is therefore considered baseflow under the technical definition of the term. With the advent of more effective

Map 16a. 2010 Baseflow Reduction Index (BRI)



Source: Capital Area RPC12/10/15

Map 16b. 2040 Baseflow Reduction Index (BRI)



Source: Capital Area RPC12/10/15

treatment technologies, wastewater is being considered a beneficial resource in some areas. Two notable examples, Badger Mill Creek and Badfish Creek, now support populations of trout because of the highly treated effluent being returned to the stream. The innovation here is promoting wastewater as a *resource* and not simply something flushed downstream. This is discussed further in the following section.

Ecological Limits of Hydrologic Alteration

It is important to point out or emphasize that flow regime is a primary determinant of the structure, function, and health associated with rivers and streams. Indeed, streamflow has been called the "Master Variable," [5] or the "Maestro…that orchestrates pattern and processes in rivers."[6] Much evidence exists that modification of streamflow induces ecological alteration. In terms of groundwater, decreased baseflow during dry weather conditions increases stream temperature, reduces oxygen level, and available habitat.

Both ecological theory and abundant evidence of ecological degradation in flow-altered rivers and streams support the need for environmental flow management. [7] In addition, strategies that focus on reducing runoff (i.e., maintaining infiltration and recharge) also reduce pollutant loads – since pollutant concentrations and loading are a direct function of runoff volume. Certainly, environmental factors other than streamflow have been recognized. But as society struggles to conserve and restore freshwater ecosystems, flow management is needed to ensure that existing ecological conditions do not decline any further, and that it may even be possible for these resources to be *improved*.[8]

The Ecological Limits of Hydrologic Alteration (ELOHA) is a management framework offering a flexible, scientifically defensible approach for broadly assessing environmental flow needs when in-depth studies cannot be performed for all rivers and streams in a given region.[9] ELOHA builds upon the wealth of knowledge gained from decades of river-specific studies and applies that knowledge to specific geographic areas. In practice, ELOHA synthesizes existing hydrologic and ecological databases from many rivers and streams within a region to generate flow alteration/ecological response relationships for other rivers and streams with similar hydrologic regimes. These relationships correlate measures of ecological condition, which can be difficult to manage directly, to streamflow conditions, which can be managed through water-use strategies and policies. Detailed site-specific data need not be obtained for each river or stream in a region.

For example, the State of Michigan has proposed a standard on groundwater pumping that protects fisheries resources for each of the 11 classes of streams in the state.[10] The state has also launched a web-based Water Withdrawal Assessment Tool (WWAT)[11] designed to estimate the likely impacts of a proposed water withdrawal on a nearby stream or river. This approach shows significant promise to the extent it could be applied to evaluating reductions in baseflow resulting from urban and agricultural land uses in Wisconsin. The WDNR is currently using an ELOHA-based process in its

[5] Poff, N. 2010a. *The Ecological Limits of Hydrologic Alteration (ELOHA): A New Framework for Developing Regional Environmental Flow Standards.*
[6] Walker, K. et al. 1995. *Rainfall-Runoff Modeling in Gauged and Ungauged Catchments.*
[7] Poff, N. 2010b. *Ecological Responses to Altered Flow Regimes: A Literature Review to Inform the Science and Management of Environmental Flows.* Freshwater Biology 55: 194-205.
[8] Palmer, M. 2008. *Climate Change and the World's River Basins: Anticipating Management Options.*
[9] http://www.conserveonline.org/workspaces/eloha
[10] Michigan Groundwater Conservation Advisory Council. 2007. *Report to the Michigan Legislature in response to Public Act 34.*
[11] http://www.miwwat.org/

high capacity well reviews. Fish response curves are one of the tools used to determine significant adverse impacts to streams and rivers.

More specifically, using existing fish population data across a gradient of hydrologic alteration (i.e., median August flow reduction – considered critical), Michigan scientists determined two flow/response relationships between populations of "thriving" (intolerant) fish species and "characteristic" (more tolerant) fish species for 11 stream types in Michigan (**Figure 10**). In developing the flow/response curves, fisheries ecologists examined the range of variation in the biological response across the flow alteration gradient and effectively smoothed the statistical scatter to create a trend line. Cut-points (vertical lines) were identified by consensus through a stakeholder process (**Figure 11**).

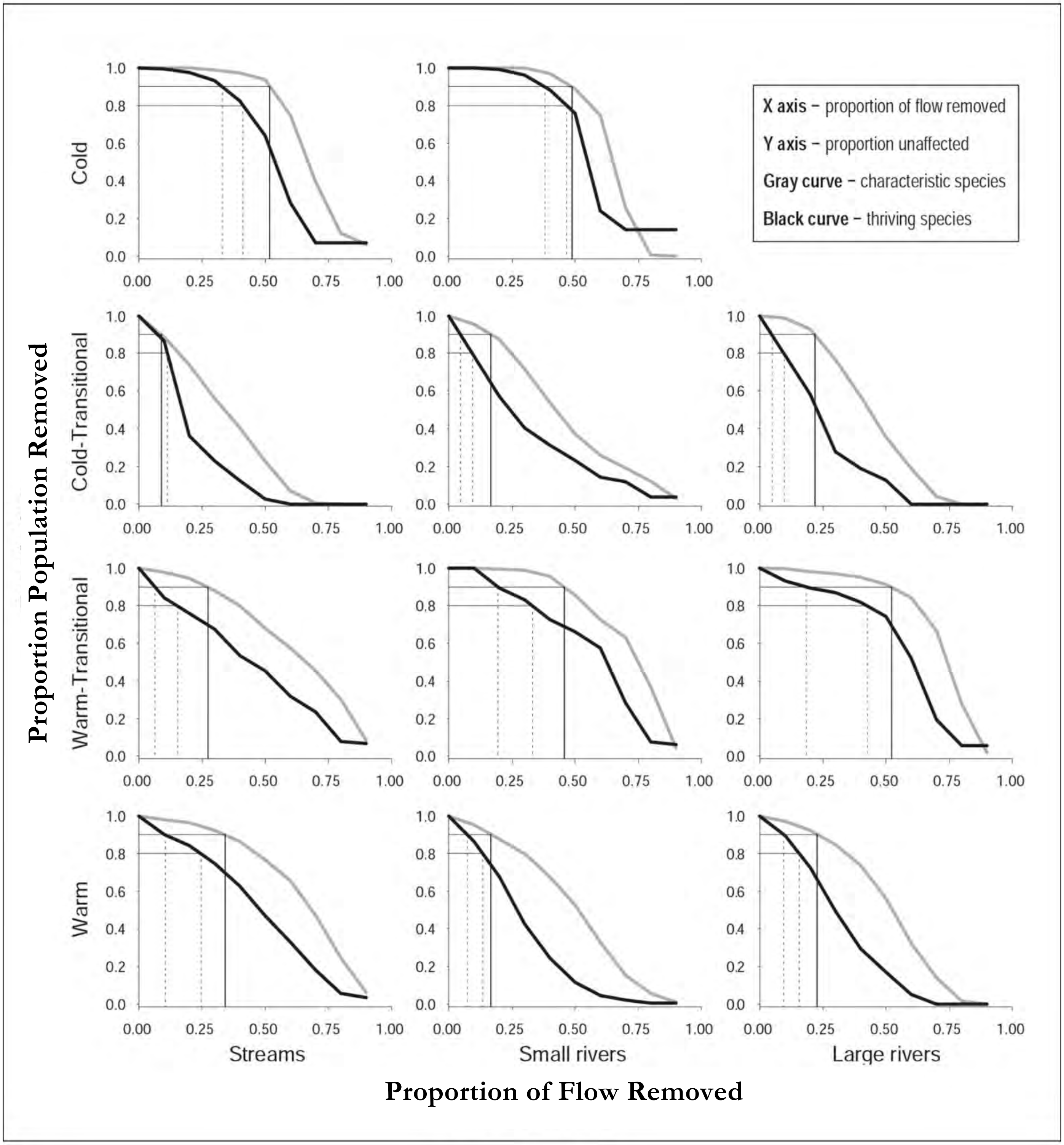
A diverse stakeholder committee proposed a ten percent decline in the thriving (sensitive) fish population as a socially acceptable or sustainable resource impact (Region A). A ten percent decline in the characteristic (tolerant) fish population was deemed to be an unacceptable adverse impact (Region D).[12] The Adverse Resource Impact (ARI) is defined as when a fish population can no longer succeed because of reduced "index flow" during critical summer months (August and September). Intermediate flow alterations (Regions B and C) trigger preventative or corrective environmental flow management actions depending on a stream's ecological condition. The Michigan "ten-percent rule" applies to each of the 11 stream types, but the shapes of the curves – and therefore the allowable or sustainable degree of hydrologic alteration – vary by stream type. Similar fish response curves are being developed by Michigan resource managers for high flow events.[13]

The Capital Area Regional Planning Commission recently contracted with WDNR Division of Science Integrated Services to construct these flow alteration/ecological response curves based on USGS flow and WDNR fisheries data in Wisconsin and the Capital Region.[14] It should be noted that, whereas the fish response curves for individual stream segments have been combined and averaged for the general stream classes in Michigan presented here (**Figure 10 above**), individual curves for individual fish species for individual stream segments throughout Dane County have been developed for analytical purposes. Common analyses include modeling the response of individual species in affected stream segments due to planned well withdrawals or impervious development, as well as the effect of practices to mitigate these impacts.

Together, these two ecological response models (baseflow reduction and increased stormflow) promise to be important tools for guiding more effective approaches to water resources management issues relating to the sustainability of urban development amid the backdrop of a historically agricultural landscape.

[12] Bartholic, J. Undated. *Michigan's Water Withdrawal Assessment* Tool.
[13] Troy Zorn, Ph.D., Michigan DNR; unpublished results, August 2010.
[14] Diebel, M. et al. 2014. *Ecological Limits of Hydrologic Alteration in Dane County Streams.*

Figure 10. Actual Flow Alteration-Ecological Response Relationships.

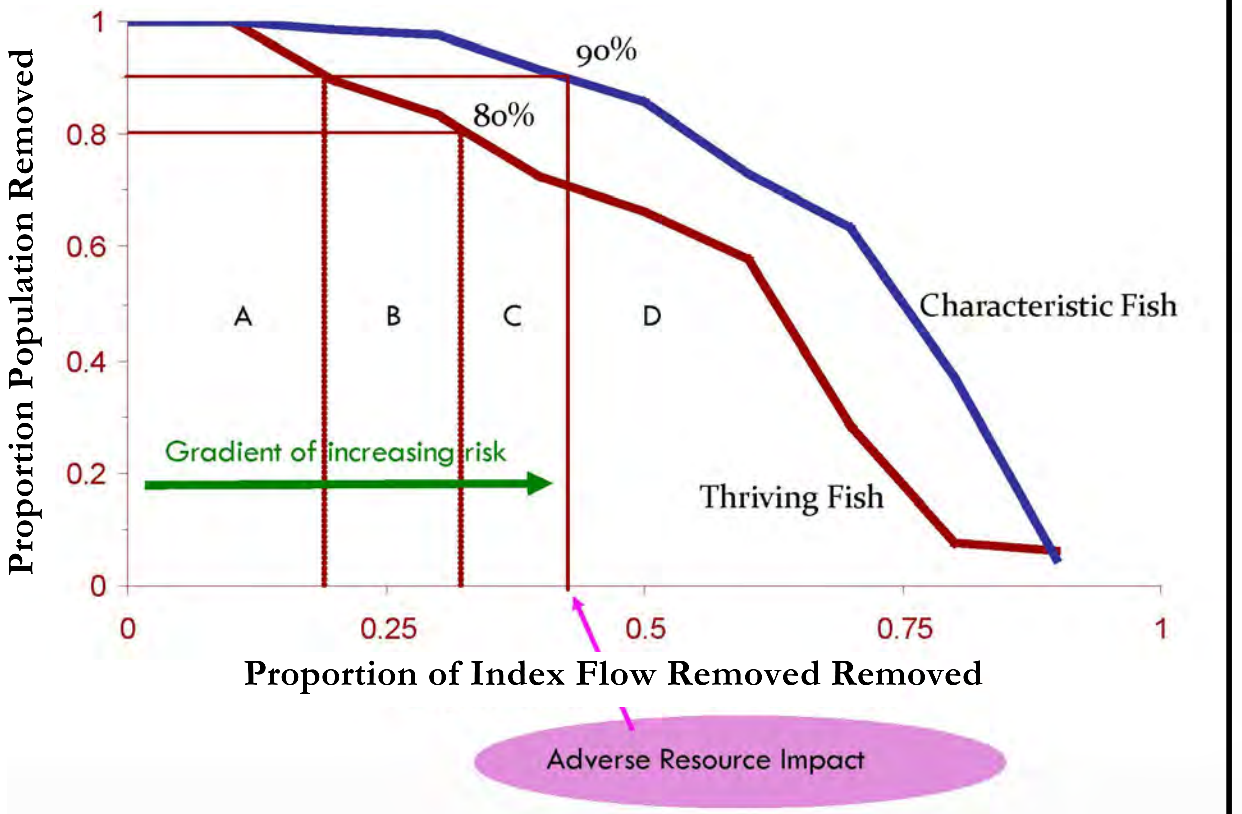


Curves describing fish community responses to water withdrawal for Michigan's 11 river types, as defined by size and July temperature characteristics. Axes are identical to those in Figure 12. The black curve describes the proportion of more sensitive "Thriving Species" at each increment of flow reduction. The gray curve quantifies the proportional change in more tolerant "Characteristic Species" at each level of water withdrawal. The right-most vertical line in each plot identifies the flow associated with an Adverse Resource Impact (Figure 12), while other vertical lines identify water withdrawal levels associated with undefined management actions to be taken in anticipation of the river baseflow yield (index flow) approaching the Adverse Resource Impact level.

Source: Zorn et.al., 2008.

Source: *A Regional-scale habitat Suitability Model to Assess the Effects of Flow Reduction on Fish Assemblages in Michigan Streams.* 2008.

Figure 11. Interpreting the Fish Response Curves with an Eye Toward Policy.



The two function response curves were interpreted using horizontal lines representing preservation of 80 and 90 percent of the initial fish population metrics. At points where these lines intersected the two curves, a vertical line was dropped to indicate the proportion of Index Flow removed associated with that point on the curves. Selected points were chosen to reflect the Council's interpretation of degrees of impairment and restrictions set by legislation. Region D indicates the range of Adverse Resource Impact, defined as when a fish population can no longer succeed because of a reduced amount of water available.

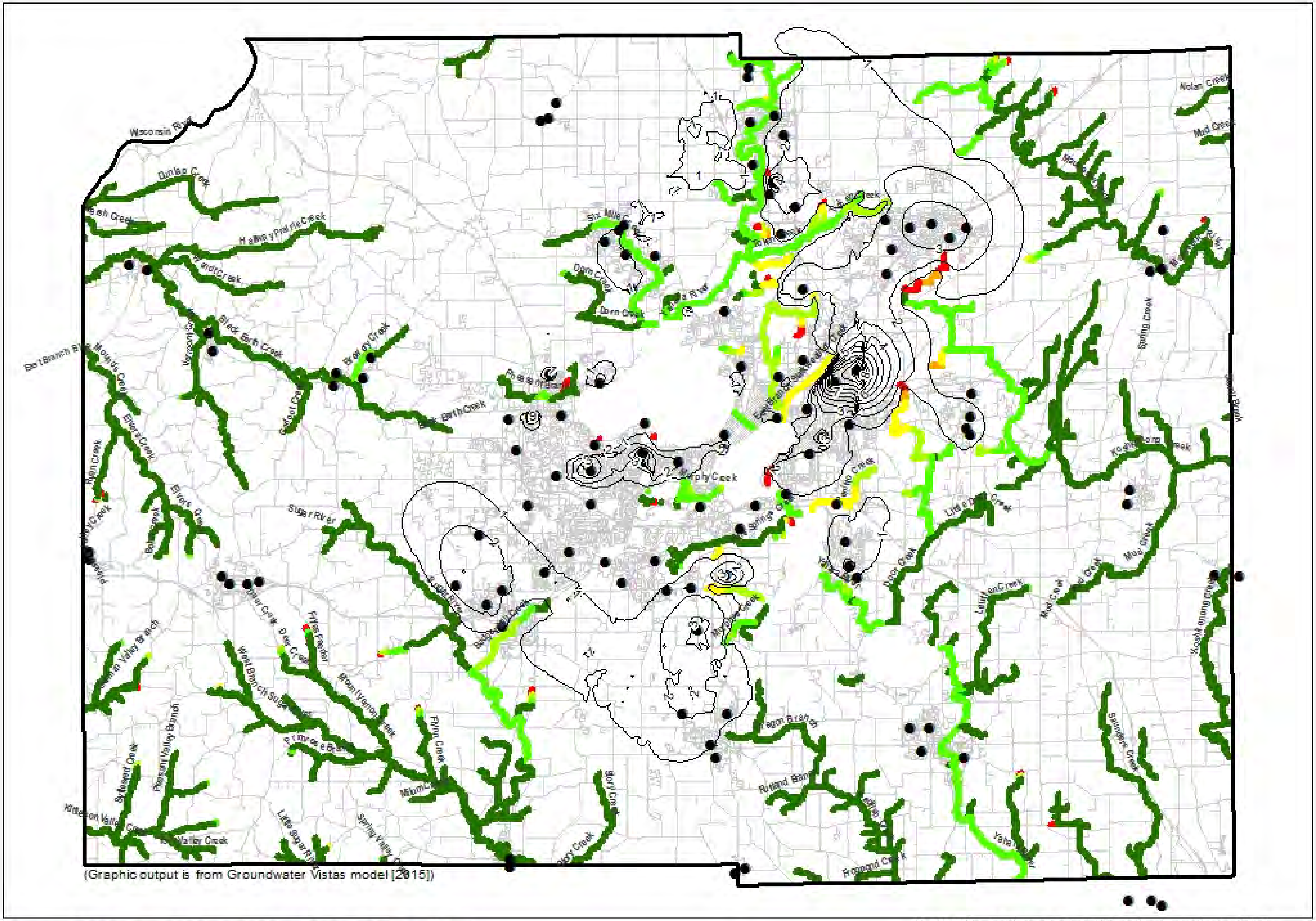
Source: Michigan Groundwater Conservation Advisory Council, 2007.

The ecological models use fish species composition as a surrogate for overall biological integrity. The objective of this analysis was to predict the response of stream fishes to changes in stream flow that are expected to occur by 2040 due to changes in land use and groundwater use in Dane County. The results can be used to identify streams where mitigation of flow changes should be addressed in the near future. For example, by 2040 significant changes to fish communities are expected to occur in about 5 percent (34 miles) of the stream length in Dane County due to reduction in summer baseflow resulting from well water withdrawals. These streams are primarily headwaters in or near Madison and the Yahara River downstream of Lake Waubesa.

Map 17 shows the 2040 reduction in baseflow as a percent of 2010. **Map 18** shows the Fish Community Status as a percent of current conditions. Note that relatively little change is expected in most streams between 2010 and 2040, typically less than a 10 percent. reduction. This is because fish communities in many impacted streams are already largely acclimated to reduced flow conditions, being composed of more tolerant fish species. In addition, as evidenced by the shallower initial slopes in **Figure 10,** coldwater streams are also pretty resilient, typically possessing larger quantities of cold, well-oxygenated groundwater to sustain them through more critical summer dry periods.

By 2040 significant changes to fish communities are expected to occur in about 5 percent (34 miles) of the stream length in Dane County due to reduction in summer baseflow resulting from well water withdrawals.

Map 17. Comparison of changes in streamflow between 2010 and 2040, assuming current wastewater discharges from existing treatment facilities.



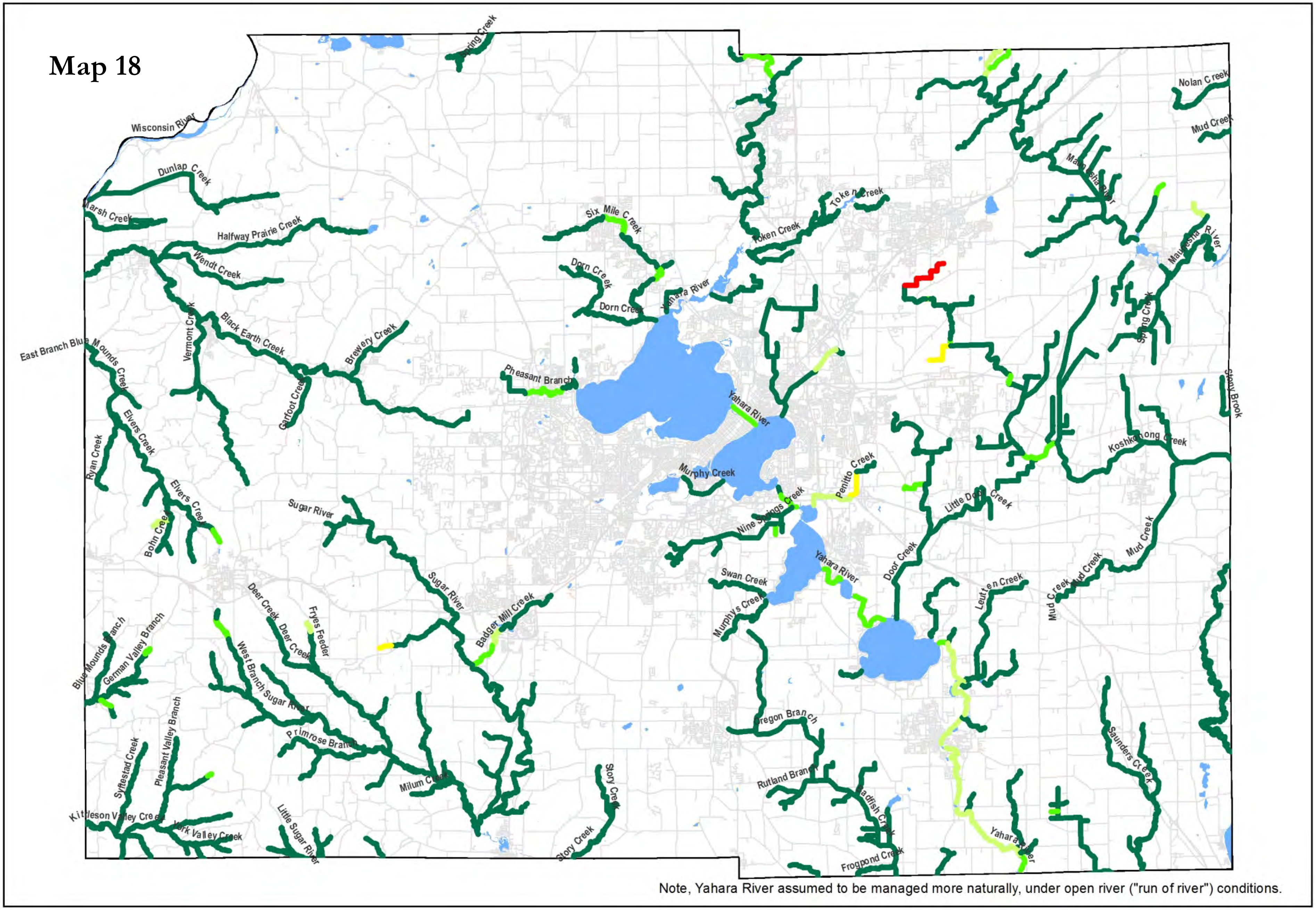
Percent Baseflow 2010 to 2040 - Baseline Condition

95-100% | 90-95% | 75-90% | 50-75% | 25-50% | 0-25%

Municipal Wells 2040 — Cone of Depression Contours

Source: Capital Area Regional Planning Commission 2015

Map 18



Percent Fish Community Status 2010 to 2040

95-100% | 90-95% | 75-90% | 50-75% | 25-50% | 0-25%

Map created by the Capital Area Regional Planning Commission
Source: M. Diebel, WDNR. 2015. Ecologic Limits of Hydrologic Alteration.

Date: 8/30/2016

Miles
0 2.5 5

The goal of ELOHA is not to maintain or attempt to restore pristine conditions in all rivers or streams; rather, it is to understand the tradeoffs between human activity on water and resulting ecological degradation. As can be seen in the response curves in **Figures 10 and 11**, increasing levels of environmental stress reflect increased levels of ecological impact. The "acceptable" ecological condition for each river segment or river type is accomplished through a well-vetted shakeholder process of identifying and agreeing on the ecological and cultural values to be protected or restored through river management. ELOHA provides the necessary basis and understanding for facilitating those discussions. It is believed that applications of the ELOHA framework in the region will help to inform decision-makers and stakeholders about the ecological consequences of flow alteration, as well as promote regional environmental flow strategies for protecting and restoring water resource conditions. While ELOHA is a new advance in environmental flow analysis and biological health, it does not supplant more specific approaches for certain water bodies that require more in-depth analysis.

Climate Change

Climate change is driven in part by the emission of green-house gases (GHG) that traps heat in the atmosphere resulting in global warming. The Wisconsin Initiative on Climate Change Impacts (WICCI)[15] temperature modeling projects an annual average temperature increase of 6-7 degrees F between 1980 and 2055 for Dane County.

Climate warming may affect surface and groundwater resources of Dane County in several ways. John Magnuson of the UW-Madison Center for Limnology notes that the average duration of ice cover on Lake Mendota and lakes in the northern hemisphere has decreased over the last 50 years while the average fall-winter-spring air temperature has increased. A trend of more intense precipitation events (i.e. the one-, two-, and three-inch storms) is also developing. Modeling shows an increased frequency of intense storms with greater than 3 inches of precipitation in a 24-hour period for Dane County.[16] Climate change is anticipated to impact every aspect of the water cycle, and many of the underlying assumptions that stormwater managers use for runoff and storm design might become outdated if these predictions become a reality. Climate change will therefore necessitate a reappraisal of existing approaches for water resource management.

In addition, A WDNR fisheries biologist working with WICCI predicts that climate change will likely cause reductions in all cold water habitats and coldwater fish species in Wisconsin.[17] Lyons et.al.[18] used water temperature models to predict the possible impacts of stream water temperature increase on certain fish species. Of the 50 species examined, 23 are predicted to decline in distribution in Wisconsin, 23 species would increase in distribution, while four fish species would see no change. The most dramatic decline of coldwater fish species would occur in small coldwater streams (**Figure 12**). The Lyons study suggests that small increases in summer air and water temperature will have major effects on the distribution of fish in Wisconsin streams. Additional modeling and vigilant monitoring will be needed to better understand the impacts of a warming climate – both on biological communities and ground/surface water budgets overall.

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[15] See the WICCI website for more information on the effects of climate change on Wisconsin. http://www.wicci.wisc.edu/.
[16] Potter, K. 2010. *Adapting the Design and Management of Storm Water Related Infrastructure to Climate Change.*
[17] Pomplum, S. et al. 2011. *Managing Our Future: Getting Ahead of a Changing Climate.*
[18] Lyons, J et al. 2010. P*redicted Effects of Climate Warming on the Distribution of 50 Stream Fishes in Wisconsin.*

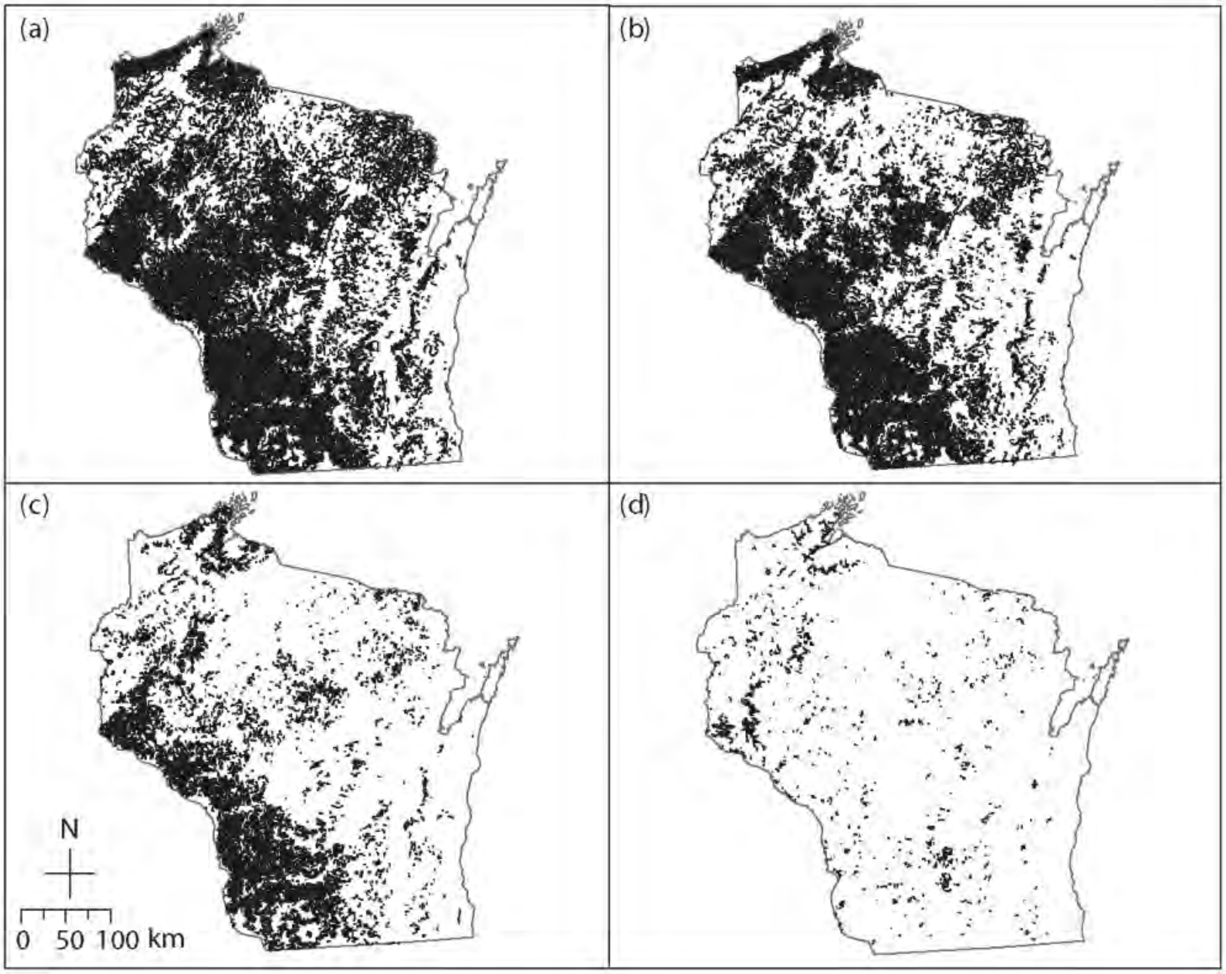


Figure 12. Predicted distribution of Mottled Sculpin, a cold-water species, under four climate warming scenarios: (a) Current conditions, (b) Limited warming, (c) Moderate warming, and (d) Major warming. Only stream segments where the species is predicted to occur are shown.

Source: Lyons, 2010

Evaluation of Alternative Management Strategies[19]

A principal objective of the Dane County Regional Hydrologic Study has been to evaluate the effects of groundwater pumping, urban development, and wastewater diversions on ground and surface water bodies. In addition, "alternative management strategies" were modelled to evaluate specific actions and levels of control that could be taken to help mitigate those impacts and improve the future baseline condition (**Table 7**). These and other strategies may involve regulatory consideration of groundwater quantity and quality, surface water resources, and public supply infrastructure. Early consultation with the WDNR, water utilities, and others will be needed to assess the relative feasibility beyond that presented more generally in **Table 13**.

Table 7
Potential Management Strategies—Dane County Regional Hydrologic Study

Management Alternative	Strategies to Consider
1. Alternative Well Location & Pumping Strategies (City of Madison only)	a. Maximum pumpage from central metropolitan area wells to minimize water diversion from adjacent drainage basins b. Maximum pumpage from peripheral wells (i.e., wells close to groundwater divides) to minimize impacts on Yahara lakes
2. Aggressive Water Conservation Efforts	a. Maximize conservation efforts (10-20% domestic reduction) and determine effects on water use forecasts
3. Aggressive Pursuit of Water Infiltration Practices	a. Maximize infiltration practices for future development b. Maintain 100% predevelopment groundwater recharge for future development
4. Partial/Complete Cessation of Wastewater Diversion & Return of Wastewater to Yahara River & Other Basins	a. Regional treatment alternatives with surface water discharge to: · Upper Yahara River Basin · Sugar River Basin · Nine Springs Creek b. Infiltration of Upper Yahara River treated effluent
5. Importation of Water & Deep Aquifer Withdrawals (not feasible)	a. Importation of water from other drainage basins b. Deep pumping within Northern Yahara basin
6. Management of Yahara River Lakes as Multipurpose Reservoirs for Baseflow Augmentation	a. Increase water storage in the Yahara lakes to augment flows in Lower Yahara River and restore prediversion low-flow conditions.

Alternative Well Location and Pumping Strategies (City of Madison only)

The siting and pumping of high capacity municipal wells is a management alternative that offers one of the best opportunities to reduce environmental impacts in specific geographic areas of the county. Future siting of wells can be guided by results of the groundwater computer model.

As indicated previously, the model illustrates the type and magnitude of impacts to local surface and ground water bodies likely to occur from well-water pumping at particular locations. Accordingly, siting changes can be made and alterations in water withdrawals from proposed and existing wells can be examined in finer detail if model simulations show that the impacts to adjacent water resources will be lessened or avoided from alternative pumping strategies.

[19] Dane County Regional Planning Commission. 1997. *Evaluation of Alternative Management Strategies.* Dane County Regional Hydrologic Study.

Currently, the WDNR screens each high capacity well application to assess potential impacts to "water of the state," including streams, lakes, wetlands, springs, and water supply wells. The WDNR also assesses the cumulative effects of the proposed well or wells together with existing high capacity wells for potential impacts to waters of the state. If significant impacts are predicted, the well application may be modified or the application may be denied.

Since 1993, Wis. Adm. Code Chapter NR 811 required that a wellhead protection program plan be submitted for each new municipal well-constructed in Wisconsin after April 1992. Water purveyors need to submit recharge area, zone of influence, and flow direction determinations to the WDNR for each new municipal well. However, in the absence of a regional groundwater flow model, the capability to predict and quantify possible environmental impacts (with a reasonable degree of certainty) simply has not existed. In 1998 WGNHS completed a project to use the groundwater model to delineate capture zones for all municipal wells in Dane County existing in 1992. The overall objective of the project was to delineate the 5-, 10- and 100-year zones of contribution as well as the drawdown cone produced by each existing well. As part of the annual update of the Dane County Regional Groundwater model in 2014, additional wells have been modelled to assist communities develop wellhead protection programs for wells installed after 1992 and planned wells.

In central Dane County, municipal wells are not widely dispersed in many communities. For example, in the villages of De Forest and Waunakee and cities of Middleton and Sun Prairie several existing municipal wells are in close proximity (less than one-half mile) to one another, as well as to local surface water bodies (**Map 11**). This situation also exists in the downtown area of the City of Madison; though wells at the periphery of the city are wider apart (one- to two-mile separation distance). Previously, it has been unclear whether these siting and pumping conditions are causing significant resource impacts that could be addressed through alternative well placement and pumping scenarios, simulated by the groundwater computer model.

One alternative to lessen groundwater movement and diversion from adjacent drainage basins into the Yahara River Valley is to increase groundwater pumpage from the wells located in the central part of the City of Madison and decrease withdrawals from the outer wells. If additional groundwater could be withdrawn from the central wells, potential hydrologic impacts to lakes Mendota and Monona could be assessed since groundwater recharge would likely increase adjacent to and beneath these water bodies. Conversely, if impacts in the Lake Mendota and Monona watersheds show to be of greater concern than along the periphery, management approaches aimed at decreasing groundwater pumpage in the central city could be evaluated, and increased pumpage from existing or new outer wells assessed to compensate for this reduction.

There are restrictions, however, to the practical implementation of the above strategies. City of Madison Water Utility has indicated that, due to distribution system constraints, there is limited flexibility to alter withdrawals between existing municipal wells, particularly during the summer months when there is less reserve capacity in the water supply system. Five city wells are currently considered summer use wells or are used only part of the year. Remaining wells are used extensively, almost every month.

While a widespread alteration to current well-pumping strategies in the Central Urban Service Area may not be feasible, more modest changes to a smaller number of wells is still possible and worth consideration. Certain wells may be particularly problematic in terms of resource impacts; therefore, a compensating water withdrawal and delivery system for the specific area served by the well(s) could present a reasonable course of action to help resolve the problem.

Simulation

Management alternatives 1a and 1b (below) simulate the maximum range or extremes of possible alternatives believed available with a unit-well distribution system. Outer and Inner wells have been delineated based on half of Madison's wells being located either adjacent to or distant from the Yahara basin groundwater divides, respectively. If the effect/benefit of either alternative is found significant, then a more detailed analysis may be warranted to specifically evaluate new well locations, pressure gradients, transfer/delivery systems, etc., taking into account the constraints of a unit-well system.

The alternative strategies include:

1a. Pumping Inner and Outer wells to provide 75 percent and 25 percent of the total average daily water use, respectively; or

1b. Pumping Inner and Outer wells to provide 25 percent and 75 percent of the total average daily water use, respectively.

As indicated in **Map 19a**, future water table declines can be more centrally localized by pumping a larger percentage of well water from the inner Madison wells than pumping from the outer wells. The effect is more water being drawn from the Yahara Lakes and less from surrounding streams, which actually show an improvement over 2010 conditions. **Table 8** shows the associated effects on Dane County streams as a percentage of baseline 2040 pumping. Streamflow generally improves under the 75% Inner/25% Outer pumping scenario, with the exception of the Yahara River and Wingra Creek (>1% decline). Conversely, increased pumping from the outer wells results in more dramatic declines in water table levels and extends the cone of depression into the Black Earth Creek and Upper Sugar River basins (**Map 19b**), including reductions of baseflow in those systems. Combined with alternative measures such as treated effluent return to the Upper Yahara River (discussed below) and managing the Yahara Lakes as multipurpose reservoirs, pumping a larger percentage of groundwater from the inner Madison wells holds considerably greater promise for mitigating the impacts of future pumping and providing more sustainable water supplies for the Madison Metropolitan Area.

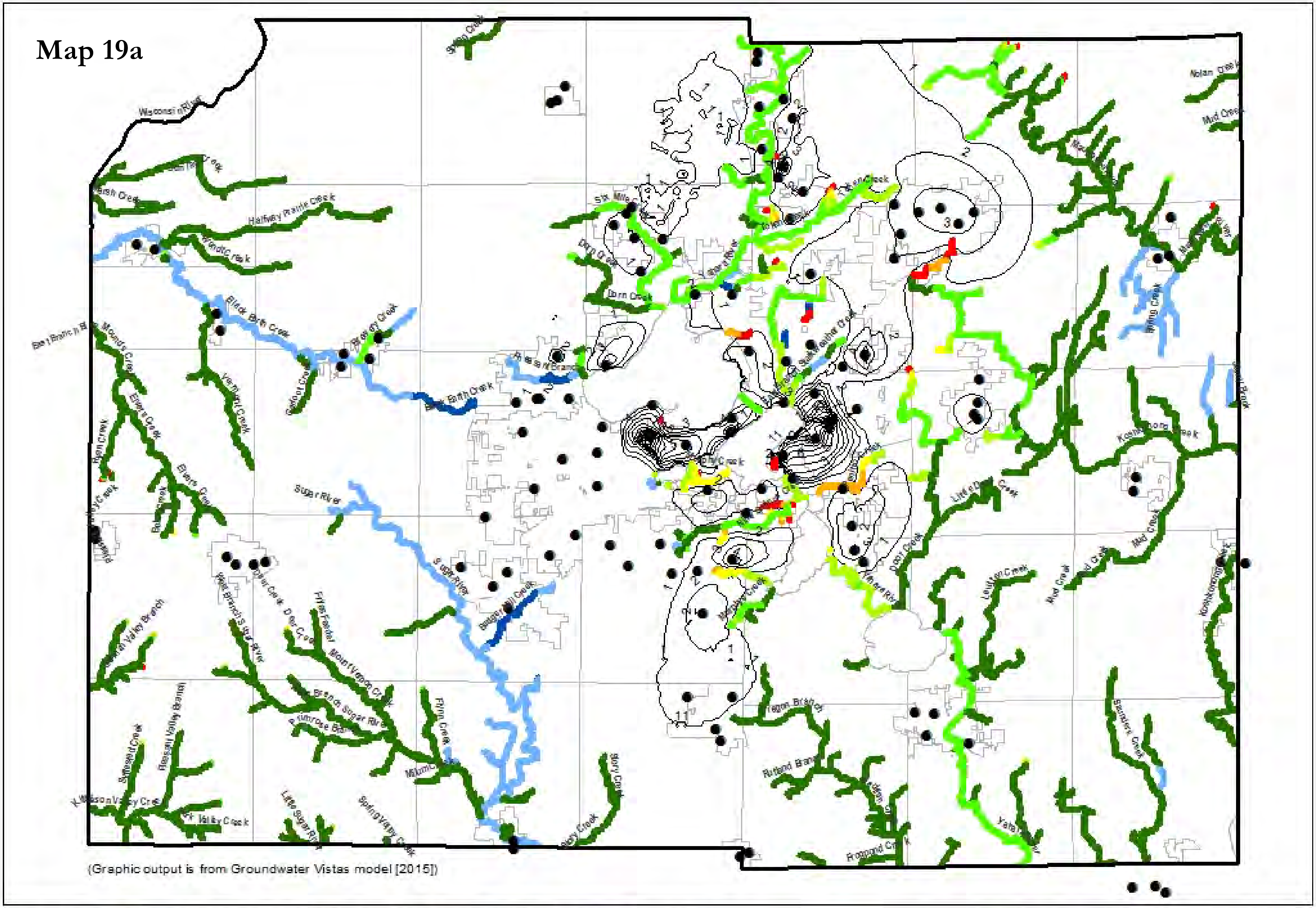
In 2000 the City of Madison explored the technical feasibility and cost of potentially altering well pump operation for the Madison Water utility so that a greater percentage of water would be produced by "central wells," defined as half the wells located furthest from the peripheral groundwater divides. The feasibility study was a follow up to a recommendation coming out of the Dane County Regional Hydrologic Study (DCRPC 1997). The study found that the additional water table declines and reductions in baseflow in tributary streams due to the projected increase in pumping could largely be mitigated or offset by drawing on wells located closer to the lakes (**Map 19a**). The conclusion of the City of Madison study was that under average day conditions, the desired average ratio of central well pumping to total well pumping of approximately 75 percent could be achieved, with certain infrastructure improvements. The total capital cost of implementing these improvements was estimated to be approximately $1.45 million, with additional operating costs of approximately $250,000 per year. The 20 year present value of these incremental costs was estimated to be $2.9 million.[20] According to the Madison Water Utility, their capability to move

[20] Madison Water Utility. 2000. *Report on Task 10 – Well Pumpage Optimization*. Water System Master Planning Study.

water around their system has been improving.[21] Future pumping station projects in the coming decades will increase their ability to move water from the central area to the city boundaries.

Additional alternatives should continue to be explored (as below) using the tools and technology available to find the best mix of strategies and practices to minimize impacts to our ground and surface water resources as well as maintaining a reliable public water supply (See Management of the Yahara Lakes as Multipurpose Reservoirs for Baseflow Augmentation and Drinking Water Supplies).

[21] Al Larson, Principle Engineer Madison Water Utility, communication January, 2016.



Percent Baseflow 2010 to 2040 (75%Inner/25%Outer Wells Pumping Scenario)

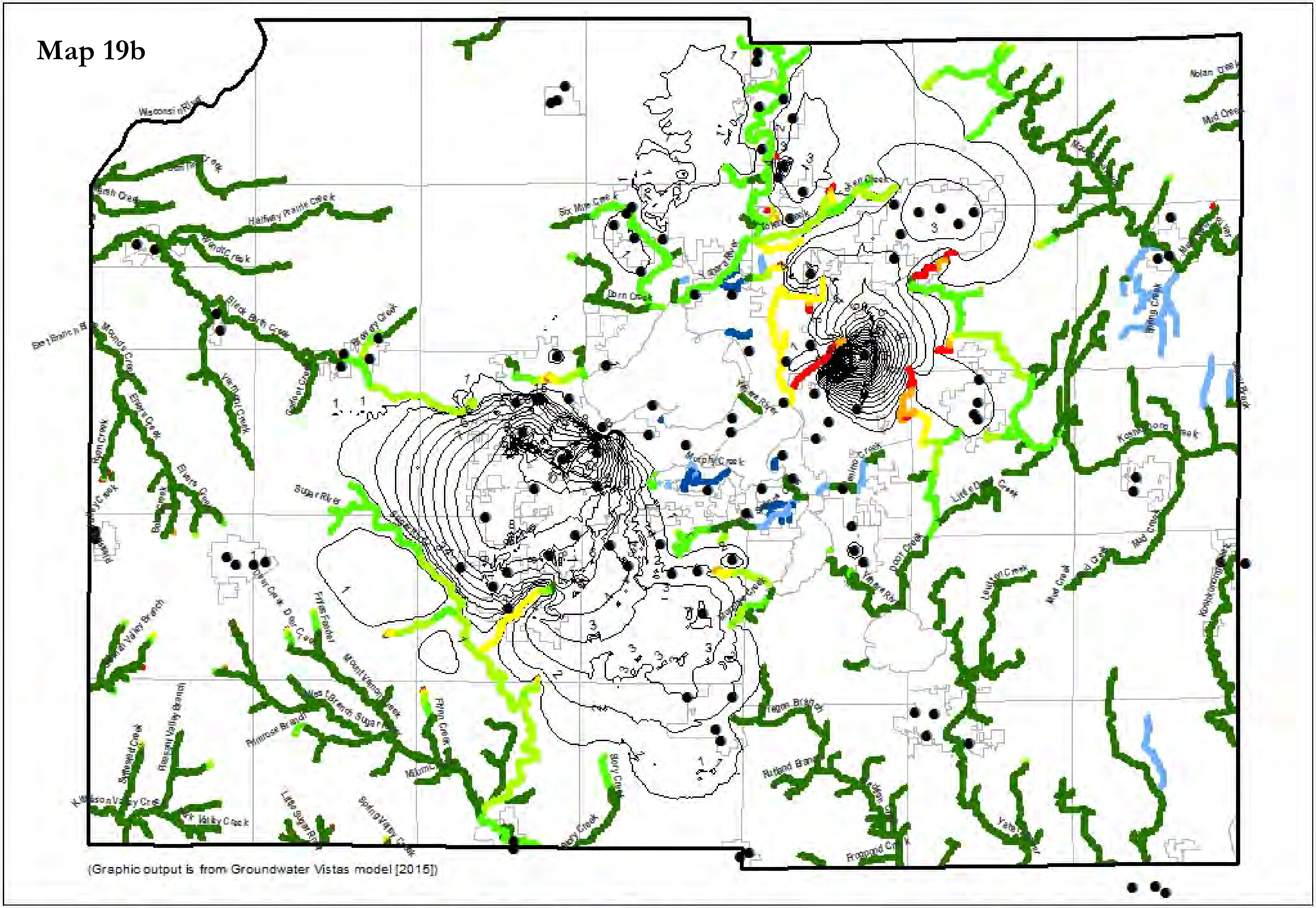
(Source: Capital Area Regional Planning Commission 2016)

95-100% | 90-95% | 75-90% | 50-75% | 25-50% | 0-25% | 100-110% | 110-120%

● Municipal Wells 2040 —— Cone of Depression Contours

0 1 2 4 Miles

Map 19b



Percent Baseflow 2010 to 2040 (75%Outer/25%Inner Wells Pumping Scenario)

(Source: Capital Area Regional Planning Commission 2016)

95-100% | 90-95% | 75-90% | 50-75% | 25-50% | 0-25% | 100-110% | >110%

● Municipal Wells 2040 —— Cone of Depression Contours

Table 8
Percent Change in 2040 Baseflows Resulting from Alternative Pumping Strategies
(Pumping 75% or 25% Annual Water Withdrawals from Inner vs. Outer Madison Wells)

	From Table 5			Alternative Pumping Strategies	
Station	PD cfs	2010 cfs	2040 cfs	Map 21a 75%I/25%O cfs (%2040)	Map 21b 75%O/25%I cfs (%2040)
Badfish Cr. at CTH A*	11.59	75.49	75.22	75.24 (100.0)	75.13 (99.9)
Badger Mill Cr. at STH 69*	3.65	4.23	3.65	4.66 (127.1)	2.38 (64.9)
Black Earth Cr. abv. Black Earth	33.33	31.36	31.23	31.67 (101.4)	30.63 (98.1)
Black Earth Cr. abv. Cross Plains	4.95	3.52	3.50	3.84 (109.5)	3.08 (87.8)
Door Cr. at Hope Rd.	7.69	5.69	5.30	5.42 (102.3)	5.16 (97.3)
Dorn Cr. at CTH M	6.27	5.65	5.50	5.44 (98.9)	5.54 (100.9)
Koshkonong Cr. nr Deerfield*	27.35	29.79	28.84	28.98 (100.5)	28.58 (99.1)
Koshkonong Cr. nr Rockdale*	62.84	65.02	63.99	64.09 (100.1)	63.70 (99.5)
Koshkonong Cr. nr Sun Prairie*	0.77	5.02	4.76	4.80 (100.9)	4.70 (98.9)
Maunesha R. south of USH 151	17.25	16.44	16.16	16.06 (99.9)	16.02 (99.6)
Mt. Vernon Cr. nr STH 92	19.16	18.49	18.32	18.44 (100.6)	18.12 (98.8)
Murphy (Wingra) Cr. at Beld St.	2.89	1.83	1.64	1.18 (71.9)	2.13 (129.6)
Nine Springs Cr. at Hwy 14	11.84	6.69	6.45	6.40 (99.0)	6.42 (99.4)
Pheasant Br. at Parmenter St.	2.85	1.19	1.13	1.33 (117.0)	0.88 (77.7)
Sixmile Cr. south of Waunakee	9.07	7.59	7.06	7.01 (99.6)	6.99 (99.4)
Spring Cr. nr Lodi	22.23	21.70	21.65	21.62 (99.9)	21.61 (99.9)
Starkweather Cr. East Br.	3.01	0.73	0.41	0.64 (157.6)	0.15 (37.0)
Starkweather Cr. West Br.	8.86	4.16	3.27	3.45 (106.1)	2.97 (91.3)
Sugar R. abv. Badger Mill	16.58	13.66	13.01	13.74 (105.5)	12.01 (92.2)
Token Cr. at USH 51	20.35	17.99	16.81	16.64 (101.4)	16.05 (97.8)
West Br. Sugar R. at STH 92*	18.96	19.20	19.13	19.15 (100.1)	19.06 (99.6)
Yahara R. at Windsor	6.77	6.28	6.13	5.98 (99.7)	5.97 (99.6)
Yahara R. at McFarland	157.12	109.09	102.02	96.50 (95.5)	105.20 (104.1)
Yahara R. nr Stoughton	207.46	156.65	148.91	143.23 (96.7)	152.04 (102.7)

*Streams having wastewater treatment plant discharged to them

Aggressive Water Conservation Efforts

Even though Dane County has an abundant supply of groundwater to meet existing and projected water use needs, the benefits of water conservation programs should not be overlooked. Water conservation can be effective in achieving a number of community goals, including reducing investment requirements for meeting anticipated water demand, reducing wastewater flows/treatment costs, reducing operating costs for water supply systems and more equitably allocating an important resource. Simply stated, water conservation saves money and energy, and reduces pollution and hydrologic impacts.

The kind of water conservation program pursued by a municipality depends on community goals and should be tailored to its anticipated water demands and conservation opportunities. For example, various water supply and demand management measures can be considered by municipalities to lessen water use. These include: water audit and leak detection, metering, pricing, education, water-saving fixtures, and regulation. Community attitudes toward such conservation measures and their technical and fiscal merit need to be understood prior to the design of any specific water conservation plan.

Historically, the use of water has been declining compared to population growth in central Dane County over the last 20 years (**Figure 8**). In 1970, average total groundwater use in central Dane County was 169 gallons per capita per day and by 1992 per capita water use had dropped to 151 gallons per day.[22] By 2012 groundwater use had dropped to 109 gpd and 102 gpd in 2014. A single definitive reason for this trend is not apparent, though a possible explanation is that more aggressive water conservation measures have been implemented by the City of Madison and other communities, coupled with water-saving effects of energy conservation programs. A significant decline in self-supplied industrial water use has also occurred since the 1970s, with Kraft Foods Oscar Mayer accounting for a large portion of this reduction, having moved to more efficient water processing technology.

Table 3 shows the classification of water use for municipal water utilities in the county in 2014. Since residential and commercial use represents over 70 percent of the total water use for all Dane County communities, these sectors represent a logical focal point for water conservation efforts – especially the City of Madison with the largest population. Conservation programs would also postpone certain electrical costs associated with peak pumping demands and provide other economic benefits as well, such as reducing wastewater flows for regional treatment and disposal. Also, by reducing groundwater pumping, hydrologic and environmental impacts are reduced correspondingly.

Water conservation is not a new concept to the Madison Water Utility (MWU). Water conservation in Madison has a tradition reaching back more than 30 years of water use control techniques including but not limited to: metered water usage for all its customers, leak detection and abatement programs, and an outdoor water use restriction ordinance (to control water use during emergency conditions). In response to declining groundwater levels, impacts of well pumping on surface water features, and a desire to preserve the aquifer for generations to come, the MWU adopted a Water Conservation and Sustainability Plan in 2008.

[22] DCRPC. 1994. *Historic and Projected Groundwater Use and MMSD Wastewater Flow Data, Dane County, WI.*

The Plan has a primary goal of maintaining the current annual rate of groundwater withdrawal in existing areas and secondary goals of:

Residential – reduce residential water use by 20 percent by 2020 to an average use of 58 gpcd
Commercial – promote water conservation through rebate promotions and education
Industrial – develop a water conservation plan for each industrial customer
Municipal – enact water savings programs for all government buildings that support the primary goal

Interest in conservation has been in response to numerous factors including: reducing the need for adding additional or maintaining well capacity, declining aquifer levels, surface water impacts, contaminant transport, and the potential for declining water quality. In addition, there is a growing public awareness and demand for using natural resources in a more sustainable manner. Water conservation not only saves water it also reduces chemical usage and can provide a significant energy savings to a utility and reduce it's overall carbon footprint. To be successful, conservation efforts are implemented as a combination of public education, institutional regulations, monetary incentives, and physical changes which results in a change in water use patterns within the general public.

In its Conservation Plan, the MWU outlined the recommendations outlined in **Table 9**. In order to reduce residential usage by 20 percent, the MWU will need to reduce the per capita usage from a 2003-2006 average of 73 gpcd to 58 gpcd. Based on information from the *Handbook of Water Use and Conservation: Homes, Landscapes, Industries, Businesses, Farms* (Amy Vickers, 2001) changing from standard toilets to high efficiency toilets can reduce water usage by approximately 10.3 gpcd, which is one of the easiest and most effective indoor water use conservation steps. These and other literature sources provide useful information and strategies for reducing a community's water use. In 2011 Administrative rule NR 852 went into effect establishing a mandatory water conservation and efficiency program for new or increased Great Lakes Basin ground and surface water withdrawals. While Dane County is not included in the Great Lakes Compact, the rule helps guide voluntary water conservation and efficiency efforts program throughout the rest of the state. The program provides information and education, identifying and disseminating information on new conservation and efficiency measures, and identifying water conservation and efficiency research needs. As the MWU implements the Conservation Plan recommendations, as in other communities, the overall effectiveness of the program will need to be evaluated, refined, and expanded as needed.

For comparison, other northern mid-sized cities with established conservation programs were evaluated. **Table 10** summarizes the conservation results from those communities.

Table 9. MWU Conservation Recommendations		
Recommendation	**Description**	**Status as of 4/16**
Residential		
High efficiency toilets	MWU implemented a $100 per household and apartment rebate program to replace old toilets with high efficiency "Water Sense" toilets	Implemented
Install an Advanced Metering Infrastructure (AMI) billing system	Install an AMI-system and start monthly billing	Implemented
Provide customers with current consumption data through the AMI system	Instruct customers on tracking their water use	Implemented
Inclining rate structure	Change the MWU rate structure to an inverted rate structure to reward low water usage and penalize high water usage	Implemented
Outdoor water use restrictions	Restrict outdoor water use when pumping exceeds 50 mgd for 2 consecutive days	As needed/Has not been required
Residential water audit program	Allow individual residential customers to request an on-site or individual water audit of their home	Future
High efficiency washing machines/dishwashers	Develop financial incentive program for washing machines and dishwashers similar to the Utility's toilet rebate program	Future
Industrial		
Water conservation plans	Perform individual audits and develop water conservation plans for industrial customers	Future
Commercial		
Education	Target high-use customers with education/ outreach to promote water conservation	Implemented
Landscaping ordinance	Enact landscaping ordinance with water limiting requirements and drought resistant plantings for new development/major redevelopment	Planning
Appliance upgrade program	Develop appliance upgrade program for heavy water use commercial clients	Future
Certification program	Develop a certification program for water-efficient buildings	Superseded by EPA whole house certification
Car wash reclamation ordinance	Enact an ordinance requiring car washes to use water reclamation	Future
Municipal		
Quantify water use	Improve record keeping to quantify water use for municipal accounts	Implemented
Minimize reservoir dumping	Improve operational control of water reservoirs to minimize dumping	Implemented
Leak detection program	Expand leak detection program to identify and correct leaks	Future
Water utility bill	Upgrade water utility billing with new software	In progress
Meter raw water pumping	Install use meters in well buildings	In progress
Water conservation plans	Perform individual audits and develop water conservation plans for other government buildings	Future
Reduce hydrant flushing	Reduce the Utility's annual unidirectional flushing program as well as filters installed, operational changes are implemented and overall water quality in the distribution system is improved	Implemented
Source: Madison Water Utility 4/15/16		

Table 10 Comparison of Conservation Programs for Northern North American Communities			
Utility	**Start Year**	**Programs**	**Estimated Reduction in Water Demand**
Lincoln, NE[1]	1988	Increasing block rate structure Public education	7%
Waterloo, ON[2]	Early 1980s	Toilet retrofit Water efficient shower heads	13%
Wichita, KS[3]	1990s	Toilet retrofit 2 day per week watering School education program Proposed increasing block rate structure	13% (projected)
Barrie, ON[4]	1994	Toilet retrofit Water efficient shower heads	7% (16.5 gpcd)
Waukesha, WI[5]	2006	Toilet retrofit Daytime irrigation ban 2 day per week watering restriction School education program Proposed increasing block rate structure	11%

[1] From www.lincoln.ne.gov/city/pworks/water/conserve/ and *2007 Facilities Master Plan Update* (Black and Veatch, 2009).
[2] From *Regional Case Studies: Best Practices for Water Conservation in the Great Lakes-St. Lawrence Region* (Great Lakes Commission, June 2004).
[3] From "IRP: A Case Study from Kansas," *Journal of the American Water Works Association* 87, No. 6 (June 1995: pp. 57-71.
[4] From *Cases in Water Conservation: How Efficiency Programs Help Water Utilities Save Water and Avoid Costs*. (U.S. EPA, 2002).
[5] From "Waukesha, WI Promotes Water Conservation, Environmentally Responsible Water Supply Planning" by Mayor Larry Nelson, *U.S. Mayor Newspaper*, March 23, 2009 and "Proposed Waukesha Water Rates Encourage Conservation" by Lisa Kaiser, www.expressmilwaukee.com, May 20, 2009.

Source: Black and Veatch Technical Memorandum Madison Water Utility 5/20/11

In 2008, Madison's *Water Conservation & Sustainability Plan* outlined an ambitious goal: Drop daily per-person water use in the city by 20 percent – from 73 gallons to 58 gallons – by the year 2020. Madison currently uses 64 gallons of water per person per day, so it appears they are well on their way thanks to a significant commitment by area residents to water conservation, an effective widespread education program, restrictions on outdoor water use, development of other conservation programs, and an expansion of the toilet retrofit rebate program. Madison reported $227,732 in program expenditures for water conservation to the Public Service Commission in 2014. Program expenditures in other municipalities in Dane County were either very low or have not been reported. While Madison sets a good example for other communities in the region, there is additional room for improvement throughout the region (see http://www.cityofmadison.com/water/sustainability).

It is also important to note that, because of a growing population, a 20 percent reduction in water use really only postpones or delays the onset of future impacts by slowing the increase in water use. A 20 percent reduction in water use by all the communities in the Madison Metro region could reduce projected water use by 8.75 mgd (from 43.79 mgd in 2040 to 35.04 mgd., **Table 3**). In any event, water conservation is an important management strategy which should be encouraged at every opportunity to provide more efficient use of available water supplies. By reducing groundwater pumping, hydrologic and environmental impacts would be reduced correspondingly. Conservation programs would also **reduce or postpone** certain electrical costs and provide other benefits such as reducing wastewater flows for regional treatment and disposal.

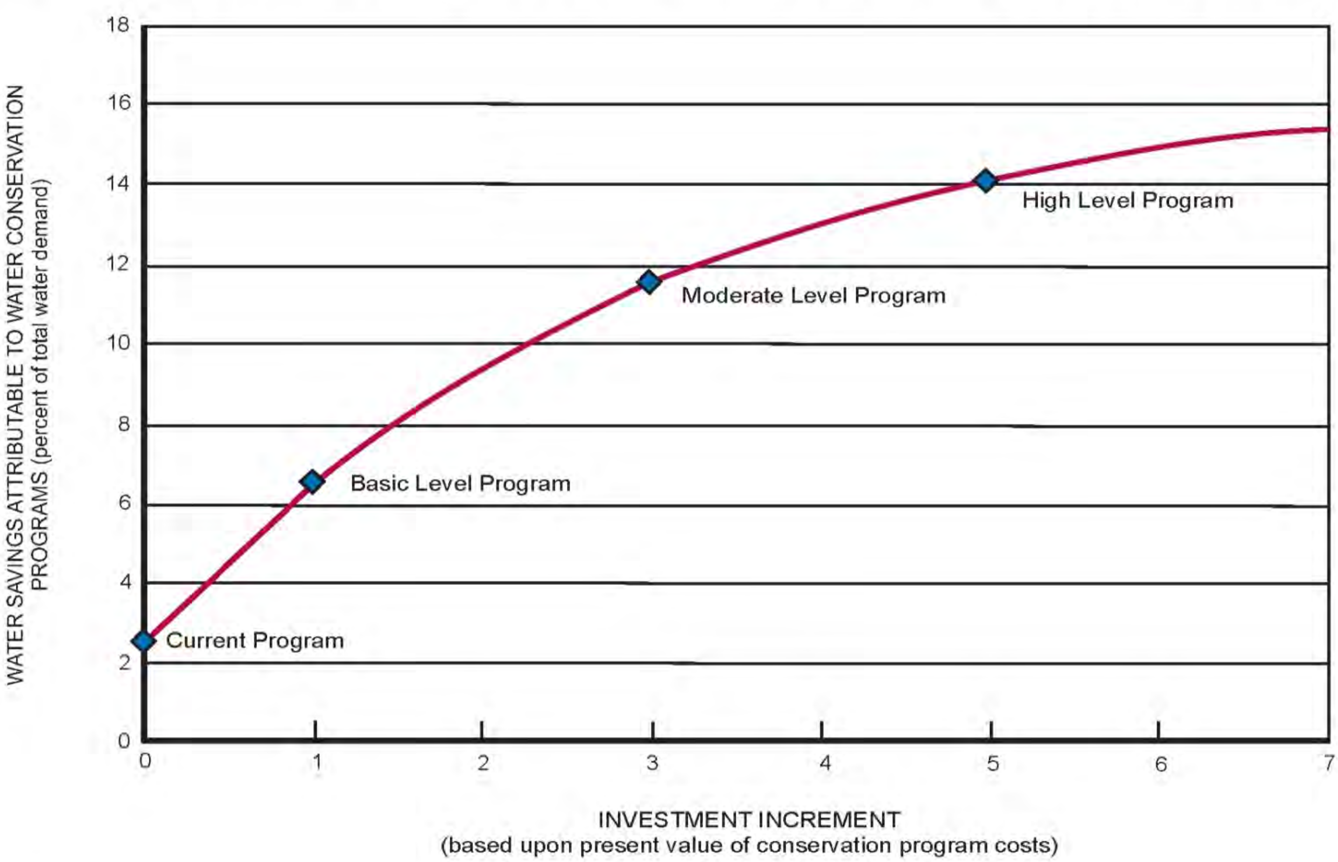
Each community should develop its own Water Conservation and Sustainability plan tailored to its unique opportunities and circumstances using the most cost-effective mix of practices and programs. *State of the Art Water Supply Practices* SEWRPC Technical Report 43 provides useful information including cost data for communities wishing to maximize their conservation efforts. This information should be incorporated into a public outreach campaign targeted to specific audiences.

Supply-side strategies focus on achieving efficiency in utility operations by minimizing the amount of water that must be produced and conveyed to meet user demand, primarily through he reduction of unaccounted for water. Associated practices include metering and system performance monitoring, leak detection and repair, and system operational refinements. Water supply efficiency programs and measures are well established but are system-specific in application.

Demand-side strategies focus on reducing or delaying infrastructure needs. Associated practices include water rate modifications to discourage use, use of water-saving plumbing fixtures, water recycling, and educational activities.

The conceptual conservation investment curve and cost data provided in **Figure 13 and Table 11** portray the relationship that may be expected between the costs of water conservation programs and attendant savings in water use. The actual conservation program levels and costs, as well as the attendant savings in water production costs and reductions in water use, will be utility specific.

Figure 13
Conceptual Relativity of Water Conservation Program Costs and Savings



Source: SEWRPC. 2007. *State of the Art Water Supply Practices.* Technical Report No. 43.

Table 11
Average Cost Data and Water Savings of Example Conservation Plan Options in Southeastern Wisconsin

Community Population	Conservation Plan Level	Average Annual Water Savings (millions of gallons per day)	Range of Percentage of Water Savings	Average Annual Cost of Program	Average Cost of Program per 1,000 Gallons Saved	Average Net Annual Savings[a]	
						Savings	Percent of Total Budget
3,000	Low	2	2-5	$ 1,106	$0.78	$ -562	-0.1
	Intermediate	4	5-12	2,536	0.73	-1,176	-0.3
	Advanced	6	8-20	37,821	7.07	-35,835	-8.7
70,000	Low	181	4-9	$ 26,265	$0.18	$ 23,167	0.4
	Intermediate	259	5-14	34,675	0.17	35,893	0.6
	Advanced	334	7-18	172,050	0.64	-87,857	-1.3
600,000	Low	1,953	3-7	$ 224,725	$0.14	$ 128,591	0.2
	Intermediate	3,345	4-12	689,450	0.25	-83,214	-0.1
	Advanced	4,085	5-15	1,359,450	0.41	-618,998	-1.1

NOTES: Assumptions: Energy and chemical expenses for example community of 3,000 = $16,000 per year.
Energy and chemical expenses for example community of 70,000 = $750,000 per year.
Energy and chemical expenses for example community of 600,000 = $7,250,000 per year.

Water conservation measures included are focused on the residential water customers, excepting for rate structure modification, which applies to all customers. Savings due to avoided capital costs are not included because of the variability of such costs community to community. For each community, factors such as the need for increased infrastructure, the location of new water sources, the number and size of wells that must be constructed, the cost of water that must be pumped from source waters outside community boundaries, etc., will vary greatly.

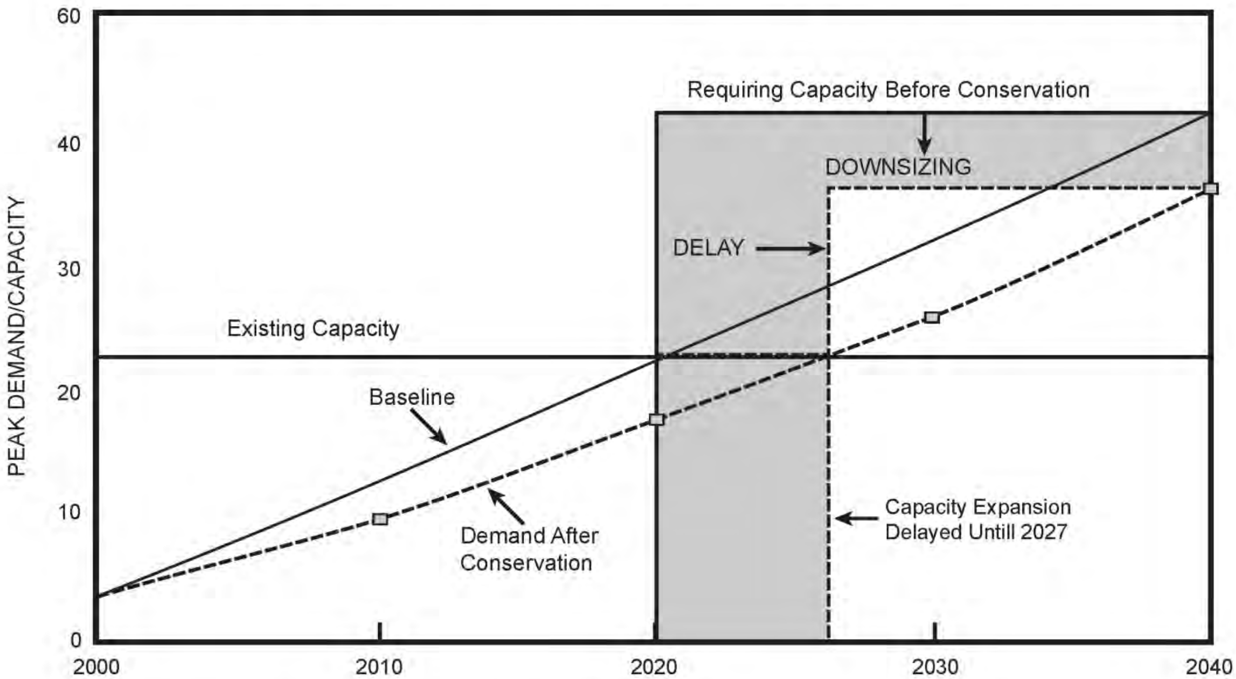
[a]*Annual savings are based on avoided chemical and energy costs associated with pumping and treating water less the cost of the conservation plan.*

Source: SEWRPC. 2007. *State of the Art Water Supply Practices*. Technical Report No. 43.

Note the cost of implementing an advanced-level water conservation program, which may be expected to achieve a 10 percent reduction in average daily water demand, could exceed the direct savings in operation and maintenance costs. All the utilities in Dane County already engage in some water conservation practices. Those practices include billing based upon metered water use, leak detection, and correction programs, some outdoor restrictions, and water main maintenance and replacement. Also note that higher levels of water conservation program may not be offset by savings in operation and maintenance costs. It may be possible to achieve a reduction from 3 to 5 percent in average daily water demand, with no significant increase in cost above the resultant savings in operational costs. Water conservation programs designed to achieve water use reductions over and above those levels will likely result in increased annual operational costs and higher water bills. Such considerations must be made on a water utility-specific basis, balanced with the community's priorities and fiscal constraints.

Even though the costs of water conservation programs may exceed the attendant savings in operational costs, there may be sound reasons to develop higher-level water conservation programs in cases where avoided capital costs and water supply sustainability are important factors. Water conservation programs may extend the useful life of municipal water supply and treatment facilities, and defer needed capital investment in increased capacity. **Figure 14** illustrates how water conservation can affect the timing of capital facilities and assist in delaying infrastructure investments. In the example shown, a 20 percent downsize in the 2040 demand could permit needed capacity expansion to be delayed by approximately seven years (from 2020-2027). The capital required for expansion of an existing water utility can be significant. The associated cost of drilling a well, installing a transmission pipeline, and constructing a new pump station can cost approximately $1 million. In situations where groundwater supplies are being depleted, however, the development of high-level water conservation programs may be warranted to promote more efficient use of existing water supplies. It should be considered along with other strategies to reduce the impacts of high capacity well water withdrawals described in other sections of this plan.

Figure 14
Example of Delaying and/or Downsizing a Capital Facility



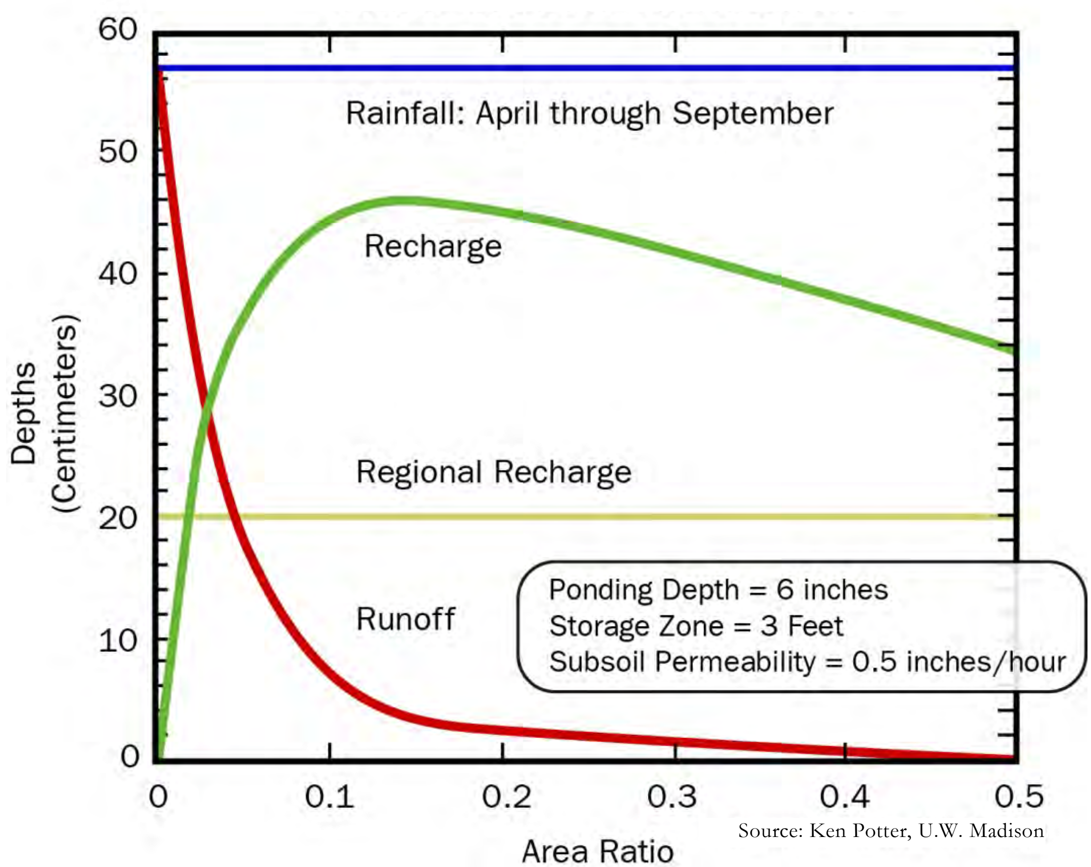
Source: Maddaus, W. et al. 1996. *Integrating Conservation into Water Supply Planning.*

Aggressive Pursuit of Water Infiltration Practices

The siting and development of practical infiltration practices in urban areas of Dane County is another management approach to be considered. Such practices can help maintain groundwater recharge and offset negative hydrologic effects associated with impervious urban development. In areas that are suitable, enhanced infiltration can also be used to help make up for well water withdrawals. For example, modeling developed at UW-Madison provides important insight into the beneficial aspects of rain gardens. It has been theorized that over 90 percent of the annual runoff can be infiltrated into the ground by using a rain garden sized only 10 percent of the impervious area draining to it (see **Figure 15**). The optimum area ratio is between 10 and 15 percent before experiencing a rate of diminishing return. In this manner, infiltration rates in rain gardens can be designed to exceed natural infiltration rates, helping to make up lost infiltration caused by past development and groundwater depression caused by well withdrawals. Infiltrating as much rainfall and snowmelt into the ground as possible has the multiple benefits of maintaining groundwater recharge, water table levels, and baseflow discharge to nearby wetlands and other surface water features. Stormwater runoff rates and volumes are also lowered through infiltration practices, reducing flooding and damage to streams. Also, since pollutant loading is a function of runoff volume, reducing runoff also results in reduced pollutant loads washing off the land surface into area waters. Rain gardens are just one example of the many options available to promote greater infiltration of precipitation, both on-site and off-site.

Infiltration practices can provide significant groundwater recharge and pollution control benefits depending on the degree of storage and infiltration achieved. Principal considerations for infiltration practices are siting, soils, stormwater pretreatment, and the need for routine maintenance.

Fig. 15. Rain Garden Simulation



Source: Ken Potter, U.W. Madison

Relative Infiltration

A key stormwater management strategy for addressing the impacts of development is to infiltrate as much rainfall and snowmelt into the ground as possible, thereby reducing overland runoff and replenishing groundwater supplies. In collaboration with Dane County, WDNR, and UW-Madison, relative infiltration maps have been developed for Dane County by the Capital Area Regional Planning Commission. The maps are meant to be used as a screening tool early on in the planning/design/development process to identify relatively high infiltration areas, as well as areas that might be enhanced through engineering techniques (e.g., replacement with engineered soils). While the maps do not replace the need for site specific analysis, they do provide a useful planning and decision-making tool for infiltration and stormwater management. They also help promote discussion of innovative methods and design techniques to enhance infiltration, as well as potential retrofit opportunities in previously developed areas.

Map 20 shows relative infiltration as it occurs naturally. Areas with naturally high infiltration should be used to recharge the groundwater to the greatest extent possible. They may also be prime locations for regional infiltration facilities that could be used for recycling treated water and to infiltrate stormwater generated in other parts of the watershed. Wetland and floodplain areas are generally not conducive to infiltration practices. Other areas, such as clay soils with low permeability, are also less suitable for infiltration.

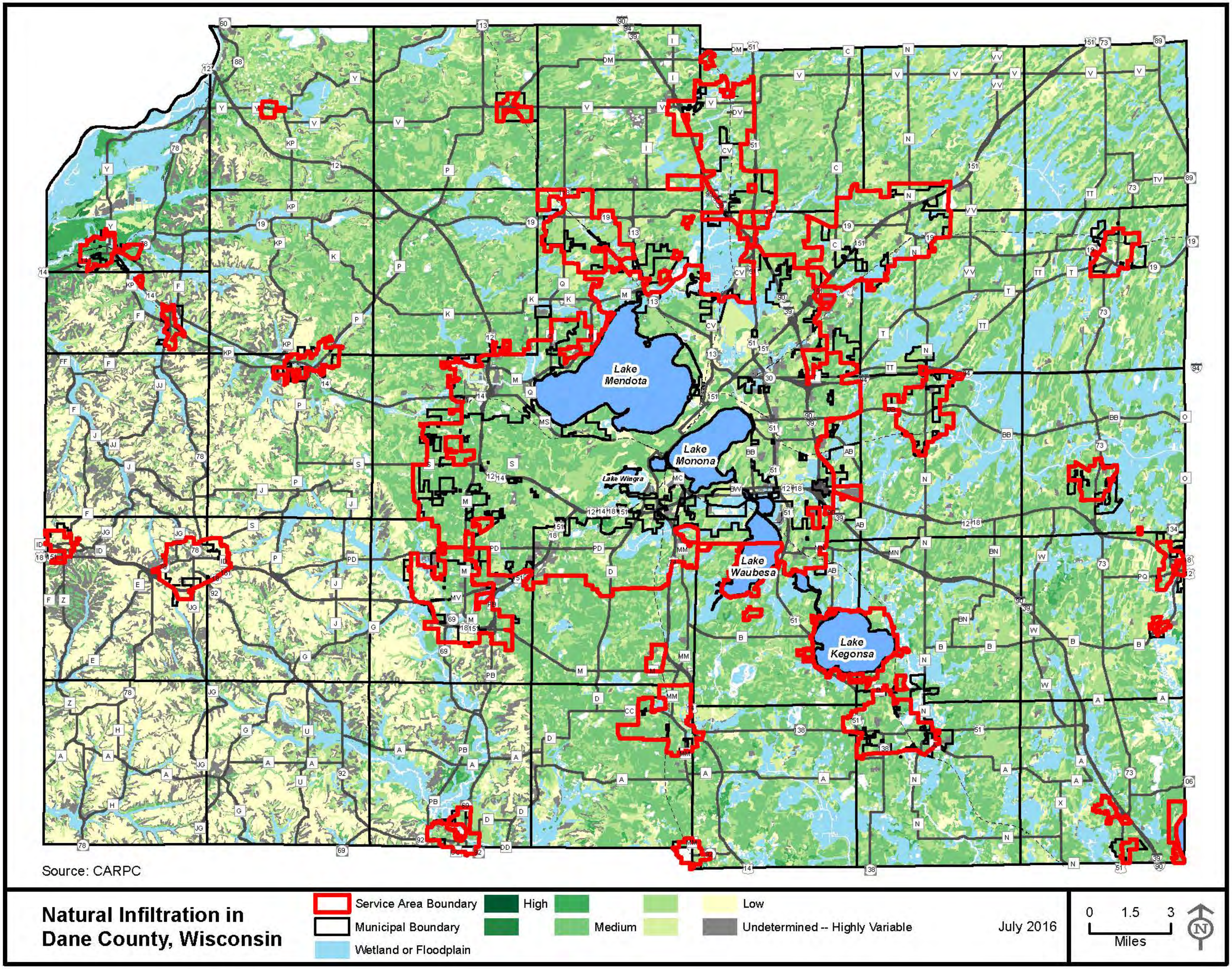
Map 21 presents enhanced infiltration that could result through removal of shallow layers of soils with low permeability and tapping into deeper sand and gravel deposits. The use of engineered soils (e.g., mixtures of sand, clay, and compost, along with native prairie plants) can enhance natural infiltration and enhance opportunities for infiltrating stormwater. There may also be enhanced opportunities or improvements that could be gained by retrofitting previously developed areas.

Map 22 indicates areas where infiltration enhancement potential may be the greatest. These areas show the greatest difference in scores between the natural and engineered states, highlighting opportunities where more permeable soils (e.g., sand and gravel deposits) may be present deeper in the soil column. These may be prime locations for regional stormwater facilities that could be used to infiltrate stormwater generated in other parts of the watershed.

A distinction between infiltration and recharge should be made. Whereas all precipitation that reaches groundwater is infiltrated into the soil, not all infiltrated precipitation actually makes it all the way to recharging groundwater supplies. Some of it may be captured by plants and evaporated or transpired back into the atmosphere. The distinction is that infiltrating stormwater runoff into the soil can reduce the volumes of runoff washing over the land surface, but not all of the infiltrated stormwater will necessarily reach the groundwater.

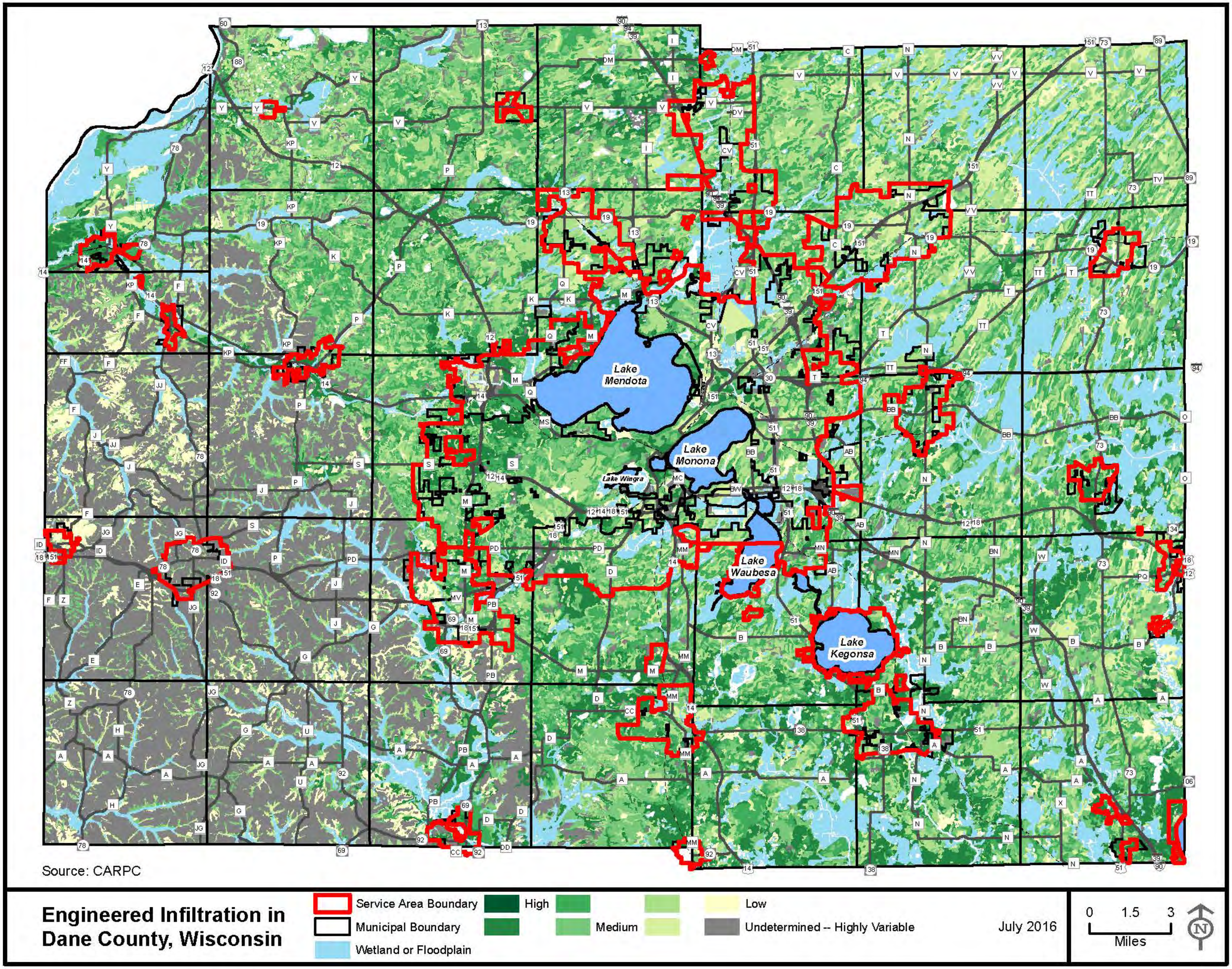
Maintaining baseflow discharge to streams and the water supply to springs and wetlands is an important resource objective. Annual groundwater recharge rates can be maintained by promoting infiltration and recharge through the use of both structural and non-structural methods. Since there are several best management practices that can be used to meet a volume control standard that do not provide groundwater recharge, it is desirable to meet this resource objective with a separate groundwater recharge standard. This approach is currently used in the City of Middleton and has been used in many urban service area amendments as well.

Map 20

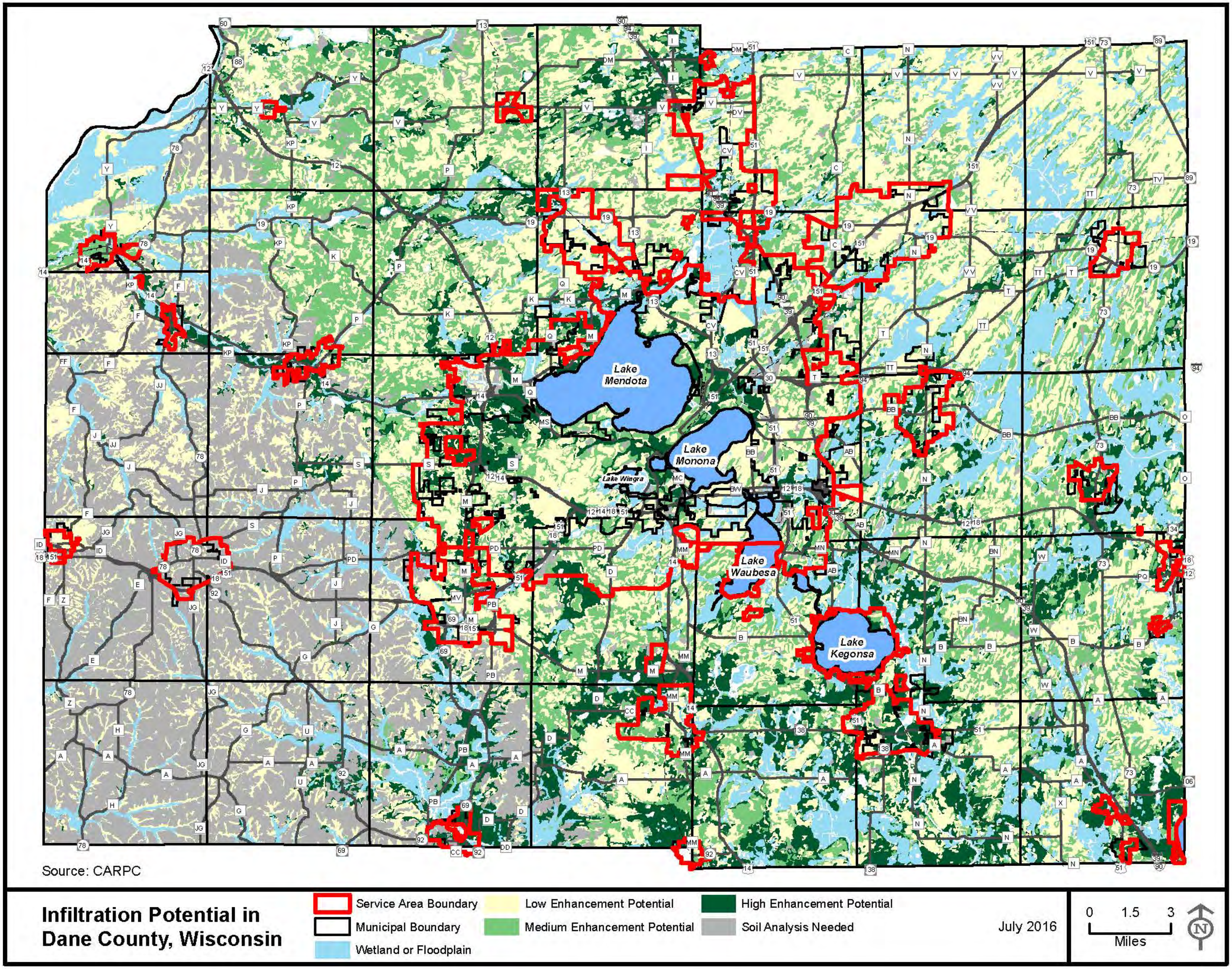


Lake Mendota
Lake Monona
Lake Wingra
Lake Waubesa
Lake Kegonsa
Source: CARPC
Natural Infiltration in Dane County, Wisconsin
Service Area Boundary
Municipal Boundary
Wetland or Floodplain
High
Medium
Low
Undetermined -- Highly Variable
July 2016
0 1.5 3
Miles
N

Map 21


Lake Mendota
Lake Monona
Lake Wingra
Lake Waubesa
Lake Kegonsa
Source: CARPC
Engineered Infiltration in Dane County, Wisconsin
Service Area Boundary
Municipal Boundary
Wetland or Floodplain
High
Medium
Low
Undetermined -- Highly Variable
July 2016
0 1.5 3
Miles
N

Map 22


Lake Mendota
Lake Monona
Lake Wingra
Lake Waubesa
Lake Kegonsa
Source: CARPC
Infiltration Potential in Dane County, Wisconsin
Service Area Boundary
Municipal Boundary
Wetland or Floodplain
Low Enhancement Potential
Medium Enhancement Potential
High Enhancement Potential
Soil Analysis Needed
July 2016
0 1.5 3
Miles
N

In most areas permeability is so variable that more detailed site investigation is needed. **Map 23** indicates depth to bedrock throughout the region, which is characteristically shallow in the unglaciated western third of the county. **Map 24** indicates shallow depth to water table, indicating low lying areas. **Map 25** indicates potential karst areas that may have vertical fractures and conduits that can dramatically increase groundwater susceptibility when present. These areas may limit the suitability of some stormwater infiltration practices due to the potential for groundwater contamination and induced flooding. Preliminary site planning and design can help maximize infiltration while protecting both existing and planned development as well as groundwater quality. This may be accomplished through on-site soil borings and analyses, engineered soils, dispersed infiltration practices of various performance and designs, as well as off-site facilities or practices in areas that may be more suitable.

It is interesting to point out that for nearly every large-scale development that might be proposed in the area there is an infiltration area located nearby that could be used to great advantage. The overall purpose of these maps, therefore, is to highlight these areas early on as important elements of site design so that they may be more fully utilized for water quality protection and groundwater recharge. While the maps do not replace the need for more in-depth analysis for a particular site, they do provide a useful planning tool to encourage the incorporation of innovative stormwater management practices into urban design.

Maintaining and enhancing groundwater recharge is a general practice promoted in the literature and throughout the country. Dane County is fortunate in that all groundwater originates as precipitation (rainfall and snowmelt) in or just outside of the county's jurisdictional boundary.[23] Dane County has adopted a stormwater volume control standard that is currently more protective than current state requirements. Municipalities have either adopted or exceeded the County requirements. This builds on work pioneered by the Dane County Regional Planning Commission requiring maximum infiltration since the late 1990s and working with the Lakes and Watershed Commission to adopt the countywide standard. Protecting and taking full advantage of high recharge areas helps offset the loss of recharge experienced locally and should be employed at every opportunity to help reduce damaging stormwater volumes and flow, treat urban runoff, and even help mitigate well water withdrawals where site conditions are favorable.

However, there are limits to the extent to which shifts in water balance can be addressed using infiltration practices alone.[24] Regional water balance transfer and large-scale recharge projects are certainly possible, but expensive. Groundwater induced flooding is another area of concern. Additional mitigation measures will likely be required to achieve the objective of minimal distortion of the hydrologic balance, and these measures will likely take the form of beneficial reuse of runoff, to supplement current infiltration approaches. Options such as aggressive conservation measures, graywater reuse, and treated effluent return to the groundwater system have been researched and successfully implemented elsewhere. In Dane County, these alternatives have substantial engineering, public health and regulatory issues that must be addressed before widespread implementation is possible. While progressive stormwater management at development sites is crucial, regional approaches to stormwater, drinking water, and wastewater management are also needed.

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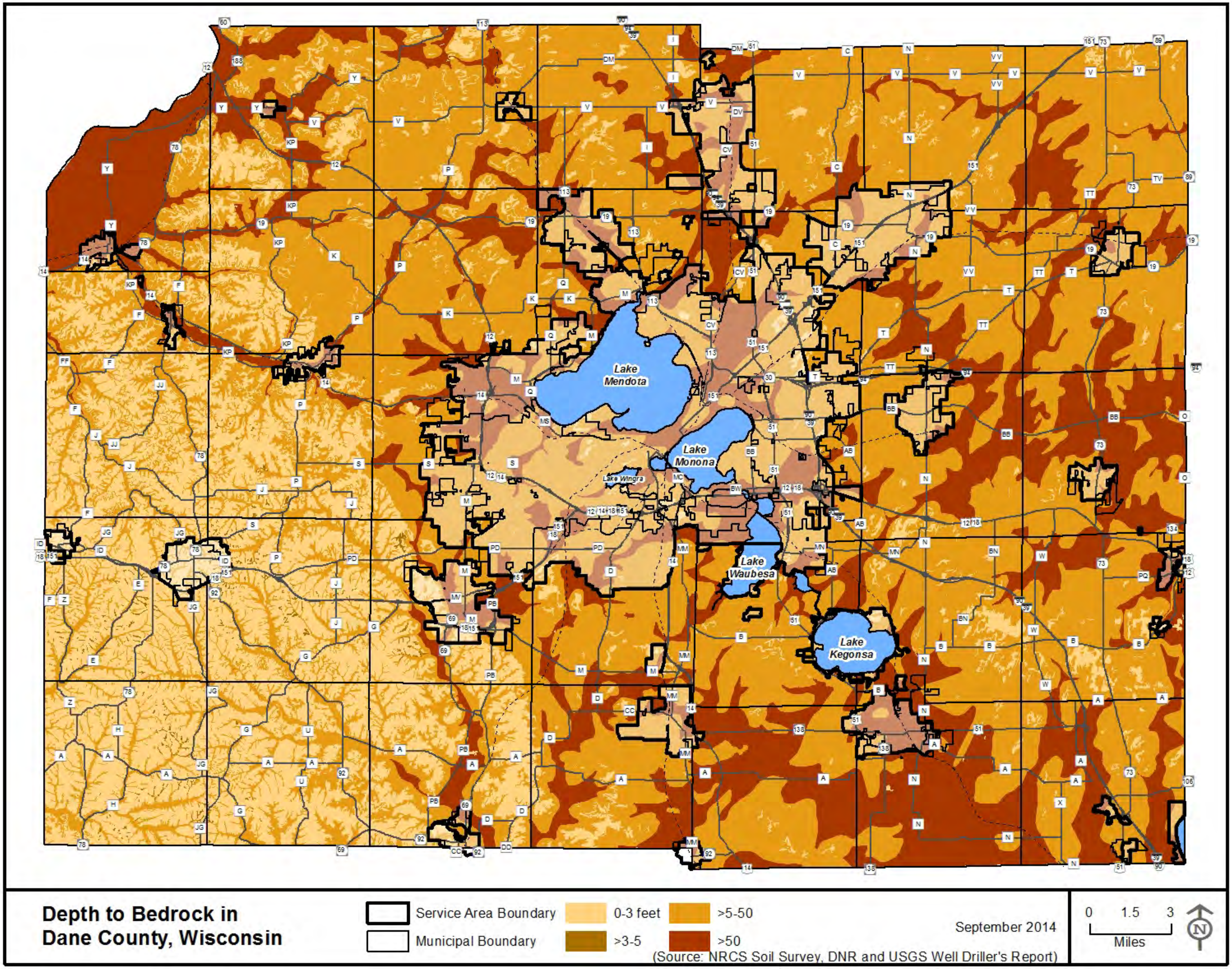
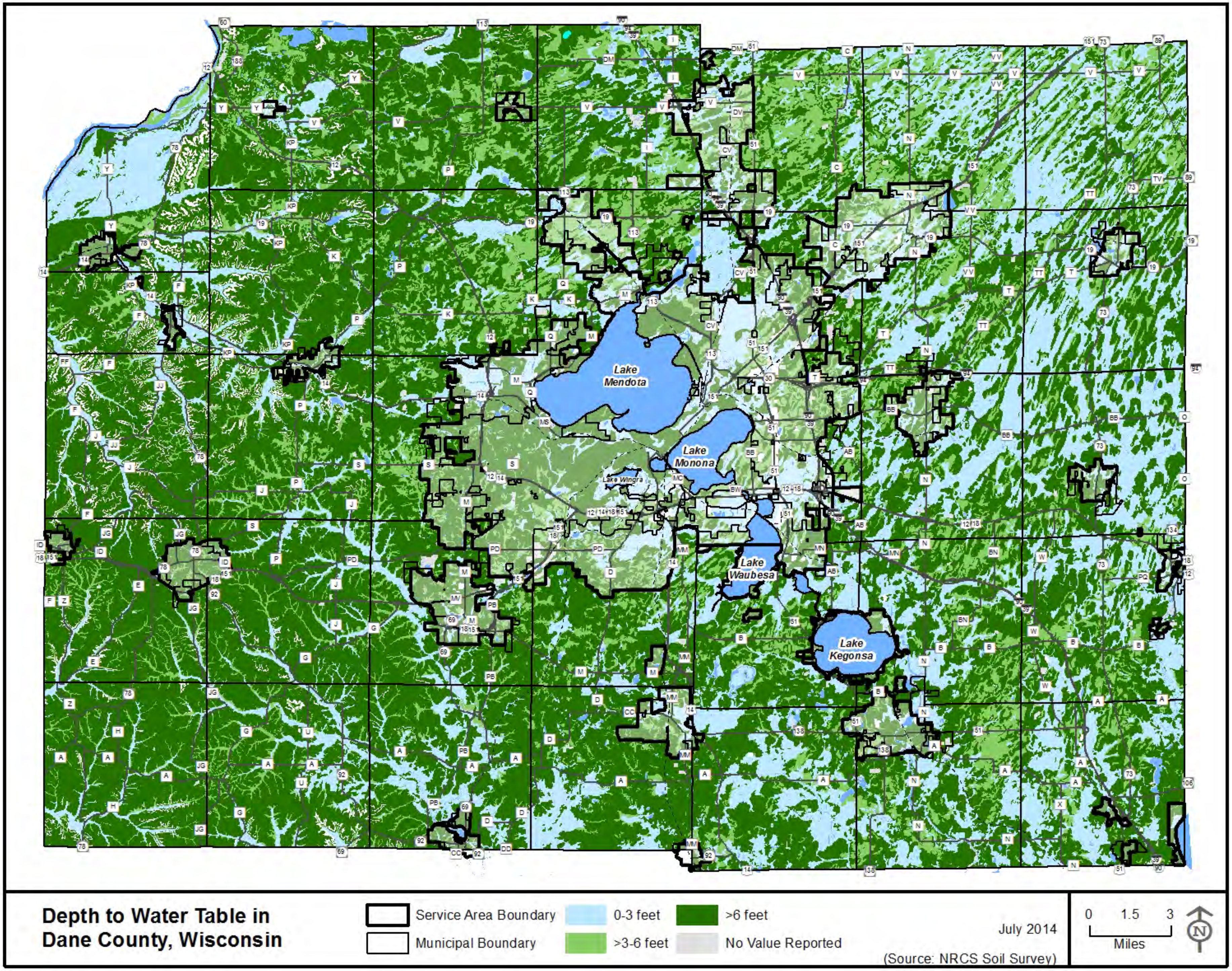
[23] Bradbury, K., et al. 1999. *Hydrogeology of Dane County, Wisconsin.*

[24] Montgomery Associates: Resource Solutions. Undated. *The Challenges of Mitigating Hydrologic Impacts of Development: Lessons Learned in Dane County, Wisconsin.*

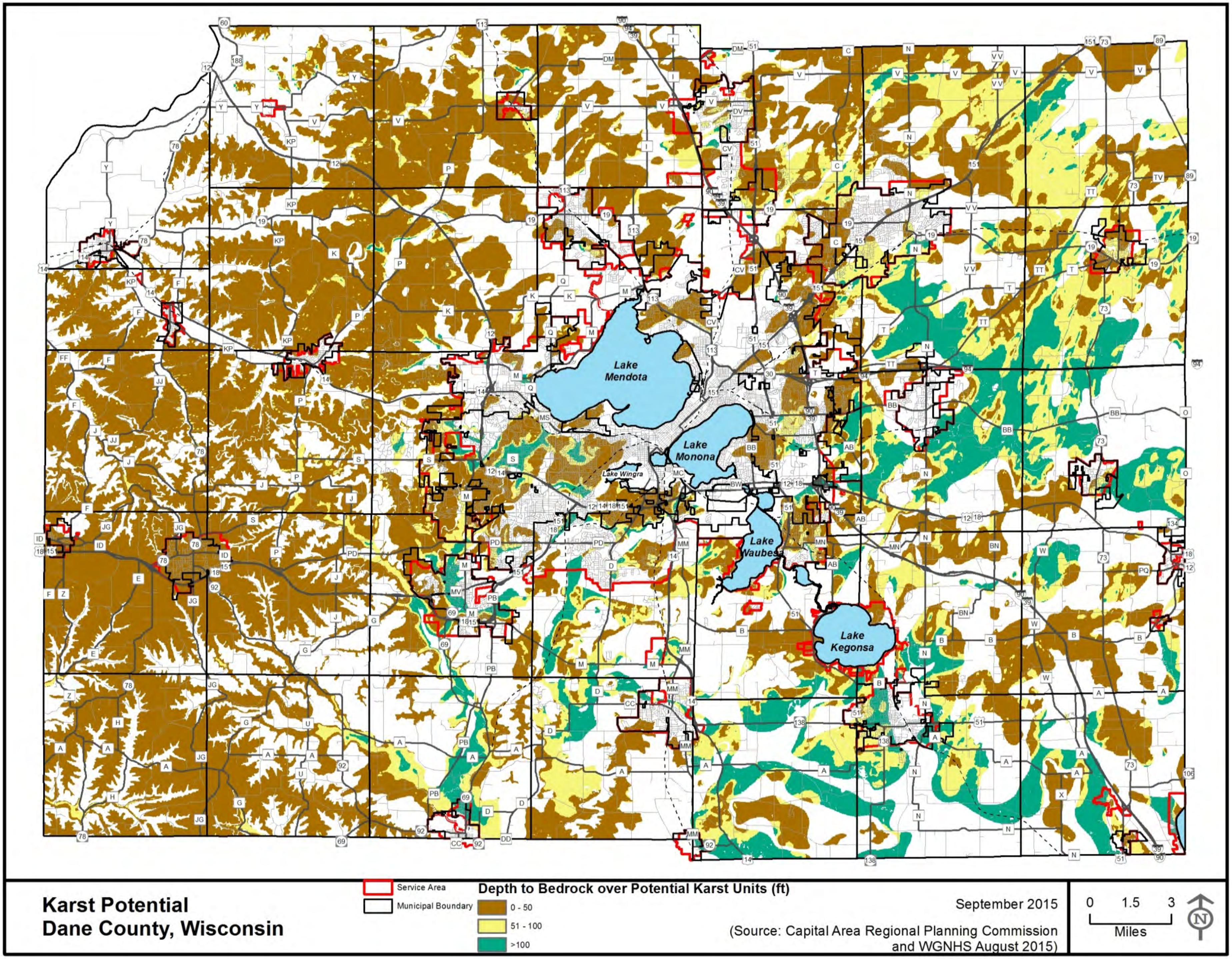
Map 23


Lake Mendota
Lake Monona
Lake Wingra
Lake Waubesa
Lake Kegonsa
Depth to Bedrock in Dane County, Wisconsin
Service Area Boundary
Municipal Boundary
0-3 feet
>3-5
>5-50
>50
September 2014
(Source: NRCS Soil Survey, DNR and USGS Well Driller's Report)
0 1.5 3
Miles
N

Map 24


Lake Mendota
Lake Monona
Lake Wingra
Lake Waubesa
Lake Kegonsa
Depth to Water Table in Dane County, Wisconsin
Service Area Boundary
Municipal Boundary
0-3 feet
>3-6 feet
>6 feet
No Value Reported
July 2014
(Source: NRCS Soil Survey)
0 1.5 3
Miles
N

Map 25


Lake Mendota
Lake Monona
Lake Wingra
Lake Waubesa
Lake Kegonsa
Service Area
Municipal Boundary
Depth to Bedrock over Potential Karst Units (ft)
0 - 50
51 - 100
>100
Karst Potential
Dane County, Wisconsin
September 2015
(Source: Capital Area Regional Planning Commission and WGNHS August 2015)
0 1.5 3
Miles

Treated Wastewater Effluent Return and Reuse

Heavy groundwater pumping in the middle and upper Yahara River basins, followed by wastewater diversion around the Yahara Lakes to MMSD's effluent discharge point in Badfish Creek, causes a disruption in the region's natural hydrologic system. The reason wastewater has been historically diverted around the lakes was to protect them from water quality impacts. However, wastewater treatment technology has improved dramatically compared to when this practice was initiated in the 1930s. Due to this diversion, water bodies in the Yahara River basin are not being replenished with water that is being withdrawn, leading to reductions in groundwater discharge and stream baseflow. Pumping and diversion is also affecting water bodies in adjacent drainage basins, such as Badger Mill Creek and the Sugar River, since induced groundwater movement is suspected from these basins into the Yahara River Valley as a result of lowered groundwater levels, an expanding cone of depression, and migrating groundwater divides (**Maps 12a and 5**).

The most direct method for addressing the diversion issue is to discharge treated wastewater back into the Upper Yahara River and Sugar River basins rather than conveying it all to Badfish Creek. This could be done either through a land dispersal and groundwater recharge system, or a surface water outfall. A third option, to inject treated wastewater directly into underlying aquifers, is presently prohibited in Wisconsin.

In 1998 MMSD completed a $5 million project to return treated effluent to Badger Mill Creek and the Sugar River. Similar plans are being considered for the Yahara River. The innovation here is treating wastewater as a resource to be recovered for beneficial use. Some cities such as the City of Lake Geneva in southern Wisconsin return treated wastewater to the shallow aquifer. In effect these strategies would decrease the Demand to Supply Ratio (DSR) by increasing the Human Input element of the equation (**Table 6**), which is currently zero. The costs and benefits of each alternative need to be studied in much more detail, as was done in the last update of the MMSD 50 Year Master Plan in 2009.

<u>MMSD 50 Year Master Plan</u>

The current MMSD model is collecting all wastewater to a centralized treatment facility (the Nine Springs Wastewater Treatment Plant – NSWTP) for treatment with subsequent discharge of the treated effluent to Badfish Creek (75 mgd maximum flow rate) and Badger Mill Creek (3.6 mgd permitted flow rate). There may be advantages to altering this model by decentralizing treatment through the construction of satellite treatment plants or altering the conveyance system to route wastewater from certain parts of the service area to an existing municipal treatment plant in a nearby community. These advantages could include:

- Environmental benefits realized by returning the effluent closer to the original source of the water
- Lower capital costs in the conveyance system and at the NSWTP, and
- Reduced operational costs associated with pumping the wastewater and effluent

The purpose of the 50-Year Master Plan is to provide MMSD with a general guidance tool for providing service over the next 50 year planning period. Key areas evaluated as part of the master planning process include:

- Population growth and resulting impacts
- Collection, conveyance and treatment capacity/condition
- Centralized vs. decentralized treatment
- Mitigation of inter-basin water transfers
- Effluent reuse
- Regulatory drivers

Detailed information regarding each of the above areas is presented in a series of nine technical memoranda associated with the approved Master Plan.

"Near-Term" projects are those that would address the need for capacity expansion in the conveyance system required in the next ten to twenty years. "Long-Term" projects are those which, while still viable, cannot be implemented prior to the time the collection system capacity improvements would be required. Examples of long-term projects would include those that would discharge highly treated effluent to Lake Mendota or Lake Monona; effluent reuse projects that would be primarily driven by the economic need to reuse water; or turf irrigation projects on a larger scale that would require the development of a distribution network for the highly treated effluent, discussed below.

Near-Term Master Planning Alternatives

The following two near-term master planning alternatives have been developed. Implementation of either of these alternatives between 2010 and 2030 will address the wastewater treatment and conveyance system capacity needs in a portion of MMSD's service area, namely service in the Sugar River basin:

Alternative MP-1 – Westside Conveyance System Expansion
This alternative would expand the existing conveyance system and continue the current model of centralized treatment at the NSWTP. This alternative includes four variations for pumping treated effluent from the NSWTP to Badger Mill Creek and the Sugar River basin ranging between 3.6 mgd (currently) to 7.9 mgd, with the balance being discharged to Badfish Creek.

MP-1A (3.6 mgd, $69 million total life cycle costs) scored the highest, however it will not be able to alleviate the issue of imbalanced inter-basin water transfer. This represents the current operation by MMSD. It serves as the baseline alternative to be compared with other alternatives.

MP-1B scored second highest among the alternatives to return an additional 4.3 mgd of treated effluent to the Sugar River watershed ($103 million), whereby baseflow reduction in the Sugar River would be avoided. This is an additional cost of $34 million, assuming the current discharge limits stay unchanged. Higher quality effluent limits would likely be required for discharge in the Sugar River watershed.

Alternative MP-2 – Sugar River WWTP
This alternative includes construction of a new high quality effluent treatment plant in the Sugar River watershed to treat wastewater generated in the Verona service area and discharge its

effluent to the Sugar River (4.3 mgd, $112 million). This alternative represents a decentralized approach towards an effluent reuse and watershed balanced solution.

If mitigation of the inter-basin flow imbalance between the Sugar River basin and the Yahara River basin is determined to be necessary, satellite facilities in the Sugar River Basin may be favorable from both economic and non-economic standpoints to address west side conveyance capacity issues. More detailed cost and non-economic comparisons between alternatives with centralized treatment and alternatives with satellite treatment will need to be conducted since their life cycle costs and social and environmental benefits are closely ranked.

Since the Sugar River is an Exceptional Resource Water (ERW), it is subject to more stringent anti-degradation requirements (NR 207). In general, a new discharge to an ERW needs to meet upstream water quality. For example, if the background phosphorus concentration in the Sugar River is 0.050 mg/L, the effluent limit could be set at 0.050 mg/L. The effluent limits for ammonia, BOD, total suspended solids, chlorides, and other parameters may also need to be equal to background concentrations. Regulations are not as stringent for an increased existing discharge; however, the permittee would still need to demonstrate there will either be no significant lowering of water quality or that the project has offsetting sociological and economic benefits.

Long-Term Master Planning Alternatives

Long-term alternatives are those planning alternatives that cannot be implemented soon enough to provide relief in the conveyance system; however, they remain potentially viable options beyond the year 2030 for mitigating inter-basin transfers of water, or providing high quality effluent for reuse options. Due to growing demands on available groundwater supplies and the long-term goal of stabilizing the groundwater aquifer operating level in the Dane County area, high quality effluent utilization could be a promising way to solve these issues in the future, especially if population growth occurs as expected. The following two long-term alternatives emphasizing effluent reuse were selected for further evaluation. These two alternatives have potential to be implemented after 2030 and provide high quality effluent to various locations for reuse options and to mitigate inter-basin transfer of water.

Alternative MP-3 – Centralized High Quality Effluent Treatment & Distribution
This alternative would include construction of facilities at the NSWTP for an additional 4 mgd treatment capacity ($51 million) that would produce a high quality effluent for use in various applications, including streamflow augmentation, infiltration, industrial reuse, or turf irrigation. It also includes a new effluent pumping station and effluent force main to convey the effluent from Nine Springs to a point of use near Starkweather Creek.

Alternative MP-4 – Decentralized High Quality Effluent Treatment Facilities:
This alternative would include construction of facilities northeast of the Dane County Regional Airport, for an additional 4 mgd treatment capacity ($76 million). The new treatment plant would receive wastewater flows tributary to Starkweather Creek or both Starkweather Creek and the Yahara River south of Cherokee Lake. Effluent from this facility could be used for streamflow augmentation to Starkweather Creek, wetland restoration at Cherokee Marsh, groundwater infiltration, industrial reuse, or turf irrigation.

Future service alternatives such as satellite plants in the upper Yahara River basin that would discharge to the Yahara lakes and regional service options involving Sun Prairie and Stoughton were not evaluated beyond initial screening in the Master Plan. At this time, the strict regulatory constraints, high construction and operation costs, lack of proven technology, and potential strong public resistance make these service alternatives less favorable than the services provided under the current treatment model. However, these alternatives may become more viable in the future with changes in the political environment, water resource demand, or improvements in wastewater treatment technologies.

WDNR interpretation of requirements in Wisconsin State Statute 281.47 was the driver for MMSD diverting effluent around the Yahara Lakes beginning in the late 1950s. The statute does not explicitly prohibit direct discharge of effluent to the chain of lakes, but it does place conditions that must be met for direct discharges to occur. The WDNR is given authority to determine whether these conditions are met. Based on recent phosphorus requirements, effluent quality would need to be close to background surface water quality for phosphorus prior to approval. The total phosphorus criteria for deep lowland lakes (Lakes Mendota and Monona) are 0.03 mg/l, and 0.04 mg/l for shallow lowland lakes (Lakes Waubesa and Kegonsa). For comparison, the current MMSD total phosphorus limit for Badfish Creek is 0.075 mg/l. MMSD is currently conducting an Adaptive Management pilot project with agricultural and urban partners in the Yahara River watershed to promote and take advantage of potentially more cost-effective nonpoint source phosphorus removal practices. So-called "nutrient trading" conducted between point and nonpoint pollution sources promises a more cost-effective alternative to expensive wastewater treatment plant upgrades in achieving water quality standards.

WDNR has indicated that a discharge to wetlands may be subject to less stringent requirements than a discharge to an ERW stream or the Yahara Lakes, particularly for restored wetlands. This option may also be useful in lieu of a direct stream or lake discharge in the vicinity of the Sugar River or Nine Springs Creek and Lake Waubesa. Wetland discharges are regulated under NR 103. NR 103 applies to natural and restored wetlands but not to constructed wetlands for wastewater treatment or polishing; the latter systems typically constructed with liners separating them from natural waters and are considered a wastewater treatment unit process.

Implementation of projects to decentralize treatment will take a decade or longer to implement, either because of issues related to the receiving water into which effluent from the satellite plant would be discharged, or due to the length of time it would take to reach agreement with a community with an existing treatment plant.

Future regulatory requirements could also significantly impact MMSD's planning and operations over the 50 year planning period. Areas of particular importance include: phosphorus criteria, anti-degradation, total nitrogen, chlorides, mercury and other toxics, thermal standards, micro constituents in effluent (such as pharmaceuticals, personal care products, and endocrine disrupting compounds), water quality assessments, Rock River TMDL development, water balance issues, and groundwater rules for discharges to land and subsurface waters.

Groundwater Recharge Using Treated Effluent

Groundwater recharge using effluent is being practiced in several locations around the state, particularly in the Wisconsin River Valley and other locations where soils are sandy and thus conducive to infiltration. A typical method of effluent groundwater recharge is to use seepage cells (also called absorption ponds), which are regulated under NR 206. Current effluent limitations for discharge to absorption ponds include: Biological oxygen demand (50 mg/l), total nitrogen (10 mg/l), total dissolved solids (500 mg/l), and chloride (250 mg/l).

Groundwater monitoring is also usually required for absorption ponds and the relevant groundwater standards at the design management zone boundary (250 feet from the seepage cell boundary) or at the property line. These are contained in NR 140. The groundwater preventive action limit (PAL) for chloride in drinking water is 125 mg/l and the enforcement standard (ES) is 250 mg/l.

For this type of discharge, it appears the greatest hurdles for MMSD to overcome would be total nitrogen (TN) and chloride effluent concentrations. Biological nitrogen removal can be used to reduce TN to below 10 mg/l. If a variance could not be obtained, chloride concentrations would need to be reduced through source reduction or reverse osmosis treatment prior to discharge to an infiltration gallery and may also need to be reduced prior to a discharge to absorption ponds.

As part of the 1997 Regional Hydrologic Study, estimated 2020 wastewater discharge generated in the Upper Yahara River basin (4.4 mgd) was land-applied north of Lake Mendota over areas exhibiting high infiltration characteristics (typically glacial outwash deposits). The confining unit between the upper and lower aquifers exists generally north and west of the Yahara lakes in this area and to a large degree inhibits transmittance of water between them. This resulted in apparent mounding of the water table, rising less than 20 feet locally and generally less than 10 feet over an 11-square-mile area.

Considering depths to water table in the areas examined are more than 10 feet and generally greater than 25 feet, sufficient soil depth is available to "polish" highly treated effluent before reaching the water table. Further iterations of the model will be needed to minimize the surface area needed, yet assure adequate percolation distances. The principal objective here was to screen the benefits/validity of using this approach initially, and conduct more in-depth analysis if this alternative appears promising compared to the others presented in this report.

Nonresidential Irrigation

The current MMSD permit contains provisions related to use of effluent on the Nine Springs Golf Course in Fitchburg as a demonstration project. This type of discharge would be regulated under NR 206. Current regulations include a BOD effluent limitation of 50 mg/l. Hydraulic loading rates and load and rest cycles are determined on a case-by-case basis and generally depend on the soil type. Likewise, Total Nitrogen and fecal coliform limits are determined on a case-by-case basis. Groundwater monitoring is often required for these systems, particularly when significant pretreatment is not provided. Groundwater standards for chloride (125 mg/l PAL and 250 mg/l ES) may be of greatest concern for MMSD's effluent.

Nonresidential irrigation would generally involve spray or drip irrigation of treated wastewater onto agricultural fields, grass lands, golf courses, or similar areas. Generally Total Nitrogen applications are limited to crop uptake rates, which are on the order of 165 lb/acre-year for corn and 300 lb/acre-year for certain grasses like reed canary grass. Groundwater monitoring is often required for determining compliance with groundwater standards.

Residential Reuse

Water reuse – using the same water to perform more than one function – enables us to get the most out of every drop. Water reuse is becoming increasingly popular as a tool for Wisconsin citizens and communities to achieve their water conservation goals. Only 15 percent of the water used in homes actually needs to be potable. By reusing water that would normally just go down the drain, people can begin to dramatically cut down on their daily water consumption without having to change their daily routines. Stated simply, water reuse saves money, energy, and – ultimately – our water supply.

There are already a small but growing number of on-site water reuse systems that are operating safely and successfully in Wisconsin. When water reuse systems are *properly installed and maintained*, the health and safety concerns are no greater than those from existing municipal or private well water supplies. Because on-site reuse is largely a plumbing issue, it is regulated by the Wisconsin Department of Safety and Professional Services under the provisions of SPS 382.70.

Water reuse is not for everyone. Retrofitting plumbing systems in existing homes and businesses is often cost-prohibitive for remodeling projects. Owners interested in water reuse should be aware that additional time, cost, and maintenance are necessary to keep these systems running safely and efficiently. Homes or businesses that use large amounts of water will see the most economic benefit from the reduction in water use. Water reuse may simply be fulfilling water-use reduction standards for LEED building certification. New construction is often best when it is a part of an overall goal of making a new or existing building more water efficient or suited to installing water reuse systems. Local governments can play a major role in promoting water reuse and conservation in proposed developments, particularly in cases where tax increment financing or other incentives are awarded.

Public acceptance has been one of the major obstacles to implementing water reuse in many parts of the country. Because water reuse is still a relatively new practice in modern homes and businesses, the public often has reservations about health risks or aesthetic concerns. As more water reuse systems are properly installed and put to productive use, these concerns are expected to lessen over time. Water reuse is the next great advance in water conservation because of its tremendous potential to increase water use efficiency and reduce water consumption.

MMSD's customers have been supportive of the master planning process and would like to see MMSD investigate wastewater reuse alternatives. Many commenters suggested that new subdivisions could start requiring that wastewater reuse infrastructure be constructed with other utilities. Effluent reuse options should be evaluated during future facilities planning efforts, but will require partnerships to implement. Partnerships could potentially include other municipalities, water utilities, or public/private partnerships. Other areas of the country, especially the south and west, are already reusing treated wastewater.

It has been proposed that treated effluent could be reused for toilet flushing, residential lawn irrigation, and other residential nonpotable water uses. Such a concept would require effluent treatment to a very high level (potentially California Title 22 standards for food crop irrigation), require force mains to convey the treated effluent to the residential developments, and require a new infrastructure similar to the "purple pipe" reuse water distribution systems used in the Southwest and elsewhere. This concept may be worth considering for new developments where installation costs would be lower compared to existing developments. However, it is likely that costs of such systems would outweigh the benefits, at least in the short term in the Madison area. For the short term, it appears that residential water conservation measures may provide similar benefits at a significantly lower cost. Due to the long planning horizon, specific effluent reuse projects cannot be clearly defined for long term alternatives. Preliminary evaluation shows that the most cost effective approach to providing effluent for reuse options is to continue to treat wastewater centrally and construct an effluent delivery system(s).

Industrial or Commercial Reuse

Wastewater effluent can be used for industrial noncontact cooling and other noncontact uses. Wisconsin currently has no standards for the treatment of effluent for use in an industrial facility. Commercial car wash use may be another viable alternative; however, the locations of such facilities may be too diffuse for cost-effective conveyance of the treated effluent. The concept should be initially explored with the largest water users in Dane County who use fresh water for nonpotable uses.

Prospects for Effluent Discharge and Reuse

Increasing regulatory pressure and energy costs may limit the long term viability of pumping all treated effluent to Badger Mill Creek and Badfish Creek. The volumes and locations where MMSD discharges its effluent will be a major factor in sustaining water levels in streams and aquifers throughout the watershed. Also, water conservation within the watershed is considered a primary issue to address the timing and location of needed improvements. As part of the MMSD facilities planning process the following issues on effluent discharge and reuse were identified for more in-depth discussion and consideration:

> Current pumping of groundwater is lowering the groundwater table levels and reducing baseflow to streams and springs.

- The most apparent variable is the ability to discharge effluent into the Yahara Lake system. This will depend heavily on effluent quality limits, regulatory judgment, and public perception. Legislative changes may also be required.

- Decentralized local treatment plants could be a direction in the future. These facilities could reduce inter-basin water transfers by reusing effluent within the basin that it was generated. They would also eliminate the need to pump effluent long distances, thereby reducing energy costs associated with pumping.

- Who would ultimately be responsible for running the decentralized facilities? If operational responsibilities remain with MMSD, there may be workforce availability and other technical issues associated with operating multiple facilities.

- Conservation of water on the intake side of the water system will be essential to achieve sustainability. Current pumping of groundwater is lowering the groundwater table and reducing baseflow to streams and springs. Energy conservation and water conservation should be considered equally important.

- Augmenting low water flow areas with treated effluent is an option, but the ability is needed to divert or manage the effluent in some other manner during high flow events. Nine Springs WWTP can utilize its lagoons for storage, but they can only hold 66 million gallons, a volume of water equal to approximately one and one-half days' worth of dry-weather plant influent volume.

- Reintroduction of treated effluent back into the groundwater through infiltration or recharge could be a viable option to address water quantity concerns, but would there be enough available land area to implement effluent reuse options involving infiltration to an extent that it would have a significant impact on groundwater quantity?

- Micro constituents found in treated effluent such as pharmaceuticals, disinfection byproducts and viruses may be subject to increased regulation and create public perception issues that could limit the viability of using effluent for groundwater recharge.

- From an ecological perspective it may be better to augment existing baseflows than to recharge aquifers.

- Use of wetlands for effluent polishing and use of effluent in reclaiming wetlands need to be further investigated.

- The reuse of "gray water" in non-drinking applications appears to be a sensible option for the reduction of water consumption. How to go about implementing and integrating such systems remains an issue.

- Major water consumers such as industrial parks and golf courses should be targeted first for instituting water reuse systems.

- Public perception can influence the ability to institute water reuse options, and information/education efforts will need to be undertaken to impact public perception. The discussion in 2003 related to using effluent for cooling water at the UW cogeneration energy facility on campus highlighted the need for information/education activities. Staff from the University of Wisconsin expressed concerns related to reusing effluent because of public perceptions that use could impact human health.

- The majority of wastewater flow is generated by residential sources. The residential capacity to take on new gray water systems needs to be investigated.

The Master Plan is a dynamic document and will be reviewed and updated periodically to reflect the impact of these key factors. Signposts developed by MMSD such as technology improvements, regulatory trends, population growth/shifts, and changes in water use should be closely monitored to allow MMSD to make appropriate adjustments to the Master Plan.

Importation of Water from Other Drainage Basins and Deep Aquifer Withdrawal

As part of the 1976 Madison Metropolitan Sewerage District's (MMSD) *Wastewater Facilities Plan,* potential water quantity augmentation measures were presented including importation of water from other drainage basins and deep aquifer withdrawals.

Importation of water from the adjacent Wisconsin River Basin, through pumping and transport of groundwater from high-capacity wells, was one approach that was evaluated. At that time, the required pumping capacity to make up the estimated water deficit in the Yahara River and lakes system was determined to be 36 cfs (23 mgd). This is the balance of flow needed to offset evaporation (27 cfs) and maintain the required minimum of 25 percent of the $Q_{7,2}$ (9.0 cfs). Water importation was suggested only as a contingency during an extremely low-flow year. Capital costs for importation (i.e., well-pumping and distribution system) were projected to exceed $15 million. Most of the expense was associated with extensive force main construction.

In addition to expense, the importation of water from other drainage basins raises complex and conflicting water rights issues surrounding the interbasin transfer of water. To protect these rights, the WDNR has been charged through 1985 Wis. Act 60 with approving and permitting any proposed new or expanded use of the state's waters which results in a consumptive loss or interbasin diversion averaging more than 2 mgd in any 30-day period. Overall, flow augmentation by importing water from other drainage basins, particularly the Wisconsin River Basin, has been found to be prohibitively expensive and politically unfeasible (as evaluated in the 1976 MMSD Facility Plan). Rather, a much more favorable approach would be to augment streamflow through careful management of ground and surface water levels within the Yahara lakes' own drainage system, through more viable alternatives presented in this plan.

Another strategy to augment low flows in the Yahara River would be to pump water from the deep aquifer system near the basin divide or areas within the basin where geologic confining units are known to exist (these separate the deep and shallow groundwater flow systems). It was thought well water drawn from the deep aquifer system could be used to augment shallow water table levels, which sustain stream baseflows and lake levels. Upon closer examination, however, this alternative is seen as providing negligible long-term benefit given the close association and transmittance of water between the upper and lower aquifers, particularly in the Yahara lakes area and eastern portion of the county where the confining unit is largely absent. This alternative could be employed to mitigate short-term severe drought conditions, by augmenting streamflow with well water during critical conditions. This is currently being implemented to mitigate surface water withdrawals for the UW Co-generation energy facility during drought conditions. Further evaluation will be undertaken only if more viable long-term alternatives presented here fail to adequately satisfy prescribed management goals and objectives.

Management of the Yahara Lakes as Multipurpose Reservoirs for Baseflow Augmentation and Drinking Water Supplies

Baseflow Augmentation

The effect of municipal well water withdrawals and wastewater diversion on the lower Yahara River is of historical concern. The 1976 *Madison Metropolitan Sewerage District's Facilities Plan* proposed lake level and outflow manipulation of the Yahara River lakes as a possible management approach that could mitigate the baseflow impacts of diversion. Other studies have also recognized the need for a well-formulated lake-level management program (including specific outlet control guidelines) to address this concern.[25] However, refined operating rules for the Yahara lakes had yet to be developed, primarily because lake levels and outflows had not been technically simulated and evaluated. A critical question to address is the timing and daily quantity of water to release from the lakes' outlets preceding and during low-flow periods, which can only be accurately simulated by a routing model.

As a component of the Dane County Regional Hydrologic Study (1992-1997), a daily reservoir storage routing model for the Yahara lakes was developed. The purpose of the Yahara Lakes Reservoir Routing model was to simulate the flow through the Yahara Lakes/River system under varying conditions to determine whether or not the substantial baseflow reductions resulting from wastewater diversion can be mitigated through lake level manipulation and flow control.[26] The goal is to restore prediversion low-flow conditions ($Q_{7,2}$=36 cfs at McFarland)[27] within the tight constraints of WDNR lake level and flow limits. The Reservoir Routing Model demonstrates that, using a set of operating rules, lake levels and streamflows could be better managed and that it would be possible to restore prediversion low-flow conditions in the Yahara River system in all but the driest years without lowering the lake levels more than they have been lowered during the study period 1974 to 1994. This is accomplished using a rather detailed set of operating procedures and computations.

Achieving this result in practice, however, would require detailed computations to reach decisions on lake levels and dam operations. A USGS operations model linked to real-time lake levels and flows was subsequently developed and used to help guide the County's operation of the lakes; however, without success. A more sophisticated Yahara Lakes INFOS model[28] developed by the UW-Madison, City of Madison, and Dane County is currently being used to better manage the lake levels. This model should be expanded and configured to evaluate alternative management/mitigation strategies using the more sophisticated models and software than was available to USGS in the late 1990s.

This is part of a regional effort to help balance often conflicting goals and expectations by multiple user groups. At times the physical limits of the dams and outlet channels make it impossible to keep the lake levels within prescribed limits. Yahara lake limits were established over a century ago based primarily on human interests (recreation, property damage, etc.), possibly at the expense of natural areas. There may be some interest in revisiting the maximum/minimum lake levels. According to the USGS study, setting somewhat higher stage limits in the spring or lower in the fall would more easily accommodate restoring prediversion low-flow conditions in the Yahara River system. However, this could conflict with riparian landowners' expectations of so-called "normal" lake levels they have become accustomed to. Overall, greater flexibility on the part of all user groups will be needed to find an area of common agreement among the various interests on how best to operate the lakes to satisfy all interests – a challenge indeed.

[25] *City-County Lakes Committee Report* (DCRPC, 1978) and *Dane County Water Quality Plan* (DCRPC, 1979).

[26] USGS. 1999. *Simulation of the Effects of Operating Lakes Mendota, Monona, and Waubesa, South-Central Wisconsin, as Multipurpose Reservoirs to Maintain Dry-Weather Flow*. Open-File Report 99-67.

[27] The 7-day 2-year low flow ($Q_{7,2}$) is a statistical estimate of the lowest average flow that would be experienced during a consecutive 7-day period with an average recurrence interval of two years.

[28] Integrated Nowcast/Forecast Operating System for the Yahara Lakes http://www.infosyahara.org/

Drinking Water Supplies

In 2010 the Madison Metro Region diverted an average of 63 cfs (40.7 mgd) of groundwater from the Madison Metro Region (from municipal well withdrawals) and discharged the treated effluent to Badfish Creek. Under steady state conditions, every gallon of water pumped is a gallon of water lost from groundwater discharged to surface waters. Approximately 80 percent of this amount (51 cfs[29]) is being drawn from waters other than the Yahara Lakes. Streams and small water bodies are particularly sensitive to changes in flow. Large drainage lakes such as the Yahara Lakes, on the other hand, are considered relatively insensitive or resilient from a biological standpoint.[30] In addition, the flow in the Yahara Lake chain system is artificially managed by dams at the outlets of Lakes Mendota, Waubesa, and Kegonsa. This offers some prospect for possibly pumping more water from the wells, inducing withdrawals from the Yahara Lakes, and thereby relieving some of the impact on the more sensitive tributary streams, ponds, and wetlands in surrounding areas.

Much of this additional withdrawal could be accounted for through the normal daily operation of the dams (i.e., holding more water back, to account for the withdrawal, and releasing less runoff), providing an alternative source of drinking water previously released downstream as runoff. Since this pumping represents a relatively constant demand, it could be managed or accounted for on a daily basis through stop log changes (as is currently done) at each of the three dams. The lakes could function as water supply reservoirs, either directly (i.e., surface water withdrawal, although cost prohibitive[31]) or indirectly (i.e., induced recharge by pumping, as done presently). Note that about a third (20.43 cfs or 32 percent) of municipal well withdrawals in the MMSD service area is being taken out of the Yahara lakes through induced recharge (**Tables 12a and b**). Being a more resilient and renewable resource (as reservoir storage), taking *more* water out of the lakes could actually help reduce the impact on more sensitive surrounding streams.[32]

Figure 16 and Tables 12a and b illustrate the increased losses and decreased gains for each of the Yahara Lakes resulting from the three pumping scenarios. Note there are relatively small losses from Lakes Waubesa, Kegonsa, and Upper and Lower Mud Lakes under the 2010 and 2040 development scenarios. This indicates that municipal well withdrawals are inducing relatively little groundwater recharge from these water bodies. In the case of the urbanized lakes (Mendota, Monona, and Wingra), water losses to groundwater are increasing (induced recharge) and lake gains (from groundwater discharge) are decreasing as a result of municipal well withdrawals. **Table 12b** indicates the losses for each water body between indicated time periods taken from **Table 12a.** For example, the additional lake loss for Lake Mendota between 2010 (0.86 cfs) and 2040 (1.11 cfs) in **Table 12a** equals 0.25 cfs in **Table 12b.** Likewise, the total net loss between 2010 (20.72 cfs) and 2040 (18.70 cfs) is 2.02 cfs. The greatest decrease has already occurred (20.43 cfs in 2010), with a total loss of 22.45 cfs expected by the year 2040 compared to Pre-Development Conditions.[33]

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[29] 63 cfs minus 12.33 cfs (from **Table 12b**) equals 50.67 cfs.

[30] Dane County Regional Planning Commission. 2005. *Dane County Water Body Classification Study*, Madison, WI.

[31] Roughly $5 million per mgd for treatment plant and distribution system. Note that, because of induced recharge, this is considerably more expensive (15X per mgd) than service from a new $1 million, 3 mgd well located near the lakes, with proportionally similar effects.

[32] Dane County Regional Planning Commission. 1997. *Evaluation of Alternate Management Strategies*. Dane County Regional Hydrologic Study.

[33] Conditions existing prior to large well withdrawals (circa 1800s) simulated by removing all pumping wells from the regional groundwater model with a subsequent rebound in water table levels and groundwater discharge to surface waters.

Fig. 16. Yahara Lake Gains and Losses Resulting from Groundwater Discharge and Induced Recharge.

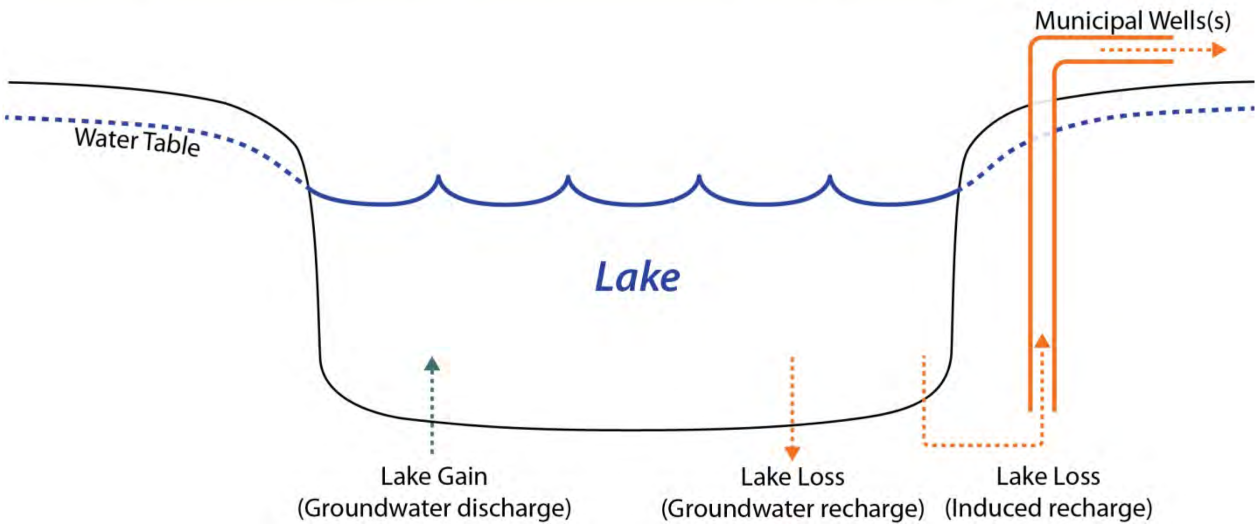


Table 12a. Modeled Losses and Gains for the Yahara Lakes For Different Time Periods (cfs)

ID*	Water Body	Pre-Development (PD)**		2010		2040	
		Loss	Gain	Loss	Gain	Loss	Gain
27	Mendota	0.00	12.22	0.86	3.69	1.11	3.27
41	Monona	0.02	4.18	0.49	0.56	0.63	0.43
49	Wingra	0.45	5.03	0.20	2.40	0.23	2.23
44	U. Mud Lake	0.00	4.65	0.01	2.10	0.02	1.55
54	Waubesa	0.00	4.09	0.01	3.02	0.01	2.84
57	L. Mud Lake	0.00	3.58	0.00	3.05	0.00	2.94
66	Kegonsa	0.00	7.88	0.00	7.47	0.00	7.44
	Sub total	0.47	41.63	1.57	22.29	2.00	20.70
Net		**41.15**		**20.72**		**18.70**	

* ID corresponds to the modeled hydrostratigraphic response units indicated on **Maps 15 and 16.**
** Pre-Development Conditions were estimated by removing all well pumping from the regional groundwater model resulting in a subsequent rebound in water table levels and groundwater discharge to surface waters.
Source: WGNHS 2014 Regional Groundwater Model

Table 12b. Differences in Modeled Losses and Gains Between Different Time Periods, from Table 11a (cfs)

ID	Water Body	PD to 2010		2010 to 2040		PD to 2040	
		Loss	Gain	Loss	Gain	Loss	Gain
27	Mendota	0.86	-8.53	0.25	-0.42	1.11	-8.95
41	Monona	0.47	-3.63	0.14	-0.13	0.61	-3.76
49	Wingra	-0.25	-2.63	0.03	-0.17	-0.22	-2.81
44	U. Mud Lake	0.01	-2.55	0.01	-0.55	0.02	-3.10
54	Waubesa	0.01	-1.06	0.01	-0.18	0.01	-1.24
57	L. Mud Lake	0.00	-0.53	0.00	-0.11	0.00	-0.64
66	Kegonsa	0.00	-0.41	0.00	-0.03	0.00	-0.44
	Sub Total	1.10	-19.34	0.44	-1.59	1.53	-20.94
	Total Loss	**20.43**		**2.02**		**22.45**	

The fact that the Yahara Lakes represent a renewable water supply source or reservoir system suggests a potential mitigation strategy. Being artificially controlled, the availability of lake water is largely represented by the amount of water held in storage or released downstream during runoff events. One of the conclusions from the Dane County Regional Hydrologic Study was that concentrating pumping closer to the lakes would largely offset future water table declines in surrounding areas (**Map 19a**). This has significant benefit for small headwater and tributary streams such as Badger Mill Creek, Black Earth Creek, and the Sugar River, among others, which have been significantly affected by municipal well withdrawals. The fact that the lakes are large, artificially managed, surface water-dominated systems suggests that the water quantity impact to more sensitive surrounding streams could be potentially mitigated without significant harm by inducing greater recharge from the lakes.

Conceptually, this could be accomplished by increasing withdrawals from municipal wells located closer to the Yahara Lakes. There are obviously tradeoffs associated with alternative water supply locations and configurations that would need to be evaluated in more detail. What has not been considered previously is capturing and using more runoff currently being released downstream – arguably, a more efficient and sustainable use of water. More importantly, pumping more water from the lakes could help reduce the impact to more sensitive water bodies in surrounding areas.

In 2000 the City of Madison explored the technical feasibility and cost of altering well pump operations for the Madison Water utility so that a greater percentage of water would be produced by "central wells," defined as half the wells located farthest from the peripheral groundwater divides.[34] The feasibility study was a follow up to a recommendation coming out of the Dane County Regional Hydrologic Study. The study found that the additional water table declines and reductions in baseflow in tributary streams due to the projected increase in pumping (1992 to 2020) could largely be mitigated or offset by drawing on wells located closer to the lakes. The conclusion of the City of Madison study was that under average day conditions (31.8 mgd in 1997) the desired average ratio of central well pumping to total well pumping of approximately 75 percent could be achieved with certain infrastructure improvements. The total capital cost of implementing these improvements was estimated to be approximately $1.45 million, with additional operating costs of approximately $250,000 per year. The 20 year present value of these incremental costs was estimated to be $2.9 million.

The downside to more centralized pumping would be that the groundwater discharge to the Yahara System would be reduced to a greater extent. The biological effects of this have not been studied – although, presumably, baseflow could be maintained through the capture and release of additional runoff (storage) at each of the lakes' dams under the dams' existing operation rules (i.e., leaving stop logs in longer to capture more runoff and thereby help maintain daily lake levels, storage, and streamflow). There are also potential water quality concerns of drawing increasing amounts of lake water into our public water supplies. Consider, however, that this is already occurring. While the sand and gravel layers serve as a large sand filter for deep municipal well supplies, current efforts to protect groundwater quality will need to continue. Municipal water utilities regularly monitor and routinely publish drinking water quality reports. Increasing nitrate and chloride concentrations due to fertilizers and road salt are particularly troublesome because they are more mobile. Continued monitoring is needed as well as reduction of these pollutants at the source – regardless of the amount withdrawn.

[34] *Report on Task 10 – Well Pumpage Optimization.* City of Madison Water System Mater Planning Study. Earth Tech Project No. 30456.

An additional concern is the drawdown of the lakes during drought. The estimated 2040 pumping from municipalities drawing from Lakes Mendota and Monona (Madison, Middleton, Monona, and Fitchburg) is estimated to be 38.13 mgd (**Table 3**), or 59.00 cfs diverted from the Yahara Lakes and surrounding basins and discharged to Badfish Creek. This volume of water equates to 5.10 million cubic feet or 117 acre-feet per day. Considering Lake Mendota is 9781 acres, this is the equivalent of 0.144 inches of drawdown per day. Drawing from both Lakes Mendota and Monona (13,139 acres) this equals 0.107 inches of lake drawdown per day. Notice in **Figures 17a and b** lake levels frequently exceed maximums in the summer (there being too much water) and are often above winter minimums for Lakes Mendota and Monona (established to help avoid ice damage and also provide runoff storage capacity in the Spring). A casual observation would suggest that a reduction of 0.107 inches per day would not be a significant impact, considering the typical range of approximately four feet over the course of a year and average annual precipitation equal to 33 inches. This reduction may be even less apparent if it is absorbed or accounted for by the daily operation of the lakes and releasing less water downstream. In many cases there is *too much* water and this withdrawal could more easily be accounted for. It appears that summer maximum lake limits are violated considerably more than summer minimums, so there appears to be some flexibility or opportunity most years (note, 2012 was considered a drought year).

The projected amount of wastewater expected to be diverted to Badfish Creek by these same communities between 2010 (32.67 mgd) and 2040 (38.13 mgd) from **Table 3** amounts to 5.46 mgd or 8.45 cfs (i.e., 59.00 cfs minus 50.55 cfs); or 0.015 inches of additional lake drawdown per day, as in the Mendota/Monona example above. That amounts to a one inch reduction in lake levels over three months (67 days). Considering more runoff could be captured daily (to maintain the same lake level targets), it is doubtful this additional drawdown would even be noticed by the casual user or riparian landowner. Also, considering the lakes can bounce as much as four feet per year, this would be well within the range experienced historically and assumes absolutely no rainfall which, of course, is atypical during the summer months.

While arguably this could result in some recreational inconvenience to riparian landowners and some boaters, note that a considerable amount of water is *already* being taken out of the lakes and will continue in the future. Taking somewhat more water out of the lakes than otherwise to help protect vulnerable streams during exceptionally stressful drought conditions may be a reasonable trade-off. Overall, every gallon of drinking water taken from the Yahara lakes (and replenished by captured surface water discharge) is another gallon available to area streams that rely more heavily on groundwater discharge.

Because of the relatively constant withdrawal and daily operation of the lake levels, this water could be captured and accounted for on a daily basis with the resultant lake levels controlled as usual to remain within prescribed limits (to the extent currently). Less water could be released downstream as runoff and more water could be used to supply our drinking water needs. This could reduce the impact on more sensitive tributary streams considerably. It is also conceivable that highly treated wastewater could at some point in the future be returned to the Yahara Lakes system – thereby "closing the loop" on a more sustainable, long-term public water supply/wastewater treatment system overall.

Figure 17a. Historic Lake Mendota Levels and Regulatory Limits

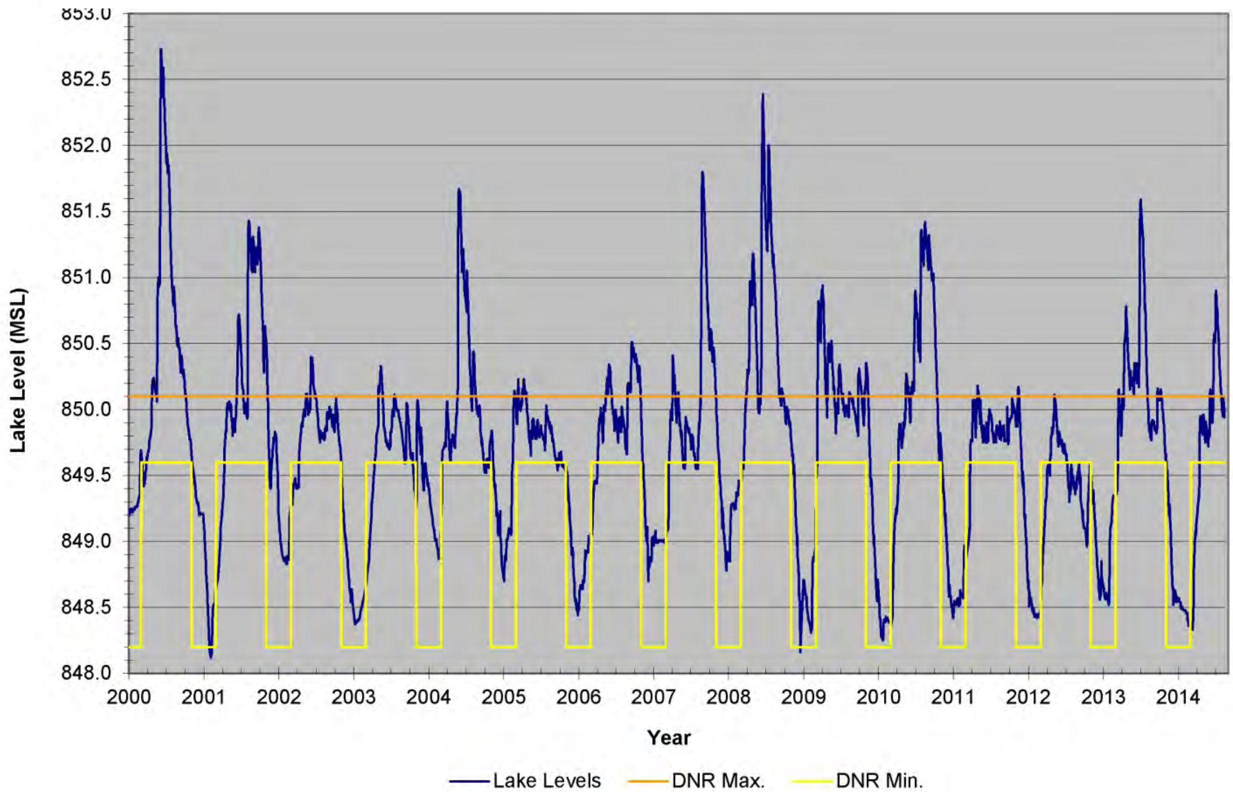
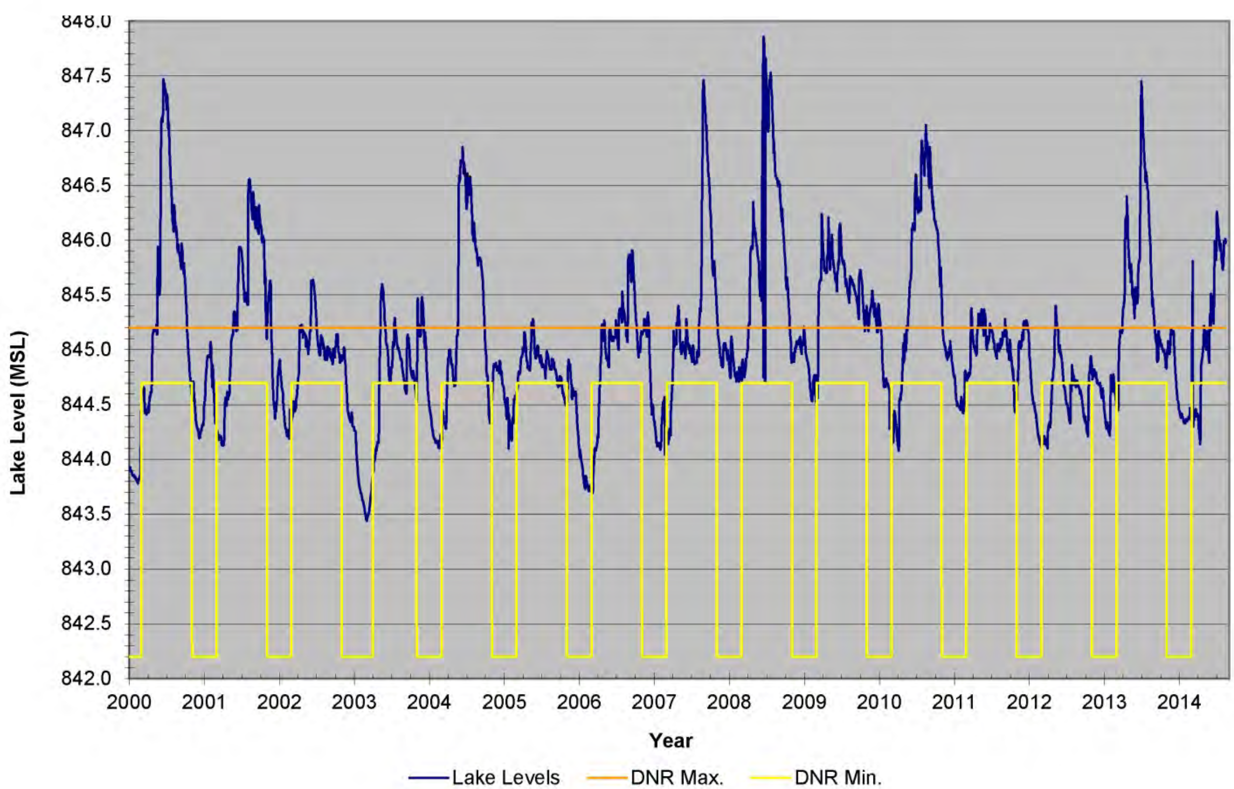


Figure 17b. Historic Lake Monona Levels and Regulatory Limits



While obviously this is a simple analysis involving an otherwise very complicated system, there are some opportunities that should be explored in greater detail. The benefit would be mitigating water table declines and reductions in stream baseflow by drawing more surface water (storage) from the Yahara Lakes – a more resilient and renewable resource. Area trout streams such as Token Creek, Sugar River, and Black Earth Creek would be better protected from well water withdrawals. A strategy focused on capturing and storing more stormwater for domestic water supplies appears to be more sustainable over the long term – rather than simply releasing this excess water downstream. In other words, we would be shifting our drinking water source from stream baseflow (i.e., groundwater discharge) to surface water runoff (i.e., lake storage), a much less critical and more renewable water supply. MMSD has also been considering the idea of returning treated wastewater to the Yahara Lakes system to help restore the pre-diversion balance – another opportunity to make more efficient use of our limited water supplies.

The possible benefits from these alternatives should be modeled through a collaborative effort using a sophisticated Yahara Lakes (INFOS) model developed by the City of Madison and the University of Wisconsin, integrated with the Dane County groundwater model developed by the WGNHS, along with fish response curves developed by the WDNR. The alternative scenarios and results should also be vetted by the Yahara Lakes Advisory Group, an ad hoc panel of local experts seeking to balance the multiple (and sometimes conflicting) goals and objectives among the lakes' many user groups. This is a community decision-making process that needs to be facilitated through more detailed water supply planning at both the local and regional levels. The fundamental consideration is, of course, what is the optimal cost/benefit among these various alternatives to meet agreed upon community and natural resource goals and objectives that best serve us in the future. It seems that under the current water supply paradigm the health of our streams was not taken into full account, largely because the impacts could not be adequately discerned. There have been significant advancements in research and technologies over the last couple of decades and an analysis of the existing approach may indicate that it is not serving us as well as an expanded one might. We need to take a broader view than we have done in the past, and explore the full range of technologies and resources available to us in providing a more sustainable water supply system over the long term.

Relative Feasibility of Management Strategies

A preliminary feasibility ranking of all of the aforementioned management strategies is presented in Table 13. The overall feasibility of each strategy is based on three judgment factors: technical feasibility, relative cost, and public/private acceptability. Relative effectiveness of mitigating future impacts is also indicated. Selected management approaches (e.g., water conservation and infiltration practices) already have been carried out to some extent in Dane County. Thus these approaches commonly have a higher ranking than other strategies (e.g., importation of water and deep aquifer withdrawals) that are either expensive and have not been demonstrated or are considered to be more speculative. More detailed regional water supply planning will be needed to develop the least cost mix of alternatives in cooperation/collaboration among municipal water utilities, MMSD, citizens, state and local resource management agencies (CARPC, WGNHS, USGS, U.W. Madison, WDNR) guided by the information and tools described in this plan.

Management Strategy	Technical Feasibility	Relative Cost	Public/Private Acceptability	Overall Feasibility Ranking
Aggressive Water Conservation Efforts	High	Low	High	High*
Aggressive Pursuit of Water Infiltration Practices	High	Low-Moderate	High	High*
Alternative Well Location and Pumping Strategies	Moderate-High	Moderate- High	High	Moderate
Management of the Yahara Lakes as Multipurpose Reservoirs (16 mgd)	Low-Moderate	Low- High**	Low-Moderate	Moderate
Treated Effluent Return and Wastewater Reuse (4-8 mgd)	Low-Moderate	High	Low-Moderate	Moderate
Importation of Water and Deep Aquifer Withdrawals	Low-Moderate	High	Low	Low

Table 13
Relative Feasibility of Hydrologic Management Strategies

*Limited effectiveness in mitigating well water withdrawals

**Cost is largely based on the infrastructure and flow conveyance improvements that might be needed to implement the desired management program

Local Groundwater Quantity Management

The water budget analysis above demonstrates that groundwater supplies are showing signs of stress. The result of this is that groundwater levels are dropping and a huge cone of depression has formed under the Madison Metropolitan Area. Smaller streams are similarly affected. The cone induces water to flow toward its center, drawing water from neighboring areas. In some areas the problem has become particularly chronic. This situation is expected to become worse as the population expands and demand for water increases. It is therefore necessary to anticipate and evaluate these impacts and to institute measures to minimize and possibly reverse them. The Dane County groundwater model and the groundwater budget indices, featured here, along with the WDNR Fish Response Curves and Yahara Lakes INFOS model, also mentioned, provide important tools and methodology for evaluating alternative future development scenarios and mitigation strategies for the region.

The impacts of pumping on surface water baseflows are widespread in Dane County. As demonstrated, drawdown is simply not the best indicator of groundwater impact. Better indicators are those that correlate well withdrawals with baseflow reductions in specific watersheds (BRI), as well as ratios of demand to supply (DSR), presented earlier. Using the groundwater model, it is possible to analyze different development scenarios featuring various combinations of shallow vs. deep aquifer withdrawals, enhanced recharge, reductions in water use, additional lake storage, etc., providing added insight into minimizing surface water impacts through alternative mitigation strategies. In addition, the WDNR Fish Response Curves could indicate how fish communities and stream health might respond to reductions (or increases) in stream baseflow. Furthermore, the Yahara Lakes INFOs model could simulate the effects on lake levels, using them as water reservoirs.

The overall focus should be on reducing demand as well as increasing supplies of available water. Water conservation and reuse, maximizing recharge with stormwater and conservation design techniques all show promise. In the Madison Metropolitan Area, the Yahara Lakes represent a renewable source of water. More importantly, they are much more resilient than smaller surrounding stream systems. In addition, the glacial sediments currently provide exceptional sand and gravel filtration system for our drinking water supplies. Concentrating pumping closer to the lakes along with proposed MMSD treated effluent return could help reverse the impacts of pumping and diversion, thereby resulting in a more sustainable condition overall. Current lake level management strategies could also help account for this relatively constant demand through current (daily) operational procedures by capturing and using more stormwater runoff. The paradigm shift here is using water and wastewater more efficiently – as a valuable resource that should not be squandered.

We are already drawing from the lakes indirectly. Often there is *too* much water, which must be passed downstream (often during the summer months when the demand is greatest). This represents a lost opportunity for drawing on lake water when it is in excess. Likewise, in the winter it is usually difficult getting the lake levels down to established winter minimums in anticipation of spring flooding and to avoid ice damage. During droughts it is believed the daily reduction in lake levels would be relatively small (particularly since we are already drawing from the lakes through induced recharge without significant or apparent effect). Some flexibility on the part of riparian landowners may be needed during extreme conditions (both flooding and droughts), as is the current situation. It may be a matter of widening the lake level limits to allow for more regulatory flexibility within the existing seasonal variability. The current six inch difference between the required summer minimum and maximum lake level limits for each the four Yahara Lakes (compared to the 4 foot seasonal range) has been described by a retired County Public Works Director as "walking a tightrope." The WDNR acknowledges that the current lake level limits may not be the best from an environmental standpoint. Setting somewhat higher stage limits in the spring or lower in the fall could more easily accommodate restoring prediversion low-flow conditions in the Yahara River system.

So, there appears to be significant prospects for addressing these water supply and demand problems by managing the lakes as multi-purpose reservoirs. Overall, a combination of techniques, cooperation, and flexibility among local units of government and residents will be necessary to meet the growing challenge if we are to maintain both the availability of our drinking water supplies and the viability and health of our more sensitive aquatic resources.

To date, there has been no serious attempt at regional management of groundwater supplies in Dane County. Individual communities have utilized the region's aquifers without coordination. The result has been problems where surface water bodies have been adversely impacted by heavy groundwater use. In other areas of the state, notably southeast Wisconsin and the Fox River Valley, this has lead to designation of these areas as Groundwater Management Areas (GMAs) by the Wisconsin Department of Natural Resources, a designation that requires development of a plan to mitigate the problems. Dane County has been identified as a Groundwater Attention Area (GAA). These are areas which are currently experiencing groundwater challenges or are likely to experience groundwater problems in the future. It serves as warning that a coordinated management plan is needed to prevent further drawdown.

Proactive management and intervention are necessary as critical components of an effective groundwater management policy overall. The indices and modeling presented earlier provide useful methodology to help quantify the relative effectiveness of various strategies and alternatives to address these challenges and meet these problems head on. Since our ground and surface waters do not recognize jurisdictional boundaries, these problems can only be successfully addressed through a cooperative and collaborative approach among units of local government, private businesses, and citizens working together towards mutually agreed-upon goals, objectives, and individual actions. In this regard, the Capital Area Regional Planning Commission should continue to promote regional water supply planning and provide ongoing assistance in collaboration with the WDNR, water and wastewater utilities, and local units of government. This effort would provide for regional water supply plan development, preparation of water supply service areas, and review and comment on local water supply service and facility plans as provided under Wis. Stats. 281.348.

Recommendations

Short term

- Implement comprehensive water conservation programs, including both supply-side water supply efficiency measures and demand-side water conservation measures.

- Implement stormwater management practices, including treatment and infiltration systems, which would maintain the natural recharge characteristics of proposed development and – to the extent practicable – redevelopment where circumstances and opportunity permit.

- Conduct locally proactive and preliminary analysis of all planned high capacity wells in the early stages of well siting to develop the necessary understanding of the hydrogeological conditions associated with each candidate site and the surrounding area and to assess the likelihood and minimize the impacts on nearby wells and surface water bodies.

Long-term

- Enhance rainfall infiltration systems to help mitigate the effects of high capacity municipal well water withdrawals; balanced with the need to avoid groundwater induced flooding.

- Investigate the feasibility of infiltrating treated wastewater into the shallow aquifer to supplement localized recharge of the shallow groundwater system.

- Delineate groundwater recharge areas to indicate that a high degree of protection and use of the best groundwater recharge areas in the region are needed to meet sustainability goals.

- While it is recognized that siting wells is dependent upon locating productive areas, some additional factors should be considered when siting wells. Preference should be given to site locations that are less likely to produce adverse impacts upon surface waterbodies and existing wells. In addition, preference should be given to sites located adjacent to the Yahara Lakes Mendota and Monona. This application of induced filtration has the potential to increase available water supplies without degrading the environment by drawing more water from surface water runoff (i.e., lake storage) typically released downstream.

- Consider the prospects of returning treated effluent to the Yahara Lakes system as part of an overall more sustainable or "closed loop" drinking water/reclaimed water system.

- Promote gray water systems and reclaimed water reuse.

Chapter 4: Groundwater Quality Protection

Groundwater Quality Overview

The groundwater in Dane County is generally of good quality and uniform in composition within all aquifers.[35] Calcium, magnesium and bicarbonate are the principal constituents of groundwater, relatively high in concentration and responsible for the very hard water here. Other groundwater constituents commonly found in lower concentrations are iron, manganese, sodium, sulfate, chloride and nitrate.

Although good groundwater quality generally exists in the region, it has been affected by certain land use activities in Dane County. The known groundwater quality problems in Dane County have largely resulted from nitrates and bacteria, pesticides, chlorides, and volatile organic chemicals (VOCs). High levels of nitrate are present in many areas of the county's shallow groundwater system. Nitrate-nitrogen contamination (above the recommended drinking water standard) has been found in numerous private and non-community wells throughout Dane County. This is believed to be the result of extensive agricultural fertilization practices conducted in the region. Pesticides (primarily atrazine) are more prevalent in shallow private wells, while VOCs have been detected in both private and municipal wells. Common VOCs that have been found are trichloroethylene and tetrachloroethylene. These hazardous chemicals, derived from household and industrial solvents, result from disposal in landfills, leaking underground storage tanks, or simply being dumped on the ground.

High priority should be given to safeguarding existing groundwater quality from further degradation. The introduction of even small amounts of some chemicals can have a significant detrimental effect on groundwater quality. Because of the slow movement of groundwater, chemical contamination often does not become apparent for many years and then only after large amounts of contaminants have been introduced. Also, unlike surface water, little mixing occurs in groundwater; thus dilution of chemical contaminants is often slow or insignificant. Due to this poor dilution and breakdown capacity, introduced chemicals can create groundwater quality problems for many years into the future and should be avoided whenever possible.

Nitrates

Nitrate (NO3) is a compound made up of nitrogen and oxygen. It is formed when nitrogen from ammonia or other sources combines with oxygen in water. In nature, water usually contains less than 2 mg/L nitrate-nitrogen and is not considered a health concern. Significantly higher nitrate concentrations can indicate that the drinking water has been contaminated and may pose a serious health concern. In 2014 the WDNR and the Wisconsin Department of Agriculture, Trade and Consumer Protection (WDATCP) reported that nitrate-nitrogen (NO_3-N) is the most widespread groundwater contaminant in Wisconsin, and that the nitrate problem is increasing both in extent and severity.[36] Common sources of nitrate include nitrogen fertilizers, manure, septic systems, municipal sewage treatment systems, and decaying plant material. Nitrate dissolves easily in water and does not adsorb to soil particles. It can easily be carried into the groundwater by rainwater and melting snow as it percolates through the soil and bedrock into the underlying aquifer.

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[35] Born, S., et al. 1987. *A Guide to Groundwater Quality Planning and Management for Local Governments.*
[36] Wisconsin Groundwater Coordinating Council., 2014. *Fiscal Year 2014 Report to the Legislature.*

Nitrates in Wisconsin

The maximum contaminant level (MCL), set by USEPA, is the level of a contaminant at which no known or anticipated adverse effects on the health of persons occur and which allows an adequate margin of safety. The MCL for nitrate-nitrogen is 10 mg/L – the same as Wisconsin's enforcement standard (ES). In Wisconsin a preventive action limit (PAL) of 2 mg/L has also been established to serve as an indicator of potential groundwater contamination problems. Public water supplies, transient and non-transient noncommunity wells monitor for nitrate and must meet the ES. Private water supplies are largely unregulated.

Human health is the primary reason high levels of nitrate in drinking water are of concern. Nitrate can cause a condition called methemoglobinemia or "blue-baby syndrome" in infants under six months of age. Nitrate in water used to make baby formula converts to nitrite in the child's stomach and changes the hemoglobin in blood to methemoglobin. The infant's body is then deprived of oxygen and appears blue-gray or lavender in color. In extreme cases, methemoglobinemia can be fatal; the long-term effects of lower-level oxygen deprivation are unknown. The Wisconsin Department of Health Services (DHS) has investigated several cases suspected blue-baby syndrome in Wisconsin and associated at least three with nitrate contaminated drinking water. Some scientific studies have also found evidence suggesting that women who drink nitrate contaminated water during pregnancy are more likely to have babies with birth defects. This may be because nitrate ingested by the mother may also lower the amount of oxygen available to the fetus.

Concerns are also being raised regarding the effect of nitrate on thyroid function, diabetes, and cancer. Nitrate converts to nitrite in the human body and can then convert into N-nitroso compounds (NOC's). NOC's are some of the strongest known carcinogens and have been found to induce cancer in a variety of organs. As a result, additional human health concerns linked to nitrate contaminated drinking water include increased risk of: non-Hodgkin's lymphoma (Ward et al., 1996); gastric cancer (Xu et al., 1992; Yang et al., 1998), and bladder and ovarian cancer in older women (Weyer et al., 2001). There is also growing evidence of a correlation between nitrate and diabetes in children (Parslow et al., 1997; Moltchanova et al., 2004).[37]

Wells contaminated with high nitrate levels are also more likely to be contaminated with agricultural pesticides. Evidence suggests that common pesticides (Aldicarb and Atrazine) interacting with nitrate can affect the immune, endocrine, and nervous systems (Porter 1999). People who have heart or lung disease, certain inherited enzyme defects, or cancer may be more sensitive to the toxic effects of nitrate than healthy individuals. Owners of wells contaminated with nitrate may also wish to have their water tested for pesticides, especially if the well is located near farm fields.

In addition to the effects of elevated nitrate concentration on human health, a number of studies have shown that nitrate can have lethal and sublethal effects on a variety of species of fishes, amphibians, and aquatic invertebrates (Crunkilton et al. 2000; Camargo et al. 1995; Marco et al. 1999; Smith et al. 2005; McGurk et al. 2006; Stelzer et al. 2010). This is significant in that many baseflow-dominated streams in agricultural watersheds can exhibit elevated nitrate concentrations, with levels in some Wisconsin streams at times exceeding 30 mg/L NO3-N. In Wisconsin, exposure of animals to potentially lethal nitrate concentrations would be most likely to occur in springs and in groundwater-fed low-order streams in agricultural or urban areas, and in nitrate-rich water bodies on farms such as ditches and ponds.

[37] Wisconsin Groundwater Coordinating Council., 2014. *Fiscal Year 2014 Report to the Legislature*.

Nitrate also contributes to the eutrophication of streams and lakes and associated occurrence of water-quality issues such as harmful algal blooms. This is a particular concern in Dane County where there is a high degree of connectivity between ground and surface waters. In addition, between the late 1960s and the early 1980s, nitrate levels in waters flowing into the Gulf of Mexico more than doubled, causing a “dead zone” that in 1999 was approximately the size of the state of New Jersey.

The current drinking water limit of 10 mg/L for nitrate-nitrogen addresses only methemoglobinemia; the concentration at which these other risks occur is unknown. More research is needed in these other areas. To ensure protection of health, people of all ages are encouraged to drink water that meets the safe drinking water standard for nitrate of 10 mg/L. Common solutions include drilling a new, non-contaminated well or the removal of excess nitrate through water treatment processes. A 2012 survey of Wisconsin municipal systems found that 47 systems have had raw water samples that exceeded the nitrate ES (up from just 14 systems in 1999). This survey also showed that respondents had collectively spent over $32.5 million on remedies, up from $24 million as of 2004 and that 74 systems are experiencing increasing nitrate levels. Excessive nitrate levels have also forced the installation of treatment systems or the replacement of wells at hundreds of other smaller public drinking water systems.

About one third of Wisconsin families obtains water from privately owned wells and hence are at risk of excessive nitrate exposure. A 2008-9 DHS survey determined that one-third of private well owners have also never had their water tested for nitrate. The most common reasons cited by well owners who had not tested their water was that their water “tasted and looked fine.” Thirteen percent listed cost as a reason for not testing their water.

Owners of nitrate-contaminated private wells do not qualify for state well compensation funding unless the nitrate-N level in their well exceeds 40 mg/L and the water is used for livestock. In order to establish a safe water supply, they may opt to replace an existing well with a deeper, better cased well or to connect to a nearby public water supply. Alternatively, they may choose to install a water treatment system or use bottled water. A study published in 1999 by DHS examined this issue. Their survey of 1,500 families found that few took any action to reduce nitrate exposure. Of those who did, most purchased bottled water for use by an infant or pregnant woman.

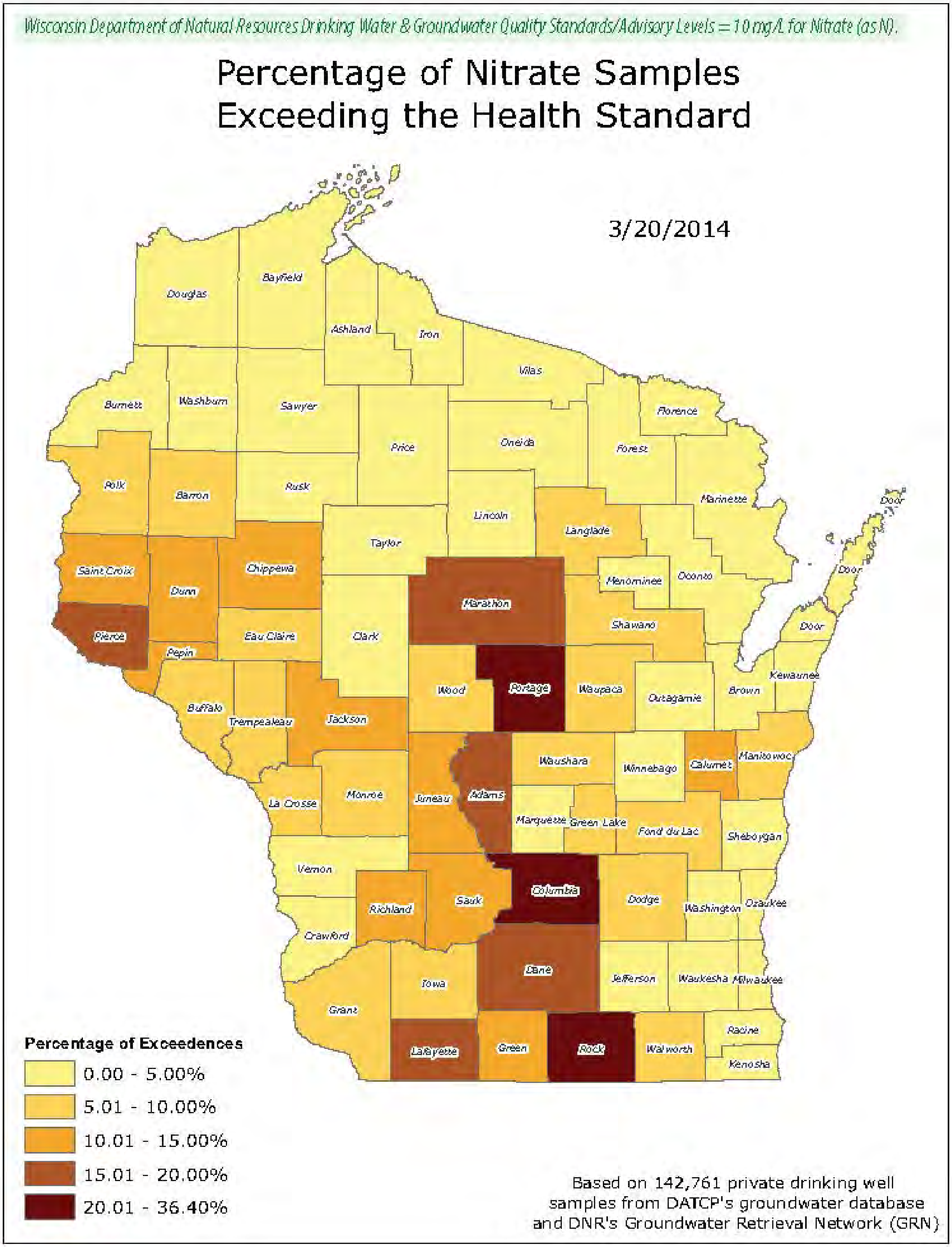
DATCP (2007) and DNR (2005, 2007) surveys and meta-analysis of state databases indicate 9 to 11% of private wells statewide exceeded the nitrate enforcement standard (ES) of 10 mg/L. Exceedance rates are greater in agricultural districts, with rates in highly cultivated areas in south-central Wisconsin estimated at 21 percent of wells. **Map 26** shows the prevalence of nitrate samples exceeding the health standard around in the state.

In Dane County, over 3,000 private well samples have been collected between 1994 and 2011 (**Table 14 and Map 27**):[38]

- 18% of the private wells tested exceeded the drinking water standard of 10 mg/L.
- 52% of the wells tested contained between 2 mg/L and 10 mg/L, indicating land use has likely affected groundwater quality.
- 30% of the wells tested below the preventive action limit of 2 mg/L.

[38] Capital Area Regional Planning Commission. 2013. *Private On-Site Wastewater Treatment Systems* Management report. Technical Appendix I of the *Dane County Water Quality Summary Plan.*

Map 26



NPM This publication is available from the Nutrient and Pest Management Program, please contact us:
by phone (608) 265-2660, email: npm@hort.wisc.edu or visit our website at ipcm.wisc.edu
August 2014

While only about 27% of the over 12,000 private water wells in Dane County have had nitrate testing data entered into the WDNR database, the percentage of private wells with high nitrate has remained relatively consistent during the past decade **(Figure 18a**). The report *Private Onsite Wastewater Treatment Systems Management*[38] includes maps of this data for each town in Dane County. The well data is located on a quarter-quarter section basis. Where multiple test results fall within the same range (i.e., greater than the Enforcement Standard, between the Enforcement Standard and the Preventive Action Limit, and below the Preventive Action Limit) a single symbol may represent multiple test results. This is often the case within rural subdivisions.

By comparison, deeper municipal wells are found to be generally below 5 mg/L (**Map 28a**). The 2010 cones of depression resulting from high capacity well water withdrawals in the region (also mapped) do not appear to be affecting nitrate concentrations as much as the effects of individual well design/casing/depth and local contributing sources.

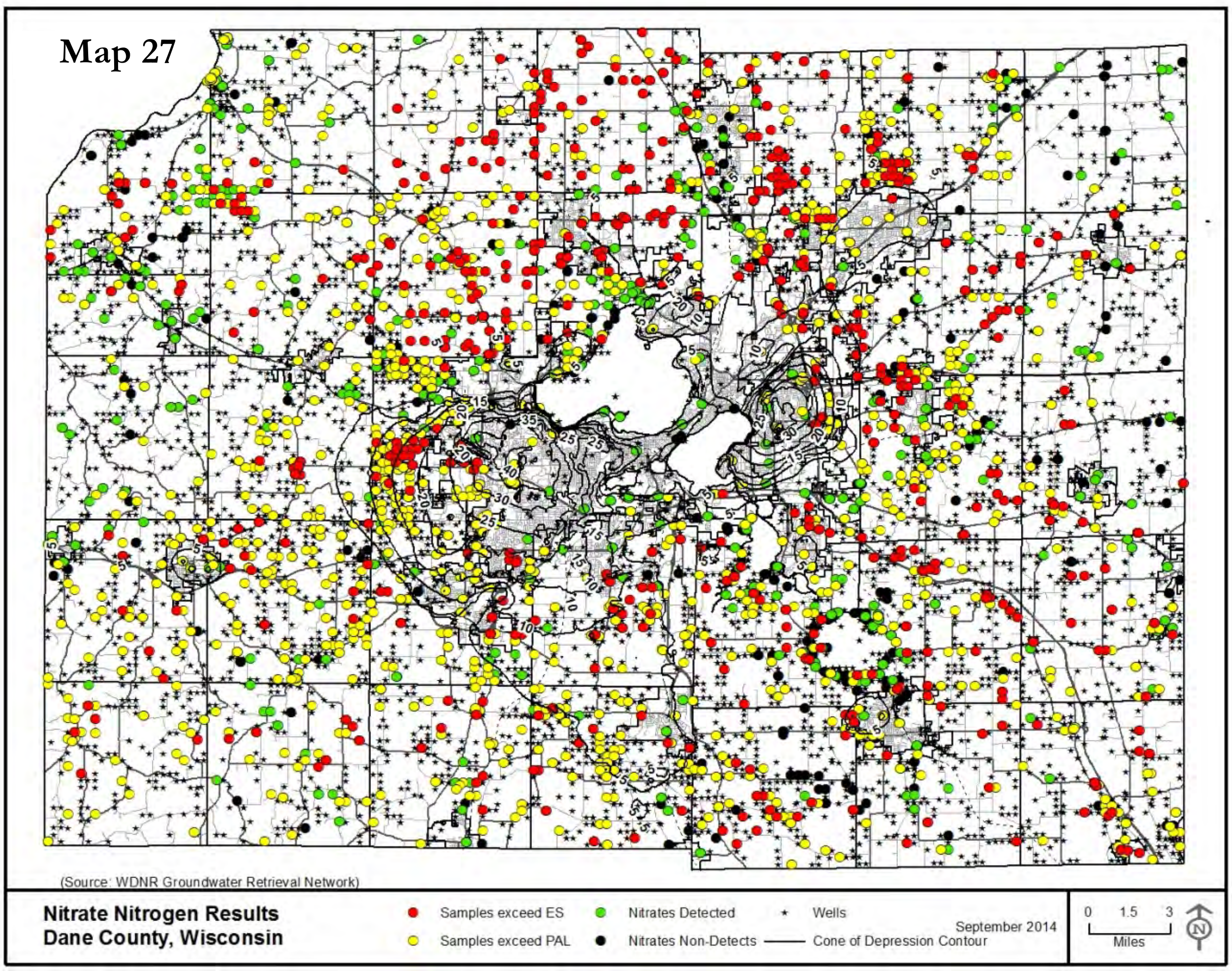


Table 14. Private Water Well Nitrate Testing WDNR Groundwater Retrieval Network (1994-2011[1])

Municipality	# Tests at Unique Well Locations[2]	Estimated % of Total Wells Tested	Nitrate Test Results		
			> 10 mg/L	2 - 10 mg/L	<2 mg/L
Albion	62	10%	31%	32%	37%
Berry	86	18%	6%	50%	44%
Black Earth	44	21%	2%	41%	57%
Blooming Grove	9	2%	44%	56%	0%
Blue Mounds	62	19%	16%	58%	26%
Bristol	228	18%	15%	61%	24%
Burke	138	12%	41%	54%	5%
Christiana	75	15%	29%	36%	35%
Cottage Grove	121	8%	22%	28%	50%
Cross Plains	98	17%	13%	61%	26%
Dane	42	11%	33%	60%	7%
Deerfield	62	11%	23%	31%	47%
Dunkirk	57	7%	32%	21%	47%
Dunn	136	20%	15%	30%	54%
Fitchburg	42	5%	31%	62%	7%
Madison	8	14%	0%	88%	13%
Mazomanie	78	16%	6%	38%	55%
Medina	50	10%	18%	42%	40%
Middleton	468	23%	19%	67%	14%
Montrose	56	13%	7%	54%	39%
Oregon	137	12%	18%	65%	18%
Perry	46	16%	13%	78%	9%
Pleasant Springs	161	19%	29%	34%	38%
Primrose	47	17%	9%	49%	43%
Roxbury	73	13%	4%	44%	52%
Rutland	101	13%	9%	49%	43%
Springdale	152	21%	11%	74%	15%
Springfield	102	10%	10%	52%	38%
Sun Prairie	106	13%	32%	52%	16%
Vermont	48	15%	2%	35%	63%
Verona	82	12%	6%	55%	39%
Vienna	70	17%	11%	43%	46%
Westport	86	21%	10%	58%	31%
Windsor	80	9%	50%	39%	11%
York	27	10%	0%	52%	48%
County-wide	***3,240***	***14%***	***18%***	***52%***	***30%***

[1] 91% of the data is from tests dated 1999 to 2008.

[2] The unique well locations included in this table represent over 95% of all test data with the database, indicating very little repeat testing.

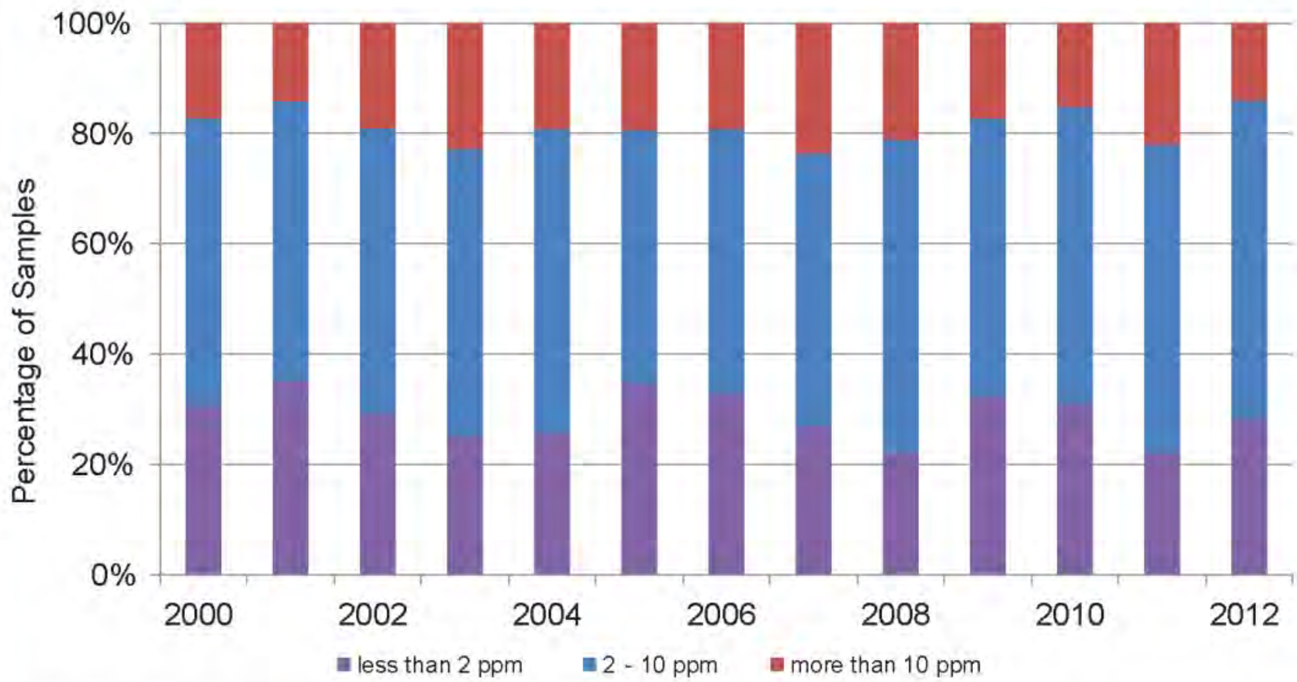
Source: Capital Area Regional Planning Commission, 2013

Dubrovsky (2010) states that nitrate concentrations are likely to increase in aquifers used for drinking water supplies during the next decade, or longer, as shallow groundwater with higher concentrations moves downward into the groundwater system. While nitrate concentrations exceeding regulatory standards are less prevalent in municipal drinking water samples in Dane County (because the wells are deeper than private wells), there has been an apparent increase in samples that have exceeded the 10 mg/L over the last few years (**Figure 18b**). Of the nearly 3,000 samples that have been tested for nitrate over the past decade (2000-2012), approximately 5 percent were found with concentrations greater than 10 mg/L. The remaining samples were within acceptable levels – approximately 42 percent had levels between 2 to 10 mg/L, while the remainder (approximately 53 percent) was below 2 mg/L. Since 2007 there have been notable increases in the annual percentage of samples with concentrations of nitrate greater than 10 mg/L and decreases in the percentage of samples lower than 2 mg/L, compared to the 2000-2006 time period. This is likely the result of historic nitrate levels migrating deeper into the groundwater system.

In some geologic settings improvements in nutrient management practices on the land surface can take years to decades to result in lower nutrient concentrations in groundwater because of the slow rate of groundwater flow. Slight increases in nitrates have been observed in some Municipal wells over the last 20 years (warm colors), along with some decreases (cool colors), Map 28b. The Capital Area Regional Planning Commission39 has conducted a long-term surface water monitoring effort including baseflow water quality (i.e., groundwater discharge) undertaken in representative streams around the county. Figure 19 shows that the concentration of nitrate in most county streams (representing the shallow aquifer) has seen an increase over the last 50 years. This is attributed to increasing fertilizer usage and livestock density in the county. However, nitrogen levels do appear to be declining recently in some areas, possibly the result of increased agricultural nutrient management planning and practices.

[39] Formerly the Dane County Regional Planning Commission.

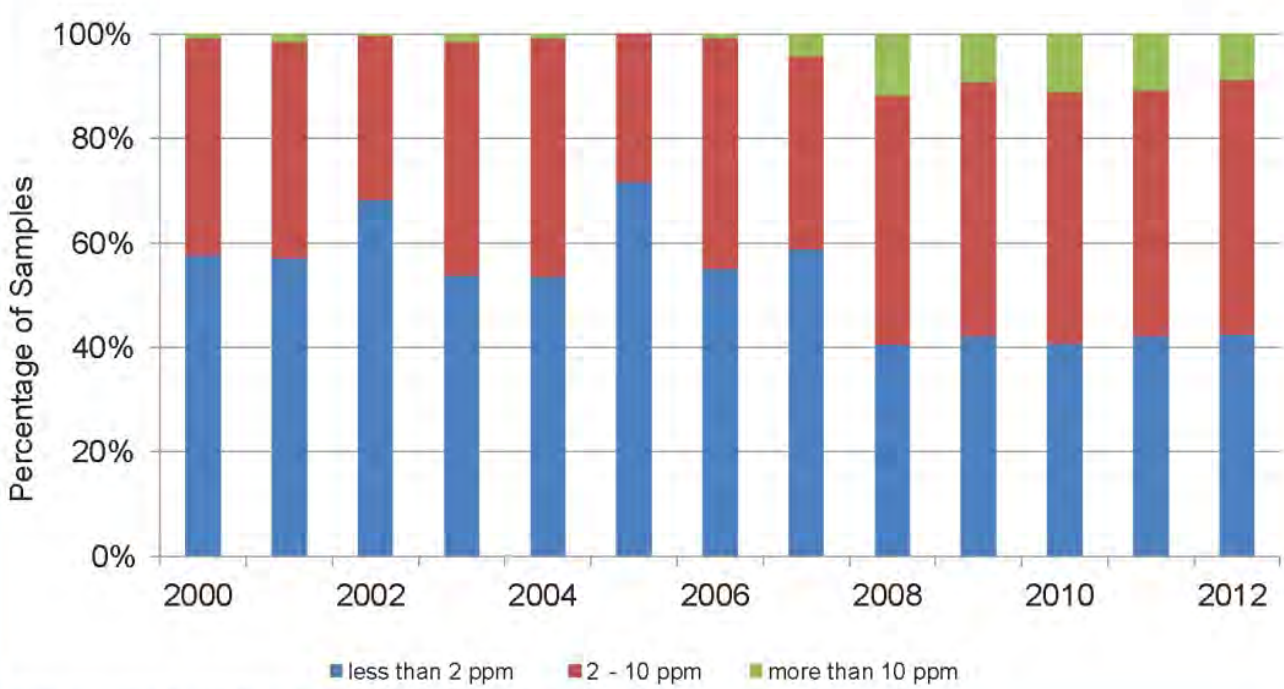
Figure 18a. Results of Nitrate Testing in Private Wells, Dane County.



Data provided by WI Department of Natural Resources

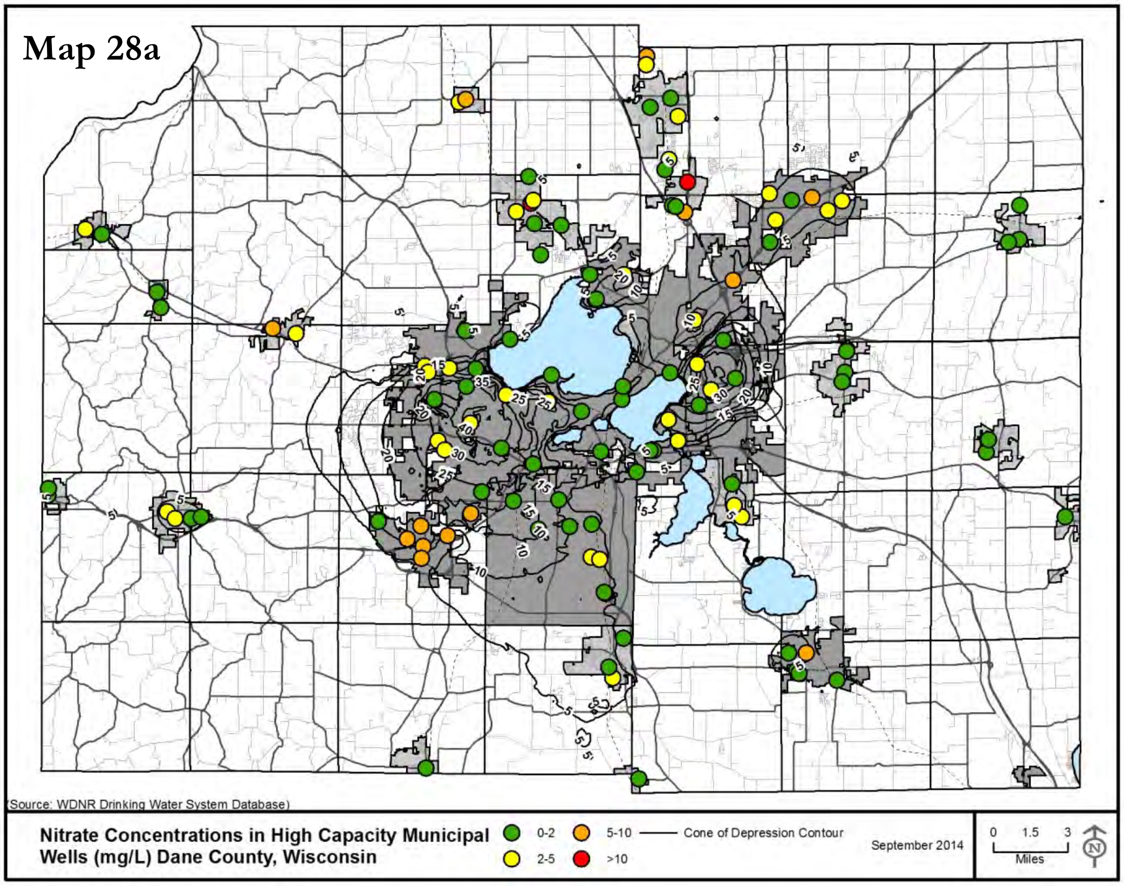
Source: Madison and Dane County Public Health, 2012

Figure 18b. Results of Nitrate Testing in Public Wells, Dane County.



Data provided by WI Department of Natural Resources

Source: Madison and Dane County Public Health, 2012


Map 28a
(Source: WDNR Drinking Water System Database)
Nitrate Concentrations in High Capacity Municipal Wells (mg/L) Dane County, Wisconsin
0-2
2-5
5-10
>10
Cone of Depression Contour
September 2014
0 1.5 3
Miles

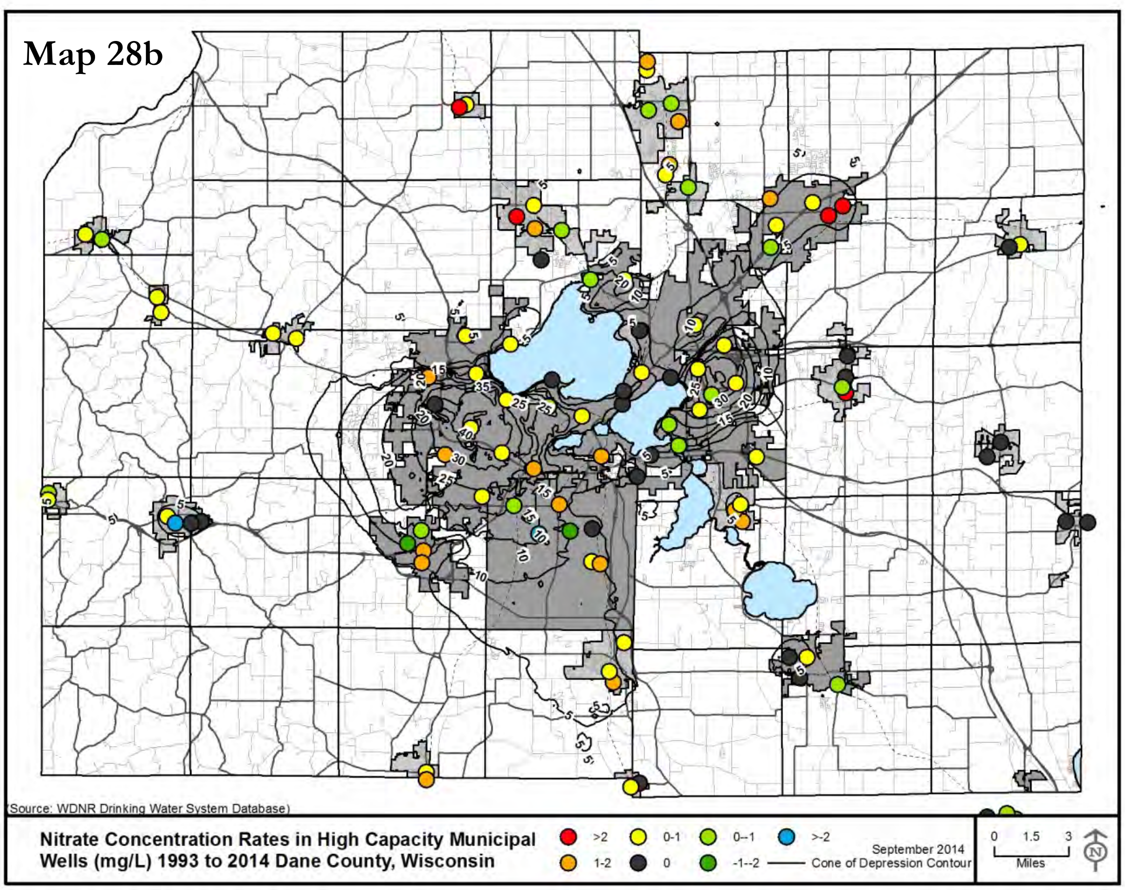
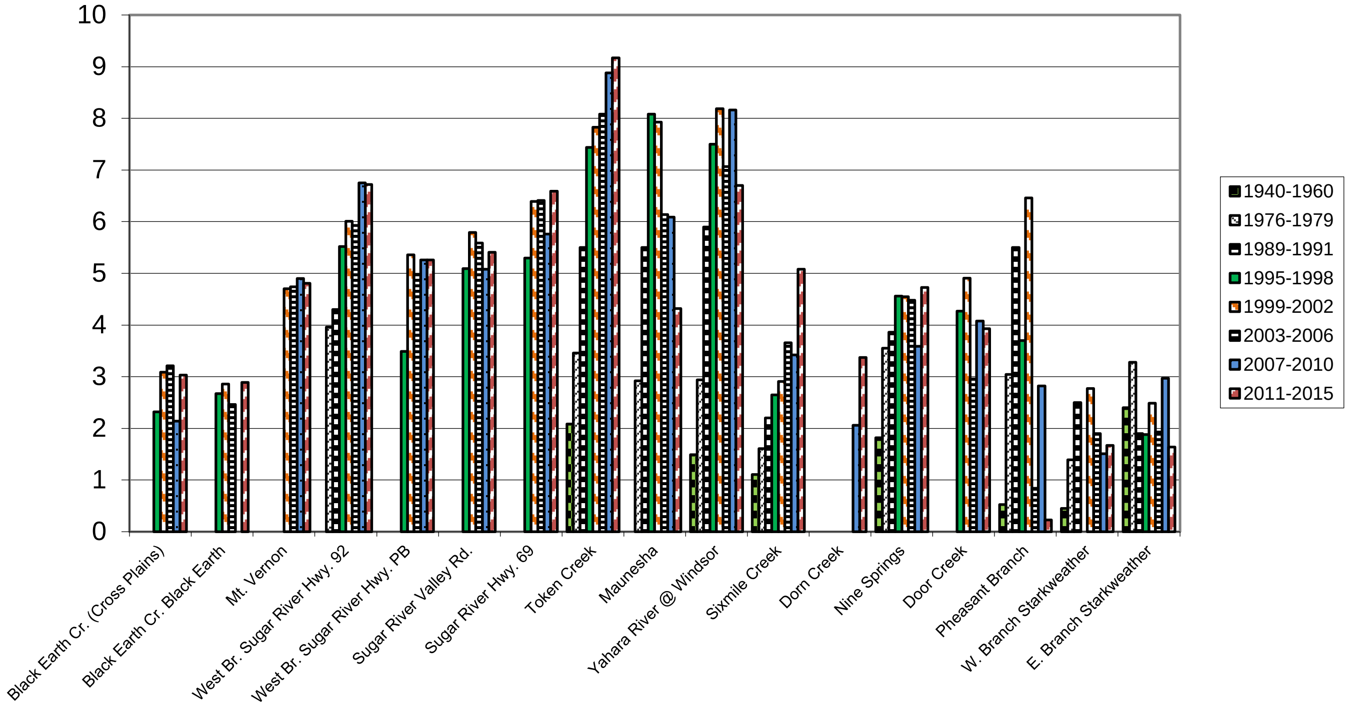

Map 28b
(Source: WDNR Drinking Water System Database)
Nitrate Concentration Rates in High Capacity Municipal Wells (mg/L) 1993 to 2014 Dane County, Wisconsin
>2
1-2
0-1
0
0--1
-1--2
>-2
Cone of Depression Contour
September 2014
0 1.5 3
Miles

Figure 19. Baseflow Nitrate and Nitrite Nitrogen in Representative Dane County Streams (mg/L)



Note: Baseflow results indicate dry weather groundwater contributions and do not include wastewater discharge streams having greater than 15% effluent volume.
Source: The Capital Area Regional Planning Commission's Cooperative Water Resources Monitoring Program and the U.S. Geologic Survey.

Sources of Elevated Nitrate in Dane County

A recent study by area researchers evaluating tens of thousands of nitrate test results in wells across the region have discovered that nitrate levels are improving slightly, attributed to improvements in agricultural nutrient management practices (**Figure 20**).[40] However, while areas with high nitrate concentrations appear to be decreasing (typically shallow domestic wells), results also indicate that wells with low nitrate concentrations (typically deeper public wells) are increasing. This suggests that the groundwater system is equalizing and that it may take some time for the reductions to become evident in deeper water sources, attributed to slow groundwater movement and an associated lag effect. Also, lower nitrate concentrations were generally observed nearer to major surface water features such as lakes, rivers, and streams and farther from groundwater divides seen in **Figure 21**. This supports the notion that nitrate concentrations and spatial patterns are a reflection of groundwater age. In other words, groundwater discharge to streams is typically older and more diluted in nitrates than more recent groundwater percolating into the ground in upland areas.

<u>Fertilizer Use</u>

Estimates of historical nitrogen loading to shallow groundwater correspond remarkably well with historical nitrogen fertilizer use, evident in **Figure 20**. In contrast, according to the study, areas of intensive residential development do not appear to exert a significant influence on regional nitrate concentrations. This does not imply that septic systems or other sources cannot be significant sources of nitrate to individual wells, but that the background fertilizer use is primarily responsible for high nitrate levels across the area.

Based on past surveys, approximately 25% of the county's tested wells exceeded the state and federal drinking water standard for nitrate of 10 mg/L, which is more than double the statewide exceedance level of 12%. Unfortunately, only about one-third of the county's private wells have ever been tested for nitrate. Since 2014, nitrate testing is now required by state law when a new well is constructed, or when repair or maintenance on a well is conducted. Some reasons for homeowners not testing their well water include: the water looks, tastes, and smells fine, perceptions that water testing is expensive, and fears of declining property values in the event of elevated nitrate levels.

So, while we seem to have turned the corner on historical increases in nitrates levels in the region, reductions in rural drinking water supplies will take time. Public health officials recommend private well owners test their water for nitrates every year or so – especially in households with pregnant women, infants, or young children if there are any changes in taste, color or odor, or if they are located in an intensive agricultural area. The WDNR also publishes brochures[41] on this and other tests for private wells, which are more shallow and vulnerable than deep municipal wells that are tested routinely and more frequently.

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[40] McDonald, C,, J. Parsen, R. Lathrop, K Sorsa, K. Bradbury, and M. Kakuska. 2015. *Characterizing the Sources of Elevated Groundwater Nitrate in Dane County, WI.*

[41] http://dnr.wi.gov/topic/DrinkingWater/documents/pubs/TestsForWell.pdf

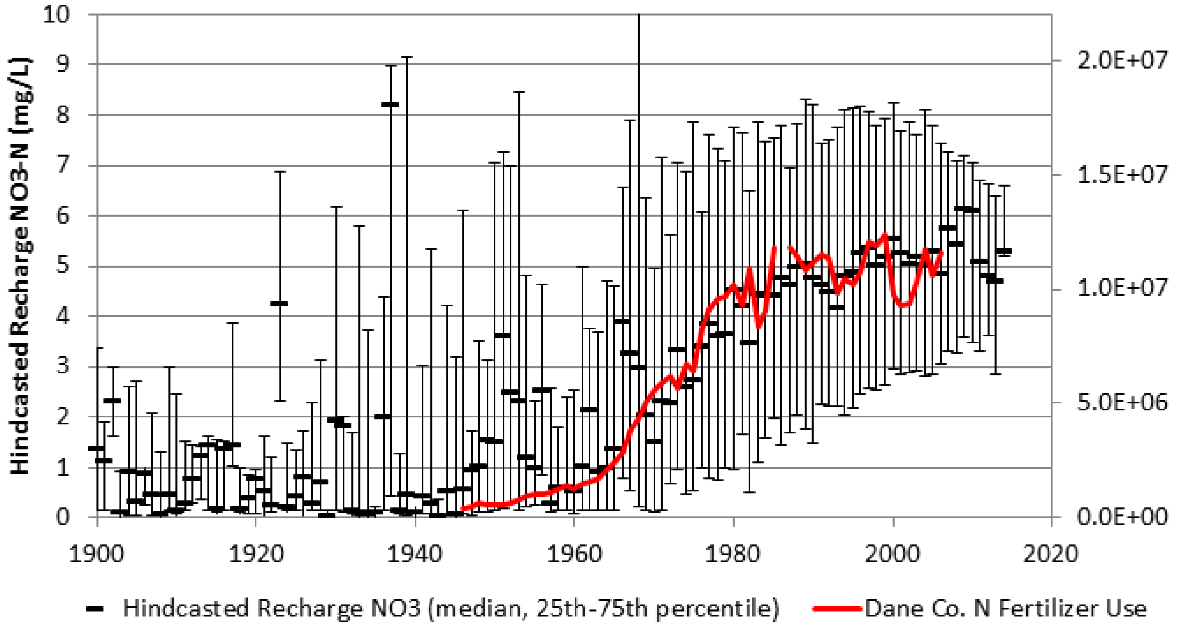


Figure 20. Median recharge nitrate concentrations overlaid with the total application of inorganic nitrogen fertilizer in Dane County.

Source: McDonald, et. al. 2015.

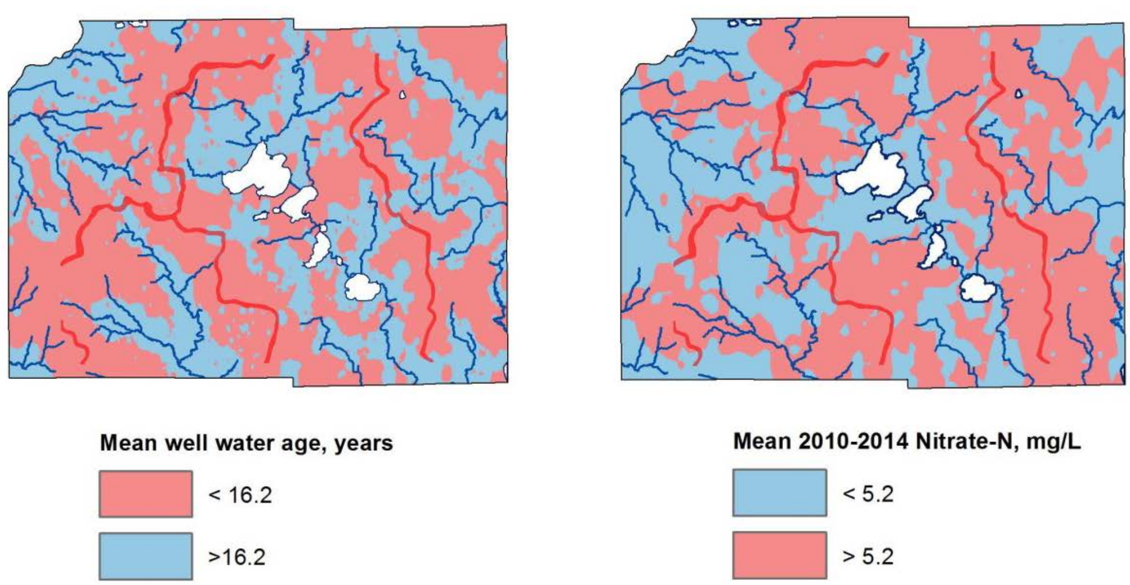


Figure 21. Dichotomous representation of mean modeled well water age (a) and interpolated mean nitrate concentrations for the 2010-2014 period (b). The breakpoints (16.2 years and 5.2 mg/L) are the spatially averaged median values, with the result that each figure is 50% red and 50% blue. The solid red lines indicate major groundwater divides.

Source: McDonald, et. al. 2015.

On-Site Septic Systems

Although not a significant source of nitrates at a regional level, on-site systems can cause increased levels of groundwater nitrate in localized areas if many systems are concentrated in a relatively small area. In such circumstances, the close proximity of systems surpasses the ability of the groundwater to dilute the nitrate concentrations released by the systems.

The limited national and state/local information suggests that it is unlikely that localized groundwater nitrate contamination will be caused by on-site systems at a density lower than one system per two acres, but that there is a greater potential for groundwater contamination where systems exceed a density of one per acre.[42] Based on this information, the following recommendation was included in the 2013 *Private On-Site Wastewater Treatment Systems Management* report, a technical appendix of the *Dane County Water Quality Plan:*

> *Large on-site wastewater systems and clusters of systems should be planned and evaluated to ensure that wells and water supplies can be protected from excessive nitrate levels. The planning of rural subdivisions or developments that include large on-site systems or clusters (more than 20) of on-site systems with an average density of one house per 1-1.5 acres, based on the gross acreage of the development, should include an evaluation to ensure that drinking water supplies are protected. If the evaluation indicates a risk for nitrate levels above 10 mg/L, alternatives such as protected water supplies (well location and depth), utilizing nitrogen-reducing wastewater treatment systems, or community scale water supply and wastewater treatment systems should be explored.*

This recommendation is intended to serve as screening criteria to direct attention and further evaluation to instances where there is a significant possibility that the added nitrogen load from on-site systems might result in violation of groundwater quality standards.

Several types of treatment processes are capable of removing nitrogen in wastewater. Nitrogen removal systems are used in onsite treatment trains to ensure protection of ground water as well as surface waters recharged by ground water. Biological nitrogen removal requires aerobic conditions to first nitrify the wastewater, then anaerobic conditions to denitrify nitrate-nitrogen to nitrogen gas. The successful removal of nitrogen from wastewater requires that environments conducive to nitrification and denitrification be induced and positioned properly. The limited ability of conventional on-site wastewater treatment systems to achieve enhanced nitrate reductions and the difficulty in predicting soil nitrogen removal rates means that systems sited in drinking water aquifers or near sensitive aquatic areas should incorporate additional nitrogen removal technologies prior to final soil discharge.[43] However, the Wisconsin Administrative Code currently exempts private sewage systems from having to meet groundwater nitrate standards.

Testing

The only way to know if a drinking water supply contains excessive nitrate is to have a water sample analyzed by a certified laboratory. Shallow private wells are typically more susceptible to contamination than deep municipal wells, which are tested regularly. A nitrate test is recommended for all newly constructed private wells and wells that have not been tested during the past 5 years. Testing is also recommended for well water used by pregnant women and is essential for a well that serves infants under 6 months of age. Wells with nitrate concentrations between 5 and 10 milligrams

[42] Capital Area Regional Planning Commission. 2013. *Private On-Site Wastewater Treatment Systems Management.*
[43] U.S. Environmental Protection Agency. 2002. *Onsite Wastewater Treatment Systems Manual.*

per liter should be tested annually. Additional testing may also be useful if there are any known sources of nitrate or if high nitrate concentrations are found in neighboring wells.

Several other areas can be checked to determine the vulnerability of a well to nitrate contamination:

- **Well location.** Nitrate-contaminated wells are often located near farm fields, barnyards, feedlots, septic tanks, municipal wastewater treatment systems or "sludge" spreading sites.
- **Well casing depth and construction.** Since nitrate enters the aquifer from the ground surface, wells that have shallow casing are more likely to be affected than deeper cased wells.
- **Geology.** Areas with highly porous, sandy soils, fractured bedrock, natural caves and sinkholes, and shallow depths to bedrock or groundwater are especially vulnerable to contamination.

If the nitrate-nitrogen concentration exceeds the 10-milligram per liter standard, the following actions are recommended:

- Avoid drinking the water during pregnancy and do not give the water to infants less than 6 months of age or use the water to prepare infant formula.
- The Wisconsin Division of Public Health recommends that people of all ages avoid long-term consumption of water that has a nitrate level greater than 10 ppm.
- Do not attempt to remove the nitrate by boiling the water. This will only increase the nitrate concentration.
- Seek medical help immediately if the skin color of an infant appears bluish or gray. Sometimes color change is first noticed around the mouth, or on the hands and feet.
- Protect your water supply from nitrate contamination by reducing fertilizer use, improving manure-handling methods, maintaining septic systems and pumping septic tanks regularly to prevent overflow.
- A safer, longer-term remedy may be to drill a new well.
- Install treatment devices approved by the Department of Commerce

Management Strategies

The Groundwater Law (1983, Wis. Act 410) is the overriding statute establishing authority for groundwater protection and numerical enforcement standards applicable to all Wisconsin agencies and programs. The enforcement standard is the health-based concentration of a substance at which a facility regulated by state agencies must take action to reduce the level of the substance in groundwater. Once enforcement standards are established, all state agencies must manage their regulatory programs to comply. Private wells are regulated under Chapter 160, Wis. Stats. However, nitrate is handled differently than other substances. Under sec. 160.25(3), Wis. Stats., a regulatory agency is not required to impose a prohibition or close a facility when nitrate-nitrogen levels attain or exceed the enforcement standard if the agency determines that this occurred in whole or in part because (a) high background levels of nitrate or (b) the additional concentration does not represent a public welfare concern.

State and local agencies are working on multiple initiatives to reduce nitrate inputs to groundwater and drinking water. It is important to note that farms cannot be required to have a nutrient management plan (NMP) unless they are offered cost share at the rate of $28/ac. or if the farm:

1) is required by local manure storage or livestock siting ordinances;
2) participates in the Farmland Preservation Program/Working Lands programs;
3) is regulated by a WPDES permit;
4) accepts cost share for manure storage; or
5) causes a discharge.

In 2015 about 31 percent of the state's cropland was covered by a NMP. NMPs can help reduce the risk of nitrogen reaching groundwater by identifying where on specific farms soils most susceptible to nitrogen leaching exist. The NMP includes restrictions on the amount, timing, and/or application method of nitrogen sources on those sensitive soils types. The UW-Extension publishes a guide to help farmers regarding the appropriate amounts of nutrients to apply to maximize yield and profitability.[44] It sets N and P application limits based on crop need, soil yield, and the economic optimum application rate. WDNR and DATCP, with USDA-NRCS, reference this document in several nutrient management codes and rules. SnapPlus is a Nutrient Management Planning software program designed for the preparation of nutrient management plans in accordance with Wisconsin's Nutrient Management Standard Code 590. The 590 nutrient management standard contains criteria for surface and groundwater protection that manages the amount and timing of all nutrient sources. These plans are annual and based on soil tests and UW soil fertility recommendations. The program helps farmers make the best use of their on-farm nutrients, as well as make informed and justified commercial fertilizer purchases. By calculating potential soil and phosphorus runoff losses on a field-by-field basis, while assisting in the economic planning of manure and fertilizer applications, SnapPlus provides farmers with a tool for protecting soil and water quality.

It is difficult to assess the impact and effectiveness of nutrient management planning on groundwater nitrate levels without full coverage and implementation of NM across the state. **Figure 22 and Map 29** track the development of nutrient management plans. While progress has been made, more work is needed to address increasing nitrate concentrations in groundwater. Additional point and nonpoint sources are addressed through UW-Madison, WDNR, DATCP, NRCS, DSPS, and County Land Conservation Departments in cooperation with local landowners, operators, and waste dischargers. More specifically:

- The University of Wisconsin-Madison and the University of Wisconsin-Extension provide research information and educational programs on nutrient management largely through the Department of Soil Science in College of Agriculture and Life Sciences. The University of Wisconsin's Nutrient and Pest Management program is an educational effort based on soil testing programs and University of Wisconsin Extension Soil fertility recommendations by soil type and crop.

- The Nonpoint Source Water Pollution Abatement Program cost shares the use of best management practices to protect water quality by reducing the amount of nutrients from urban and rural sources.

[44] Laboski, C. and J. Peters. 2012. *Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin.* UW-Extension Publ. A2809.

- The Agricultural Conservation Program is a federal program administered to restore and protect land and water resources and preserve the environment. This program uses cost sharing of best management practices and outreach efforts to reduce nutrient loads from agriculture.

- County land conservation departments provide cost-share funding to farmers for nutrient management planning through DATCP's Land and Water Resource Management grants.

- DATCP awards funds to groups who wish to assist farmers in writing their own NMPs through the Nutrient Management Farmer Education Grant Program

- The newly established Producer Led Watershed Protection Grant Program administered through DATCP funds projects developed by producers to address nonpoint pollution issues in their watershed through innovative partnerships and strategies.

- The WDNR wastewater program regulates the discharge of nitrogen containing wastewater and biosolids to the land surface and potentially to groundwater. The wastewater program regulates:

    - Discharge of municipal and industrial wastewater to land treatment systems such as spray irrigation systems, seepage cells and ridge and furrow systems.

    - Discharge of municipal and industrial sludges, biosolids and industrial liquid wastes through land application.

    - Discharge of septage through land application.

    - Impacts on groundwater from wastewater treatment and storage lagoons leaking in excess of groundwater standards.

    - Disposal of animal waste (manure) from concentrated animal facilities is also regulated. Facilities with over one thousand animal units must have a Wisconsin Pollutant Discharge Elimination permit as required under NR 243.

- The Department of Safety and Professional Services under SPS 383 Wis. Stats regulates private septic systems. The private septic system program does the following:

    - Establishes design standards and accepted waste management practices for private septic systems.

    - Establishes the criteria under which sanitary permits are issued to build private septic systems, which discharge pollutants to waters of the state.

    - Establishes soil site evaluation standards for placement of septic systems.

  It is important to point out that DSPS does not regulate nitrate in septic systems. This should not be a problem as long as septic systems are not concentrated. Groundwater dilution prevents elevated hot spots, unless groundwater has high background nitrate concentrations from agricultural land uses adjacent to or up gradient.

Map 29. Percent of County Cropland with 2015 Nutrient Management Plans Reported to DATCP

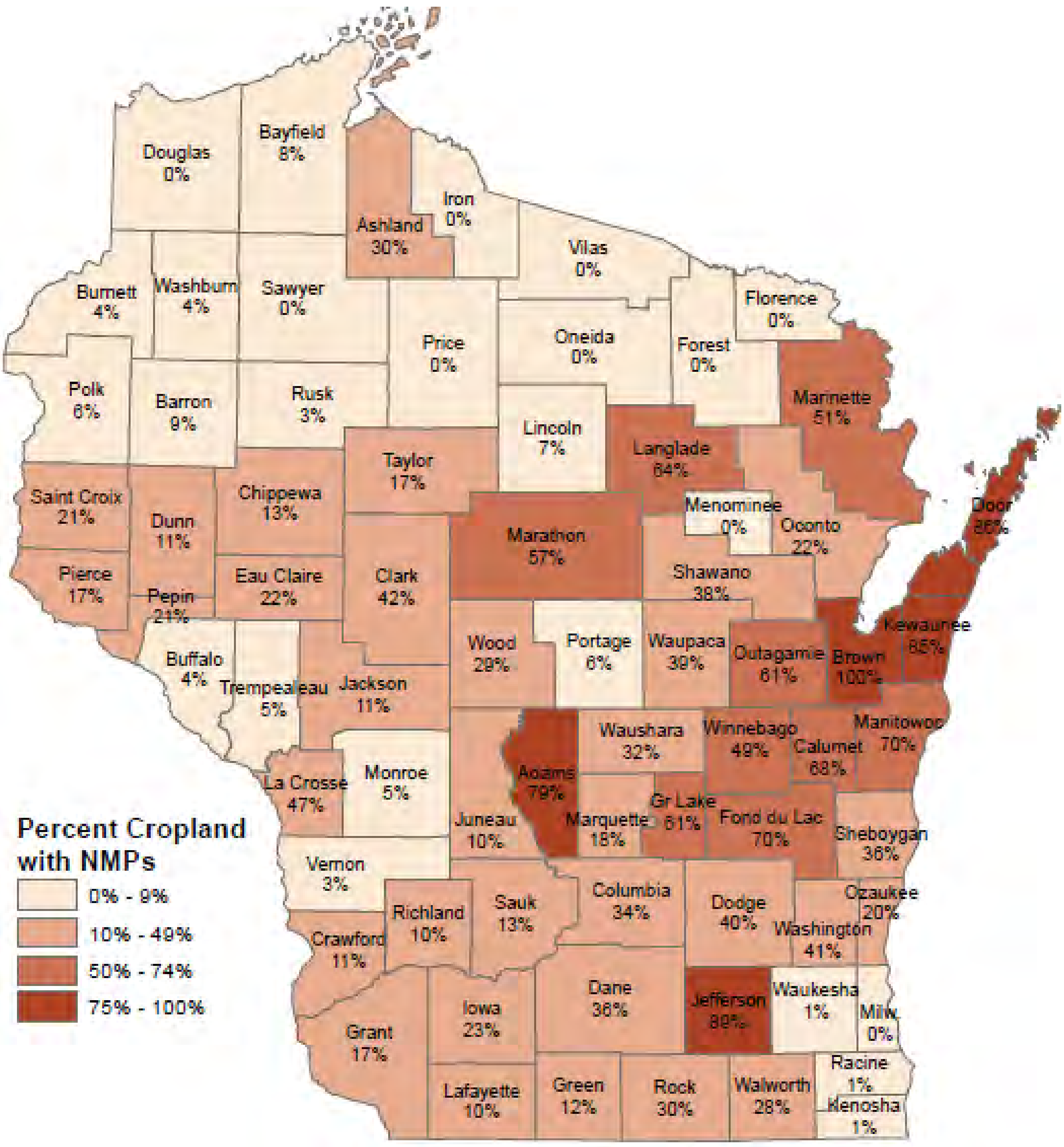
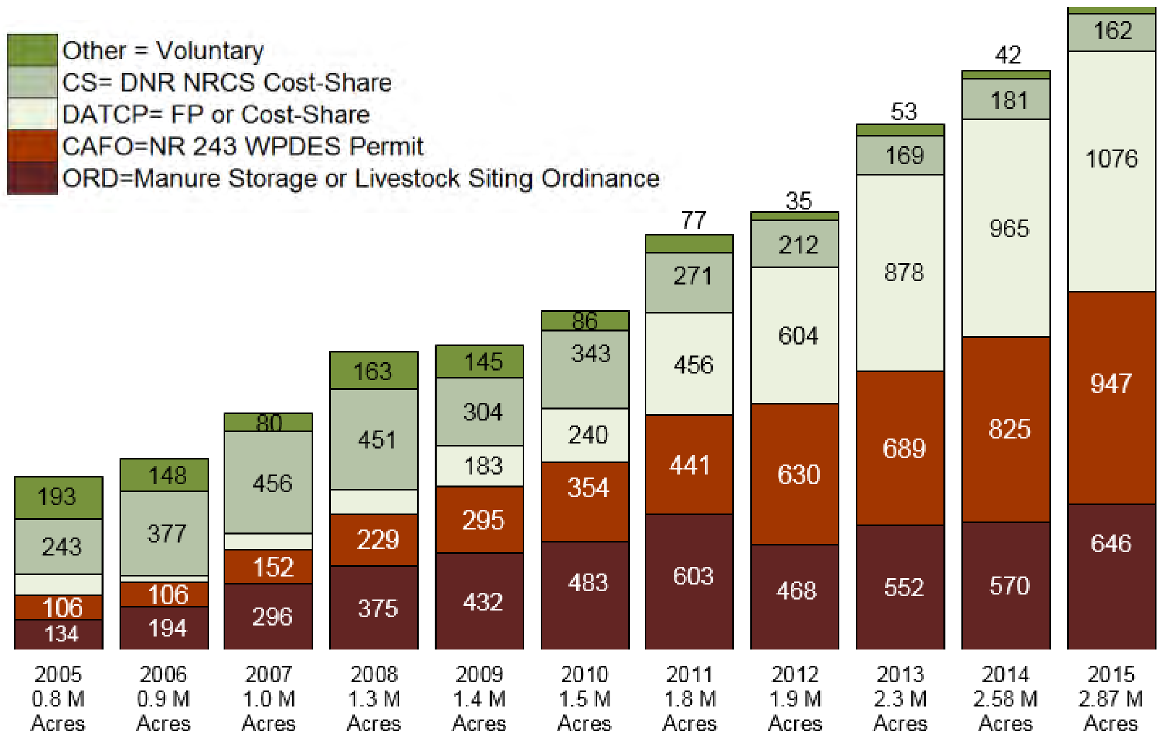


Figure 22

2005-2015 Nutrient Management Plan Acres Reported by Program (thousands of acres)



Source: Acreage Trends in Nutrient Management as Reported to DATCP.

Pesticides

A pesticide is any substance used to kill, control or repel pests or to prevent the damage that they may cause. Included in the broad term "pesticide" are herbicides to control weeds, insecticides to control insects, and fungicides to control fungi and molds. Pesticides are used by businesses and homeowners as well as by farmers, but figures for the amounts and specific types of pesticides used are not generally available on a county-by-county basis.

A 2005 DATCP report indicates that approximately 13 million pounds of pesticides are applied to major agricultural crops in Wisconsin each year, including over 8.5 million pounds of herbicides, 315,000 pounds of insecticides, one million pounds of fungicides, and 3 million pounds of other chemicals (this last category applied mainly to potatoes). The number of pounds of pesticide applied per acre in Wisconsin varies greatly by crop, from 28 pounds/acre for apples to less than one pound/acre for oats and barley (**Table 15**). The principle commodities in Dane County include corn (214,600 ac.), soybeans (80,700 ac.), and wheat (25,000 ac.).

Once a pesticide is applied, ideally it will harm only the target pest and then break down through natural processes into harmless substances. However, the actual fate of pesticides in the environment may include evaporation into the air; runoff into surface water; plant uptake; breakdown by sunlight, soil microorganisms or chemical reactions; attachment to soil particles; leaching into groundwater; or remaining on the plant surface and removal at harvest. When pesticides are spilled, disposed of, or applied on the soil, some amount can be carried into the surrounding surface water or groundwater. These products move with the water, and can eventually enter nearby drinking water wells.

Table 15. Total Pounds of Pesticides Applied to Major Crops in Wisconsin, 2004-2005

Crop	Acres	Total pounds of pesticides applied	Pounds of pesticides applied per acre
Apples	5,800	163,300	28
Potatoes	68,000	950,000	14
Tart cherries	1,800	14,700	8
Carrots for processing	4,200	29,400	7
Snap beans	76,000	251,600	3
Sweet corn	88,400	198,000	2
Field corn	3,800,000	6,503,000	2
Green peas for processing	30,200	33,500	1
Soybeans	1,610,000	1,770,000	1
Cucumbers for processing	4,600	3,800	1
Cabbage, fresh	4,400	2,700	1
Barley	55,000	5,000	1
Oats	400,000	25,000	<1

Wisconsin Agricultural Statistics Service. 2006. *Wisconsin Pesticide Use.*

How much of a pesticide application will leach to groundwater depends upon four factors:

- **Pesticide properties** such as high water solubility, low adsorption (the ability of a pesticide to attach to soil particles), and high persistence (how long it takes for the chemical to degrade)
- **Soil characteristics** such as high permeability and porosity, low soil compaction, low amounts of organic material, and high amounts of sand and gravel content
- **Site conditions** such as shallow depth to groundwater, high amount of precipitation, and excessive irrigation
- **Management practices** such as poor timing of pesticide application, not incorporating the pesticide into the soil, poor handling of the chemical, and solely relying on chemicals for pest control

Determining which pesticides are in groundwater at a given location and time is difficult and can be expensive. A pesticide test generally looks for a single chemical, or more commonly, a broad group of chemicals, but not all pesticides are detected by any one test. Pesticides also break down over time into metabolites which may not have the same testing method as the parent compound. Further, some pesticides do not have approved testing methods, so they cannot be measured in water.

Health Effects

In Wisconsin about 30 pesticides currently have health-based drinking water limits and groundwater standards in Chap. NR 140, Wis. Adm. Code. These advisory levels are calculated from available toxicological studies and are set to protect average exposed populations. Potential health effects in people consuming pesticides above the health advisory levels depend upon the kind and amount of pesticide, how long the person has been consuming the water, as well as the person's overall health. The pesticides with standards are a fraction of the 90 different pesticides Wisconsin farmers reported using on major crops.[45] Occasionally, pesticides and pesticide metabolites that do not have groundwater standards are detected in drinking water in which case the health effects cannot be properly evaluated.

Acute pesticide poisoning is extremely rare in the state. Long-term or chronic effects of pesticides in humans are not completely understood. The health effects of pesticide exposure vary by pesticide. For example, atrazine, a common corn herbicide, has been linked to weight loss, cardiovascular damage, retinal and some muscle degeneration, and cancer when consumed at levels over the drinking water limit for long periods of time. Long-term exposure to alachlor, another herbicide, is associated with damage to the liver, kidney, spleen, and the lining of the nose and eyelids, and cancer.[46] The local public health department or family doctor are the best resources for determining if an individual may have an illness related to pesticide exposure. Since only about 30 pesticides currently have health-based drinking water limits in Wisconsin, occasionally they are detected in drinking water but their harmful levels or health effects are unknown.

Also unknown are the health effects of a combination of pesticides in drinking water, even at levels below the drinking water limit for any one of the pesticides. The health effects of multiple pesticides in drinking water are not well understood. Some studies have found that pesticide mixtures at equal or less than the EPA drinking water standard can produce effects that are not found upon exposure to a single pesticide at the same concentrations. Tests of mixtures of the insecticide aldicarb, the

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[45] Wisconsin Agricultural Statistics Service. 2006. *Wisconsin Pesticide Use.*
[46] U.S Environmental Protection Agency. 2007. *Consumer Factsheet on Alachlor.*

herbicide atrazine, and nitrate in rats show endocrine, immune and behavioral effects including decrease in speed of learning, change in aggression intensity and frequency, change and reduction in memory and motor coordination in the brain, change in growth hormone, and reduction in antibodies formation capability.[47] Frogs exposed to pesticide mixtures used on a corn field (with each pesticide at 0.1 ppb) had retarded larval growth and development and induced damage to the thymus, resulting in immunosuppression.[48]

All public water systems are required to notify consumers if any contaminant, including pesticides, is detected at concentrations above the maximum contaminant level (MCL). In addition, public water systems that serve residential populations are required to complete a Consumer Confidence Report (CCR) each year. If a community well is contaminated with pesticides, consumers will be notified of the problem by the water system owner and given instructions on what to do. Typically, the water system will be required to drill a new well in an uncontaminated area. Communities can also opt to treat the water, however the cost of equipment, operation, and maintenance can be very high.

Private well owners are responsible for the safety of their own water supply. As always, if residents notice a change in taste, color, or odor, they may want to use an alternative safe drinking water source until the water can be tested. Private well owners should also have their well tested if they suspect pesticide contamination. Owners whose wells have pesticides above the MCL should contact the regional office of WDNR for assistance. In most cases owners will be advised to replace the well with a new, safe water supply. Depending on the specific pesticide and the amount of contamination, the well owner may be able to purchase a home treatment system.

Several factors can affect the vulnerability of a well to pesticide contamination. These include:

- **Location.** Wells located on or near agricultural areas, or near pesticide-related industries.
- **Quantity.** Larger spills or applications tend to affect a wider geographic region and can result in higher levels of contamination than smaller spills.
- **Well depth and construction.** Since contaminants are seeping from the ground surface, shallow wells are more likely to be affected than deep wells
- **Soil type or geology.** Areas with thin, highly porous or sandy soils, and have shallow groundwater aquifers or fractured bedrock (karst topography), are most vulnerable to contamination. Clay soils can absorb and significantly slow down the movement of some contaminants.
- **Time.** Groundwater usually moves very slowly. It can take years for pesticides to reach a well. Wells that are safe today may eventually become contaminated by a spill that happened in the past. This is why it is important to test water supplies regularly.

Serious concerns about pesticide contamination in Wisconsin were raised in 1980 when aldicarb, a pesticide used on potatoes, was detected in groundwater near Stevens Point. The WDNR, DATCP, and other agencies responded by implementing monitoring programs and conducting groundwater surveys.

[47] Porter, W., et al. 1999. *Endocrine, Immune, and Behavioral Effects of Aldicarb (carbamate), Atrazine (triazine) and Nitrate (fertilizer) Mixtures at Groundwater Concentrations.*

[48] Hayes, T., et al. 2006. *Pesticide Mixtures, Endocrine Disruption, and Amphibian Declines: Are We Underestimating the Impact?*

In 1983 WDNR and DATCP expanded sampling programs to include analysis of pesticides commonly used in Wisconsin. These programs now include sampling for pesticide metabolites (breakdown products) in the soil and groundwater. Based on DATCP monitoring surveys, the most frequently detected pesticides in Wisconsin are:

- Chemical breakdown products of alachlor (*Lasso*).
- Chemcial breakdown products of meolachlor (*Dual*).
- *Atrazine* and its chemical breakdown products.
- Metribuzin (*Sencor*).
- Chemical breakdown products of Cyanazine (*Bladex*). Note, Cyanazine is no longer manufactured.

From 2000-2001 DATCP conducted a private well water study looking for some of the most commonly used herbicides in Wisconsin. From that study, the statewide estimate of the proportion of private drinking water wells that contained a detectable level of a herbicide or herbicide metabolite was 37.7 percent. **Map 30** shows the estimated percentage of wells containing herbicide or herbicide metabolites by region. The study did not look at less commonly used herbicides or any insecticides or fungicides.

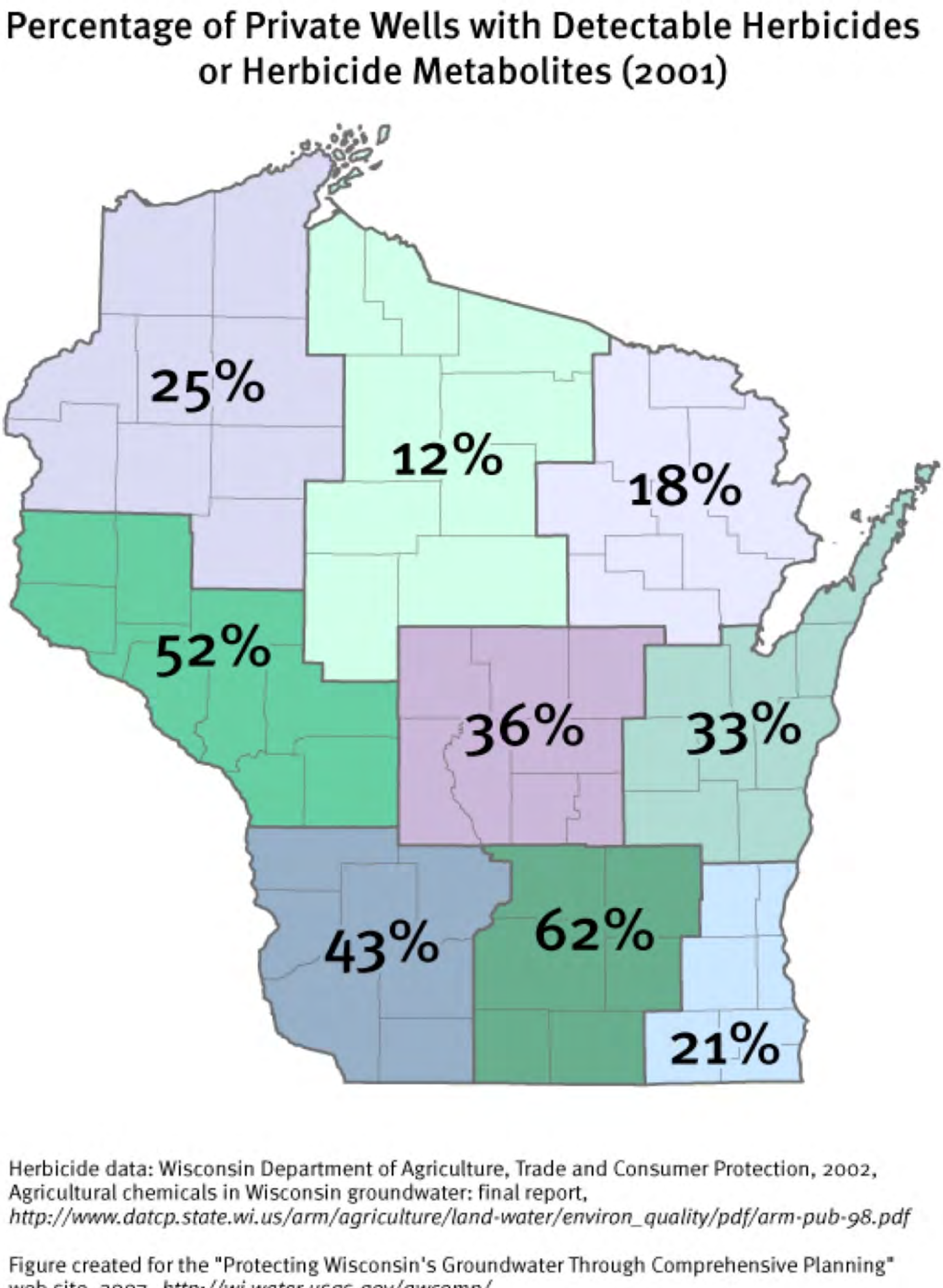
In 2007 DATCP conducted a statewide statistically designed survey of agricultural chemicals in Wisconsin groundwater. The purpose of the survey was to obtain a current picture of agricultural chemicals in groundwater, relate findings to land use, and compare results to previous surveys conducted in 1994, 1996, and 2001. Three hundred and ninety-eight private drinking water wells were sampled as part of this survey. Each well sample was analyzed for 32 compounds including 17 pesticide parent compounds, 14 pesticide metabolites and nitrate-nitrogen. Health standards have been established for 11 of the parent compounds and 4 of the metabolites. Based on the statistical analysis, it was estimated that the proportion of wells in Wisconsin that contained a pesticide or pesticide metabolite was 33.5 percent. The average number of pesticide or pesticide metabolite detects for wells with detects was 2.3. Areas of the state with a higher intensity of agriculture generally had higher frequencies of detections of pesticides and nitrate, as shown in **Figure 23.** Limited pesticide monitoring of private wells was taken from the GRN database (**Table 16 and Map 31a**). Most pesticide concentrations tested below the detection limit, except for atrazine, alachlor, cyanazine and metolachlor. Atrazine was by far the most common compound. Pesticides levels found in municipal wells in Dane County are typically below the PAL (**Map 31b)**

Table 16
Groundwater Pesticide Detection in Private Wells in Dane County

Chemical Name	Total No. of Wells	Wells With Detects	NR 140 Enforcement Standard (UG/L)	Wells Exceeding Enforcement Standard	NR 140 Preventive Action Limit (UG/L)	Wells Exceeding PAL	Highest Detection Level (UG/L)
Aatrex (atrazine)	185	107	3	10	0.3	76	12
Bladex (cyanazine)	143	3	1	2	0.1	3	14
Dual (metolachlor)	152	2	15	0	1.5	0	1.1
Lasso (alachlor)	153	11	2	0	0.2	5	0.5

Source: Wisconsin Department of Natural Resources, Bureau of Drinking Water and Groundwater, 2013.

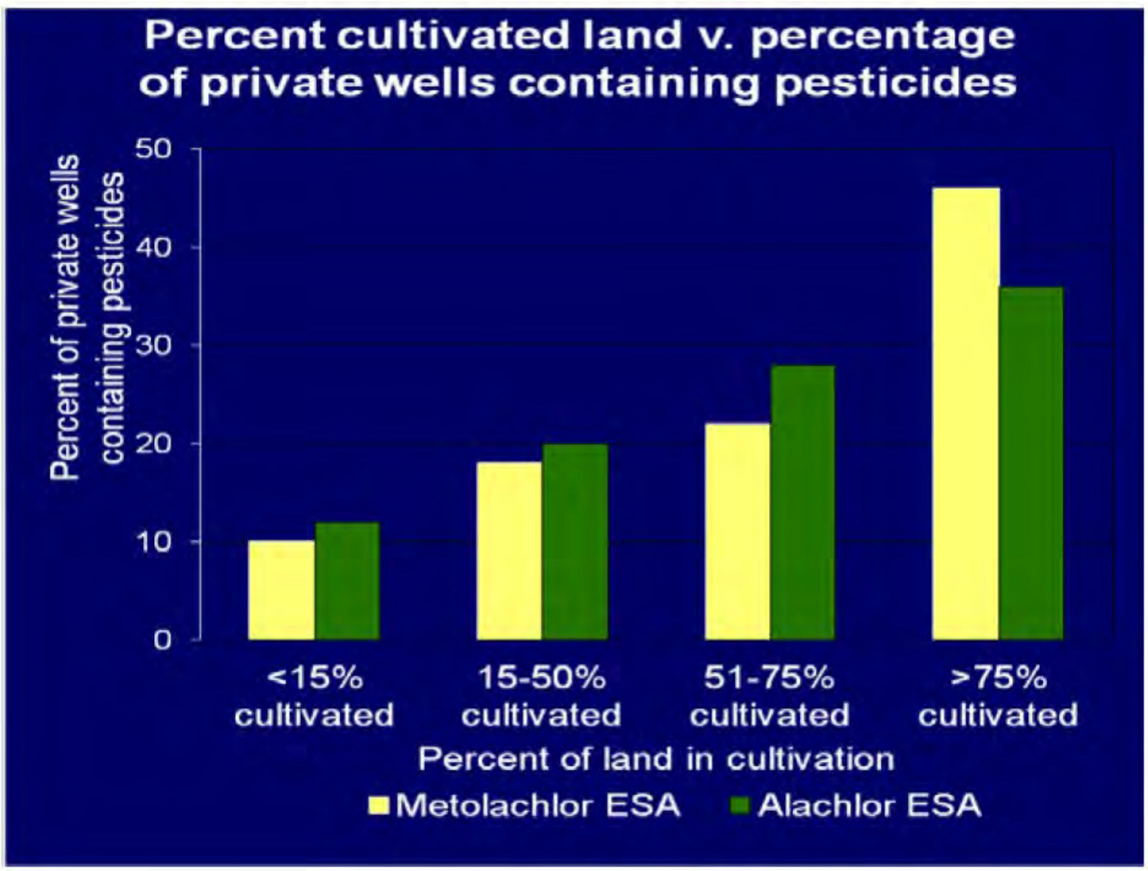
Map 30


Percentage of Private Wells with Detectable Herbicides
or Herbicide Metabolites (2001)
25%
12%
18%
52%
36%
33%
43%
62%
21%
Herbicide data: Wisconsin Department of Agriculture, Trade and Consumer Protection, 2002, Agricultural chemicals in Wisconsin groundwater: final report, *http://www.datcp.state.wi.us/arm/agriculture/land-water/environ_quality/pdf/arm-pub-98.pdf*
Figure created for the "Protecting Wisconsin's Groundwater Through Comprehensive Planning" web site, 2007, *http://wi.water.usgs.gov/gwcomp/*

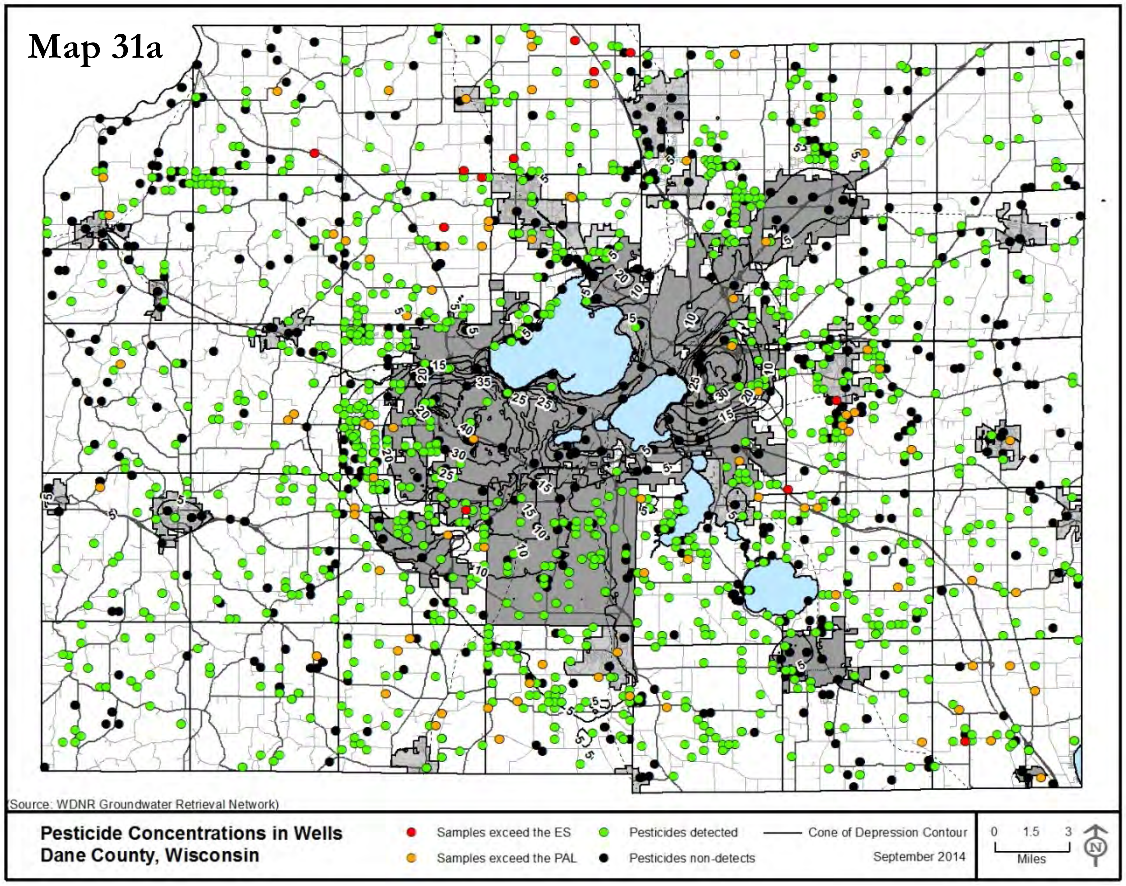
Atrazine

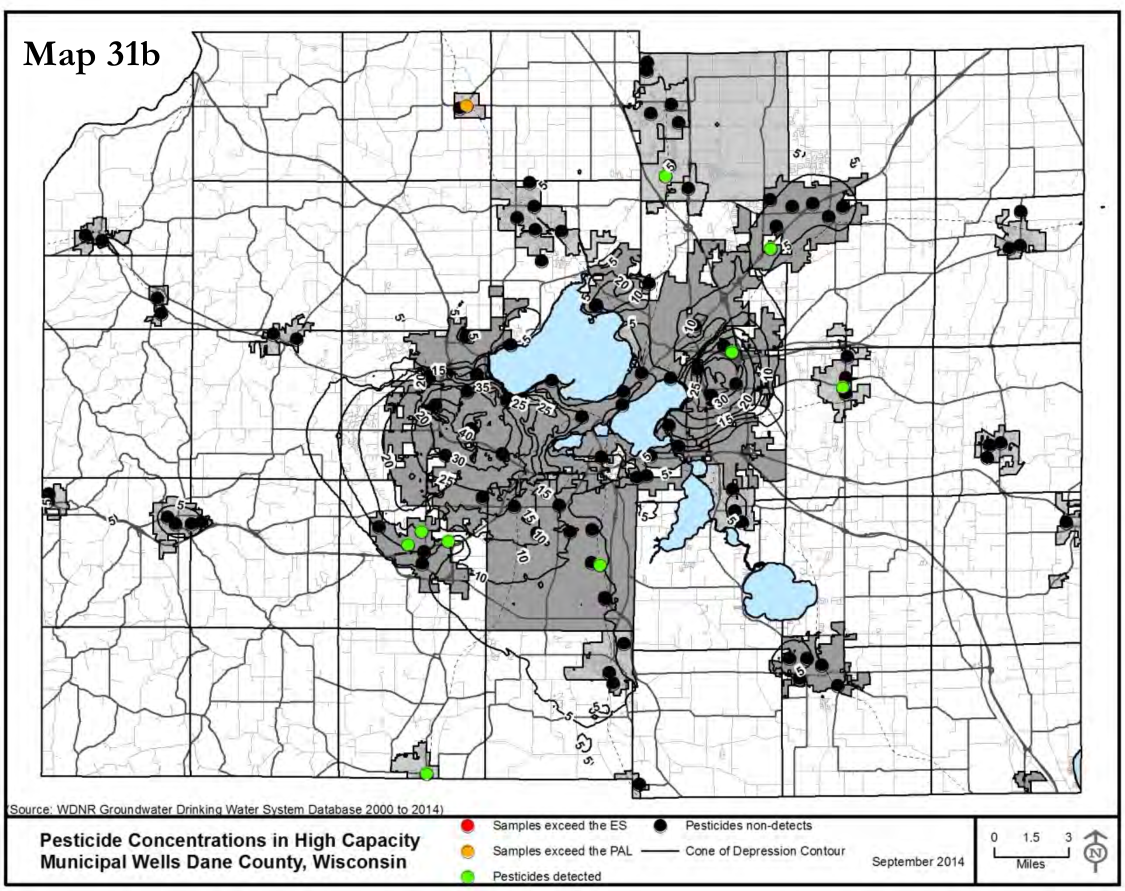
Atrazine, a herbicide used on corn, is one of the pesticides most often found in private drinking water wells in Wisconsin. The DATCP pesticide database contains test results from nearly 13,000 wells tested with the immunoassay screen for atrazine, and over 5,500 wells tested by the full gas chromatography method. In June 2013, DATCP produced a map showing locations and atrazine levels of private drinking water wells tested for atrazine in the state (**Map 32**). The immunoassay screen results showed that about 40 percent of private wells tested have atrazine detections, while about 1 percent of wells contained atrazine over the groundwater enforcement standard of 3 μg/l. The approximately 5,500 wells tested by full gas chromatography showed detectable levels of atrazine in about 38 percent of the wells and 8 percent of wells over the enforcement standard. The enforcement standard for atrazine includes parent atrazine and three of its breakdown metabolites.

Figure 23

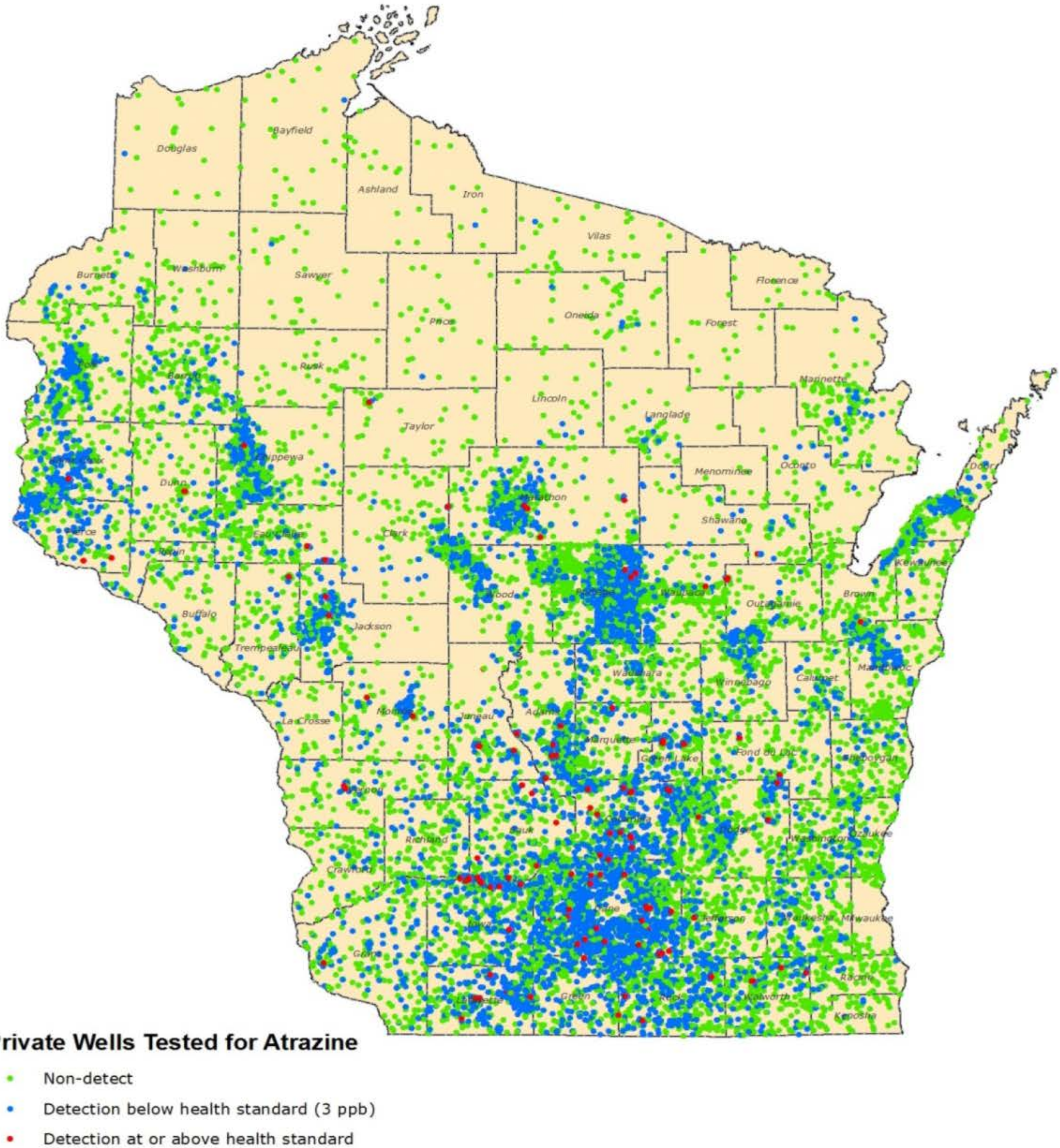


(Source: Wisconsin Groundwater Coordinating Council, 2014, with 2007 DATCP data)


Map 31a
(Source: WDNR Groundwater Retrieval Network)
Pesticide Concentrations in Wells
Dane County, Wisconsin
Samples exceed the ES
Samples exceed the PAL
Pesticides detected
Pesticides non-detects
Cone of Depression Contour
September 2014
0 1.5 3
Miles


Map 31b
(Source: WDNR Groundwater Drinking Water System Database 2000 to 2014)
Pesticide Concentrations in High Capacity
Municipal Wells Dane County, Wisconsin
Samples exceed the ES
Samples exceed the PAL
Pesticides detected
Pesticides non-detects
Cone of Depression Contour
September 2014
0 1.5 3
Miles

Map 32
Private Wells Tested for Atrazine in Wisconsin as of June 2013



This map was created June 4, 2013 and depicts the most recent atrazine results for private wells in Wisconsin.

Source: DATCP

Pesticides like atrazine get into groundwater mostly through general use, while others are only found in groundwater if they have been spilled or mishandled. A combination of factors is most likely responsible for the widespread atrazine contamination shown on the map:

Atrazine was the most widely used herbicide in Wisconsin for more than 40 years because it is effective and inexpensive. Glyphosate use has now passed atrazine use in Wisconsin due to Roundup-ready soybeans and corn, but fortunately glyphosate is not a groundwater threat because it is tightly bound to the soil. Atrazine leaches through the soil into groundwater more readily than many other herbicides Atrazine was commonly used at much higher rates and applied more often before DATCP's Atrazine rule (ATCP 30) began in 1991. As of 2011, there were 101 atrazine prohibition areas in Wisconsin, covering about 1.2 million acres where all uses of atrazine are prohibited. In Dane County 531,830 acres of land are within an atrazine prohibition area (**Maps 33a and b**).

In 1997, DATCP conducted an *Atrazine Rule Evaluation Survey* to evaluate the restrictions on the use of atrazine in Wisconsin. The purpose of the survey was to determine how levels of atrazine and its metabolites in groundwater were changing three and five years after the atrazine rule was put into effect. The results show a significant decline in atrazine concentrations in Wisconsin between 1994 and 1996. The average atrazine plus metabolite concentration in wells with detections declined from 0.96 to 0.54 in the two-year period, a 44 percent decrease. The percent of contaminated wells, however, did not show a significant decline.

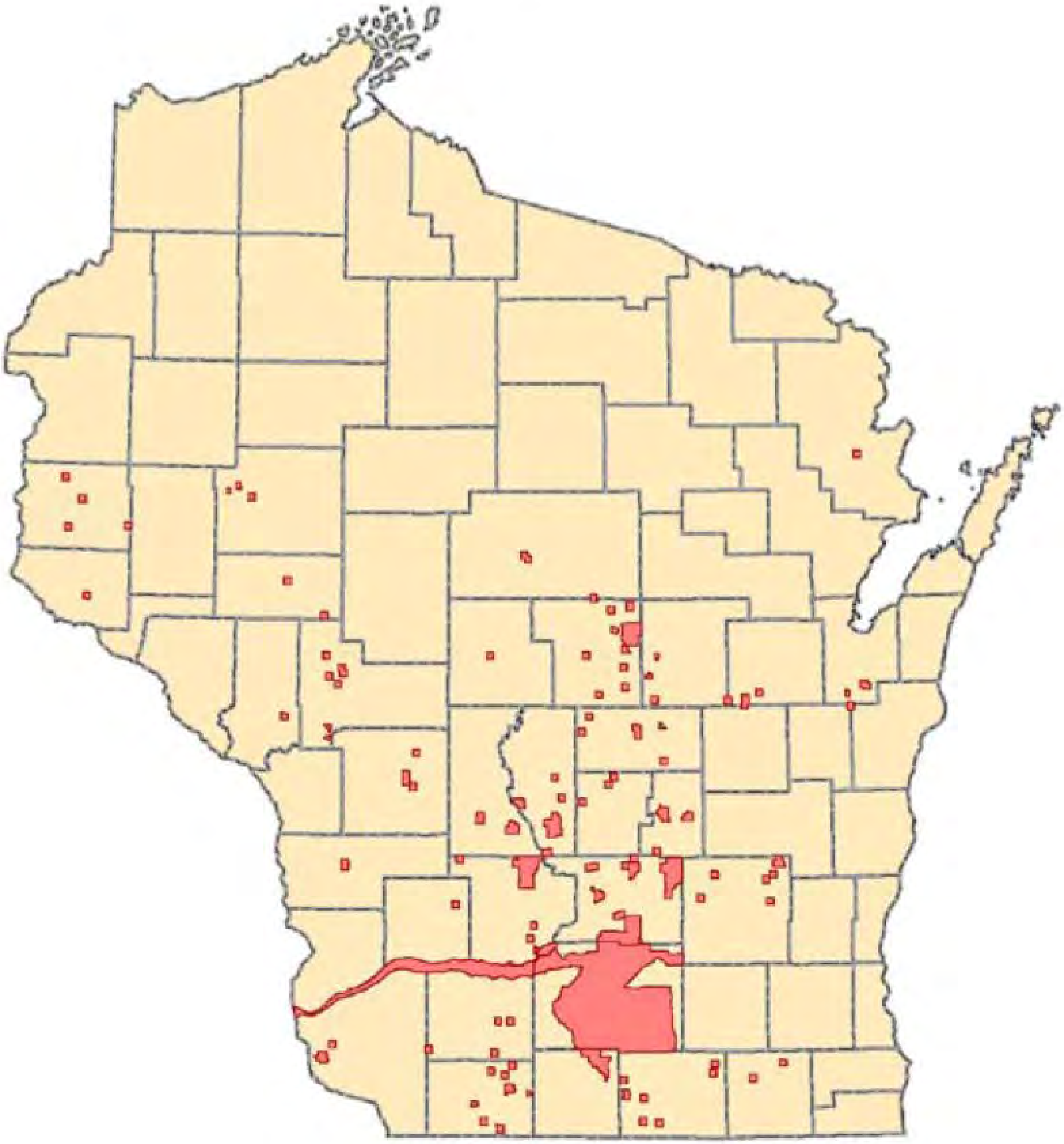
In 2011 DATCP completed a *Survey of Weed Management Practices in Wisconsin's Atrazine Prohibition Areas*. The main purpose of the survey was to evaluate differences in herbicide use and other weed control practices inside and outside of Wisconsin's atrazine prohibition areas. A specific objective was to determine whether simazine, a triazine herbicide that is similar to atrazine, is used more extensively inside prohibition areas since atrazine is prohibited and if this could become a bigger water quality problem. Information was also collected on how prohibiting the use of atrazine affects the ability to grow corn.

The results of this survey suggest that although many corn growers would like the option to use atrazine in a prohibition area, they have adapted well to growing corn without it. Half of the respondents indicated that they do not find it more difficult to control weeds in a prohibition area without atrazine. Only about eight percent of respondents indicated that it is much more difficult to control weeds in a prohibition area and another 32 percent said it is somewhat more difficult.

Corn growers appear to be split on the question of whether it costs more to control weeds in a prohibition area with 39 percent responding "yes" and 39 percent "no." The 39 percent that said it costs more reported an average cost increase of $13.60 per acre. Only 5 percent of the corn growers surveyed indicated that they had experienced a yield reduction in a prohibition area.

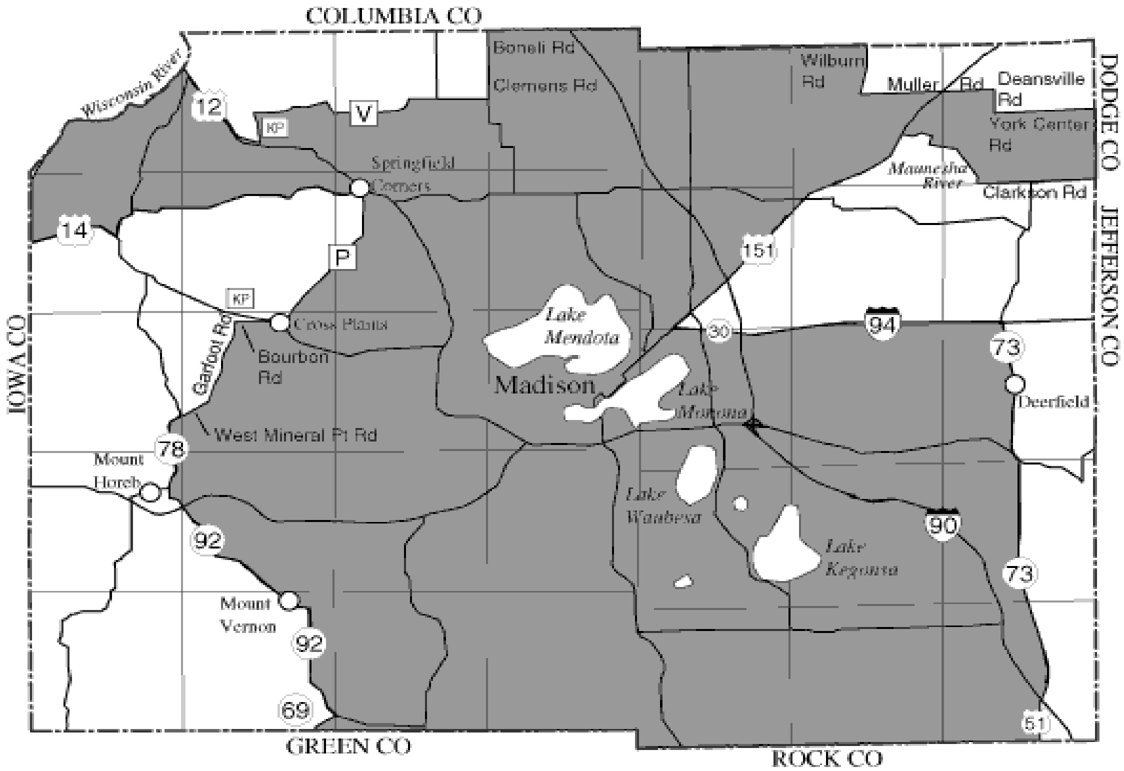
By far the most common alternative to atrazine in prohibition areas was glyphosate-containing products such as Roundup. A comparison of the use of six commonly-used herbicides inside versus outside of prohibition areas showed only minor differences. It was not possible to determine if simazine is used more inside prohibition areas due to low reported use both inside and outside of prohibition areas. A full report on this survey can be found at *http://datcp.wi.gov/uploads/Environment/pdf/WeedMgtAtrazinePAs.pdf*.

Map 33a
Atrazine Prohibition Areas in Wisconsin.



Source: Wisconsin Department of Agriculture and Consumer Protection

Map 33b
Atrazine Prohibition Area in Dane County (in gray)



Management Actions

Organic Farming

Wisconsin has seen a dramatic growth in certified organic farms (which do not use synthetic pesticides), from 422 in 2002 to 1,202 in 2007, an increase of 285 percent. Likewise, organic acreage in Wisconsin increased from 81,026 acres to 195,603 acres from 2002 to 2011, a 241 percent increase. Though the percentage of farms and farm acreage in Wisconsin that are organic remains below 2 percent, organic markets continue to expand due to increased consumer interest in organic food, and reports of increased profits by organic producers.[49] Another benefit of organic farming is the significantly decreased potential for pesticides in groundwater (drinking water in rural areas) where organic practices are followed.

Planning and Implementation

Goals for groundwater protection from pesticides include:

- Determine what pesticides are being used and where. Test wells in these areas for these pesticides and their metabolites.
- For pesticides with established drinking water limits, keep concentrations below the drinking water limit.

[49] Wisconsin Department of Agriculture, Trade, and Consumer Protection. 2011. *The Economic Impact of the Organic Sector in Wisconsin and Beyond.*

- Encourage and support the use of organic farming methods in the county.
- Limit use of lawn pesticides.

Because of differences in pesticides, soils, and management practices, knowing which crops are grown in an area alone does not accurately indicate the risk to human health. However, knowing where pesticide use is likely to be heaviest may be useful in minimizing human exposure to potential contaminants in the environment. Implementation strategies that can be used to protect the groundwater from agricultural chemical contamination include the following:

Education – Education and citizens taking private actions aimed at limiting pesticide contamination of groundwater, for example:

- Private well water testing and education programs offered by the University of Wisconsin – Extension can increase public awareness of pesticide contamination in groundwater and local government officials' interest in taking proactive planning steps to protect groundwater.

- The University of Wisconsin – Madison and UW - Extension have many educational programs to help farmers limit the use of pesticides and pesticide losses to the environment, such as the Integrated Crop and Pest Management (ICPM) program, which can be accessed and implemented locally through the county Extension office.

Environmental Assessment – Environmental assessment requirements within zoning or subdivision ordinances to ensure that suitable sources of water for private wells are available on a proposed development site.

Facility Planning – More detailed facility plans for potential contamination sources, such as spill containment plans for potential pesticide sources.

Funding – For example, WDNR grant or loan programs to help communities assess and meet their needs in areas involving sensitive natural resources such as groundwater.

Incentives – Incentives from local governments to grow groundwater-friendly crops including, for example:

- Identifying agricultural lands in the recharge area for its wells and providing various incentives for farmers to enter into cropping agreements to limit pesticide inputs.
- Hiring a specialist to evaluate areas of high pesticide use and develop possible pesticide management strategies or promote low-pesticide agricultural systems or organic farming systems which forbid the use of synthetic pesticides.
- Encouraging food processors that purchase organic or groundwater friendly foods to locate or form in the area.

Volatile Organic Compounds

Volatile Organic Compounds (VOCs) refers to a group of chemicals that are used as solvents in many industrial and household products that evaporate, or volatilize, when exposed to air. The most abundant source of VOCs are fossil fuel products such as gasoline and fuel oil. Since they also make excellent solvents, VOCs are used as cleaning and liquefying agents in fuels, degreasers, solvents, polishes, cosmetics, and dry cleaning solutions. Potential sources of VOCs in Wisconsin's groundwater include landfills, underground storage tanks, and hazardous substance spills.

When VOCs are spilled or disposed of on or below the land surface a portion evaporates, but some can be carried deep into the soil by rainwater or melting snow. Once they enter groundwater, VOCs can remain there for years decomposing slowly because of the cool, dark, environment. These chemical move with the groundwater and pose a threat to nearby drinking water wells.

Several factors can affect a well's vulnerability to VOC contamination. These include:

- **Location**. Typically VOC-contaminated wells are located near industrial or commercial areas, gas stations, landfills, or railroad tracks.
- **Quantity**. Larger spills tend to affect a wider geographic region and can result in higher levels of contamination than small spills.
- **Well depth and construction**. Since contaminants are seeping from the ground surface, shallow wells are more likely to be affected than deep wells.
- **Soil type**. Areas with thin, highly porous or sandy soils, and shallow depths to groundwater, are most vulnerable to contamination. Clay soils can absorb and significantly slow down the movement of some contaminants. This is helpful because slow groundwater movement can allow soil bacteria to break down harmful organic chemicals.
- **Time**. Groundwater usually moves very slowly. It can take years for VOCs to reach a well. Wells that are safe today may eventually become contaminated by a spill that happened in the past. This is why it is very important to test water supplies regularly.

The presence of VOCs in groundwater is cause for concern. Improper handling or disposal of VOCs can affect the quality of our drinking water for generations to come. VOCs include hundreds of different chemicals. Some VOCs are quite toxic, while others pose little risk. The most commonly detected VOCs have been used for many years and have been studied in both biological and occupational settings. Health risks vary depending on the type of VOC. Generally, effects of short-term exposure include symptoms of intoxication (dizziness, headache, confusion, nausea), anemia, and fatigue. Effects of long-term exposure can include cancer, liver damage, spasms, and impaired speech, hearing, and vision.

State and federal agencies are responsible for ensuring the safety of our drinking water. To do this, they set limits of how much of a contaminant can be in drinking water These limits are called "Maximum Contaminant Levels" (MCLs) and groundwater "Enforcement Standards" (ESs) specified in NR 890 and NR 140, respectively. Limits are set at levels that protect against short-term and long-term exposures and are cost effective to implement.

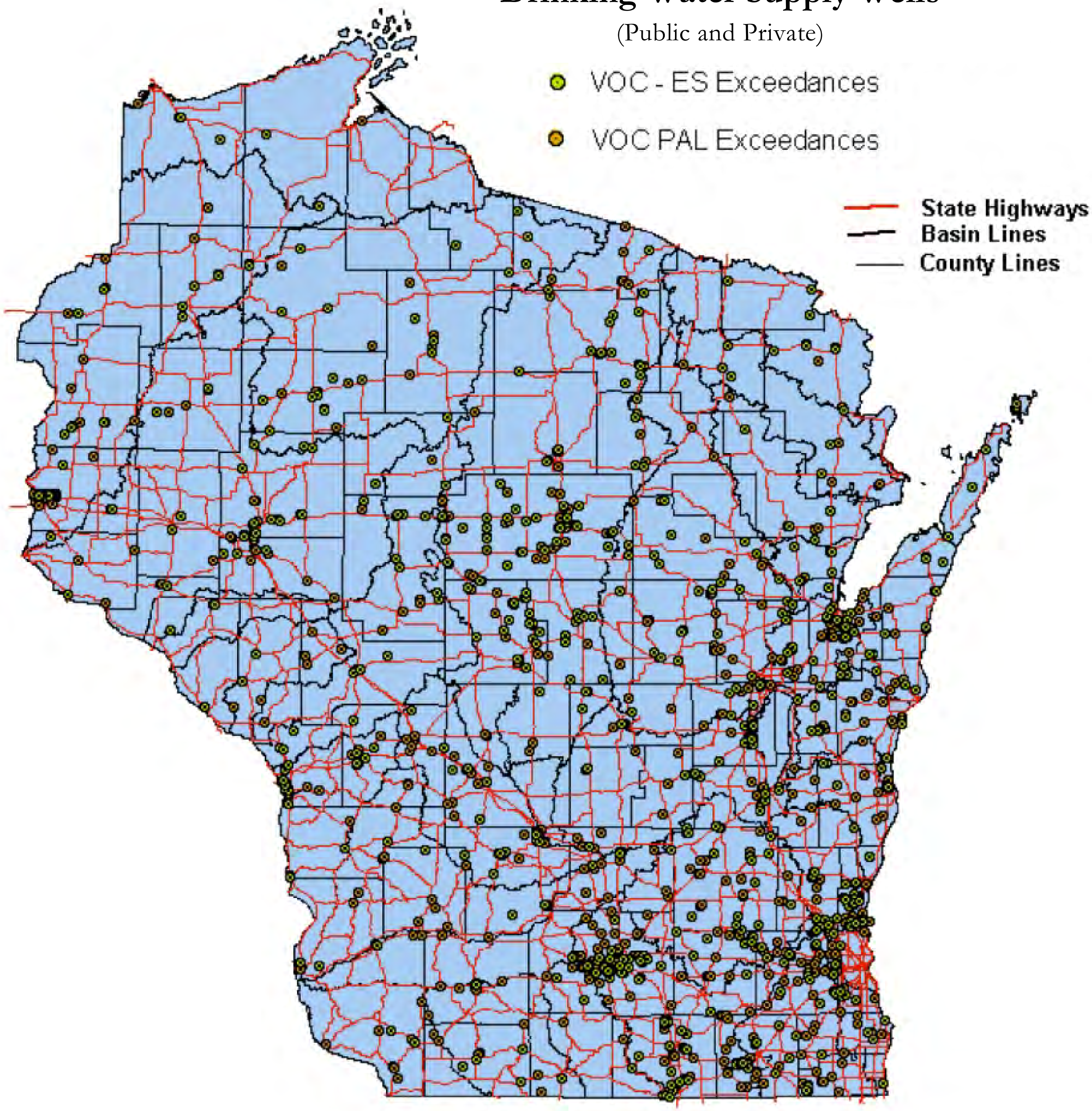
Thousands of wells have been sampled for VOC analysis across the state. Fifty-nine different VOCs have been found in Wisconsin groundwater, although only 34 of those have health based standards. Trichloroethylene, used as a solvent and degreaser and a common ingredient in many household products like paints, adhesives and spot removers, is the VOC found most often in Wisconsin's groundwater. **Map 34** shows the location of drinking water wells with past enforcement standards (ES) and preventive actions limits (PAL) exceedances based on data from 6,399 unique wells recorded in the WDNR's Groundwater Retrieval Network (GRN) database. **Maps 35a and b** indicate VOC results for Dane County and municipal wells, respectively.

The Madison water utility annually tests its wells for over 50 different VOCs including carbon tetrachloride, tetrachloroethylene (PCE), trichloroethylene (TCE), and methyl t-butyl ether (MTBE). Further monitoring is triggered if the level of one VOC exceeds a threshold, typically one tenth of the maximum contaminant level (MCL).

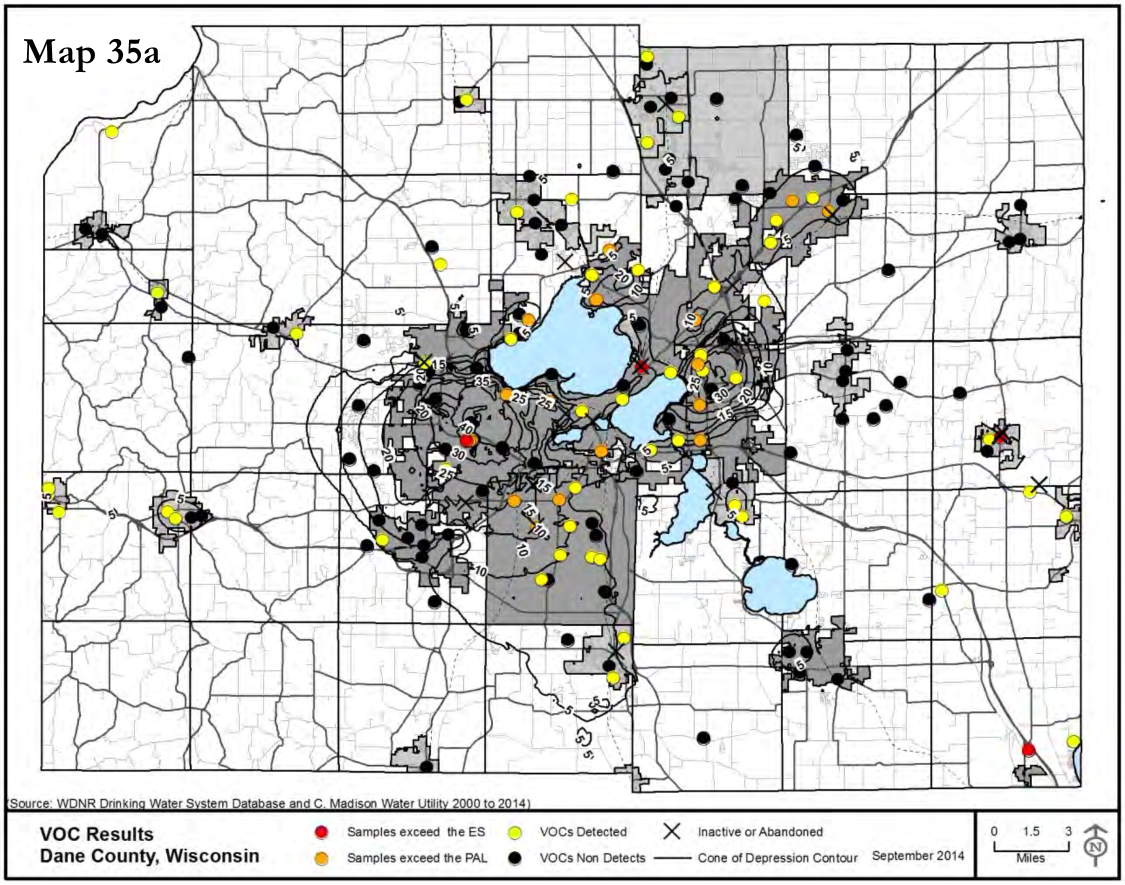
The most frequently encountered VOC in Madison water is tetrachloroethylene (PCE) widely used in dry-cleaning and metal degreasing operations. In 2012, as in previous years, PCE was detected at seven wells (**Table 17**). Although the amount found at most wells was below 1 μg/L, the average at Well 9 was 1.4 μg/L while at Well 15 it averaged 3.3 μg/L and measured as high as 3.9 μg/L. These levels compare to an MCL of 5 μg/L. The amount at Well 15 has been gradually increasing over several years and ultimately led to the decision to install an air stripper to remove VOCs from the pumped water. The treatment facility is expected to begin operation in summer 2013.

A limited number of other VOCs have been found in some Madison municipal wells. Except for trichloroethylene (TCE), these contaminants are found in only one or two wells and are generally detected at trace levels (<0.5 μg/L). **Table 17** identifies the chemical, maximum amount detected, and the well in which each was found.

Map 34
Drinking Water Supply Wells
(Public and Private)



Source: Wisconsin Groundwater Coordinating Council., 2014. *Fiscal Year 2014 Report to the Legislature.*


Map 35a
(Source: WDNR Drinking Water System Database and C. Madison Water Utility 2000 to 2014)
VOC Results
Dane County, Wisconsin
Samples exceed the ES
Samples exceed the PAL
VOCs Detected
VOCs Non Detects
Inactive or Abandoned
Cone of Depression Contour
September 2014
0 1.5 3
Miles

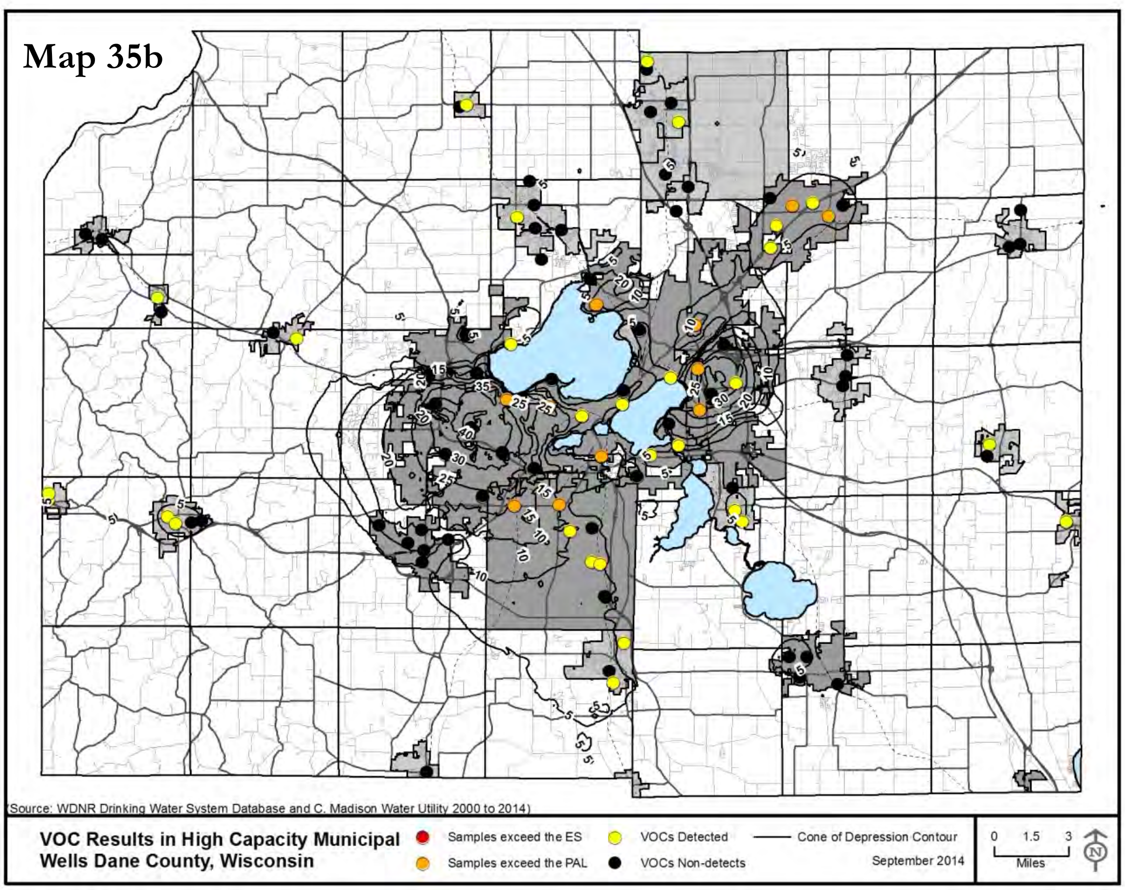

Map 35b
(Source: WDNR Drinking Water System Database and C. Madison Water Utility 2000 to 2014)
VOC Results in High Capacity Municipal
Wells Dane County, Wisconsin
Samples exceed the ES
Samples exceed the PAL
VOCs Detected
VOCs Non-detects
Cone of Depression Contour
September 2014
0 1.5 3
Miles

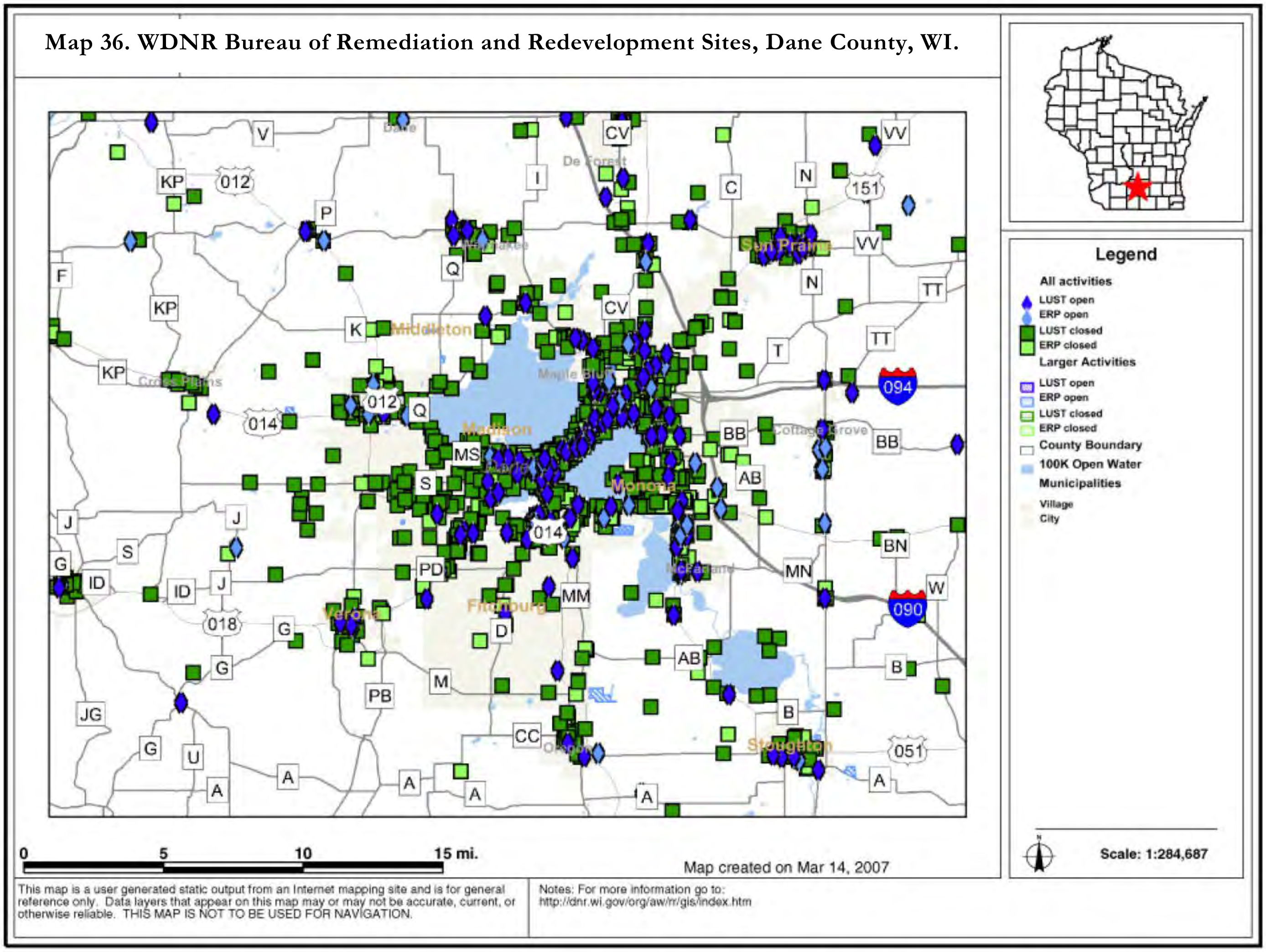
Table 17. Summary of 2012 VOC Detections in Madison Wells					
Volatile Organic Compound	Maximum	Units	Well(s) Present	MCL[1]	MCLG[2]
Dichlorodifluoromethane	[0.20][3]	µg/L	14	--	--
1,2-Dichloroethylene (cis)	[0.34]	µg/L	8, 11	70	70
Tetrachloroethylene [PCE]	3.9	µg/L	6, 9, 11, 14, 15, 18, 27	5	zero
Trichloroethylene [TCE]	0.43	µg/L	11, 14, 15, 18, 27	5	zero
Trichlorofluoromethane	0.92	µg/L	11	--	--
Xylene, Total	[1.5]	µg/L	225	10000	10000

[1] Maximum Contaminant Level (MCL) - the maximum amount allowed in drinking water
[2] Maximum Contaminant Level Goal (MCLG) - the level below which there is no known or expected risk to health
[3] Bracketed numbers correspond to measurements above the detection limit but below the limit of quantification (LOQ)

Wisconsin has 66 active and 600 closed, licensed solid waste landfills, which are required to monitor groundwater. In addition, the WDNR currently tracks about 20,000 leaking underground storage tanks (LUSTs) and about 8,000 reported releases at a variety of facilities including gas stations, bulk petroleum and pipeline facilities, plating, dry cleaning, industrial facilities, and abandoned non-approved unlicensed landfills. Many of these sites have been identified as sources of VOCs. The WDNR also tracks approximately 33,000 spills, some of which are also sources of VOCs. The WDNR Bureau of Remediation and Redevelopment Tracking System (BRRTS) is a searchable database containing information on the investigation and cleanup of potential and confirmed contamination to soil and groundwater in Wisconsin. **Map 36** indicates the contaminated and cleaned up sites in Dane County. Properties that are or were contaminated with hazardous substances can be found using the WDNR's Bureau for Remediation and Redevelopment Tracking System (BRRTS). Types of hazardous substance occurrences or discharges that are documented in the BRRTS database include:

- Abandoned Container (AC) – an abandoned container with potentially hazardous contents has been inspected and recovered, but discharge to the environment has not occurred.
- Leaking Underground Storage Tank (LUST) – a leaking underground storage tank has contaminated soil and/or groundwater with petroleum. Petroleum products contain cancer-causing and toxic substances, but may biodegrade, or break down naturally in the environment, over time.
- Environmental Repair (ERP) – sites other than LUSTs that have contaminated soil and/or groundwater. Industrial spills or dumping, buried containers of hazardous substances, closed landfills, and leaking above-ground petroleum storage tanks are potential ERPs.
- Voluntary Party Liability Exemption (VPLE) - an elective process in which a property owner conducts an environmental investigation and cleanup of an entire property and then receives limits on future liability for that contamination.
- Spills – discharges of hazardous substances, usually cleaned up quickly.

Currently, there are 189 open-status sites in Dane County that have contaminated groundwater and/or soil These sites include 3 Spills (2278 closed sites) 80 Leaking Underground Storage Tanks (1239 closed), 99 ERP sites (336 closed), and 7 VPLE sites (8 closed).



Map 36. WDNR Bureau of Remediation and Redevelopment Sites, Dane County, WI.

Figure created for the "Protecting Wisconsin's Groundwater Through Comprehensive Planning" web site, 2007, *http://wi.water.usgs.gov/gwcomp/*

Landfills

Two studies conducted over four years revealed that VOCs were significant contributors to groundwater contamination at unlined Wisconsin landfills.50 Out of a total of 45 unlined municipal and industrial landfills tested, 27 (60 percent) had VOC contamination in groundwater. All of these landfills are currently closed. Of 26 unlined municipal solid waste landfills tested, VOCs contaminated groundwater at 21 (81 percent). No VOCs were confirmed present at any of the six engineered (liner and leachate collection) landfills included in the studies. While 20 different VOCs were detected overall, 1,1 – Dichloroethane was the most commonly occurring VOC at all of the solid waste landfills.

In a follow-up VOC study conducted from July 1992 through July 1994, the WDNR reviewed historical data and sampled groundwater at 11 closed, unlined landfills and at six lined landfills. VOC levels had decreased after closure at all but two of the unlined landfills, although at many sites VOC levels did not show continued improvement. Also, the level of contamination, while below

[50] Wisconsin Groundwater Coordinating Council., 2014. *Fiscal Year 2014 Report to the Legislature*.

initial concentrations, remained high at many closed sites. No VOC contamination attributable to leachate migration was found at any of the six lined landfills investigated.

Underground storage tanks

Wisconsin requires underground storage tanks (USTs) with a capacity of 60 gallons or greater to be registered with the Department of Safety and Professional Services. Since 1991, this registration program has identified over 180,000 USTs of which 82,260 are federally regulated. About 11,978 federally regulated tanks are in use, with a total of 51,337 USTs in use total (federally regulated and state regulated). A federally regulated tank is any tank, excluding exempt tanks that is over 1,100 gallons in size, has at least 10 percent of its volume underground, and is used to store a regulated substance. Wisconsin regulates USTs down to 60 gallon capacity. Exempt tanks include: farm or residential tanks of 1,100 gallons or less; tanks storing heating oil for consumptive use on the premises where stored; septic tanks; and storage tanks situated on or above the floor of underground areas, such as basements and cellars.

Hazardous waste

Hazardous waste treatment storage and disposal facilities are another VOC source. There are approximately 140 sites statewide subject to corrective action authorities, and WDNR's Bureau for Remediation and Redevelopment is overseeing investigation or remediation at approximately half of these sites. Generators improperly managing hazardous waste are another source of VOC contamination. The majority of hazardous waste projects are being addressed in accordance with the NR 700 Wis. Adm. Code series.

Hazardous Substance Spills

The Hazardous Substance Spill Law, ch. NR 292.11 Wis. Stats., requires immediate notification when hazardous substances are discharged, as well as taking actions necessary to restore the environment to the extent practicable. In FY 13 approximately 870 hazardous substance discharges were reported to WDNR. Approximately 550 were spills, 310 were Environmental Repair Program sites or LUSTs, and 13 were agrichemical discharges reported to DATCP.

The NR 700 Wis. Adm. Code series, specifically ch. NR 706, contains the requirements for notification when a discharge or spill occurs. Chapter NR 708 contains requirements for taking immediate and/or interim actions when releases occur. Groundwater monitoring is performed when necessary to delineate the extent of contamination. The spills program develops outreach materials to help reduce the number and magnitude of spills and provide guidance for responding to spills. Topics addressed include spills from home fuel oil tanks, responses to illegal methamphetamine labs, and mercury spills, all of which can lead to significant environmental impacts, if not properly addressed.

What solutions are available for citizens?

Public water supplies are tested regularly to ensure that they meet the safe drinking water standards. If a community well is contaminated with VOCs, consumers will be notified of the problem by the water system owner and given instruction what to do. Typically, the water system will be required to drill a new well in an uncontaminated area. Communities can also opt to treat the water by aeration or filtration. These methods are highly effective in reducing VOC levels. However, the cost of equipment, operation and maintenance can be very high. Water quality must also be monitored regularly to assure that the treatment continues to work.

Private well owners are responsible for the safety of their own water supply and should have their water tested if they suspect contamination. All wells located near a potential source of VOCs, such as a landfill, airport, industrial site, or service station, should be tested periodically. If well owners notice a solvent-like or gasoline taste or odor in their water, they should use an alternate, safe source until it can be tested for VOCs. Owners whose wells have VOCs above health advisory levels should contact the WDNR for assistance. In most cases, they will be advised to replace the well with a new, safe water supply. Sometimes, a temporary solution can be used. These typically involve the use of bottled water, connecting to a neighboring well, or installing a home treatment system.

The most important action citizens can take is to prevent contamination. Pouring dirty or spent solvents or paint thinners onto the ground does not really get rid of them – they pollute the air and can contaminate drinking water supplies.

- Dispose of solvents properly. Waste VOCs should be taken to a hazardous waste collection facility.
- Use less toxic alternatives like borax, ammonia, vinegar, and baking soda whenever possible.
- Never flush solvents into a septic system. That actually releases them directly into the ground.
- Report spills immediately.
- Participate in "Clean Sweep" hazardous waste collection/exchanges in your community.[51]

For more information contact the WDNR Bureau of Water and Drinking Water.[52]

Pharmaceuticals, Personal Care Products, and Endocrine Disrupters

Pharmaceuticals, personal care products (PCPs) and endocrine disrupting compounds (EDCs) are a large group of substances present in human generated waste streams that could potentially contaminate groundwater resources. These substances are recognized by U.S EPA, along with other chemicals, as contaminants of emerging concern (CECs), emerging contaminants (ECs) or trace organic contaminants (TOCs).

The list of pharmaceuticals is long and includes such medications as tranquilizers, pain killers, antibiotics, birth control, hormone replacement, lipid regulators, beta blockers, anti-inflammatories, chemotherapy, antidiabetics, seizure control, veterinary drugs, antidepressants, and other psychiatric drugs. There is a related category of chemicals referred to as "personal care products" that includes over-the-counter non-prescription medication, cosmetics, perfumes, soaps, sunscreens, insect repellants, etc. The volume of pharmaceuticals and personal care products entering the environment each year is about equal to the amount of pesticides used.[53] New analytical methods, allowing detection of very small quantities of a substance, have helped improve investigations into the occurrence of emerging contaminants such as pharmaceuticals, PCPs, and EDCs in the environment. In 2000 the U.S Geological Survey conducted a nationwide assessment of drugs in streams and groundwater. They picked locations likely to be contaminated and found pharmaceuticals in about 60 percent of groundwater samples. Potential sources of discharge of

[51] http://www.danecountycleansweep.com/
[52] http://dnr.wi.gov/regulations/labcert/documents/testsforwell.pdf
[53] USGS Protecting Wisconsin's Groundwater Through Comprehensive Planning website. http://wi.water.usgs.gov/gwcomp/find/dane/index_full.html

pharmaceuticals to the environment include wastewater treatment plants, onsite wastewater treatment systems, landfills, sludge and manure spreading, and livestock feedlots.

Why be concerned about traces of chemicals that were designed to be consumed? We are only beginning to understand the health effects. Because of the low concentrations, any effects are likely to appear only after years of exposure. A real concern is that some of the drugs are endocrine disruptors. Endocrine glands, such as the thyroid, pituitary, or thymus send hormones, such as adrenaline, estrogen or testosterone to specific cells stimulating certain responses. There are hundreds of different hormones, and they are messengers that regulate a multitude of normal biological functions, such as growth, reproduction, brain development, and behavior. The delivery of hormones to various organs is vital, and when the delivery, timing, or amount of hormone is upset, the results can be devastating and permanent. Chemicals that are similar to hormones ("hormone mimics") can fit onto the receptor sites on the target cells and either block the real hormones or trigger abnormal responses in the cells. Scientific studies have indicated links between endocrine disruptors and reproductive disorders, immune system dysfunction, certain types of cancer, congenital birth defects, neurological effects, attention deficit, low IQ, low sperm counts, and early onset of puberty in girls.[54]

The mobility and fate of discharged/released substances in the subsurface is a function of a variety of factors including the substance's adsorption and biodegradability properties and the amount and characteristics of any soil through which the substance percolates before reaching groundwater. Recent studies in other states have shown that pharmaceuticals, PCPs, and EDCs can be present at sites where treated wastewater is used to recharge groundwater. In Wisconsin, research has been done evaluating the occurrence and movement in the subsurface of some pharmaceuticals, PCPs, and EDCs.

The WDNR is using the results of pharmaceutical, PCP, and EDC research studies to evaluate whether current state groundwater protection regulations are adequate to address potential adverse impacts from the discharge of these substances. Studies comparing the levels of pharmaceuticals, PCPs, and EDCs present in wastewater influent with treatment system effluent levels are providing information on the removal effectiveness of wastewater treatment processes. Research into the behavior of pharmaceutical, PCP, and EDC substances in soil and groundwater is helping the WDNR develop effective monitoring strategies. Studies evaluating new sampling techniques and analytical test methods have helped assure that the WDNR is utilizing the best available tools to assess the occurrence of these substances in the environment.

In the meantime, the WDNR recommends that household pharmaceuticals be managed as follows:

1. REDUCE pharmaceutical waste whenever possible.

- Use all antibiotics as prescribed by your doctor.
- Buy only as much as can reasonably be used before the expiration date.
- When your doctor prescribes a new medication, ask the doctor to prescribe only enough to see if the medication will work for you and in the lowest dose advisable. That way, if the medication doesn't suit you, less goes to waste. Do the same for your pet's medications.

[54] Morse, E. 2005. *Drugs in Our Water?*

- Reconsider the use of products that claim to be antimicrobial or antibacterial. Plain soap and water is as effective as antibacterial soaps. The Centers for Disease Control recommends plain soap in its hand washing procedure.
- For more ideas, see UW-Extension's pharmaceutical waste reduction information http://www4.uwm.edu/shwec/pharmaceuticalwaste/reduceHome.cfm

2. REUSE/RECYCLE drugs when possible.

- Wisconsin allows certain pharmacies to take back unit doses of drugs for cancer and chronic diseases. Certain drugs can be returned for re-issuance through the Cancer Drug Repository.
- Citizens may be able to donate other items; however, the circumstances where this is possible are limited. While it is a noble intention, it is very unlikely that medications from households would be acceptable for use overseas. If you see an opportunity to do this, approach with caution and research the program well.

3. DISPOSE of the remainder properly.

- If you have narcotics or other controlled substances, contact your local police department to find out if the police will accept them. Some police departments accept non-controlled substances too, but you should find out exactly what yours will accept before dropping off the items.
- Whenever possible, take your unused pharmaceuticals to a pharmaceutical collection program or event.[55]
- **Note:** If you choose to store your waste for a pharmaceutical collection, please minimize the risk of accidental poisoning, overdose or diversion (illegal use by someone other than the intended person) by storing medications out of reach of children or in a locked cabinet.

Microbial agents

Microbial agents include bacteria, viruses, and parasites. These agents can cause acute illness and result in life-threatening conditions for young children, the elderly, and those with chronic illnesses or depressed immune systems. Some of the more familiar organisms include *Cryptosporidium*, *E. coli*, and *Salmonella*. Common symptoms include diarrhea, nausea, vomiting, cramps, or fever. When people bathe or shower in this contaminated water, it is less likely that they become ill. However, they can still get sick with ear and respiratory infections, skin rashes, or infections in open wounds.

Bacteria

In one assessment,[56] approximately 23 percent of private well water samples statewide tested positive for total coliform bacteria, an indicator species of other biological agents. In Dane County between 15-20 percent of private wells tested positive for total coliform bacterial over the last 25 years.[57] The reason is often a construction defect (e.g., loose or cracked well cap, poor grout, corroded casing, improper backflow prevention, etc.). A percentage of bacterial contamination much higher than 15 percent is often an indication of geologic or aquifer susceptibility in an area.

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[55] http://www.safercommunity.net/meddrop.php
[56] Warzecha, C. et al. 1995. *Wisconsin Private Well Water Quality Survey.*
[57] UW-Stevens Point Well Water Quality Viewer. http://gissrv2.uwsp.edu/cnr/gwc/pw_web/.

A survey of WDNR's GRN database in Dane County indicates bacterial pollution of shallow wells is widespread (**Map 37).** Shallow private wells are typically more vulnerable than deep municipal wells, which are also disinfected. Increased frequency of results observed near subdivisions may be the result of many factors including greater numbers and frequency of tests, higher concentrations of homes resulting in greater potential for contamination, older homes, as well as surrounding land uses. WDNR recommends private well owners test water for total coliform bacteria annually, especially when there is a change in taste, odor, or appearance. Municipal water suppliers typically disinfect their water supplies and sample quarterly.

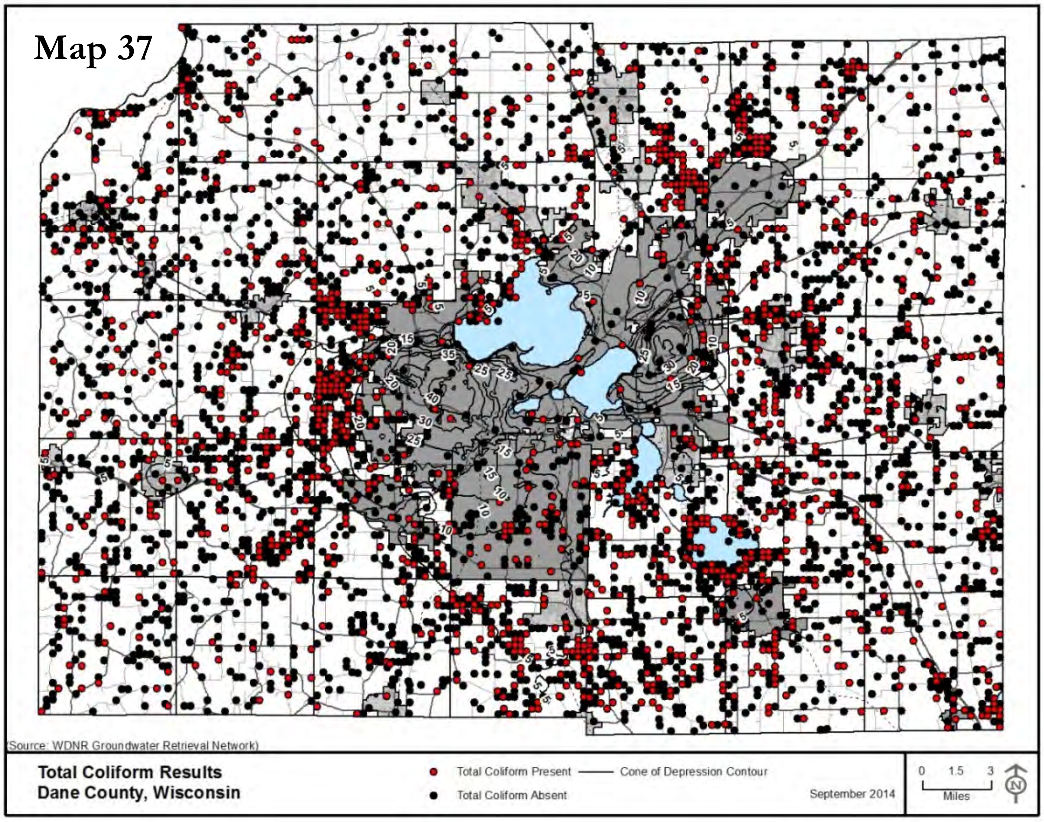
Bacterial contamination is likely from a local source and is often associated with poorly constructed or located wells. Problems may be solved on-site and future problems minimized if wells are constructed according to the Wisconsin well construction code (NR 112) and located at appropriate distances and direction from pollution sources. Bacterial pollution can be treated by chlorination and other methods, although this does not always solve the problem. If bacteria persist, the source of pollution should be identified and corrected.

WDNR responds to homeowners regarding private well contamination, many of which correspond to manure spreading. Until 2007 there were no readily available methods for testing for manure in these wells. Standard methods for testing for bacteria do not indicate whether the source is human or non-human sources. Recently developed laboratory techniques have made it possible to discern whether bacteria are from human, animal, or other sources.[58] Since 2007 groundwater analyses by WDNR indicate that the majority of well water samples were contaminated with grazing animal waste (i.e., manure). Less than ten percent of samples collected indicate microbial contamination from human sources.[59] The manner in which manure is spread on the landscape does make it more likely to result in sudden or widespread contamination of a groundwater aquifer. Whatever is taking place within a quarter to half mile of the well is likely influencing well water. WDNR and DATCP oversee liquid manure spreading, particularly during late winter and early spring, when manure should not be tilled and cannot be absorbed by soil.

Some common factors that can lead to contamination of residential wells include:

- Thin or sandy soils above fractured bedrock,
- Groundwater near the surface,
- Depressions where runoff water stands (or drains into the ground),
- Sink holes,
- Winter or early spring spreading of manure nearby (especially liquid manure),
- Winter and early spring rains or snow melt causing runoff from nearby fields,
- Nearby unused or improperly abandoned wells,
- Residential wells with shallow or cracked casings, and
- Poorly constructed wells.

[58] These microbial source tracking (MST) tools include tests for *Rhodococcus coprophilus* (indicative of grazing animal manure) and *Bifidobacteria* (indicative of human waste).
[59] Groundwater Coordinating Council. 2014. *Report to the Legislature*.



Runoff risks can be substantially reduced if manure spreading is done according to an approved nutrient management plan, which includes a number of restrictions on manure applications. Currently, 36 percent of Dane County's cropland is covered by a state-approved nutrient management plan.

The State Well Code requires all new wells to be tested for bacteriological quality. Wells must also be tested following the installation or reinstallation of a pump, or anytime a well is entered for repairing or reinstalling equipment within the well. The Wisconsin Department of Health and Family Services recommends that all wells be sampled for bacteria at least once a year, or whenever there is any change in the taste, odor, or appearance of the water. Even if none of these factors are present, activities or circumstances that put well water at risk cannot always be seen by well owners. The best times of the year to test well water are when it is most likely to be unsafe. Statistically these times occur following a period of heavy snowmelt in early spring or during the hot stagnant time of late summer and early fall. If the water is found to be unsafe then the area surrounding the well should be checked for possible sources of contamination including animal yards, septic systems, sewers, improperly abandoned wells, landfills, sinkholes, quarries, bedrock outcroppings, etc.

Other possible causes of an unsafe water condition include inappropriate openings in the well head, a damaged or corroded casing, an inadequate casing depth, faulty installation of an adapter or any other component of the pump installation. If any of these items seems to be a likely cause of the well contamination, the necessary repairs should be made to the water system. A licensed Well Driller, or Pump Installer can assist in inspecting the well and water system and to recommend whether or not the system should be modified, upgraded, or replaced.

Viruses

Viruses in groundwater are becoming an increasing concern as new analytical techniques have detected viral material in private wells and public water supplies. Research conducted at the Marshfield Clinic indicates that 4-12 percent of private wells contain detectible viruses. Another study, conducted in conjunction with the USGS, found that 50 percent of water samples collected from four La Crosse municipal wells were positive for intestinal viruses.[60]

Public and private water samples are not regularly analyzed for viruses due to the high cost of the tests. The presence of coliform bacteria has historically been used to indicate the water supply is not safe for human consumption. However, recent findings show that coliform bacteria do not always correlate with the presence of enteric viruses. For example, municipal water sampled by Borchardt and others (2004) showed that, even though 50 percent of the samples were positive for viruses, none of the same samples tested positive for coliform or other indicators.[61] Indicators have a high positive predictive value but a low negative predictive value for pathogen occurrence. In other words, when an indicator is present in drinking water there is a high probability that particular water source will be contaminated with a pathogen at some time. However, if an indicator is absent, no inferences can be made about pathogen occurrence. Additional study is needed to determine what virus results mean to human health.

Microbial contamination of groundwater is also not restricted to aquifers typically regarded as vulnerable or shallow aquifers. In a novel study, researchers discovered human viruses in the confined aquifer supplying Madison's drinking water .[62] This finding was completely unexpected because it was believed the 3 to 9 meter shale confining layer protected the aquifer from microbial contamination. Additional research by the Marshfield Clinic, WGNHS, and USGS on the Madison wells has shown virus transport from leaking sanitary sewers to the wells is very rapid, on the order of weeks to months instead of years.[63] The virus transport and contamination levels were particularly high after extreme rainfall events or rapid snowmelt. From a public health perspective, the lesson learned is that *all* aquifers are potentially vulnerable to microbial contamination. Public water supply systems in cities, towns, or villages that supply groundwater are particularly vulnerable to pathogen contamination from leaky sanitary sewer systems. While there is no federal or state requirement for such systems to disinfect their drinking water, the vast majority of Wisconsin's municipal water utilities do, killing viruses and bacteria that can unexpectedly occur in groundwater.

[60] Wisconsin Groundwater Coordinating Council., 2014. *Fiscal Year 2014 Report to the Legislature*.

[61] Borchardt M. et al. 2004. *Vulnerability of Municipal Wells in La Crosse, Wisconsin, to Enteric Virus Contamination from Surface Water Contributions*.

[62] Borchardt, M. et al. 2007 *Human Enteric Viruses in Groundwater from a Confined Bedrock Aquifer*.

[63] Bradbury, K. 2013. *Source and Transport of Human Enteric Viruses in Deep Municipal Water Supply Wells*.

Inorganic Elements of Concern

Inorganic compounds are rather simple chemicals. They can be described as mineral in nature and usually exist as ions – substances with a positive or negative charge – when dissolved in water. Familiar examples include calcium, chloride, sodium, iron, magnesium, manganese, nitrate, sulfate, and zinc. Many inorganics are naturally occurring minerals that are dissolved from the rock which makes up the aquifer. However, some of these compounds may be introduced to surface and groundwater by human activities – nitrate (a component of fertilizer) and sodium chloride (road salt) are two examples. Municipal water utilities in Dane County routinely test their wells for different inorganic compounds including those named above plus arsenic, barium, cadmium, chromium, lead, mercury, selenium, thallium, among others.

For example, **Table 18** summarizes the annual inorganic test results for Madison well samples collected in 2013. With few exceptions, notably nitrate, the regulated inorganic contaminants that were detected are found at levels near the detection limit, generally <1 µg/L, and well below the maximum contaminant level (MCL). The ranges of results are similar to those observed in previous years. Representative test results for municipal wells in Dane County can be found in **Attachment A**. In addition, annual Consumer Confidence Reports (CCRs) required by U.S. EPA and the federal Safe Drinking Water Act can be obtained from individual water utilities, which detail the quality of their drinking water supplies.

Table 18
Summary of Annual Inorganic Test Results After Chemical Treatment for Madison Wells

Parameter	Units	MCL	Minimum	Median	Maximum
Alkalinity ($CaCO_3$)	mg/l	-	270	313	343
Aluminum	µg/l	50-200*	0.3	0.4	2.6
Antimony	µg/l	6	<0.206	<0.206	<0.206
Arsenic	µg/l	10	<0.206	<0.206	1.2
Barium	µg/l	2000	7.8	19	53
Beryllium	µg/l	4	<0.206	<0.206	<0.206
Cadmium	µg/l	5	<0.103	<0.103	<0.103
Calcium	mg/l	-	56	70	100
Chloride	mg/l	250*	2.1	20	109
Chromium	µg/l	100	0.4	1.1	2.8
Conductivity	umhos / cm	-	507	667	1040
Copper	µg/l	1300	1.0	3.1	58
Fluoride	mg/l	4	0.6	0.8	0.9
Hardness ($CaCO_3$)	mg/l	-	278	340	464
Iron	mg/l	0.3*	<0.0013	0.06	0.58
Lead	µg/l	15	<0.103	0.12	9.2
Magnesium	mg/l	-	33	42	52
Manganese	µg/l	50*	<0.206	9.6	90
Mercury	µg/l	2	<0.0206	<0.0206	<0.0206
Nickel	µg/l	100	0.4	0.9	3.7
Nitrogen-Nitrate	mg/l	10	<0.12	0.7	3.9
Nitrogen-Nitrite	mg/l	1	<0.04	<0.04	0.08
pH (Lab)	s.u.	6.5-8.5*	7.5	7.6	7.9
Potassium	mg/l	-	1.0	1.4	1.7
Selenium	µg/l	50	<0.412	0.4	1.1
Silver	µg/l	100*	<0.206	<0.206	<0.206
Sodium	mg/l	20*	2.1	8.8	37
Sulfate	mg/l	250*	7.0	18	55
Thallium	µg/l	2	<0.103	<0.103	0.32
Total Solids	mg/l	500*	296	417	784
Zinc	µg/l	500*	4.3	11	194

Shaded boxes correspond to regulated contaminants

*U.S. EPA Secondary Drinking Water Regulations – non-enforceable Federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color).

Source: Madison Water Utility 2013.

Chloride

The issue of chloride in ground and surface waters warrants particular mention. Chloride is very soluble and therefore mobile in the environment. Chloride at levels greater than 10 mg/L usually indicate contamination by de-icers, onsite wastewater treatment systems, fertilizer, animal waste, or other wastes. Chloride is not toxic in concentrations typically found in groundwater, but some people can detect a salty taste at 250 mg/L. Levels of chloride that are above what is typical under natural conditions indicate that groundwater is being affected by human activities, and extra care should be taken to ensure that those activities do not degrade water quality further.[F42] Since there are no cost effective treatment options currently available at the landscape scale (reverse osmosis or microfiltration being prohibitively expensive), reduction in usage appears to be the best and most effective salt management strategy to-date.

Increasing chloride (salt) concentrations in the Yahara Lakes, area streams, and some municipal wells have been well documented (**Figures 24, 25, and 26,** respectively). **Figure 26** compares past chloride concentrations with deeply cased wells, which draw water from the lower Mt. Simon aquifer, and wells with short casings which draw water from both the upper and lower aquifers. The bisecting line represents the median concentration. Generally the deeper wells show lower chloride levels because of their distances from the land surface, dilution, and a protective shale layer (the Eau Claire formation) between aquifers in some areas. While these levels have been found to be generally below the secondary (aesthetic) drinking water standard of 250 mg/L, they do indicate an increasing trend. **Figure 27** shows historic salt use in Madison and Dane County, the two largest salt users. The increase indicates road building has been increasing faster than salt reduction efforts can offset. Salt applied to sidewalks and parking lots is believed to equal or exceed City use.[64]

Map 38a shows chloride concentrations in wells tested in Dane County. Two factors that influence the sodium and chloride levels at a well are length of the steel casing and proximity to major roadways (salt routes). A well with a short casing draws proportionally more water from the upper aquifer and water quality is more impacted by surface activities such as road salt application. Note that reductions in water table levels represented by the cones of depression northeast and southwest of the Yahara Lake chain do not indicate a significant relationship or cause of higher chloride levels. Also, research indicates that salt concentrations in northern U.S. streams are more associated with deicer application than other sources (e.g., water softeners).[65]While these concentrations are all below drinking water standards (maximum 146 mg/L west of Madison), increasing levels in some wells is certainly cause for concern. **Map 38b** shows the rate of increase in municipal high capacity wells over the last 20 years (shown as warm colors in the map) along with some decreases (shown as cool colors in the map).

The use of sodium chloride for street deicing is the norm throughout much of the northern United States and Canada for a reason: it is cheap and effective. Although some communities augment their deicing capabilities with alternative deicers, there is currently nothing available to adequately replace sodium chloride. Substitute deicers are usually either a different salt, which still contributes to the chloride issue, or an organic compound. Organic compounds contribute nutrients, oxygen demand, and/or metals instead of chloride. So, replacement of sodium chloride with an organic deicer would trade chloride toxicity for increases of already problematic algal blooms, lake dead zones (maybe fish kills), and/or metals toxicity, as well as a substantial increase in cost.

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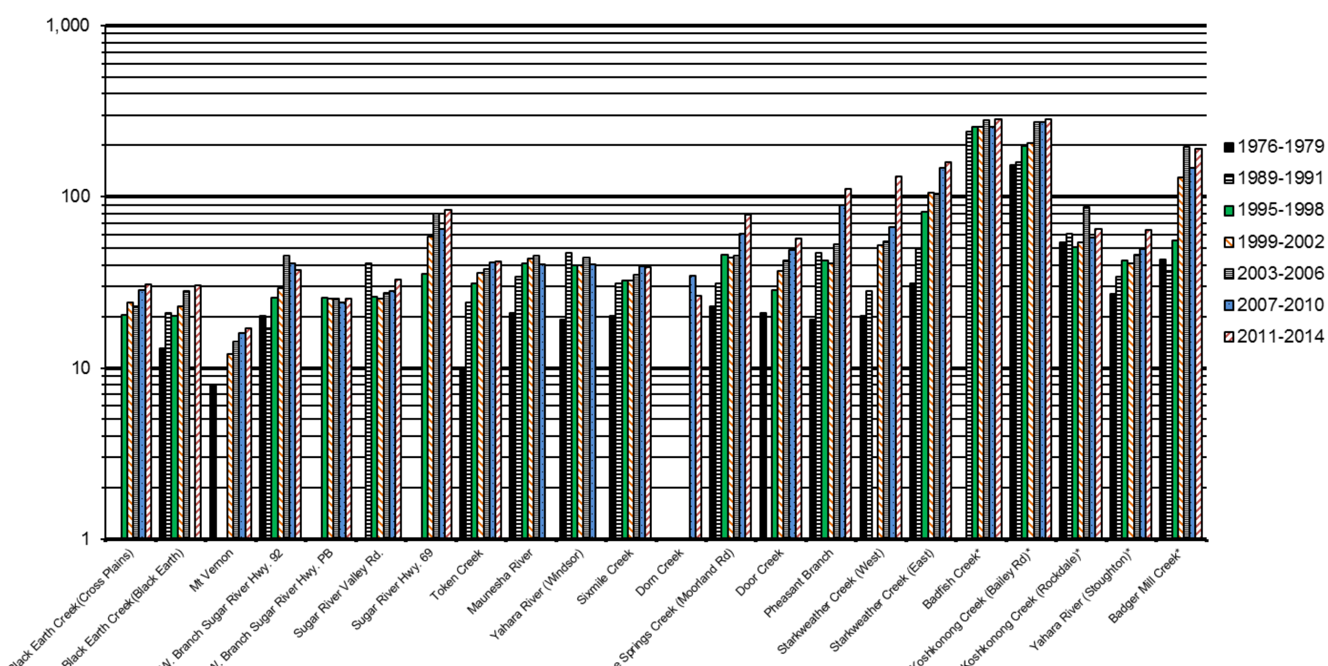
[64] City of Madison 2012 Road Salt Report

[65] Corsi, S. et. al., 2010. *A Fresh Look at Road Salt: Aquatic Toxicity and Water Quality Impacts on Local, Regional, and National Scales*.

Figure 24. Average Annual Chloride Levels in the Yahara Lakes, 1915 to present.

Source: *2014 Road Salt Report*. Public Health Madison and Dane County.

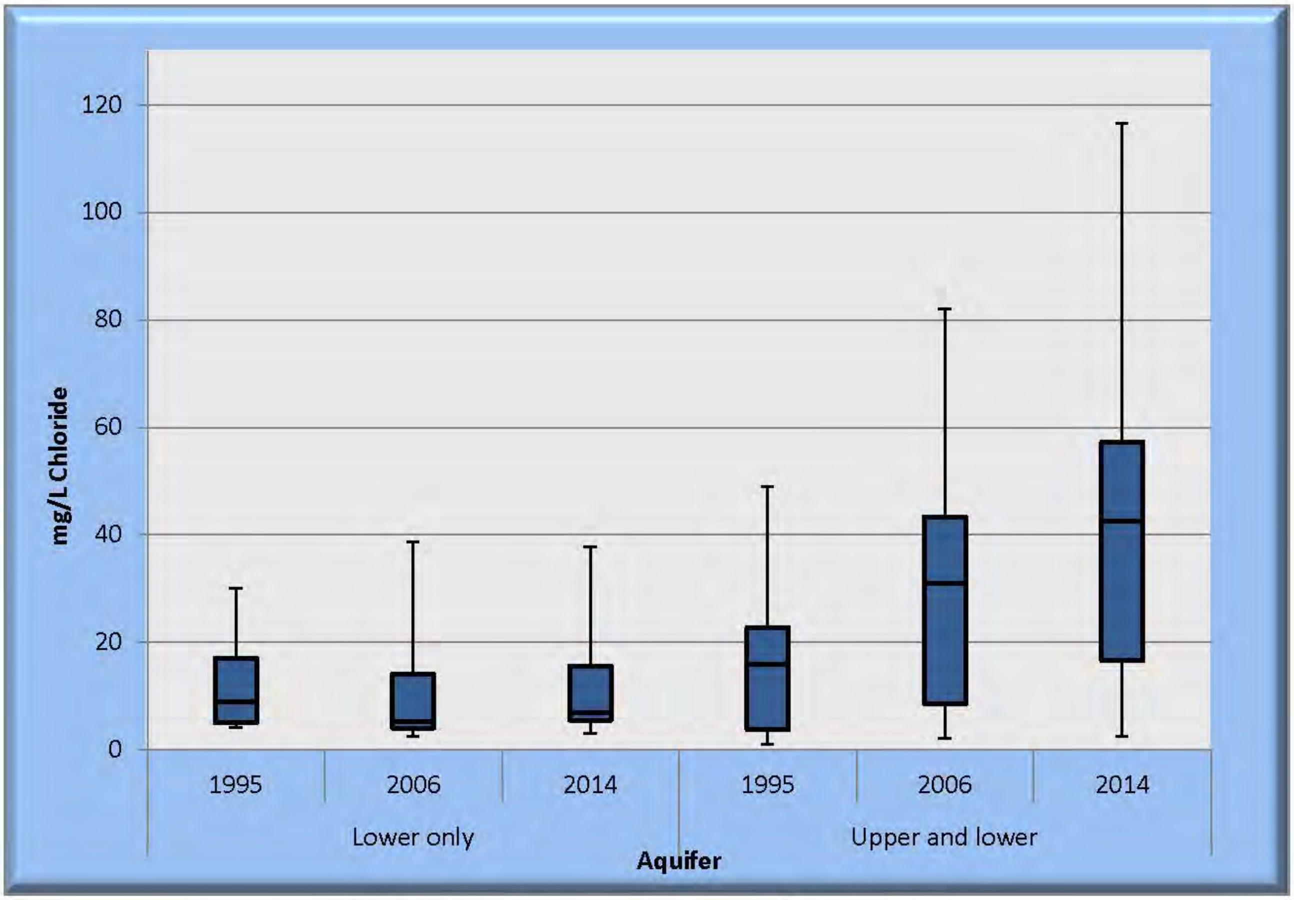
Figure 25. Historical Comparison of Mean Baseflow Chloride Concentrations in Area Streams (mg/L).



* Wastewater Discharge Streams

Source: The Capital Area Regional Planning Commission's Cooperative Water Resources Monitoring Program and U.S. Geological Survey

Figure 26. Chloride Trends in Madison Wells.



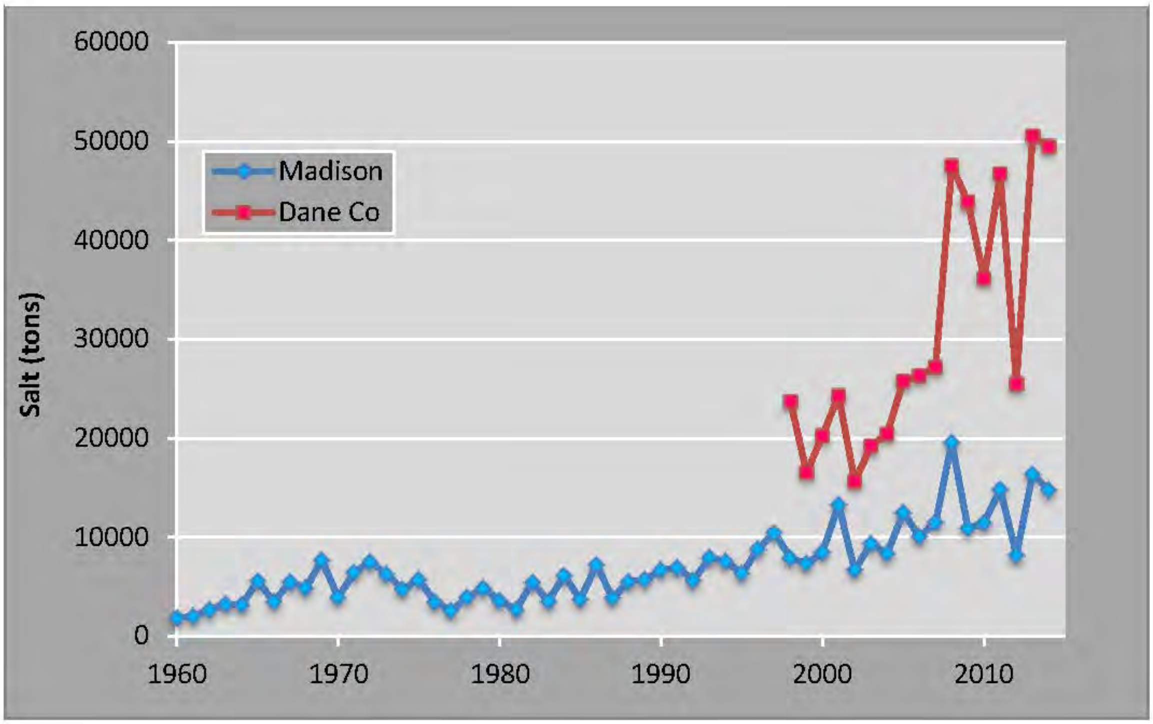
lower aquifer only								
Year	#7	#8	#19	#24	#27	#28	#29	#30
1995	9.0	17.0	4.0	5.0	30.0			
2006	13.4	16.0	5.4	5.1	38.6	2.5	2.6	4.6
2014	15.1	17.6		6.3	37.7	2.9	5.3	5.8

upper and lower aquifers													
#6	#9	#11	#12	#13	#14	#15	#16	#17	#18	#20	#23	#25	#26
23.0	35.0	18.0	1.0	6.0	41.0	22.0	14.0	21.0	7.0	1.0	49.0	1.0	3.0
28.9	33.0	47.3	2.5	8.3	76.8	41.6	34.2	43.9	9.5	2.1	82.0	2.6	11.4
59.2	45.7	57.1	3.5	39.6	116.6	53.6	57.3	34.9	13.2	2.4	71.7	3.6	26.7

Source: Madison and Dane County Public Health 2014 Road Salt Report.

Sodium chloride appears to be the best choice at this time, however, once it is applied road salt cannot be recovered. The only remediation currently available is the dilution and flushing provided by precipitation. So communities must use less to minimize its detrimental effects. Reductions through judicious and efficient application won't be enough, and may have already reached their potential. A shift in maintenance goals from "bare pavement" to "safely passable" is required, and other reduction efforts will be necessary too. Salt application in capture zones around drinking water wells should be restricted. Salt use on parking lots and sidewalks should be substantially reduced. Lastly, and just as important, every community within the Yahara Lakes watershed (as elsewhere) should be engaged in a collaborative, basin-wide salt reduction effort. There is little satisfaction for one community to forego the convenience of bare pavement if upstream communities are not similarly self-constrained.

Figure 27. Annual Road Salt Use: Madison and Dane County.

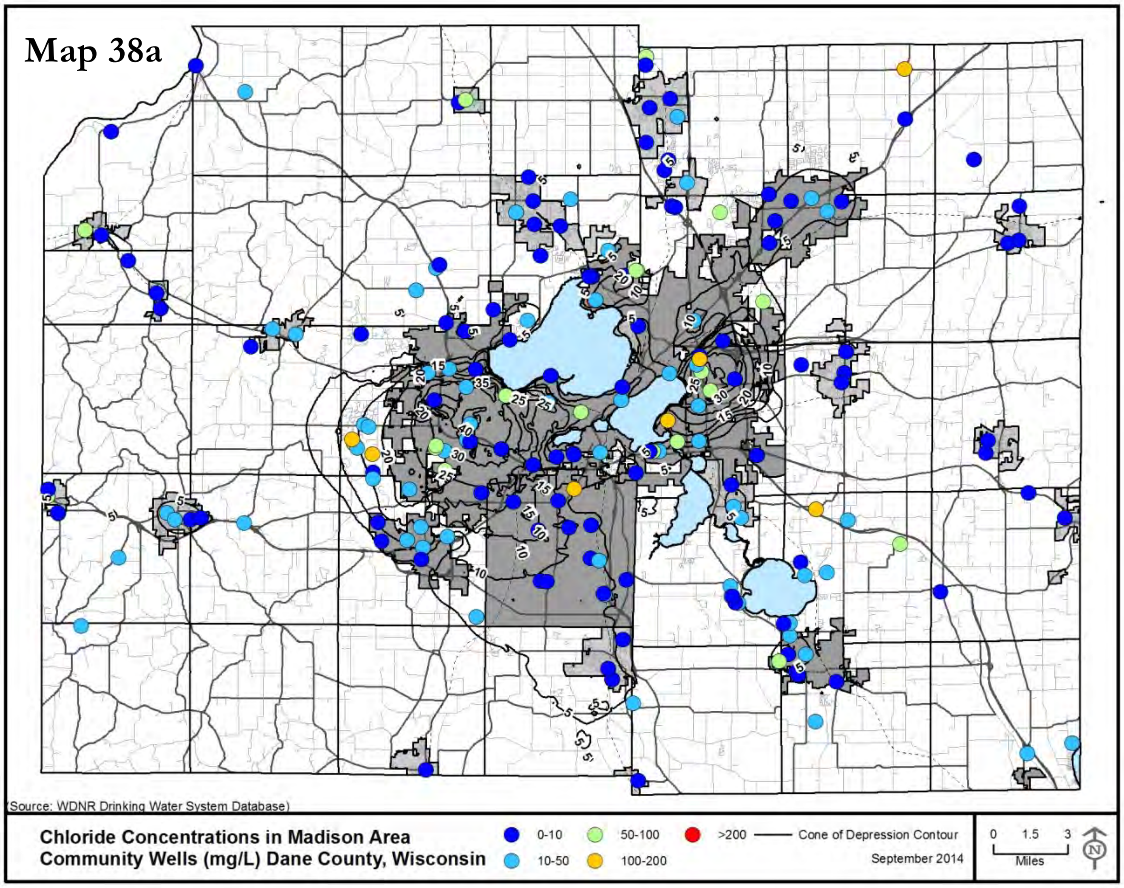


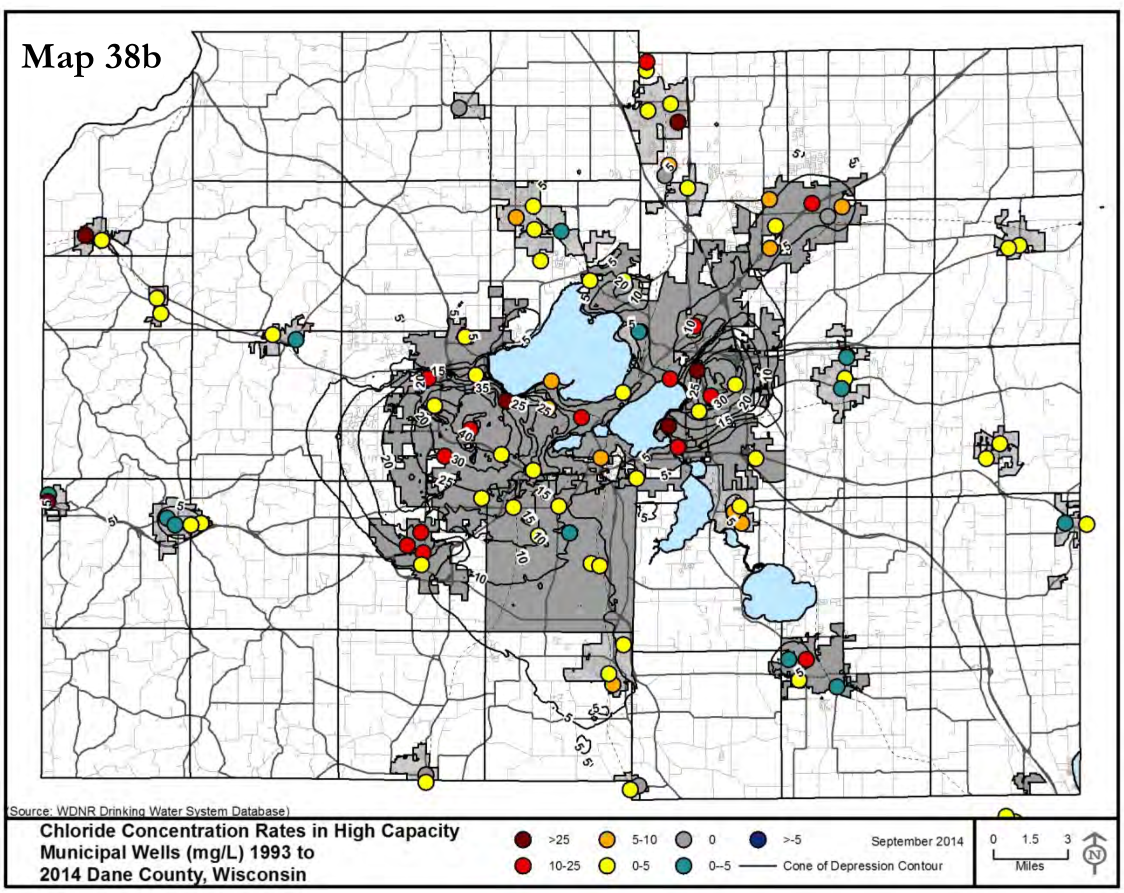
Source: Public Health Madison and Dane County Road 2014 Salt Report.

Forty years ago, Madison had the foresight to recognize the fate and effects of wholesale road salt application. Since then, a commendable effort has been made to maintaining a balance between safe roadways and judicious deicing. However, steadily increasing chloride levels indicate more reductions are necessary in this as well as in other communities. Homeowners can also assist in reducing the amount of salt in our ground and surface waters:

- Keep walkways shoveled as snow quickly becomes ice when walked upon
- Pre-treat walkways before the storm, less deicer will be need in the long run
- Mix sand with salt to gain additional traction
- Consider not using a water softener
- Use a portable exchange-type softener, which contains a replaceable cartridge and does not release used brine into the wastewater stream
- Place self-regenerating softeners "On-Demand" to regenerate itself as needed and not automatically on a timer
- Set water softener for the correct water hardness level, many are installed at the highest setting

The Wisconsin Salt Wise Partnership provides useful information for reducing salt usage across the spectrum of public and private groups https://www.wisaltwise.com/


Map 38a
(Source: WDNR Drinking Water System Database)
Chloride Concentrations in Madison Area Community Wells (mg/L) Dane County, Wisconsin
0-10
10-50
50-100
100-200
>200
Cone of Depression Contour
September 2014
0 1.5 3
Miles
N

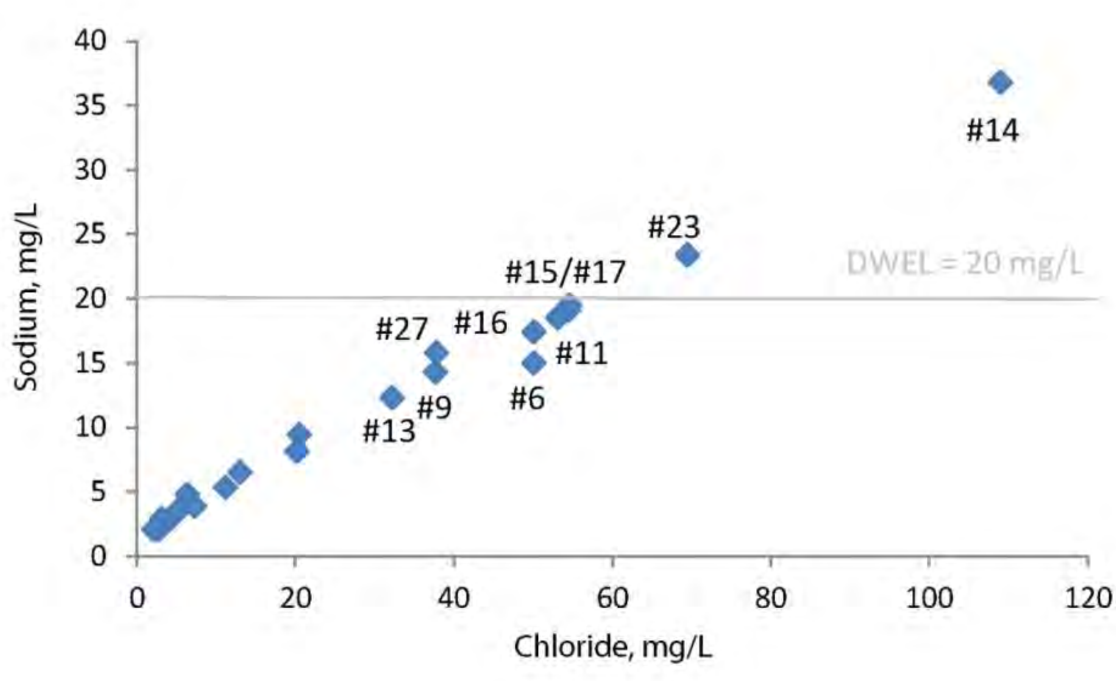

Map 38b
(Source: WDNR Drinking Water System Database)
Chloride Concentration Rates in High Capacity Municipal Wells (mg/L) 1993 to 2014 Dane County, Wisconsin
>25
10-25
5-10
0-5
0
0--5
>-5
Cone of Depression Contour
September 2014
0 1.5 3
Miles
N

Sodium

Sodium is the sixth most abundant element on earth and is widely distributed in soils, plants, water, and foods. It is essential to human life. When salt such as sodium chloride dissolves in water it breaks up into positively- and negatively-charge sodium and chloride ions, respectively. Every water supply contains some sodium and chloride from the natural weathering of rocks and soils. The total concentration of sodium in groundwater is dependent on the local geologic conditions as well as contamination from other sources. Salt used in de-icing can elevate sodium concentrations in groundwater and drinking water supplies. Domestic water softeners can also contribute additional sodium to household drinking water by replacing the calcium and magnesium that make the water hard.

The U.S. EPA recommends that sodium concentrations in drinking water not exceed 20 mg/L for higher-risk individuals on low-sodium diets.[66] This is the same level recommended by the American Heart Association. A diet high in sodium has been identified as a risk factor and in health complications due to high blood pressure. Currently, the EPA requires that all public water systems monitor sodium levels and report levels greater than 20 mg/L to local health authorities so that physicians treating people on sodium-restricted diets can advise patients accordingly. A review of City of Madison wells found wells #14 and #23 have sodium levels in excess of 20 mg/L (**Figure 28)**, as do other wells around the county (**Maps 39a and b**).

Figure 28. Sodium and Chloride Levels at Madison Municipal Wells

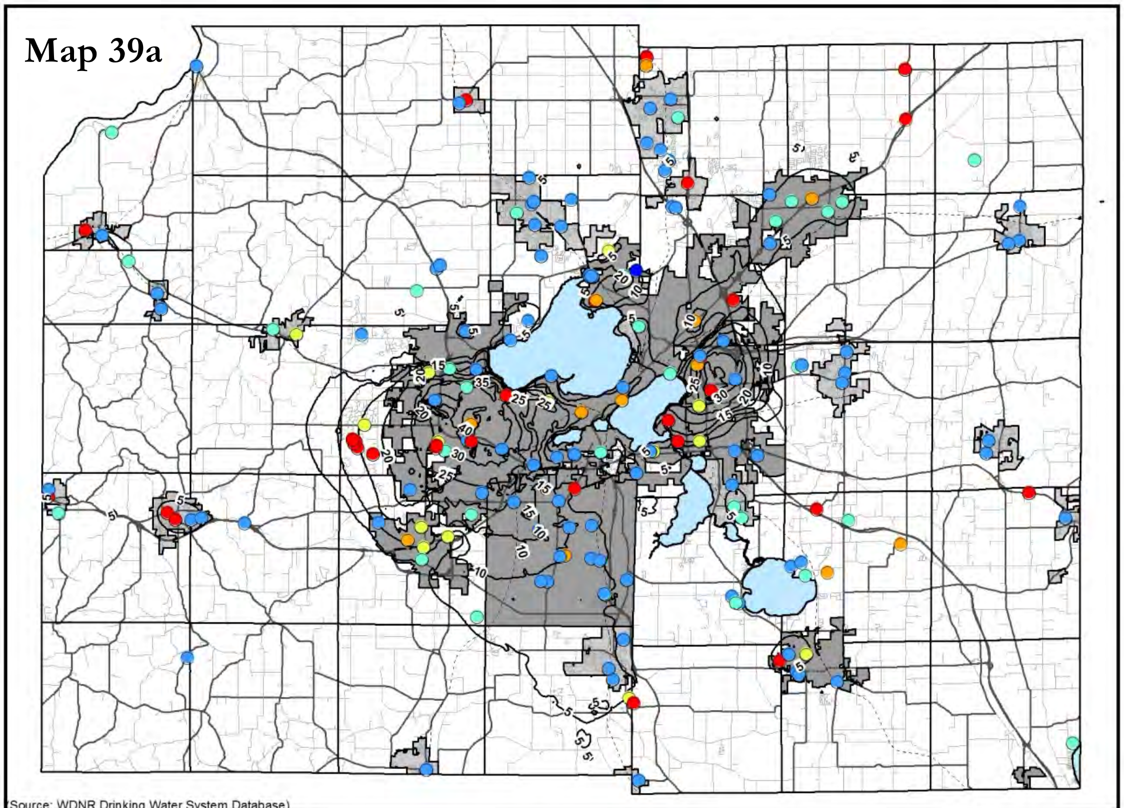


[66] The Drinking Water Equivalent Level (DWEL) for sodium of 20 mg/L is a lifetime exposure level at which adverse, non-carcinogenic health effects would not be expected to occur.

It should be noted that this is a very stringent level. For comparison purposes, regular milk has a sodium concentration of approximately 500 mg/L. A review of scientific data from U.S. EPA shows that the vast majority of sodium ingestion is from food rather than drinking water. Sodium levels in drinking water from most public water systems are unlikely to be a significant contributor to adverse health effects. Drinking water contributes only a small fraction to a person's overall sodium intake. When considering the health importance of sodium, EPA assumed that water users consume two liters of water per day and found that 10 percent or less of a person's daily sodium intake comes from drinking water. The rest is usually from food. While persons on a sodium-restricted diet should evaluate all sources of sodium when attempting to reduce their sodium intake, it is often much easier (and less expensive) to make a dietary change than to purify drinking water.

Several years ago the water conditioning industry was pleased to announce the advent of sodium free salt – potassium chloride. Potassium salt works in the same way as sodium salt in the ion exchange softener, but instead of exchanging the hardness minerals for sodium it exchanges them for potassium. Not only does this new product contain no sodium but in fact contains a mineral which is useful and beneficial to the body, potassium. The drainage from softeners using potassium salt during regeneration is also more environmentally friendly than sodium because potassium is an important plant nutrient.

Map 39a



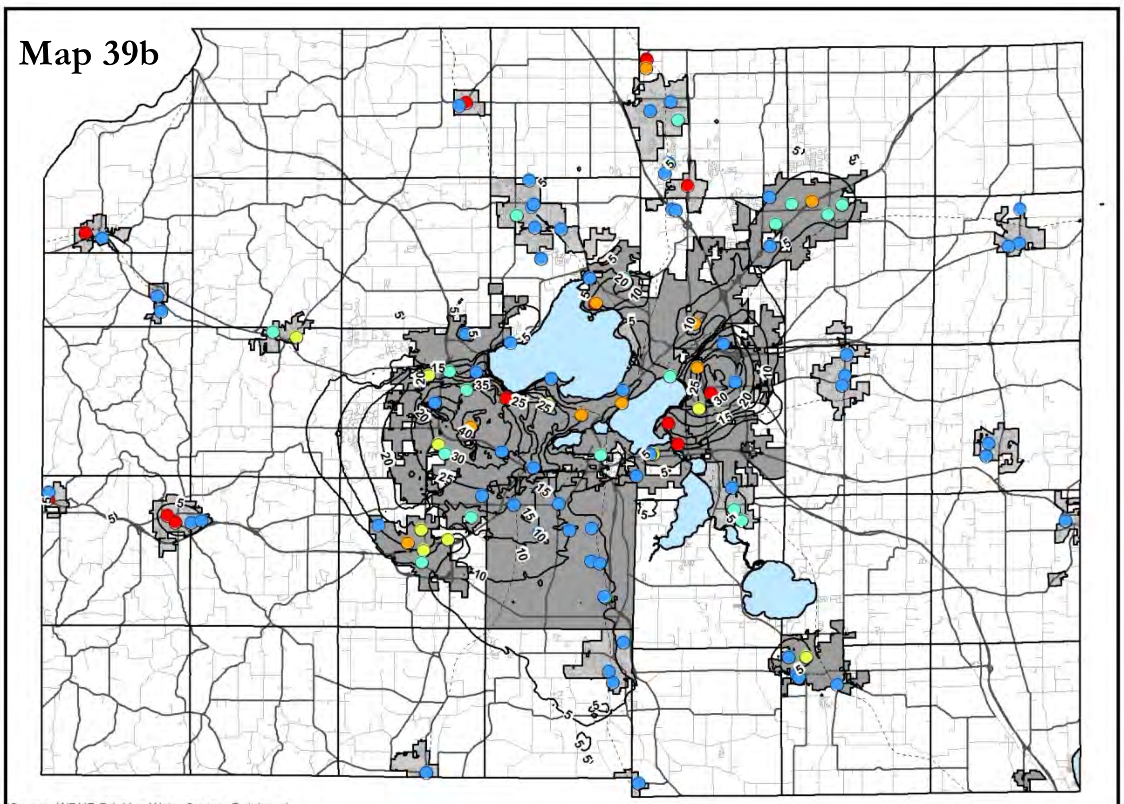
Sodium Concentration in Madison Area Community Wells (mg/L) Dane County, Wisconsin

0-1 | 1-5 | 5-10 | 10-15 | 15-20 | >20 | Cone of Depression Contour

September 2014

0 1.5 3 Miles

Map 39b



Sodium Concentration Rates in High Capacity Municipal Wells (mg/L) 1993 to 2014 Dane County, Wisconsin

0-1 | 1-5 | 5-10 | 10-15 | 15-20 | >20 | Cone of Depression Contour

September 2014

0 1.5 3 Miles

Iron and Manganese

Iron and manganese are common elements found in minerals, rocks, and soil. Iron is one of the earth's most plentiful resources, making up at least five percent of the earth's crust. When rainfall seeps through the soil, the iron in the earth's surface dissolves, causing it to seep into almost every natural water supply, including well water. While present in drinking water, iron is seldom greater than 10 mg/L. Iron is not considered hazardous to health. In fact, iron is essential for good health because it transports oxygen in our blood. In the United States, most tap water supplies less than 5 percent of the dietary requirement for iron.

Under WDNR drinking water standards (NR 809.60), iron is considered a secondary or "aesthetic" contaminant. The recommended limit for iron in water is 0.3 mg/L, based on taste and appearance rather than on any detrimental health effect. Concentrations of iron as low as 0.3 mg/L can cause water to turn a reddish brown color and leave stains on plumbing fixtures, tableware, and laundry that are very hard to remove. The water may also have a metallic taste and an offensive odor. Water system piping and fixtures can also become restricted or clogged with iron bacteria.

Manganese is another common element found in drinking water. It is also part of a healthy diet, but can be harmful if consumed in excess. The U.S. EPA has established a drinking water health advisory for manganese of 300 μg/L. Many years of exposure to high levels of manganese can cause harm to the nervous system. A disorder similar to Parkinson's disease can result. This type of effect is most likely to occur in the elderly. The federal health advisory for manganese is intended to protect against this effect.

Manganese is also a concern for infants and young children, especially for bottle-fed infants. Certain baby formulas contain manganese as a nutrient, and if prepared with water that also contains manganese, the infant may get a higher dose than the rest of the family. In addition, young children appear to absorb more but excrete less manganese than older age groups. This adds up to a greater potential for exposure in the very young. Some studies suggest that early childhood and prenatal exposures to manganese can have effects on learning and behavior. Thus, it is very important to know what the manganese levels in drinking water are when using it to make baby formula.

Otherwise, manganese is found in small amounts in meat and vegetables. A normal diet provides 2000 to 5000 μg manganese per day. Mineral supplements may contain as much as 5000 μg of manganese. As a comparison, drinking 8 cups of water at 300 μg/L would contribute 600 μg manganese – about a quarter of one's diet.

While manganese levels are not regulated in public water supplies, the U.S. EPA and WDNR have established an aesthetic water quality standard of 50 μg/L. Manganese levels below 50 μg/L should prevent the staining of bathroom fixtures and laundry. This standard is considerably lower than the health advisory established to protect public health.

Accumulation and later re-suspension of iron and manganese sediment in water mains is the primary cause of discolored water at the tap. Periodic flushing of hydrants helps remove the accumulated sediment where it is a problem; however, the groundwater source continually introduces new iron and manganese into the distribution system building the levels up again.

In Madison, monthly samples are collected at wells that consistently have iron and manganese above 0.15 mg/L and 20 μg/L, respectively. Four wells produce water with iron ranging from 0.15 to 0.25 mg/L, while two exceed the secondary drinking water standard of 0.3 mg/L, see **Table 19.** Eight wells have manganese levels above 20 μg/L but below the secondary standard of 50 μg/L. Due to aesthetic concerns by residents, such as staining of laundry or unpleasant taste, the Madison water utility is planning to add treatment at four wells to remove the iron and manganese from the source water.

Table 19. Summary Statistics for Wells with Higher Levels of Iron and Manganese

Well	Samples	Manganese (µg/L)		Iron (mg/L)	
		Mean	St Dev	Mean	St Dev
7	11	27	0.7	0.37	0.02
8*	3	45	8.0	0.52	0.13
17*	7	34	6.2	0.13	0.04
19	11	44	3.6	0.19	0.01
23*	7	34	25	0.10	0.12
24	8	27	3.4	0.17	0.04
27*	5	31	1.2	0.14	0.02
28*	7	21	1.9	0.18	0.01
30	11	14	0.5	0.20	0.01

* Seasonal well, typically operating between April and September

Private Water Supplies

Shallow private wells are typically more susceptible to contamination than deep municipal wells. Also, unlike public water supplies, private wells are largely unregulated when it comes to regular or routine water quality monitoring. Private well owners are therefore responsible for the monitoring and safety of their own water supplies. Several factors can affect a well's vulnerability to contamination. These include:

Well location Contaminated wells are often located near farm fields, barnyards, feedlots, septic tanks, or industrial facilities.

Well casing depth and construction Since contaminants can enter the aquifer from the ground surface, wells that have shallow casing are more likely to be affected than deeper cased wells.

Soil type or geology Areas with thin, highly porous or sandy soils, and have shallow groundwater aquifers or fractured bedrock (karst topography), are most vulnerable to contamination. Alternatively, loamy soils can help absorb and significantly slow down the movement of some contaminants (like pesticides) but not others (like nitrates).

While construction codes and standards exist for the proper location, installation, and initial testing of private wells, this does not necessarily guarantee protection from the effect of surrounding land uses and practices, especially in an area with as productive of an agricultural industry as is found here. Since the situation and circumstances surrounding each well are different, it is usually a good idea for rural landowners to periodically test their wells.

Nitrates and Pesticides

A nitrate test is recommended for all newly constructed private wells and wells that have not been tested during the past 5 years. Testing is also recommended for well water used by pregnant women and is essential for a well that serves infants under 6 months of age. Wells with nitrate concentrations between 5 and 10 mg/L should be tested annually. Additional testing may also be useful if there are any known sources of nitrate or if high nitrate concentrations are found in neighboring wells.

Private well owners should also have their well tested if the suspect pesticide contamination. Wells contaminated with high nitrate levels are also more likely to be contaminated with agricultural pesticides. Owners whose wells have pesticides above the MCL should contact the regional office of WDNR for assistance. In most cases owners will be advised to replace the well with a new, safe water supply. Depending on the specific pesticide and the amount of contamination, the well owner may be able to purchase a home treatment system.

VOCs

All wells located near a source of VOCs, such as a landfill, airport, industrial site, or service station, should be tested periodically. If well owners notice a solvent-like or gasoline taste or odor in their water, they should use an alternate, safe source until it can be tested for VOCs. Owners whose wells have VOCs above health advisory levels should contact the WDNR for assistance. In most cases, they will be advised to replace the well with a new, safe water supply. Sometimes, a temporary solution can be used. These typically involve the use of bottled water, connecting to a neighboring well, or installing a home treatment system.

The most important action citizens can take is to prevent contamination. Pouring dirty or spent solvents or paint thinners onto the ground does not really get rid of them – they pollute the air and can contaminate drinking water supplies.

For people using private wells:

- Have your well system professionally inspected and water sampled annually (this is relatively inexpensive health insurance for you and your family)
- Identify and remove possible contamination sources away from your wellhead
- Be current on the cleaning and inspection of your septic system
- Properly decommission any abandoned wells using a licensed professional
- Never flush solvents into a septic system. This actually releases them directly into the ground

For those on public wells:

- Be informed about your Public Water Supply and regularly read its Consumer Confidence Reports
- Dispose of solvents properly. Waste VOCs should be taken to a hazardous waste collection facility

Things everyone can do:

- Use hazardous household substances and solvents according to manufacturer's recommendation and dispose of them properly after use

- Participate in "Clean Sweep" hazardous waste collection/exchanges in your community.[67]
- Report spills immediately
- Use less toxic alternatives like borax, ammonia, vinegar, and baking soda whenever possible
- Install water-saving devices
- Modify water use to conserve water

Bacteria

The Wisconsin Department of Health and Family Services recommends that all wells be sampled for bacteria at least once a year, or whenever there is any change in the taste, odor, or appearance of the water. Even if none of these factors are present, activities or circumstances that put well water at risk cannot always be seen by well owners. The best times of the year to test well water are when it is most likely to be unsafe. Statistically these times occur following a period of heavy snowmelt in early spring or during the hot stagnant time of late summer and early fall. If the water is found to be unsafe then the area surrounding the well should be checked for possible sources of contamination including animal yards, septic systems, sewers, improperly abandoned wells, landfills, sinkholes, quarries, bedrock outcroppings, etc.

Public Water Supplies

Public water supplies in Dane County are regularly sampled and tested by local municipalities and the WDNR to ensure compliance with federal and state drinking water regulations. The quality is generally quite high and safe for use. A listing of recent water analyses for Dane County municipal supply systems is provided in **Attachment A**. Passed in 1974, the Safe Drinking Water Act requires any water system serving 25 or more people to regularly test its water and comply with contamination limits. Since then, the number of contaminants regulated by the Act has grown from 13 to 87 primary contaminants, plus 15 secondary (aesthetic) substances.

Beginning in 1999, customers of all public water systems receive an annual Consumer Confidence Report from their water supplier. The report is mandated by the federal Safe Drinking Water Act and Environmental Protection Agency Rules. The annual water quality report includes information about the source of the drinking water supply, a list of any contaminants detected in the water and their concentrations, the potential sources and health effects of contaminants, and special health effects language for immuno-compromised individuals or other sensitive subpopulations if appropriate. The objective of the report is to provide consumers with clear, concise and accurate information about the quality of their drinking water in a readable, easily understandable format.

The recent analyses indicate that most water quality parameters are within federal safe drinking water standards (Ch. NR 809). Some municipal wells, though, have total residue, iron and manganese concentrations above secondary drinking water standards (representing objectionable water quality, such as taste or odor, rather than public health risks). The concentration of these constituents is often reduced by chemical or physical treatment. In more extreme cases, such as contamination by VOCs, wells have been abandoned and new wells drilled.

A water source exceeding a primary MCL may not serve a public water system until treatment is provided which brings the concentration below the MCL prior to entering the distribution system. Under the Consumer Confidence Report Rule, contaminants must be reported if detected at any level, but health effects information must be provided only if the level exceeds the MCL. It should

[67] http://www.danecountycleansweep.com/

be noted that drinking water contaminants are not necessarily related to the water source. Most drinking water samples are taken at customers' taps and could contain substances that contaminate the water in the distribution system or in the home. Several communities in Dane County, for example, have experienced elevated levels of copper and lead in drinking water and have taken measures to reduce concentrations of these metals. Lead and copper are not found in the groundwater in Dane County. Rather, high concentrations in tap water are the result of corrosion in lead and copper pipes and fixtures in water service lines and home plumbing systems.

Groundwater Contamination Risk Maps

Because residents of the county rely so heavily on groundwater, preventing contamination from occurring is the easiest and most efficient way of maintaining a clean and usable groundwater supply. Once groundwater becomes contaminated it is sometimes physically impossible or technically unfeasible to clean it up. Groundwater remediation costs are also very expensive. Therefore, prevention of groundwater contamination is essential. One way to do this is to identify those areas where the groundwater is most vulnerable to contamination.

Aquifer Vulnerability

As part of the Dane County Hydrologic Study, Fritz (1996) constructed and tested an aquifer contamination susceptibility Map for Dane County. This Map rates the relative risk (extreme, high, moderate, low) of groundwater aquifers to contamination from surface pollution sources (**Map 40**). The Map represents a combined overlay of the effects of soil properties, the hydrogeologic setting, and the distribution of groundwater recharge and discharge areas, described in **Attachment B**. By removing the attenuating soil layer, using this same methodology, a groundwater contamination risk Map from subsurface pollution sources was also created (**Map 41**).

By removing the soil layer, as was done in creating the subsurface map, all of the low, many of the moderate, while only a few of the high risk areas shift to the next lower risk classification (see **Table B-4 in Attachment B**). This shifts some areas with fair or good soils to the next lower susceptibility classification, emphasizing the importance of soil attenuation for reducing pollutants.

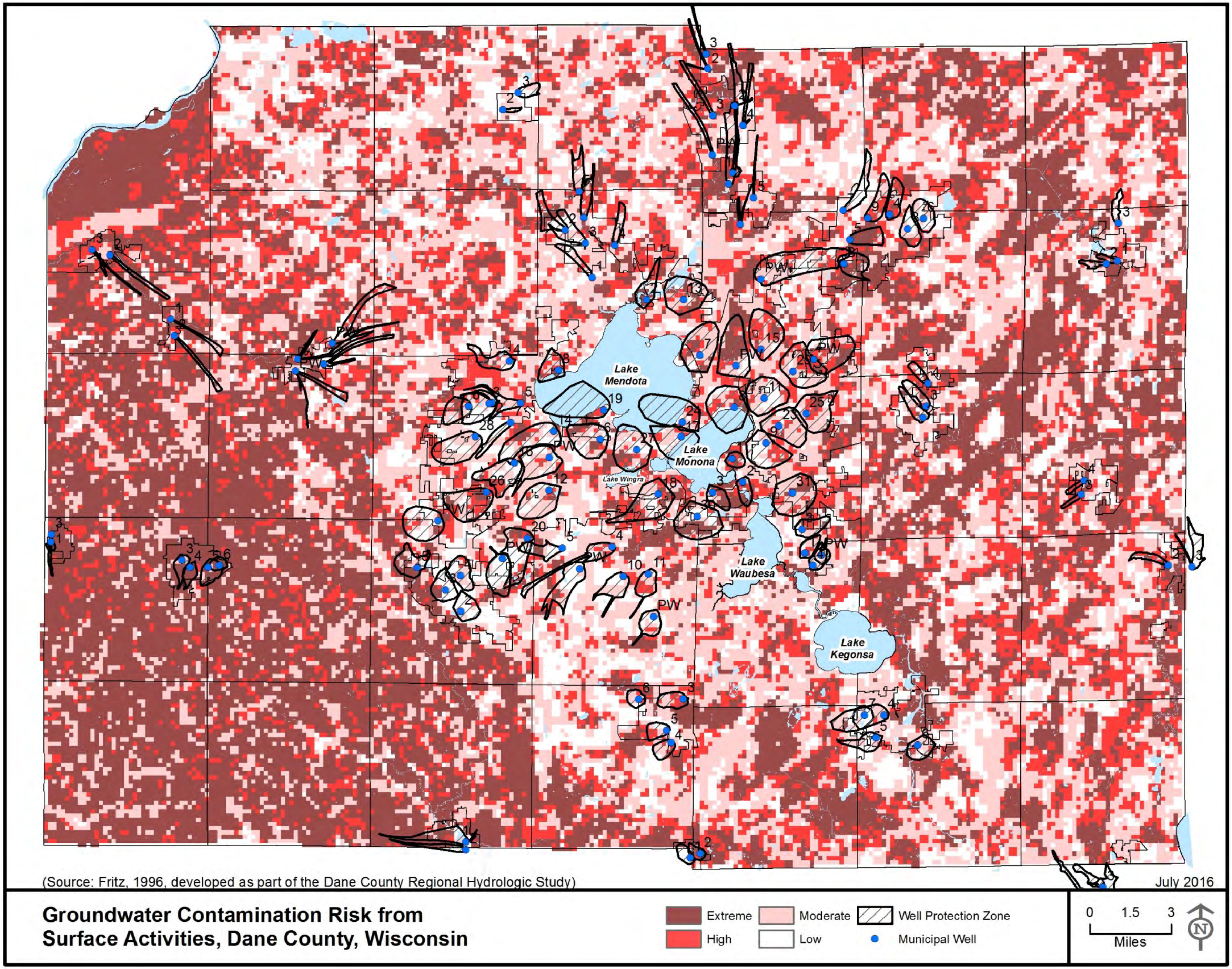
There are four final risk classifications shown on the maps: extreme; high; moderate; and low. Areas considered to be of extreme risk to contamination are areas of shallow bedrock or shallow groundwater, such as in the Driftless Area and the Wisconsin River Valley in the western part of the county, and the alluvial valleys in the eastern part of Dane County. Areas considered to be of low or moderate risk are located throughout the glaciated portion of Dane County, along the hummocky moraine zone and the Yahara lowlands.

Because of attribute variability within a single cell (one cell is 62,500 m^2—15.44 acres), it is recommended that the maps be used at the township level or larger. At this level, differences in topography and meaningful differences between risk classifications can be distinguished. Areas within 250 meters of the county boundary are likely to contain cells with no data; consequently, there is no risk classification for these areas.

Groundwater Contamination Risk Maps are also very useful for cities, villages and towns to assess the threat of groundwater contamination posed by an actual contaminant source, such as a pesticide mixing area or leaking underground storage tanks. Suggested guidelines and criteria for using the Surface and Subsurface Groundwater Contamination Risk Maps are shown in **Table 20 and** presented in **Chapter 5.**

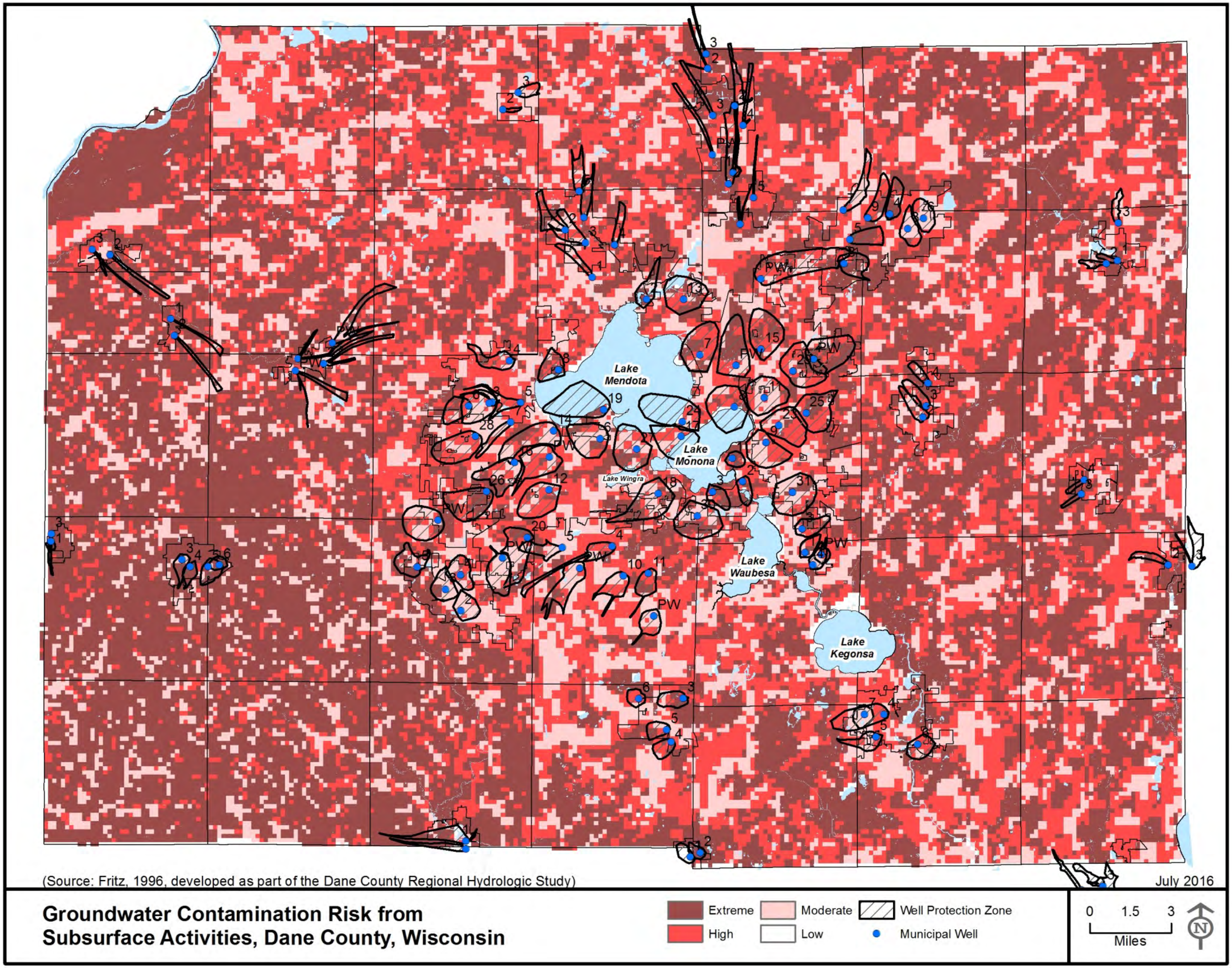
The Groundwater Contamination Risk Maps, together with the individual data layers, can be used as a screening tool for land and water planning and decision making, and for informing the public about the attributes of the environment that can protect groundwater.

Map 40



Lake Mendota
Lake Monona
Lake Wingra
Lake Waubesa
Lake Kegonsa
(Source: Fritz, 1996, developed as part of the Dane County Regional Hydrologic Study)
July 2016
Groundwater Contamination Risk from Surface Activities, Dane County, Wisconsin
Extreme
High
Moderate
Low
Well Protection Zone
Municipal Well
0 1.5 3
Miles
N

Map 41



Groundwater Contamination Risk from Subsurface Activities, Dane County, Wisconsin

Wellhead Protection

The Zone of Contribution (ZOC) of a well is the land surface area over which recharging precipitation enters a groundwater system and eventually flows to the well (**Fig. 29**). The ZOC is distinctly different from the zone of influence (ZOI) of a well, which is the area within the cone of depression created by the withdrawal of water from the well.

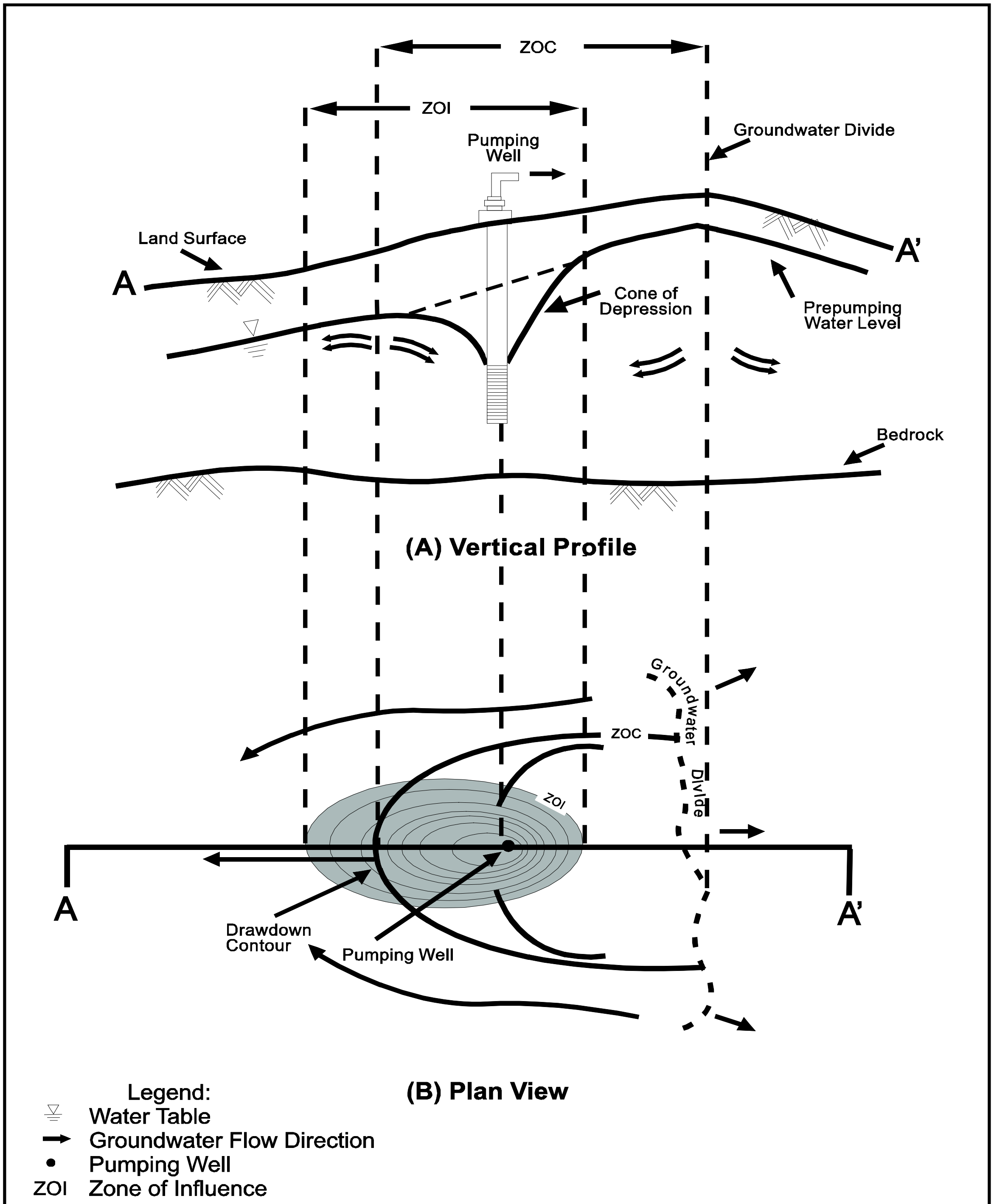
Delineating ZOCs for municipal wells is a critical step in establishing wellhead protection areas for the wells. A wellhead protection area (WHPA) is defined by the federal Safe Drinking Water Act as the "surface and subsurface area surrounding a water well or well field, supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water or well field." In practical terms, the ZOC is a technically defined area based on groundwater hydraulics, while the WHPA is a legally defined area including all or part of the ZOC within which management practices or land-use controls can be implemented to help protect groundwater from contamination.

The Wisconsin Department of Natural Resources (WDNR) has the responsibility and authority to delineate wellhead protection areas for all public water supplies in Wisconsin. In 1992, the WDNR prepared the Wisconsin Wellhead Protection Program Plan, which required WDNR to perform initial ZOC delineations for all existing municipal wells in the state. At the same time, the Wisconsin Administrative Code, Ch. NR 811, was revised to require that a wellhead protection plan be submitted for each new municipal well constructed after April 1, 1992.

The technical methodologies for ZOC delineation range from simple to complex, and are described in a number of publications.[68] Most of these authors suggest simple techniques, such as the fixed-radius methods, as a first approach, but most also recommend the use of numerical groundwater flow models as more sophisticated and reliable methods for ZOC delineation. The Dane County Groundwater Flow Model is ideally suited for delineating ZOCs for high-capacity wells. As such, Bradbury (1998) used the model to delineate ZOCs for high capacity municipal wells throughout Dane County. These maps were subsequently revised using the updated groundwater model in 2014.

[68] U.S. EPA 1997, Born 1998, Bradbury 1991, Kreitler 1991, and Muldoon 1993, among others identified in Bradbury, K. 1998. *Zones of Contribution for Municipal Wells in Dane County, Wisconsin: Results of Delineations from the 1997 Regional Hydrologic Modeling and Management Program.*

Figure 29.
Diagram and Terminology for Wellhead Protection in a Simple Hypothetical Groundwater Flow System.



Source: U.S. EPA, 1987.

Delineation of ZOCs

One of the primary goals of the Regional Hydrologic Modeling and Management Program in 1997 was to delineate zones of contribution (ZOCs) as the basis for each municipality's wellhead protection strategy.[69] Various pumping rates and travel times were modeled as the basis for delineating ZOCs, offering each community a range of protection alternatives. Alternative ZOCs were delineated based on 5-, 50- and 100-year travel times for each of three different pumping rates:

1. 2020 Pumping – projected 2020 average daily water use distributed evenly among existing and future wells for each community;
2. Maximum Sustained Pumping – 50 percent of the pumping capacity for both existing and proposed new wells; and
3. Maximum Pumping Limit – full capacity pumping, indicating the worst-case scenario for individual wells under extreme water demand conditions. (It is unlikely that this could actually occur under sustained conditions, so it represents an extreme assumption.)

In 2014 the 5-, 50-, and 100-year ZOCs for both existing and planned wells were delineated using the upgraded groundwater model and average 2040 pumping rates (**Map 42**). The ZOCs indicate the area contributing groundwater to the well for an assumed pumping rate and travel time. These ZOCs can be used as a basis for delineating wellhead protection areas or zones which are used to evaluate or regulate land use or waste disposal activities which could have an adverse impact on the well.

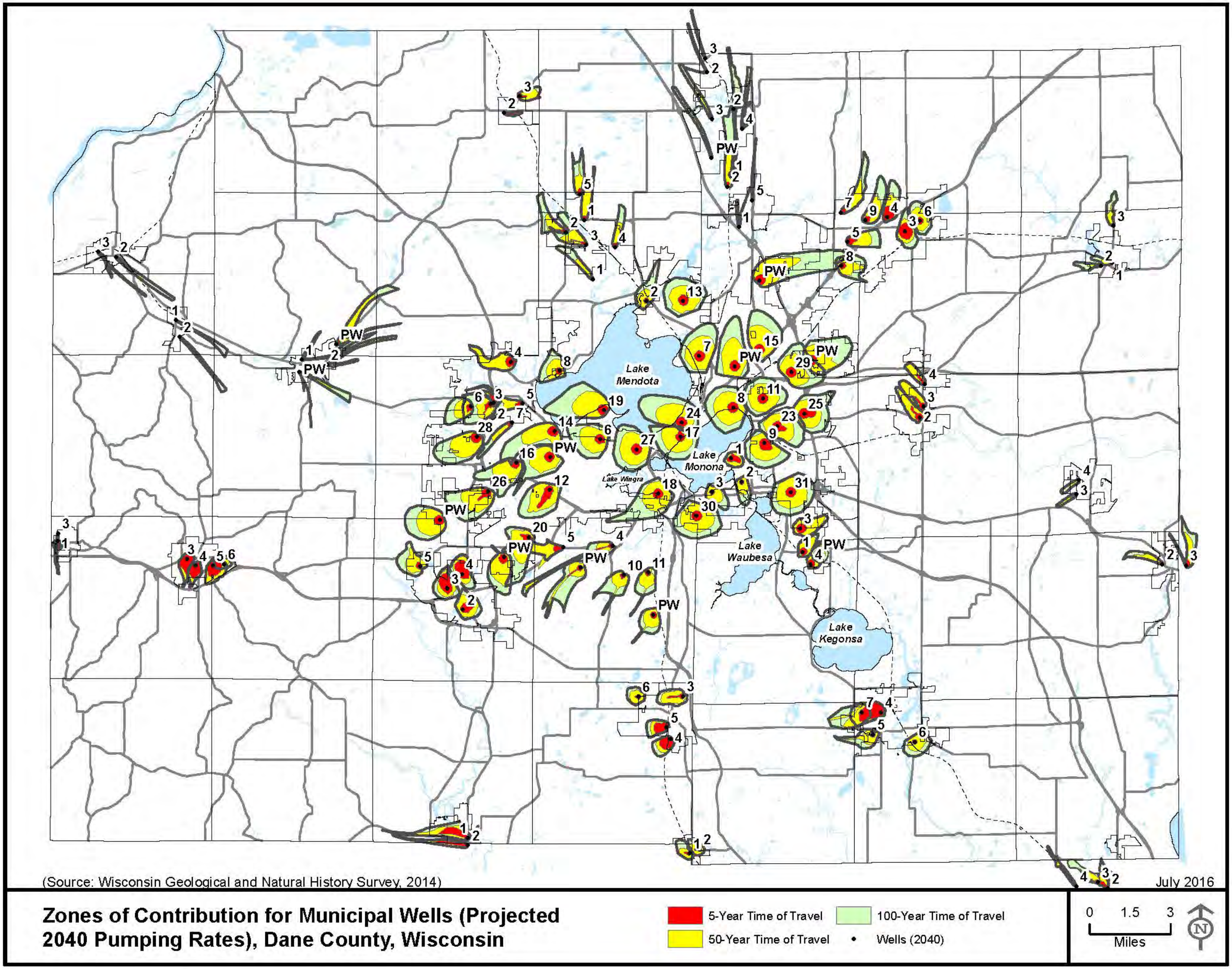
Accuracy of the ZOC Delineations

The accuracy of the locations of the ZOCs depends on the accuracy of the groundwater flow model and of the field data and data interpretations used to construct it. The MODFLOW and PATH3D codes themselves are mathematically very precise, and numerical errors associated with these codes are probably insignificant. However, the calibration of the groundwater flow model (the "fit" of the model to observed field data) is not perfect, although it is considered good from a groundwater modeling standpoint. In general, the model results are probably most precise in areas where hydrogeologic data are abundant, such as in the Madison metropolitan area. The model is less accurate in areas where hydrogeologic data are sparse, such as in western Dane County, where very few deep wells exist.

Also, all ZOCs assume steady-state conditions, meaning that groundwater levels and recharge rates do not change over short time periods. In areas where this assumption is not met the ZOCs may differ slightly from those shown here.

[69] Bradbury, K. 1998. *Zones of Contribution for Municipal Wells in Dane County, Wisconsin: Results of Delineations from the 1997 Regional Hydrologic Modeling and Management Program.*

Map 42



Zones of Contribution for Municipal Wells (Projected 2040 Pumping Rates), Dane County, Wisconsin

In two municipalities, the Village of Brooklyn and City of Verona, the potential for error in the ZOC delineations is larger than in other areas. In both these municipalities the wells are located on or very near the regional groundwater divide between the Yahara River basin and the Sugar River basin. At these locations, the position of the divide is critical in controlling the direction of groundwater flow and thus the configuration of the zones of contribution. Field data in these areas are too sparse to allow a precise delineation of the position of the divide or to confirm the groundwater flow model. Therefore, the ZOCs for wells in these municipalities, while consistent with the groundwater flow model, are currently unconfirmed by field data, and should be used with caution. There is significant interference between wells, particularly in the Madison metropolitan area, that results in complex ZOCs. Simpler ZOC delineation methods, such as the fixed-radius techniques or even simple two-dimensional numerical models would fail to capture these interference effects and so would probably give inaccurate ZOC estimates. Even the more accurate ZOCs that have been developed could be substantially altered by removing a single interfering well from service.

Well Protection Zones

Previously developed well protection zones, delineated in the 1999 Dane County *Groundwater Protection Plan* as areas of special concern, were originally used to identify land areas where contaminants could potentially migrate to a municipal well. The zones were generalized and based on simplifying assumptions. They were used primarily as a screening device to evaluate the pollution risk from potentially harmful waste disposal or land use practices.

The modeled ZOCs are more precise and accurate than the previously developed (1999) well protection zones, which completely encompass the modeled 100-year travel time ZOCs for each municipality. However, the modeled ZOCs are still based on somewhat generalized assumptions, which do not reflect local variability in climatic and geologic conditions, seasonal variations or variations in pumping patterns or rates at nearby wells. It may be prudent, therefore, to define wellhead protection zones or areas which are larger than the modeled ZOCs to reflect and include the effects of uncertainties and local and seasonal variations.

WDNR requires wellhead protection plans for all new wells constructed after 1992, but requires only a 5-year time of travel. For most Dane County wells, the 5-year ZOC—typically less than 1,000 feet across—is probably too small to offer much protection. At the other end of the scale, the ZOC based on the maximum well pumping capacity is probably too severe an assumption, as this condition is unlikely to occur over a sustained period of time. The 50- and 100-year ZOCs—generally several thousand feet to a mile in length—probably represent more appropriate areas for groundwater protection efforts.

Well Protection Zones (**indicated on Maps 43 through 52**) were delineated for both existing and planned municipal wells throughout Dane County using the length of the ZOC for the 100-year, 2040 pumping rate. Well Protection Zones can thus serve as a useful technical basis for a community's wellhead protection program, or for legally defined Wellhead Protection Areas developed by a community, which may include land use controls, contingency planning or other drinking water safeguards.

Areas of Special Concern

Naturally Vulnerable Areas

The areas classified as Extreme on the Groundwater Contamination Risk Maps represent the most vulnerable areas in the county. Due to a combination of limiting physical factors (e.g., poor attenuating soils, shallow depth to bedrock and high groundwater table), these areas can be expected to provide a minimal amount of pollutant attenuation. Thus, siting of potential pollution sources or practices should be made with extreme caution or, if possible, avoided at these locations. Siting for a particular land use practice may require special conditions or provisions which establish groundwater safeguards, such as stricter maintenance, operating or monitoring requirements than are normally expected.

Potential Problem Areas

Potential problem areas are sites where existing pollution sources are located in vulnerable resource areas or which potentially threaten public drinking water supplies. These areas are a particular concern due to poor environmental attenuation conditions, or location of a nearby well and the existence of a pollution source. Consequently, many of these areas should receive a high priority for careful land use management, facility maintenance, or groundwater quality monitoring. Although these areas are primary concern, inferences should not be made that groundwater is already polluted at these sites.

Potential problem areas can be determined by overlaying pollution source locations with the Surface and Subsurface Groundwater Contamination Risk Maps. This has been done for many of the potential pollution sources in **Chapter 5** of this report.

Local Groundwater Quality Protection

Since groundwater represents the source of all water supplies in Dane County, protection and management of the groundwater resource is a high priority. The discussion of groundwater quality conditions and problems in Chapter 3 indicated that groundwater in Dane County is of generally good quality, but that there have been localized instances of contamination from nearby pollution sources, particularly in the upper or shallow aquifer affecting most individual private water supply wells. Areawide water supply concerns relate primarily to potential increases in nitrates, dissolved salts, and volatile organic compounds, which could affect the deep aquifers, from which most municipal water supplies are drawn.

The basic approach to groundwater protection and management is founded on two major considerations:

1. Siting and Land Use Decisions
    - Locating potential pollution sources in areas which minimize the risk of contaminating groundwater supplies
    - Locating groundwater supply sources in areas where they will be protected from potential pollution sources
2. Employing management practices and programs designed to reduce the risk of groundwater contamination from existing and potential pollution sources.

Siting and Land Use Decisions

Siting and land use decisions based on an evaluation of potential groundwater impacts are the most effective defense against groundwater contamination problems, which may otherwise be irreversible or very costly to remediate. All land use and siting decisions in Dane County should include evaluation of potential groundwater and hydrologic impacts. Applicants for any land use or siting approvals should be required to provide sufficient information so that regulatory agencies can evaluate the potential groundwater and hydrologic impacts of the proposed activity; such as for zoning or subdivision approvals, site or development plans, urban service area additions, and state, federal or local land disturbance or discharge permits. Unaddressed or unmitigated groundwater or hydrologic impacts would provide the basis for withholding approval for the requested activity, or require additional information to be submitted by the applicant before approval is granted. Compliance with state surface and groundwater quality standards should be included in the evaluation along with hydrologic impacts.

The groundwater contamination risk maps have been developed as a tool to assist in initial screening and evaluation of the relative groundwater contamination risk from potential pollution sources. One of the maps indicates the relative contamination risk from subsurface activities such as landfills, underground storage tanks and other pollution sources which are located below the soil zone. The other Map indicates the relative contamination risk from those activities conducted on the land surface, such as pesticide, fertilizer, biosolids and septage application. The guidelines and criteria listed in **Table 20** should be used in conjunction with the groundwater contamination risk maps for preliminary screening and evaluation of proposed impacts, and determination of whether more in-depth evaluation is needed.

Using the Groundwater Contamination Risk Maps

Table 20 suggests guidelines and criteria for using the Surface and Subsurface Groundwater Contamination Risk Maps in setting priories and making groundwater management decisions for various pollution sources. These maps can also be used to establish priorities for monitoring and more detailed investigations, as well as focusing attention on problems or decisions involving greater risk of groundwater contamination. While the contamination risk maps are useful for these purposes, it must be emphasized that the generalized nature of these maps makes them insufficient for important decisions on specific sites, and that more detailed site-specific investigations will often be needed.

Water Supply Protection

Another aspect of groundwater protection and management includes programs and practices designed to ensure that water supplies are protected from potential contamination sources. The groundwater contamination risk maps also indicate well protection zones where pollutants have a greater likelihood of reaching municipal water supplies.

Protecting drinking water supplied by groundwater ultimately comes down to managing land uses and human activities in areas contributing groundwater to existing or planned wells. Protecting these source areas requires a regional approach, in that groundwater flow systems do not recognize local governmental boundaries. The state, under the direction of the federal Safe Drinking Water Act and acting through the WDNR, currently has a program by which local units of government can protect their "wellheads" – areas influencing the groundwater quality of their water supply wells. This program is required for all new high-capacity municipal wells. As indicated earlier, sufficient information and technical capacity exists in Dane County, through the federal, state, and local agencies participating in the Regional Hydrologic Modeling and Management Program, to delineate zones of contribution for wells and wellhead protection areas for special management strategies.

Land use regulatory agencies in Dane County should develop wellhead protection programs to protect municipal water supplies, including adopting more stringent siting and land use regulations for potentially polluting activities in wellhead protection zones. The Capital Area Regional Planning Commission staff can provide review and comment as part of the permitting. Along these line, the guidelines and criteria contained in **Table 20** can provide a basis for these more stringent land use and siting criteria in well protection zones. Practices might also include locating wells away from potential pollution sources, utilizing water from the lower and more protected Mt. Simon sandstone aquifer to reduce the risk and exposure for large resident populations, and employing adequate construction standards to ensure that water supply wells are protected from direct and inadvertent contamination. In addition, proper procedures for sealing and abandoning wells, as well as restrictions on using wells for disposal of waste directly to groundwater are also important management tools.

Information and Education Needs

In some cases, there is a lack of information on potential groundwater contamination problems, and additional monitoring is needed to determine the extent and seriousness of these problems. Problem areas which should receive priority for additional monitoring include monitoring of existing and abandoned landfills in municipal well protection zones; monitoring of agricultural pesticides in groundwater, particularly in areas most susceptible to contamination; and more frequent sampling and testing of shallow private wells for bacterial, nitrate, and pesticide contamination.

An expanded public information and education program on groundwater is also needed. It should be directed at those households most vulnerable to potential groundwater contamination—rural households depending on shallow, individual water supply wells. The information and education program should include guidance on proper siting, construction and (especially) maintenance and servicing of on-site wastewater disposal systems; proper siting, construction and testing needs for wells and water supplies; and information and recommendations on proper use, storage, and disposal of potentially hazardous or toxic materials such as pesticides, cleaning agents, and other potential household hazards or pollutants. Education efforts should emphasize the vulnerability of groundwater to contamination and that once it is contaminated it is very difficult, if not impossible, to restore.

The application of regulations and management practices designed to reduce the risk of groundwater contamination from potential pollution sources are treated separately in the following chapter on groundwater management controls for the major potential sources of groundwater contamination. Programs have been developed to address these areas of groundwater protection, which need to be expanded in some cases. The issue of cumulative impacts of well withdrawals on ground and surface water features and overall sustainability is another area of growing concern.

Table 20: Groundwater Contamination Risk Maps, Guidelines and Criteria

	Pollution Source	Contamination Risk Map to Use	Guidelines and Criteria
1.	Sanitary Landfill	Subsurface	Proposed landfills should be located outside of municipal well protection zones and areas of high or extreme contamination risk, or meet protective design standards. High priority for monitoring active and abandoned landfills should be for those landfills in areas of high or extreme risk in municipal well protection zones.
2.	On-Site Wastewater Systems	Subsurface	The planning of rural subdivisions or developments that include large on-site systems or clusters (more than 20) of on-site systems with an average density of one house per 1-1.5 acres (based on the gross acreage of the development) should include an evaluation to ensure that drinking water supplies are protected. If the evaluation indicates a risk for nitrate levels above 10 mg/L, alternatives such as protected water supplies (well location and depth), utilizing nitrogen-reducing wastewater treatment systems, or community scale water supply and wastewater treatment systems should be explored.
3.	Wastewater Lagoons and Infiltration Ponds	Subsurface	Proposed wastewater lagoons and infiltration areas should be located outside of municipal well protection zones and areas of high or extreme contamination risk, or meet protective design standards. Existing lagoons and ponds in municipal well protection zones should be monitored.
4.	Underground Storage Tanks	Subsurface	Stringent design and periodic testing for corrosion protection and leak containment should be required of all existing and proposed underground tanks storing hazardous or flammable materials within municipal well protection zones and in areas of high or extreme contamination risk outside of well protection zones. Existing tanks in these areas not providing adequate corrosion protection or leak containment should be immediately replaced or properly abandoned.
5.	Above-ground Storage Tanks	Surface	Strict design criteria should be required for spill or leak containment for all above-ground tanks storing hazardous or flammable materials within municipal well protection zones and in areas of extreme contamination risk outside of well protection zones. Existing tanks in these areas without adequate spill or leak containment should be replaced or properly abandoned.
6.	Land Application of Sludge (Biosolids) and Septage	Surface	Application sites should not be located in areas of extreme contamination risk. Sites in areas of high or moderate risk should receive highest priority in enforcement of existing siting guidelines, and should receive increased surveillance to ensure applications adhere to state guidelines and criteria.
7.	Wastewater Irrigation and Landspreading Sites	Surface	Proposed wastewater irrigation and landspreading sites should not be located in areas of extreme contamination risk. Existing and future sites in municipal well protection zones should be monitored and subject to stringent design and operating requirements.
8.	Large Feedlots and Manure Storage Lagoons	Surface	Proposed large feedlots and manure storage lagoons should not be located in areas of high or extreme contamination risk. Strict design criteria and monitoring of storage lagoons should be required for all large lagoons in areas of moderate contamination risk.

Chapter 5: Inventory of Potential Pollution Sources

A wide array of human activities may potentially have an adverse impact on groundwater quality. Examples of such activities include the disposal of municipal and industrial waste, storage of petroleum products, and agricultural practices such as pesticide and fertilizer applications.

Many of the activities and land use practices that can impact groundwater are basic to our way of life; however, adequate safeguards can and should be placed on these practices to minimize detrimental water quality effects. The necessary safeguards may range from minor modifications of existing practices to active regulatory controls and siting requirements.

The key to groundwater protection is prevention, because groundwater pollution is extremely difficult to correct or reverse. Knowing what to emphasize in the prevention of groundwater pollution is important to maximize available financial and human resources. In order to determine this, an inventory of land use trends and potential pollution sources are included as a part of this plan.

Land Use

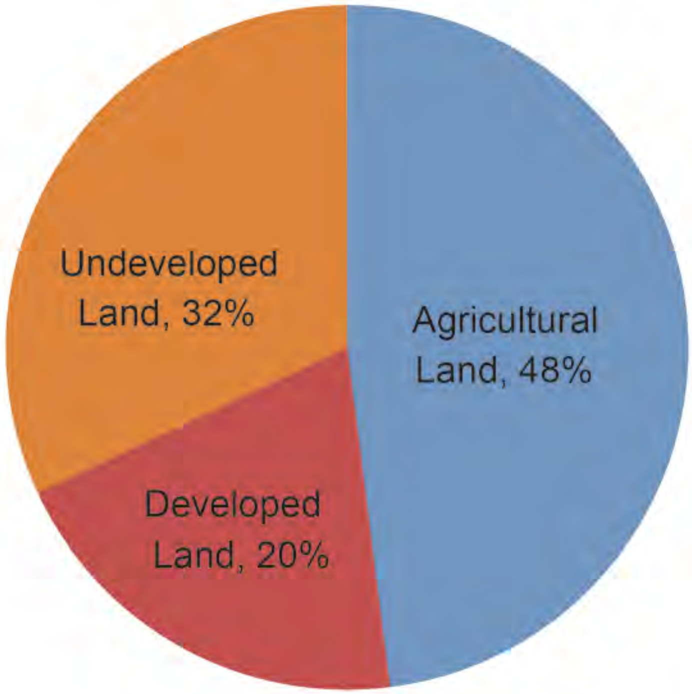
Groundwater quality and consumption can be related to land use patterns. Dense populations in urbanized areas, for example, use large quantities of groundwater, and activities in these areas can pose significant threats to groundwater quality. Such activities include industrial and municipal waste disposal, deicing, storage of petroleum products and other hazardous materials, lawn care, automobile maintenance, etc. In rural areas, less groundwater is used and different threats to groundwater quality exist. Animal waste storage, on-site wastewater disposal, and fertilizer and pesticide applications are the primary potential pollution sources in these areas.

Agriculture is the predominant land use in Dane County (**Map 8 and Figure 30**). In 2010 nearly 50 percent (384,634 acres) of the total area of the county was devoted to crop and pastureland. An additional 32 percent (249,724 acres) was categorized as woodland, water, vacant, or open land). Total developed area in the county comprised about 158,297 acres, or 20 percent of the total area of the county.

Table 21 summarizes land use by category in Dane County, comparing the results of land use inventories conducted from 1990 to 2010. The figures indicate that the total developed area of the county increased by about 25 percent between 2000 and 2010 at a rate of about 3,124 acres per year. This is almost double the rate for growth compared to the decade of 1990 to 2000 when 1,439 acres per year was developed in Dane County. Residential land use grew by 26 percent between 2000 and 2010, an increase of 12,785 acres. Most of this residential land use increase occurred in cities and villages where public sanitary sewers are available. Although some of the development in towns is served by public sanitary sewers, 1,564 single-family dwelling units with on-site wastewater systems were constructed between 2000 and 2010, totaling 21,916 dwelling units. Between 2000 and 2010 the number of on-site systems in cities and villages decreased by 117, totaling 1183 dwelling units (**Table 23**).[70]

[70] Capital Area Regional Planning Commission. 2013. *Private On-Site Wastewater Treatment* Systems Management. Appendix I of the Dane County Water Quality Plan.

Figure 30
Distribution of Land Use in Dane County in 2010



Source: Capital Area Regional Planning Commission

Table 21: Land Use in Dane County: 1990-2010

Land Use	1990			2000			2010		
	acres	% Total	% Dev'd	acres	% Total	% Dev'd	Acres	% Total	% Dev'd
Residential	48,002	6.1%	42.6%	49,194	6.2%	38.7%	61,979	7.8%	39.2%
Industrial	5,190	0.7%	4.6%	7,362	0.9%	5.8%	7,054	0.9%	4.5%
Transportation	37,418	4.8%	33.2%	43,842	5.5%	34.5%	47,286	6.0%	29.9%
Communication/ Utilities	1,515	0.2%	1.3%	1,778	0.2%	1.4%	2,232	0.3%	1.4%
Commercial Retail	2,522	0.3%	2.2%	3,009	0.4%	2.4%	3,771	0.5%	2.4%
Commercial Services	2,203	0.3%	2.0%	3,655	0.5%	2.9%	4,855	0.6%	3.1%
Institutional/ Governmental	4,707	0.6%	4.2%	5,083	0.6%	4.0%	5,994	0.8%	3.8%
Outdoor Recreation	11,103	1.4%	9.9%	13,133	1.7%	10.3%	25,011	3.2%	15.8%
Under Construction	na	na	na	na	na	na	115	0%	.1%
Agriculture & Undeveloped	674,161	85.7%	--	666,280	84%	--	634,358	80%	400.7%
Total Developed Area	112,660	14.3%	100%	127,055	16%	100%	158,297	20%	100%
Total Area*	**786,821**	**100**%	--	**793,335**	**100**%	--	**792,655**	**100**%	--

*Differences in total area results from improved methods and source data
Source: Capital Area Regional Planning Commission

In rural areas, although the number of farms and farmers has been declining, the average farm size has increased. Also, many farmers have switched from dairying and livestock operations to cash crops, especially corn. Cash crop agriculture is concentrated in the eastern and central portions of the county due to the prevailing soils and topography. Dairy and livestock operations are more common in the western, driftless area.

If present trends continue, most of the land in Dane County will remain in agriculture over the next 75 years. Population growth and development will continue in the towns, villages and small cities adjacent to the City of Madison, in the outlying cities and villages, and in Madison itself. Groundwater consumption will increase with population growth, and new development (both urban and rural) may present additional threats to groundwater supplies.

Dane County Sources

The inventory of potential pollution sources in Dane County is a major element in determining subsequent groundwater protection strategies. The following inventory provides a brief description of each pollution source; a list of common pollutants that result from the source; specific data regarding the pollution source in Dane County; and, in many instances, estimates of the relative significance of the source. Such estimates represent judgments based on the likelihood of groundwater quality degradation and the size of the population that may be at risk. Although general estimates of pollution significance are stated, it should be kept in mind that pollution hazards are site-specific and very dependent on source use. For example, an old, poorly designed landfill containing hazardous chemicals represents a greater groundwater threat than a recently designed sanitary landfill which does not receive hazardous chemicals. Thus, a particular source causing a groundwater quality problem in one area may not be a threat in another. Also, while this inventory lists the major potential sources of groundwater pollution in the county, it is not comprehensive in addressing every possible source.

Ideally in preparing the inventory, information on the location, size, design, etc. for all potential sources of pollution should be available. In reality, data availability varies with each source. Potential pollution sources are presented in the inventory according to their occurrence relative to the land surface, rather than in order of importance (**Table 22**). This was done because the approach in the plan to evaluate groundwater pollution hazards is based upon effects of pollution sources located at the land surface, and below the land surface. This is reflected in the use of groundwater contamination risk maps which are presented later in this report.

Subsurface Pollution Sources

Land Disposal of Solid Waste

Solid waste disposal sites are important potential sources of groundwater pollution. Contact between water and refuse in the disposal site and subsequent decomposition produces a polluted liquid called leachate. If not adequately contained and collected, this liquid can seep into the groundwater.

Groundwater pollution hazards are dependent upon the type and amount of leachate produced in waste disposal sites (primarily landfills) and how well leachate is eventually collected and treated. Leachate composition is extremely variable and is a function of refuse composition and volume of water in the landfill. Landfills containing only domestic waste and a minimal amount of water pose a lower pollution risk than landfills having more toxic industrial or commercial chemicals and a greater volume of water. Most landfills in Dane County will produce at least some leachate due to humid climatic conditions. Movement of groundwater, though, is usually very slow, both vertically and laterally. In Dane County, vertical migration is typically less than 1 foot/year and lateral movement ranges from less than 1 foot to 100 feet/year.[71]

Table 22

Potential Groundwater Pollution Sources

Potential Pollution Sources	Waste-Related				Non-Waste			
Place of Origin	**Municipal**	**Industrial**	**Agricultural**	**Other**	**Municipal**	**Industrial**	**Agricultural**	**Other**
At or near the land surface	Sludge or biosolids landspreading		Feedlots	Septage landspreading	Roadway deicing	Above and on-the-ground storage of chemicals		
(Use Surface Contamination Risk Map)		Waste-water irrigation & land-spreading	Manure storage & spreading	Junkyards & salvage yards	Salt Piles Snow Piles	Stockpiles Spills	Irrigation Fertilizers Pesticides Silage	Lawn fertilizers, pesticides
					Contaminated Stormwater Infiltration			
Below the Land Surface	Landfills		Manure pits	On-site wastewater systems		Underground tanks		Improperly constructed & abandoned wells
(Use Subsurface Contamination Risk Map)	Wastewater impoundments or infiltration ponds					Pipelines		
	Sanitary sewers							

Adapted from: *Groundwater Protection Principles and Alternatives for Rock County, Wisconsin* (1985). A. Zaporozec, editor. Wisconsin Geological and Natural History Survey. Special Report 8.

The problem of solid waste disposal reached enormous proportions in this country in the 1960s. Federal legislation was enacted to charge the states with responsibility for dealing with this problem. As early as 1970 Dane County made a commitment to develop a countywide solid waste management program. This commitment was confirmed when Dane County adopted a comprehensive *Solid Waste Management Plan* in 1976 and opened its first sanitary landfill in 1977. The comprehensive solid waste management plan adopted by the RPC and the County as a specific element of the *Dane County Water Quality Plan*, sets the policy framework for every segment of the solid waste system including storage, collection, transportation processing, recycling, and disposal. In 1980 the *Dane County Solid Waste Plan* was updated and adopted by the Dane County and the RPC. The plan contained significant new information on sanitary landfill siting and recycling. Most of the major proposed programs and recommendations contained in the Solid Waste Plan and its update have been implemented. In 1988 Dane County and the RPC adopted the *Dane County Recycling Plan* as a supplement to the 1980 Solid Waste Plan. Many of the Recycling Plan recommendations have been implemented, promoting recommended strategies of waste reduction, recovery of organic wastes, and waste-to-energy alternatives.

In addition, landfills are now developed according to stricter siting and design standards than those constructed in the past; thus they have less potential for degrading groundwater quality. (Since the 1980s landfills must be lined and equipped with leachate collection systems.) However, many landfills were developed before the stricter regulatory standards were adopted. These older landfills were sometimes located in worked-out sand and gravel pits, or in low-lying wetland areas. Such

[71] Dane County Regional Planning Commission. 1988. *Residual and Solid Waste Disposal.*

landfills pose a much greater risk to local groundwater quality than modern sanitary landfills because of poor location and absence of liners or leachate collection systems. As time progresses, leachate can move farther off-site from unprotected landfills. Groundwater monitoring is important to detect the presence and movement of leachate near these landfills to determine if problem areas exist.

Wisconsin's solid waste management program has been in place for over 30 years. In the first two decades of the program, efforts were primarily directed toward licensing existing solid waste facilities; closing poorly located or operated facilities; and ensuring that new solid waste facilities were properly located, designed, constructed, operated, closed, and maintained. During this period, the vast majority of municipal and industrial solid waste generated was landfilled.

In the 1990s, things began to change. Wisconsin's Recycling Law was passed in 1990, with most of the requirements taking effect in 1995. In 1997 NR 538, Wis. Adm. Code was promulgated, facilitating the beneficial use of industrial byproducts. These two milestones resulted in significant and still-increasing quantities of waste being diverted from landfills.

Today, the primary source of information about properties where solid waste has been disposed in Wisconsin is the Solid & Hazardous Waste Information Management System (SHWIMS). This on-line database includes locations and facilities regulated by WDNR's Waste and Materials Management program, including:

- engineered and licensed solid waste disposal facilities;
- older unlicensed waste disposal sites (e.g. town dumps);
- licensed waste transporters;
- hazardous waste generators;
- composting sites, wood-burning sites, waste processing facilities and more.

A casual search of the database indicated over 2,100 businesses or facilities listed in Dane County as either operating or closed.

The Contaminated Lands Environmental Action Network (CLEAN) is an inter-linked system providing information on different contaminated land activities in Wisconsin, to assist with the investigation, cleanup and eventual re-use of those lands.

There are two main ways to view information about contaminated land activities.

- BRRTS on the Web - **http://dnr.wi.gov/botw/SetUpBasicSearchForm.do**
- RR Sites Map - **http://dnr.wi.gov/topic/Brownfields/rrsm.html**

The Bureau for Remediation and Redevelopment Tracking System (BRRTS) on the Web (BOTW) is WDNR's on-line database that provides information about contaminated properties and other activities related to the investigation and cleanup of contaminated soil or groundwater in Wisconsin. The database includes (but is not limited to) the following contamination data:

- Emergency spills
- Investigations and cleanups of contaminated soil and/or groundwater
- Cleanup of sites under the federal Superfund (CERCLA) statute
- Sites where WDNR has determined no cleanup action is required
- Properties identified by street address

The Remediation & Redevelopment (RR) Sites Map is the WDNR's web-based mapping system that also provides information about contaminated properties and associated activities. The RR Sites Map is a spatial view linked to BRRTS through the web.

Either system may be used to find the following information:

- Completed and ongoing investigations and cleanups of contaminated soil and/or groundwater;
- Public registry of sites with residual soil or groundwater contamination, or where continuing obligations have been put in place;
- Liability exemptions and clarifications at contaminated properties (i.e., brownfields); and
- WDNR funding assistance.

Prior to development of on-line databases, WDNR provided public information about old waste disposal facilities in a printed publication called the Historic Registry of Waste Disposal Sites (the "Registry"). The department now provides searchable on-line databases that include this type of information (above). Because some information in the Registry has not yet been reviewed and incorporated into other databases, the agency has posted the Registry spreadsheet on-line: **http://dnr.wi.gov/topic/Landfills/Registry.html**

The Registry of Waste Disposal Sites includes active, inactive, and abandoned sites where solid or hazardous wastes were known, or were likely, to have been disposed. The inclusion of a site on the Registry does not mean that environmental contamination has occurred, is occurring, or will occur in the future. The Registry is intended to serve as a general informational source for the public, and State and local officials, as to the location of waste disposal sites in Wisconsin. For example, while there are only two active licensed landfills in Dane County (WMWI Madison-Prairie and Dane County Rodefeld landfills), there are approximately 200 closed waste disposal sites listed in the Registry. These are displayed on **Map 43** and included in **Attachment C**.

On-Site Wastewater Management

The disposal of domestic and commercial wastewater in rural areas outside of urban service areas is handled through the use of individual on-site wastewater disposal systems, primarily septic tanks discharging to subsurface tile disposal fields. The primary pollutants potentially released by on-site wastewater systems include nitrogen, phosphorus, bacteria, viruses, and hazardous materials from septic tank cleaning agents or inappropriate disposal of household chemicals into septic systems. Most of these pollutants are captured and neutralized in the soil; however, even in properly functioning septic systems, some pollutants may leach to the groundwater. For example, where high septic system densities exist, nitrate concentrations in excess of the recommended drinking water standard (10 mg/L) may be present in local groundwater. In Dane County, sufficiently high densities and clusters of residential on-site systems may exist in some rural subdivisions and hamlets which rely on these systems.

Private on-site wastewater treatment systems currently serve over 23,000 households in Dane County. This is about 11 percent of the total 216,022 housing units in the county according to the 2010 Census. It is expected that the number of on-site wastewater systems will increase to over 28,000 by the year 2030 serving about 73,000 people. **Map 44** shows residential on-site wastewater units in Dane County in 2010. **Map 45** shows subdivisions with on-site systems and their location with respect to subsurface contamination risk areas. **Table 23** shows data on the dwelling units in

Dane County served by on-site wastewater systems. The five towns of Middleton, Cottage Grove, Bristol, Oregon, and Burke contained over 30 percent of the total number of on-site systems in Dane County in 2010. Onsite systems represent an important segment of the wastewater management and water quality planning programs in the region. Appendix I of the Dane County Water Quality Plan provides more detailed information concerning on-site wastewater management in Dane County, summarized here.[72]

The primary concern regarding on-site wastewater systems is their effect on nitrate levels in groundwater. Excessive nitrate levels in shallow groundwater and private wells are a problem throughout Dane County. A significant percentage (18 percent) of private wells tested in Dane County exceed the 10 mg/L enforcement standard for nitrate in drinking water. An additional 52 percent of private wells tested in Dane County exceed the 2 mg/L preventative action limit for nitrate in drinking water. While nitrate levels in groundwater have generally been increasing over the last half century, there is recent evidence that nitrate levels in groundwater may be decreasing due to nutrient management and other conservation practices being employed.

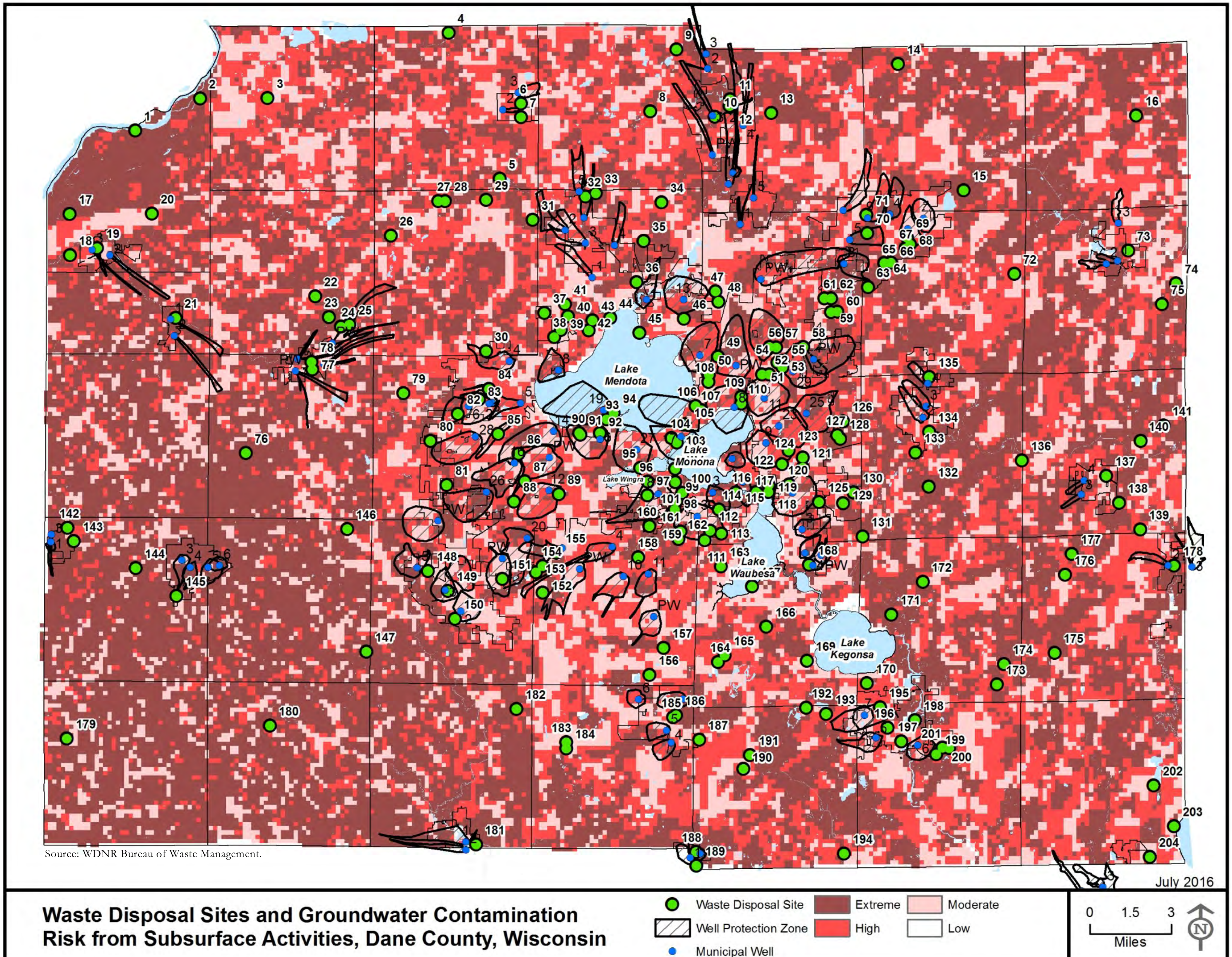
It is difficult to determine the relative contribution to the nitrate problem from past and present agricultural practices versus on-site wastewater treatment systems. It is not likely that scattered on-site systems contribute significantly to the overall problem, but they can be a source of local nitrate contamination of nearby shallow wells. There is some concern that large on-site systems or clusters of systems (such as in rural subdivisions or hamlets) can, when added to background nitrate levels in groundwater, result in raising nitrate levels in nearby shallow wells to above drinking water standards if the density or loading of on-site systems is too high.

The potential impacts of nitrate contamination resulting from large on-site systems or clusters of on-site systems can be addressed by review and evaluation of specific proposals (permit applications, subdivision plat reviews, etc.) to determine if there is likelihood that waste disposal practices will affect nitrate levels in nearby water supply wells. Because dilution in the groundwater is the primary mechanism of controlling nitrate levels in the groundwater once introduced, it is prudent to evaluate the groundwater impact of proposed development at densities greater than one house per 2 acres. Limited national and state/local information suggests that it is not likely that localized groundwater nitrate contamination will be caused by on-site systems at a lower density than one system per two acres, but that there is a greater potential for contamination where systems exceed a density of one per acre.

Based on this information, the planning of rural subdivisions or developments that include large on-site systems or clusters (more than 20) of on-site systems with an average density of one house per 1-1.5 acres (based on the gross acreage of the development) should include an evaluation to ensure that drinking water supplies are protected. If the evaluation indicates a risk for nitrate levels above 10 mg/L, alternatives such as protected water supplies (well location and depth), utilizing nitrogen-reducing wastewater treatment systems, or community scale water supply and wastewater treatment systems should be explored. The US EPA recommends that private on-site wastewater treatment systems sited in drinking water aquifers or near sensitive aquatic areas incorporate additional nitrogen removal technologies prior to final soil discharge. However, very few of these systems are currently in use in Dane County. The Wisconsin Administrative Code exempts private sewage systems from having to meet groundwater nitrate standards.

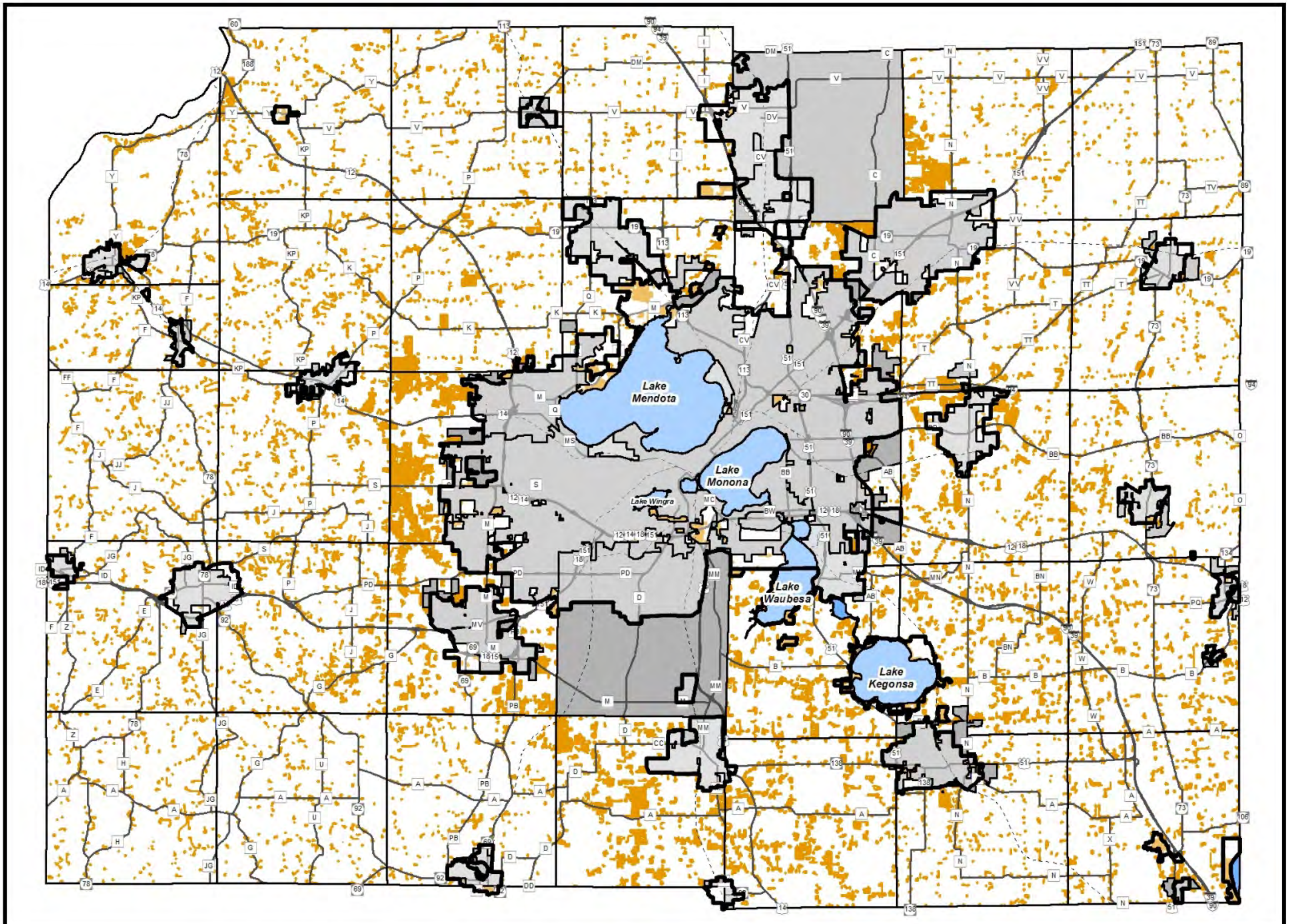
[72] Capital Area Regional Planning Commission. 2013. *Private* On-Site Wastewater Treatment Systems Management. Appendix I of the Dane County Water Quality Plan.

Map 43



Waste Disposal Sites and Groundwater Contamination Risk from Subsurface Activities, Dane County, Wisconsin

Map 44



Residential On-Site Wastewater Systems
Dane County, Wisconsin

Service Area Boundary
Residential On-Site Wasterwater Systems (2010)
September 2014
(Source: Capital Area Regional Planning Commission)

0 1.5 3
Miles

Map 45

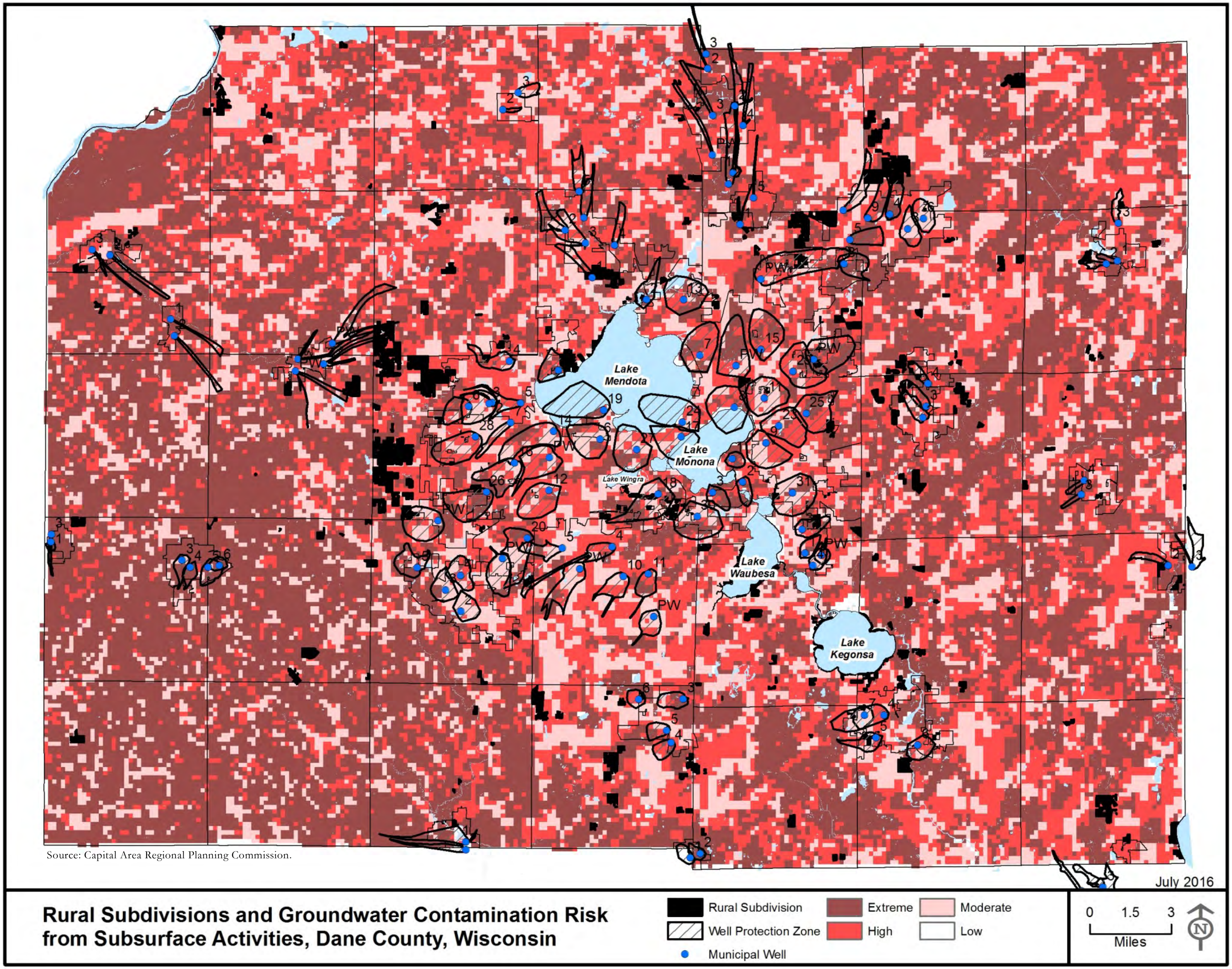

Lake Mendota
Lake Monona
Lake Wingra
Lake Waubesa
Lake Kegonsa
Source: Capital Area Regional Planning Commission.
July 2016
Rural Subdivisions and Groundwater Contamination Risk from Subsurface Activities, Dane County, Wisconsin
Rural Subdivision
Well Protection Zone
Municipal Well
Extreme
High
Moderate
Low
0
1.5
3
Miles
N

Table 23.
Dwelling Units with On-Site Wastewater Systems in Dane County

	1970	1980	1990	2000	2010
Towns					
Albion	566	503	549	643	493
Berry	229	345	365	428	489
Black Earth	99	132	136	149	205
Blooming Grove	180	350	379	372	375
Blue Mounds	197	229	226	309	321
Bristol	369	518	595	956	1,278
Burke	476	816	886	968	1,130
Christiana	358	393	397	480	486
Cottage Grove	458	910	1,120	1,473	1,433
Cross Plains	237	317	416	526	571
Dane	196	258	292	371	357
Deerfield	220	353	371	466	550
Dunkirk	605	688	691	738	778
Dunn	1,021	1,107	678	657	670
Fitchburg[73]	876	1,063	-	-	-
Madison	147	56	45	54	56
Mazomanie	235	316	392	493	437
Medina	292	334	397	445	492
Middleton	451	786	1,142	1,593	2,063
Montrose	262	343	377	447	436
Oregon	274	559	789	1,113	1,167
Perry	212	206	229	270	280
Pleasant Springs	580	828	1,031	780	851
Primrose	169	207	205	247	281
Roxbury	280	390	467	547	558
Rutland	336	485	550	700	786
Springdale	308	402	456	584	724
Springfield	459	677	857	1,013	943
Sun Prairie	386	583	629	742	839
Vermont	156	229	260	302	331
Verona	395	503	529	673	608
Vienna	288	398	422	401	363
Westport	538	540	443	395	410
Windsor	376	450	707	749	890
York	194	215	212	268	265
Subtotal	12,425	16,489	17,240	20,352	21,916
Cities and Villages	1,009	749	1,479	1,300	1,183
Total	13,434	17,238	18,719	21,652	23,099

Sources: 1970 – 1990 US Census data
2000 Estimated from US Census data, DCRPC USA and LSA data, and Department of Public Health Madison & Dane County records
2010 Department of Public Health Madison & Dane County records
[1] The Town of Fitchburg incorporated as a city on April 26, 1983.

The problems and impacts associated with excessive nitrate concentrations near some existing rural subdivisions need to be evaluated and solutions to any significant problems assessed and pursued. The Towns of Bristol, Burke, Middleton and Windsor, in particular, appear to have some significant nitrate contamination issues. Appropriate solutions to the problems can range from on-site improvement or replacement of individual systems to providing centralized sewerage collection and treatment systems, depending on the magnitude and scale of the problem. In other cases, providing a protected water supply may be the best solution.

Many existing on-site wastewater disposal systems were installed before modern wastewater codes were enacted. Some of these older systems may fail or function poorly because of inadequate design and construction standards in effect at the time they were built, unsuitable site conditions, or lack of proper maintenance. Septic systems should be inspected at least every three years and pumped when the tank is 1/3rd full of scum or sludge to prevent clogging and failure. Although proper maintenance and servicing is not costly, it is sometimes postponed or neglected until a serious problem or failure occurs.

Since 1998, Dane County has required periodic evidence of adequate maintenance and servicing for all on-site systems. Revisions to Chapter Comm 83 of the Wisconsin Administrative Code (now SPS 383) in 2000 also required that maintenance plans be submitted with every application for an on-site system. Regular inspection and pumping are the most important aspects of an on-site system maintenance program. SPS 383.54 and Dane County Chapter 46 require all private sewage systems to be inspected at least every 3 years, or more frequently if required for aerobic treatment units or other alternative systems. These changes have dramatically improved system performance, reduced system failures, and increased the prompt replacement of failed systems.

When the revisions to Comm 83 were promulgated in 2000, a major concern of several municipal and environmental groups was that the new regulations would cause an increase in rural development because they allowed alternative technology systems to be used in areas that were previously undevelopable with on-site systems due to restrictive soil conditions. Thus far, however, the data does not substantiate this concern (**Fig 31)**.[74] From 1986 to 2000 the number of new residential units with on-site wastewater systems was 12.9 percent of the total new units on average. Since 2000, it has been 8.5 percent on average.

In general, the current siting, design, construction and maintenance standards for on-site wastewater disposal systems result in systems that are reliable and have minimal environmental impact. Test results suggest that that the nitrate loading from modern subdivisions can actually be equal to or less than the agricultural production activities preceding the development.[75] On-site systems also have the beneficial effect of replenishing groundwater supplies and avoiding the impacts of groundwater pumping and diversion through the sewer system. Other designs, including mound systems, are available to replace failing systems where site conditions do not permit in-ground system replacement.

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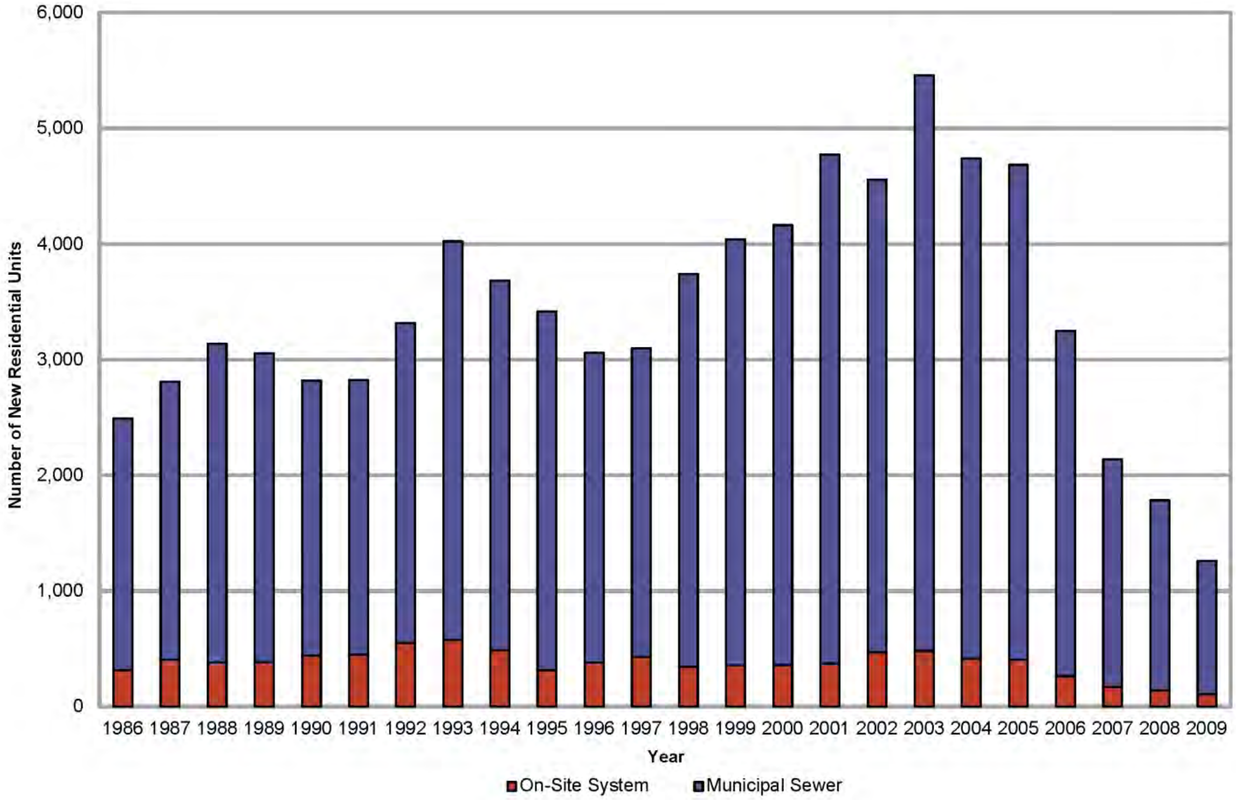
[74] Capital Area Regional Planning Commission. 2013. *Private* On-Site Wastewater Treatment Systems Management. Appendix I of the Dane County Water Quality Plan.

[75] Bradbury, K. et al. 2005. *Monitoring and Predictive Modeling o f Subdivision Impacts on Groundwater in Wisconsin*.

Figure 31. Residential Development Trends in Dane County



Current regulations and inspection programs are generally ensuring the level of maintenance and servicing of on-site systems necessary to reduce failures, ensure continued functioning, and provide a long system life. According to the Department of Public Health for Madison & Dane County records, 89 percent of the on-site wastewater treatment systems in Dane County were operating in full compliance in 2010. The majority of those systems issued corrective action notices were due to failure of the owner to submit the required system maintenance reports. Only 14 systems (less than 0.1 percent) were identified with a failure or other maintenance problem requiring system modification. There is a system in place to refer problem property owners to Dane County's Corporation Counsel for legal action if they do not comply with a citation issued by the Department of Public Health.

Daily care in the use of an on-site system also contributes to its proper functioning. Such care would include avoiding the installation of garbage disposals in the house, because they contribute high per capita loads of organic matter and suspended solids (higher than even toilets), and are therefore not suited for use with septic systems. Large inorganic solids and toxic materials should also be kept out of the plumbing system. Local contamination of the groundwater by inappropriate disposal or use of toxic chemicals in septic systems can pose health and environmental threats, especially considering the relatively short distances the pollutants would have to travel to contaminate nearby private wells in rural subdivisions. In addition, water conservation measures such as using dishwashers and washing machines only for full loads, taking shorter showers, fixing leaks in the water system, using front loading washers, low flow or dual flush toilets and water conserving fixtures can all help to reduce the hydraulic load placed on an on- site system. This information should be included as part of an effective public information and education campaign regarding the proper use and maintenance of on-site systems, including emphasis on the vulnerability of groundwater to contamination and the difficulty and expense of restoring drinking water supplies. Information should also be provided which provides guidance for testing private wells for homeowners concerned about their drinking water quality. Overall, proper siting, appropriate choice of technology, good design and installation practices, and adequate operation and maintenance are crucial in assuring proper treatment of wastewater and the protection of the groundwater from contamination.

Disposal of Emerging and Unregulated Contaminants

Water quality contaminants of emerging concern include pharmaceuticals, personal care products, and endocrine disrupting compounds. Research indicates that these contaminants are entering surface and groundwater and may be producing adverse effects on fish and other aquatic organisms.[76] The extent of the threat posed to human health and to the integrity of surface waters and groundwater by the presence of these compounds is not currently known. Several factors account for this lack of knowledge. These categories represent a large number of chemical compounds. The concentrations of most of these compounds in surface waters and groundwater have not been determined. The biological and toxicological effects of many of these compounds on human health have not been characterized, especially at environmentally relevant concentrations and under long-term conditions. Few data are available on the fate of these compounds in the environment. Studies examining the presence of these compounds in the environment and the toxicological properties of these compounds have generally not examined their metabolites and transformation products, which may be biologically active.

In view of the potential risks posed by the release of pharmaceuticals and personal care products into the environment, it would be prudent and protective of human health and the integrity of surface waters and groundwater to reduce inputs of these materials into the environment. Therefore, it is recommended that public informational and educational programs be carried out to encourage the use of the collection sites available for expired and unused medications. The WDNR has issued guidance on regulatory aspects of collecting unwanted household pharmaceuticals. Communities should continue to support the collection of pharmaceuticals through the MedDrop program. Because some of these compounds are considered controlled substances and are strictly regulated by the U.S. Drug Enforcement Administration, such collections require the participation of local law enforcement agencies. In addition, Wisconsin allows some unused cancer and chronic disease drugs and supplies to be donated to participating pharmacies or medical facilities for use by other patients. Rules governing these donations are set forth in Chapter HFS 148 of the *Wisconsin Administrative Code*.

Wastewater Infiltration Ponds

Infiltration ponds or seepage cells are used at some wastewater treatment plants to absorb treated wastewater, and are often preceded by stabilization lagoons for the settling of solids. Wastewater varies according to water sources, but often contains pollutants such as nitrogen, chlorides, dissolved solids, and oxygen-demanding material. If infiltration ponds are properly sited and operated, many pollutants in the wastewater will be biologically degraded or attenuated while percolating through the ground and pose a limited threat to water quality. The possibility of groundwater pollution exists, however, particularly from nitrogen, chlorides or other pollutants, which are less attenuated by the soil.

[76] http://dnr.wi.gov/topic/HealthWaste/Pharm.html

Dane County no longer has any municipal wastewater treatment plants discharging to groundwater. The Village of Dane and the unincorporated community of Morrisonville have connected to MMSD, and Roxbury has converted to a surface discharge.

Sanitary Sewers

Recently, viruses and other microbial pathogens have been found in deep municipal wells, challenging previous assumptions about their occurrence. Public water systems that supply groundwater in Wisconsin are not required to disinfect their drinking water (although municipal water utilities in Dane County do). Public and private water samples are also not regularly tested for viruses. Viral testing is expensive and very few labs are capable of conducting the test. The presence of coliform bacteria has historically been used to indicate the water supply is not safe for human consumption. However, virus data complicates this interpretation since the presence of coliform (and other indicators as well) do not always correlate with the presence of human viruses. These indicators have a high positive predictive value but a low negative predictive value for pathogen occurrence. In other words, when an indicator is present in drinking water there is a high probability that particular water source will be contaminated. However, if an indicator is absent, no inferences can be made about pathogen occurrence.

In a novel study, researchers discovered human viruses in the confined aquifer supplying Madison's drinking water.[77] This finding was completely unexpected because it was believed the 3 to 9 meter shale confining layer protected the aquifer from microbial contamination. Water isotope analyses indicated surface water (the Yahara Lakes) to be an unlikely source of viruses. The most likely source of the viruses in the wells was traced to leakage of untreated sewage from the Madison sewer system, which contains a large number of clay pipes installed before 1950. Additional research has shown virus transport from leaking sanitary sewers to the wells can be very rapid, on the order of weeks to months instead of years.[78] The virus transport and contamination levels were particularly high after extreme rainfall events or rapid snowmelt. From a public health standpoint, the lesson learned is that all aquifers are potentially vulnerable to microbial contamination and require a similar level of disinfection for drinking water purposes.

Because sanitary sewers are commonly located near municipal wells and can carry very high numbers of infectious viruses, and very small numbers of infectious viruses in water can constitute a health risk, drinking water wells can be considered vulnerable to fast groundwater flow paths even though they may only contribute a very small amount of virus-laden water to a well. Thus, these results suggest that evaluations of drinking well vulnerability should include low yield-fast transport pathways in wellhead protection – especially in communities that do not disinfect their water supplies.

Until recently, few water utilities or researchers were aware of possible viruses in water from deep wells in Madison. Because of their small size, viruses have a high potential to move deeply through the subsurface environment, penetrate aquitards, and reach confined aquifers. During 2008 and 2009 researchers collected a time series of 26 monthly virus samples from six deep municipal water supply wells in Madison. Viruses were detected in at least eight samples from each of the six municipal wells chosen for long-term sampling, and the percentages of samples testing positive for viruses ranged from 31 to 61 percent. These findings are consistent with previous work and show that even deeply cased municipal wells in confined aquifer settings can be susceptible to pathogen contamination.

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[77] Borchardt, M. et al. 2007 *Human Enteric Viruses in Groundwater from a Confined Bedrock Aquifer.*
[78] Bradbury, K. 2013. *Source and Transport of Human Enteric Viruses in Deep Municipal Water Supply Wells.*

It is clear from these results that casing these deep wells across a regional aquitard (such as the Eau Clair formation) does not prevent virus contamination, or even significantly reduce the percentage of virus detections (although the absolute concentrations of viruses were appreciably lower in two of the deeply cased wells, indicating larger casing depth appears to be correlated with lower virus concentrations). In addition, multiple samples from each well tested positive for infectivity, showing that these viruses can represent a public health threat if the water is not disinfected by chlorination or other means. The simultaneous detection of viruses in multiple wells miles apart shows that virus presence cannot be attributed to a single surface source or a single defective well. Instead, these detections suggest widely distributed or multiple virus sources and multiple pathways from the virus source to the wells.

Virus detections were correlated with recharge events when sewers are often surcharged with water and increased leakage from sewers is very likely. Leakage from urban sewers beneath Madison is the most likely source of the viruses detected in in municipal wells as supported by several lines of evidence. First, the raw sewage carries a very high virus load, and both the physical characteristics of the sewers (age, location) and visual inspections (video logs showing breaks and root invasions) suggest they leak. Second, with one exception, all viruses detected in well water were also detected in untreated sewage. Third, variations in virus serotypes identified in the sewage also appear in well water, with significant temporal correlation. Fourth, the hydraulic gradients beneath Madison are strongly downward, which would transport viruses downward from the near-surface toward the deep aquifer.

One of the most intriguing findings of this work is the temporal variation and correlation between virus serotypes in sewage and groundwater. In several instances an occurrence of a "new" virus in sewage is followed within weeks by detection of the same virus in water produced from municipal wells. The implied transport from the sewers to the wells occurs much more rapidly than previous porous- media calculations or modeling have suggested. Transport along preferential pathways such as fractures or poorly-grouted well casings is required to explain the virus occurrence. If such rapid transport exists, then deeply-cased municipal wells may be much more vulnerable to shallow contamination than previously assumed. By the same token, this work supports the concept of viruses as potentially excellent groundwater tracers. Viruses have the desirable tracer properties of mobility, unique identification and, most importantly, quantification over a broad concentration range. Further research on viruses as tracers is needed.

The high rates of detection of human intestinal viruses in groundwater sampled during this study suggests that exfiltration from sanitary sewers has a significant impact on groundwater quality. Sanitary sewers are a major part of civic infrastructure in urban settings and represent a significant potential source of groundwater contamination. Sewer exfiltration or outward leakage of sewage wastes, represents a potential source of pathogens, toxic chemicals, pharmaceutical compounds and other materials to the subsurface environment.[79] There have been two schools of thought on the significance of sewer exfiltration. Some investigators argue that the overall impact of sewer exfiltration is insignificant due to the small volumes of leakage and to biodegradation and sorption of contaminants in the soil zone.[80] Others believe that exfiltration can be a major source of groundwater contamination. [81, 82] Most studies conclude that the impact of sewage exfiltration on groundwater is quite variable in time and space and there is currently a lack of knowledge about both the quantity of leakage and its consequences for the

[79] Bishop, P. et al. 1998. *Impacts of Sewers on Groundwater Quality*.
[80] Rutsch, M. et al. 2008. *Towards a Better Understanding of Sewer Exfiltration*.
[81] Wolf, L. et al. 2004. *Impact of Leaky Sewers on Groundwater Quality*.
[82] Osenbrück, K. et al. 2007. *Sources and Transport of Selected Organic Micropollutants in Urban Groundwater Underlying the City of Halle (Saale), Germany*

environment. While similar studies have not been conducted in deep wells in other Wisconsin or Midwestern cities it seems likely that other municipalities might have similar virus occurrences. Many of the viruses detected in this study were shown to be infective. Therefore it is important that municipal water systems using groundwater as a source disinfect the water to deactivate viruses.

Underground Storage Tanks

Tanks are commonly used for storing various substances such as petroleum, fertilizers, pesticides and industrial chemicals. Petroleum is stored in both aboveground and underground tanks, while fertilizers, pesticides and industrial chemicals are usually stored in aboveground tanks. There are many of these tanks located throughout the county, being particularly common in urban areas. Although aboveground and underground chemical storage tanks are both of concern; underground tanks often represent a greater hazard, since leaks are more difficult to detect and the tanks are located closer to the groundwater table. Leaking underground tanks also have greater potential to contaminate groundwater and threaten municipal and private water supplies.

Wisconsin requires underground storage tanks (USTS) with a capacity of 60 gallons or greater and above ground storage tanks (ASTs) with a capacity of 110 gallons or greater to be registered with DATCP. Exempt tanks include: farm or residential tanks of 1,100 gallons or less; tanks storing heating oil for consumptive use on the premises; septic tanks; and storage tanks situated on or above the floor of underground areas, such as basements and cellars.

DATCP's inventory reveals there are 8597 USTs and 2641 ASTs registered in Dane County. These sites are shown on **Map 46.** The Petroleum Environmental Cleanup Fund Award (PECFA) program was created in the late 1980s in response to enactment of federal regulations requiring release prevention from underground storage tanks and cleanup of existing contamination from those tanks. It is funded by a tax added to all petroleum products sold. PECFA was a reimbursement program returning a portion of incurred remedial cleanup costs to owners of eligible petroleum product systems, including home heating oil systems. However, as of July 20, 2015, no new sites will be accepted into the program.[83] Over $126 million have been spent in Dane County on petroleum cleanup from leaking underground storage tanks.[84]

As of May 2014, 1319 tanks were identified by the WDNR as leaking. Of this total, 1239 sites have been closed (cleaned up completed) with 80 sites remaining open (cleanup ongoing). These sites are shown on **Map 47** along with other open Remediation and Redevelopment Sites (185 total). **Table 24** shows the Wisconsin LUST program status compared to efforts throughout the U.S. New regulations require existing tank systems to be upgraded. This will help prevent future problems.

However, the 2015-2017 Wisconsin budget does not include any funding for PECFA and effectively sunsets the program for releases after July 2017 and any claims after July 2020. According to the WDNR, any Wisconsin tank owner who has a release in the future will no longer be able to seek assistance from the State to handle the contamination, yet the environmental clean up requirements remain in place. While the Governor's office has stated the program has existed for a sufficient time and that its primary purpose has been completed, the sudden end of the PECFA fund will likely affect individuals and small business owners who lack the resources to respond adequately to a leaking tank on their own.

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[83] See http://dnr.wi.gov/topic/brownfields/pecfa.html
[84] Wisconsin Legislative Fiscal Bureau. 2015. *Petroleum Environmental Cleanup Fund Award (PECFA)*. Information Paper 66.

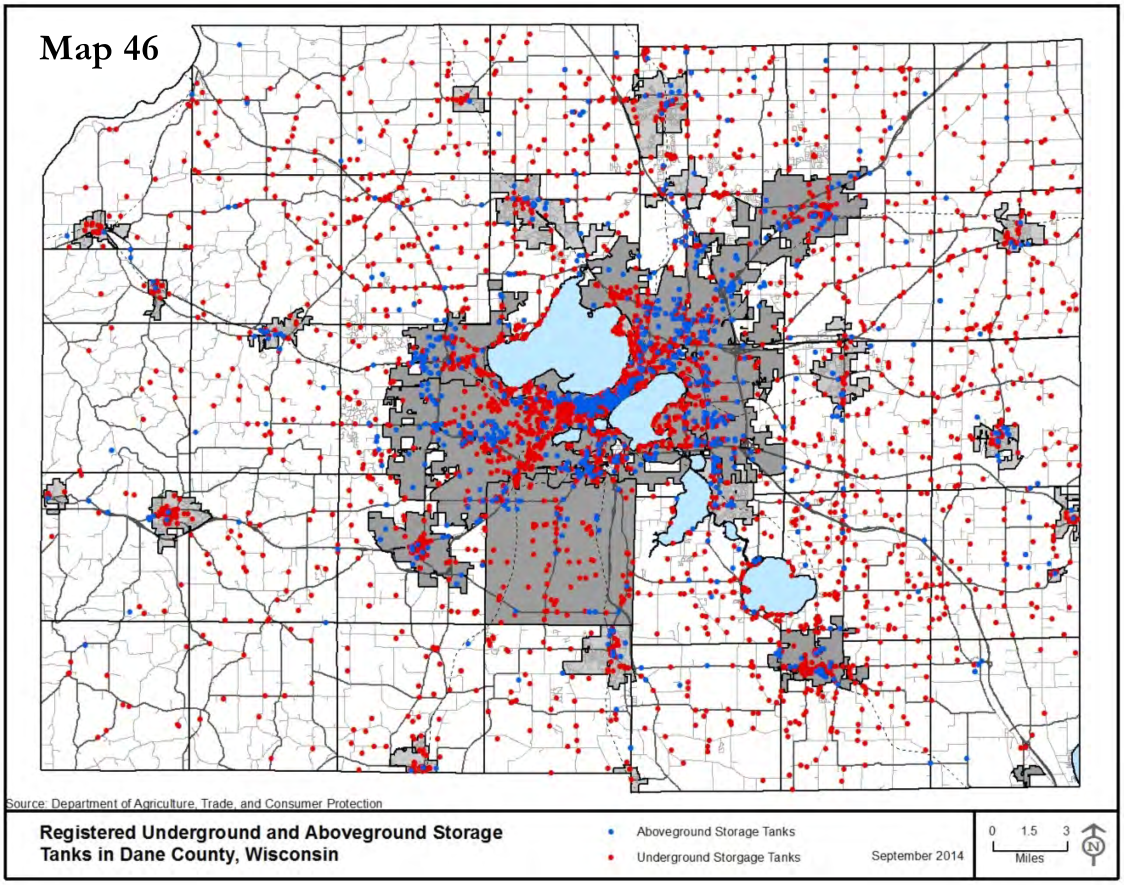


Table 24. LUST Program Status In Wisconsin

Number of active underground storage tanks	14,284 (national total: 565,956)
Number of confirmed releases	19,442 (national total: 528,521)
Number of cleanups completed	18,400 (national total: 456,660)
Number of cleanups in backlog to be completed	1,042 (national total: 71,861)

Source: U.S. EPA LUST Performance Measures as of September 30, 2015

Underground storage tanks have been associated with several groundwater pollution incidents in Dane County. Volatile organic chemicals (VOCs) have been detected in private wells at various sites where gasoline leaks from underground tanks have occurred. The contaminants most commonly associated with leaks from petroleum underground storage tanks are benzene, toluene, ethyl benzene, and xylene (BTEX compounds). There has also been documentation of other underground tank leaks which have reached the groundwater table, but have not yet impaired drinking water supplies.

DATCP maintains Wisconsin's tank registration database and is responsible for tank regulations for both underground and aboveground tank systems. The Storage Tank Regulation Section is the primary unit responsible for the administration and regulation of Wisconsin Administrative Code ATCP 93 regarding the storage, transfer, and handling of flammable, combustible, and hazardous liquids.

As of July 2013, Wisconsin's regulatory program for cleanup of contamination from petroleum storage tanks is run by the WDNR. The WDNR is responsible for:

- Establishing investigation and remedial action requirements for contamination in the Ch. NR 700, Wis. Adm. Code, series of environmental rules.
- Oversight of cleanups at petroleum tank discharges.
- Wisconsin's fund for reimbursement of environmental cleanup costs (the Petroleum Environmental Cleanup Fund Award (PECFA) – since sunsetted).

When contaminated soil or groundwater is encountered, the first step is to report the contamination to WDNR in accordance with the Spills Law, Chapter 292, Wis. Stats. Property owners or the person who caused the discharge are responsible for reporting contamination, although an environmental consultant may make this report on behalf of the responsible person. The Spills Law applies equally to a recent spill and to an old contamination that has been discovered. If WDNR determines that further investigation is needed, the responsible person will receive a letter from WDNR outlining the requirements.

A private consultant is usually hired to do an environmental investigation and to recommend cleanup options. The cleanup must address the full extent of contamination in soil and groundwater, even if it has gone beyond the property boundaries. The WDNR is responsible for all environmental cleanups in the state, other than agricultural-related cleanups, which are the jurisdiction of the Department of Agriculture, Trade and Consumer Protection.

The NR 700 rule series governs the process of investigating and cleaning up contamination. The rules allow development of site-specific soil performance standards and the use of natural attenuation for groundwater, which means that the contamination is allowed to naturally break down over time. Chapter NR 140 covers Wisconsin's groundwater standards. Most, but not all, of Wisconsin groundwater standards are the same as federal drinking water standards.

Wisconsin, like most states, may allow some residual contamination to remain after an environmental cleanup. The WDNR ensures long-term protection of public health and the environment in regard to those residuals by establishing continuing obligations in the state's cleanup approval document (closure letter). The most common obligations are obtaining WDNR approval prior to constructing a water supply well and properly treating or disposing of any excavated contaminated soil. Other obligations may include property-specific land use controls, such as maintaining pavement over a specified area of soil contamination. The WDNR adds these properties to an internet database (the Contaminated Lands Environmental Action Network – CLEAN) that advises the public and potential future property owners of these obligations.

CLEAN is an inter-linked system providing information on different contaminated land activities in Wisconsin to assist with the investigation, cleanup and eventual re-use of those lands. There are two main ways to view information about contaminated land activities:

1. **BRRTS[85] on the Web** - (BOTW) is a comprehensive on-line database that provides information on contaminated properties and other activities in Wisconsin. Updated daily. http://dnr.wi.gov/topic/Brownfields/botw.html

[85] Bureau for Remediation and Redevelopment Tracking System

2. **RR[86] Sites Map** - RR Sites Map is a web-based mapping system that allows a user to view different layers of contamination data using a Geographic Information System (GIS) tool. Updated on a regular basis. http://dnr.wi.gov/topic/Brownfields/rrsm.html

Much of the BRRTS on the Web information can be viewed via the RR Sites Map.

Use either system to find:

- Cleanups still underway
- Cleanups that are completed
- Financial assistance (e.g., WDNR loans and grants)
- Liability incentives (e.g., liability clarifications and limitations)
- Other redevelopment information (i.e., brownfields)
- Continuing obligations (other states/agencies use terms such as "institutional control" or "land use control")
- Documents submitted for cleanups that are completed with residual contamination

Use BOTW to find:

- emergency spills (these are not on RR Sites Map);
- sites where WDNR has determined no cleanup action is required (these sites are not on the RR Sites Map); and
- properties identified by street address.

Transmission Pipelines

Leaks in petroleum-product transmission lines can also pollute groundwater. Three petroleum pipelines exist in Dane County (**Map 48**). One is the Lakehead Petroleum line (actually two adjacent pipelines) which crosses northeastern Dane County. It carries crude oil from Superior, Wisconsin to Illinois. The second line is operated by the Badger Pipe Line Company, and it transmits refined petroleum products through southeastern Dane County. The third pipeline, operated by Koch Pipelines, Inc. carries petroleum product through northeast Dane County.

No significant leakage problems from these lines have been noted in the county. In early 1987, though, a backhoe struck the Badger pipeline causing about 2,500 gallons of fuel oil to be discharged southeast of Stoughton. The oil did not reach the water table, and remedial actions to remove contaminated soil were taken. Also in 1987, a leak occurred in the Lakehead pipeline near Rio in Columbia County. Over 30,000 gallons of oil were discharged, but nearby well water was not expected to be degraded.

Many natural gas pipelines are present in Dane County; however, these lines are not considered a threat to groundwater quality. In the event of a spill or leak, natural gas would be emitted to the air rather than seep into the groundwater.

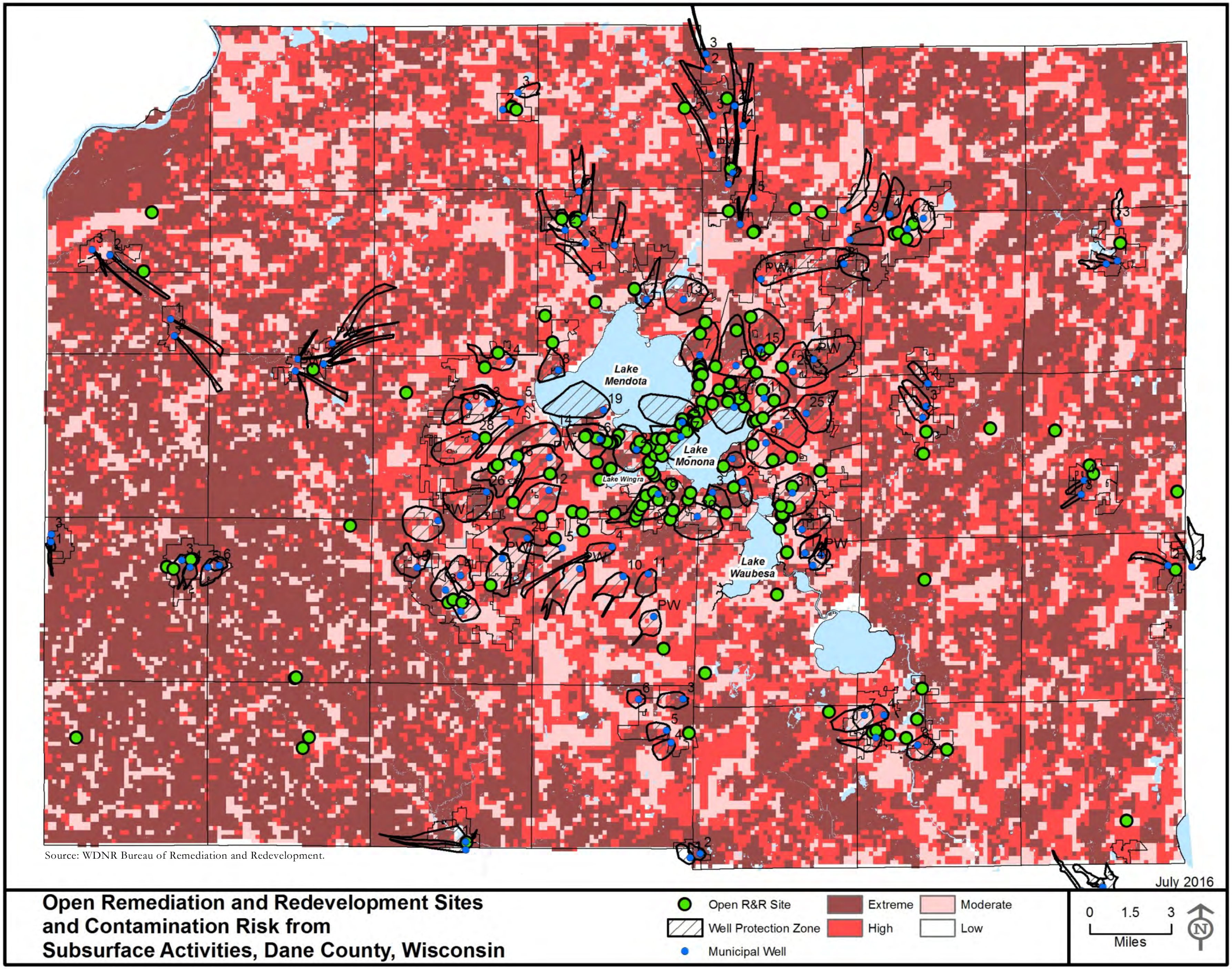
[86] Remediation and Redevelopment

Abandoned and Improperly Constructed Wells

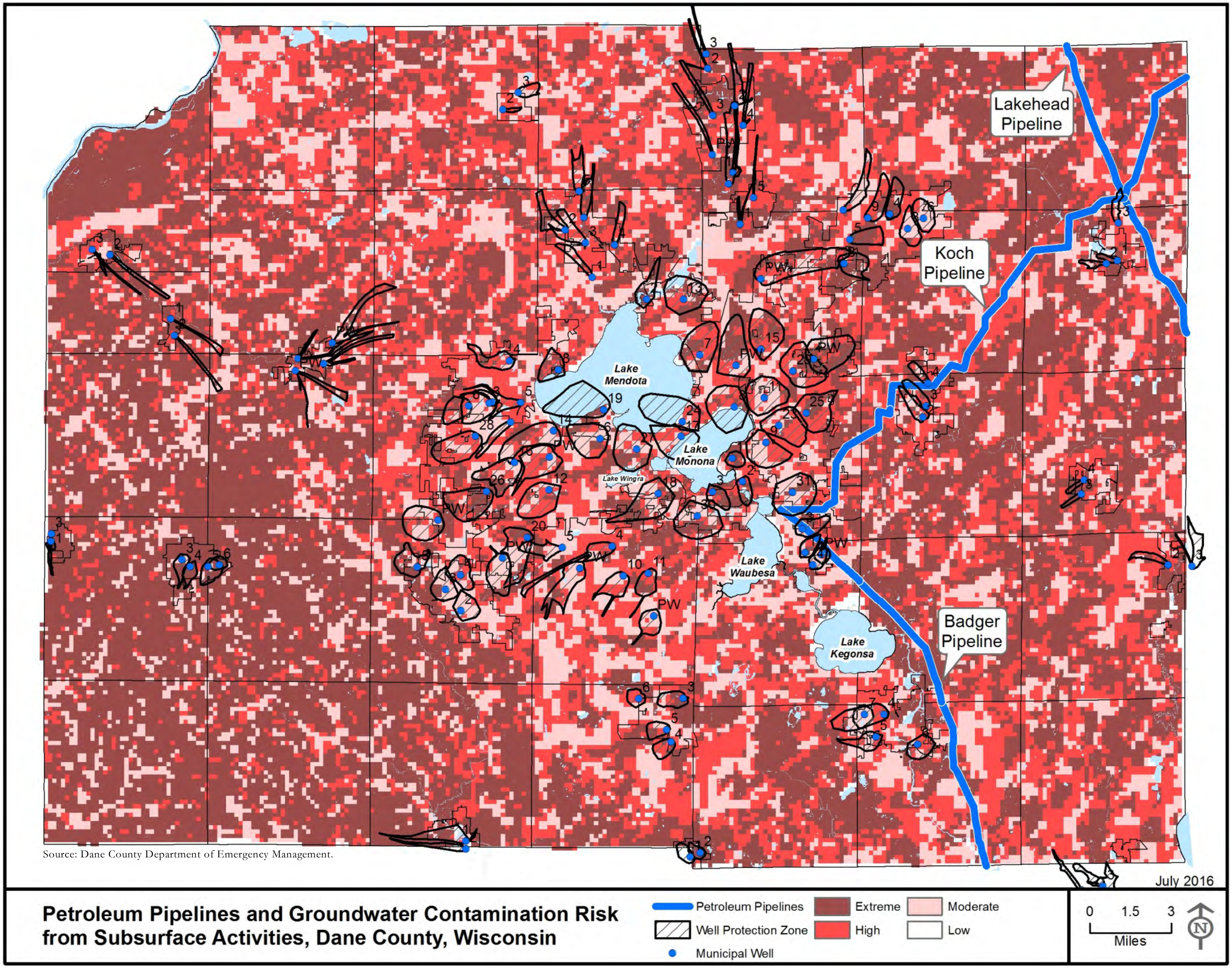
Unused, unsafe, or poorly constructed wells exist in Dane County and pose a threat to groundwater quality. Water wells can act as conduits for contaminants from the land surface to groundwater or from one geologic unit to another. For this reason, wells must be properly constructed, sealed, and maintained, as mandated by the WDNR well code, NR 811 and NR 812. Unused, unsafe, or noncomplying wells represent an unnecessary threat to groundwater, and efforts to ensure that these wells are properly abandoned should be given high priority.

Improperly abandoned wells represent a real threat to groundwater that can be removed at relatively low cost. Dane County ordinance Ch. 45 details the county's well construction and abandonment program. The Department of Public Health for Madison and Dane County (PHMDC) typically issues 60 to 70 abandonment orders each year. Unsafe wells are identified primarily as new wells are constructed through the well site permit review program. Some unsafe or unused wells are identified through complaints and are required to be abandoned as appropriate but many unsafe wells may go undetected. Since June 1, 2008, changes to Wisconsin Statutes require that wells be properly abandoned by a licensed well driller or pump installer.

Map 47


Lake Mendota
Lake Monona
Lake Wingra
Lake Waubesa
Source: WDNR Bureau of Remediation and Redevelopment.
July 2016
Open Remediation and Redevelopment Sites and Contamination Risk from Subsurface Activities, Dane County, Wisconsin
Open R&R Site
Well Protection Zone
Municipal Well
Extreme
High
Moderate
Low
0 1.5 3
Miles

Map 48



Lakehead Pipeline
Koch Pipeline
Badger Pipeline
Lake Mendota
Lake Monona
Lake Wingra
Lake Waubesa
Lake Kegonsa
Source: Dane County Department of Emergency Management.
July 2016
Petroleum Pipelines and Groundwater Contamination Risk from Subsurface Activities, Dane County, Wisconsin
Petroleum Pipelines
Well Protection Zone
Municipal Well
Extreme
High
Moderate
Low
0 1.5 3
Miles
N

Surface Pollution Sources

Bulk Storage of Fertilizers and Pesticides

Facilities that store bulk quantities of liquid fertilizers and pesticides present a potential groundwater pollution threat. At the state level, increasing attention is being placed on these facilities due to the large quantity of chemicals that may be released into the environment and documented cases of chemical impacts in nearby wells. Standards for storage containers, secondary containment (i.e., back-up containment for spills and leaks) and maintenance have been established for bulk storage facilities by DATCP. If the proper precautions are taken, the possibility of groundwater pollution can be greatly minimized at these facilities. Chapter ATCP 33, Wis. Adm. Code governs the bulk storage of fertilizer and pesticides. Chapter ATCP 29 contains general rules related to the manufacture, storage, labeling, distribution and use of pesticides. Persons who manufacture, label, distribute or commercially apply pesticides must be licensed by the department.

There are 25 active major chemical suppliers in the county (17 additional suppliers no longer active) providing area farmers and businesses with a vast variety of chemicals ranging from non-hazardous solid and liquid fertilizers to anhydrous ammonia and listed extremely hazardous herbicides and insecticides. Their names and locations are displayed on **Map 49** and in **Table 25**.

Agricultural operations are ubiquitous in the county and the potential exists for agricultural chemicals to be in transit between supplier locations and farm sites throughout Dane County at all times. These materials may be found in quantities from 50 pound bags to 1000 gallon anhydrous ammonia tanks. People that are paid to apply pesticides, or those who work for a pesticide application business or farmers who wish to use restricted use pesticides must be certified. DATCP is responsible for administration of the state's pesticide applicator certification and licensing programs. Certification is required to show that individuals can competently apply pesticides and follow regulations; licensing gives individuals the professional credentials to be a pesticide applicator. The department licenses pesticide application businesses, restricted-use pesticide dealers and commercial pesticide applicators. In 2014 there were 1102 commercial, and 616 private certified applicators in Dane County.

In 1991, the DATCP and WDNR published a study on pesticide mixing and loading sites. The agencies investigated 27 randomly chosen agricultural pesticide application businesses across Wisconsin, which ranged from farmers who custom apply pesticides to major facilities that handle and apply very large quantities. The results of the study indicated that soil and groundwater contamination is common at agri-chemical facilities. Soil contamination was found at almost all of the sites, while half of the sites had some groundwater contamination. In most cases, the contamination had not yet reached drinking water wells, but wells in close proximity to the sites were potentially at risk.

In 1993 the Agricultural Chemical Cleanup Program (ACCP) was established to help address these point sources of contamination by reimbursing responsible parties for cleanup costs related to pesticide and fertilizer contamination. The program directs cleanup of pesticide and fertilizer contamination that results from sudden accidental spills (acute spills) as well as small releases that occur through normal handling practices that, over time, can add up to significant contamination (long-term cleanup) of soil or groundwater at a given site. The program helps minimize contamination of surface water, groundwater, and the surrounding environment by ensuring that all agricultural chemical cleanups are conducted effectively and in a timely manner.

Map 49

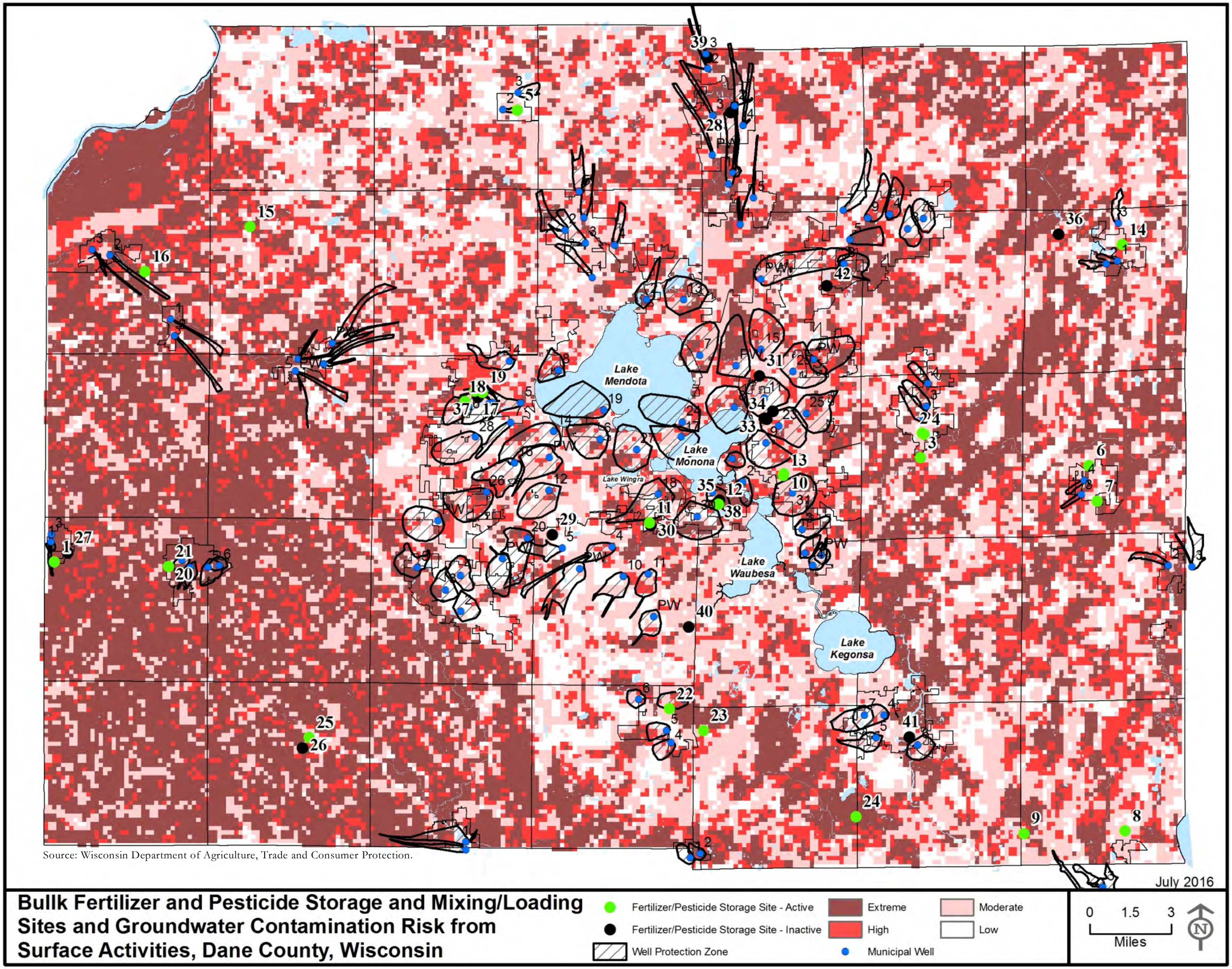

Lake Mendota
Lake Monona
Lake Wingra
Lake Waubesa
Lake Kegonsa
Source: Wisconsin Department of Agriculture, Trade and Consumer Protection.
July 2016
Bullk Fertilizer and Pesticide Storage and Mixing/Loading Sites and Groundwater Contamination Risk from Surface Activities, Dane County, Wisconsin
Fertilizer/Pesticide Storage Site - Active
Fertilizer/Pesticide Storage Site - Inactive
Well Protection Zone
Extreme
High
Municipal Well
Moderate
Low
0 1.5 3
Miles
N

Table 25. Bulk Fertilizer and Pesticide Storage Facilities in Dane County

Map No.	Facility Name	Status	Address	Community
1	MIDWESTERN BIOAG PRODUCTS & SERVICES	Active	10955 BLACKHAWK DR	BLUE MOUNDS
2	HYDRITE CHEMICAL CO	Active	150 W DONKLE ST	COTTAGE GROVE
3	LANDMARK SERVICES COOPERATIVE	Active	2580 COFFEYTOWN RD	COTTAGE GROVE
4	LANDMARK SERVICES COOPERATIVE	Active	126 CLARK ST	COTTAGE GROVE
5	LANDMARK SERVICES COOPERATIVE	Active	301 HIGH ST	DANE
6	K & S KUSTOM SERVICE INC	Active	928 ZECHZER RD	DEERFIELD
7	UNITED COOPERATIVE	Active	841 LONDON RD	DEERFIELD
8	BLUE RIVER AG SUPPLY LLC	Active	170 US HIGHWAY 51	EDGERTON
9	HELENA CHEMICAL COMPANY	Active	156 COUNTY ROAD N	EDGERTON
10	HELENA CHEMICAL COMPANY	Active	2929 PROGRESS RD	MADISON
11	NATURESCAPE INC	Active	3110 WATFORD WAY	MADISON
12	TRUGREEN LIMITED PARTNERSHIP	Active	2251 KILGUST RD	MADISON
13	VITA PLUS CORPORATION	Active	3019 PROGRESS RD	MADISON
14	GROWMARK INC	Active	814 LEWELLEN ST	MARSHALL
15	GROWMARK INC	Active	9119 STATE ROAD 19	MAZOMANIE
16	PREMIER COOPERATIVE	Active	10216 US HIGHWAY 14 W	MAZOMANIE
17	FUTURE RETIREMENT INC	Active	2211 EAGLE DR	MIDDLETON
18	MIDDLETON FARMERS COOPERATIVE CO.	Active	1755 PLEASANT VIEW RD	MIDDLETON
19	RANDAN AGRISERVICE INC	Active	2000 DEMING WAY	MIDDLETON
20	PREMIER COOPERATIVE	Active	501 W MAIN ST	MT HOREB
21	WINFIELD SOLUTIONS LLC	Active	510 W GARFIELD ST	MT HOREB
22	OREGON FARM CENTER INC	Active	321 MARKET ST	OREGON
23	OREGON FARM CENTER INC	Active	4636 STATE ROAD 138	OREGON
24	TITAN PRO SCI INC	Active	511 DANKS RD	STOUGHTON
25	HANNA AG LLC	Active	1100 COUNTY ROAD U	VERONA
26	HANNA BROS SOIL SERVICE INC	Inactive	983 COUNTY ROAD U	BELLEVILLE
27	MIDWESTERN BIOAG PRODUCTS & SERVICES	Inactive	10851 COUNTY ROAD ID	BLUE MOUNDS
28	DANCO PRAIRIE FS COOPERATIVE	Inactive	209 E HOLUM ST	DE FOREST
29	DOLPHIN SWIMMING POOL COMPANY INC	Inactive	5256 VERONA RD	FITCHBURG
30	CHEMLAWN CORPORATION	Inactive	925 WATSON RD	MADISON
31	COMSTOCK SEED & FEED COMPANY	Inactive	3710 COMMERCIAL AVE	MADISON
32	GROWER SERVICE CORPORATION	Inactive	537 ATLAS AVE	MADISON
33	ROYSTER CLARK RESOURCES LLC	Inactive	902 DEMPSEY RD	MADISON
34	THERMOGAS COMPANY OF MADISON	Inactive	700 COTTAGE GROVE RD	MADISON
35	TRUGREEN LIMITED PARTNERSHIP	Inactive	2100 INDUSTRIAL DR	MADISON
36	MARTINS FEED CO INC	Inactive	1240 MILL ST	MARSHALL
37	RANDAN AGRISERVICE INC	Inactive	8309 UNIVERSITY AVE	MIDDLETON
38	LESCO INC	Inactive	2300 KILGUST RD	MONONA
39	HOME FEED INC	Inactive	7837 MORRISON ST	MORRISONVILLE
40	DANCO PRAIRIE FS COOPERATIVE	Inactive	2200 COUNTY ROAD MM	OREGON
41	DANCO PRAIRIE FS COOPERATIVE	Inactive	700 E SOUTH ST	STOUGHTON
42	AGRO DISTRIBUTION LLC	Inactive	3525 TERRA CT	SUN PRAIRIE

Source: Wisconsin Department of Agriculture, Trade and Consumer Protection, May 2014.

Hazardous Waste Storage

Leaks or spills of hazardous waste from storage tanks can be a major groundwater pollution threat. Due to the nature of waste stored, even a small spill could have a tremendous groundwater quality impact if not properly contained. Common hazardous wastes that are stored include solvents, paint and sludge residues. There are only a few facilities which store or transfer hazardous waste in Dane County (**Table 26**). These facilities are closely regulated and licensed by the WDNR.

Facilities which use or store hazardous chemicals in quantities greater than 10,000 pounds or listed extremely hazardous substances in quantities greater than 500 pounds are required to file annual Tier II Hazardous Chemical Inventory Reports with state and local emergency management agencies. In Dane County, approximately 500 facilities report each year. Dane County Emergency Management maintains a listing of these facilities.

A total of 50 hazardous materials spills/incidents occurred in Dane County in the three years between July 1, 2010 to June 30, 2013, the majority of which occurred within the City of Madison. The materials most frequently involved include diesel fuel, agricultural chemicals, gasoline, miscellaneous oils, and solvents. Eight of the reported releases involved extremely hazardous substances. Overall, Dane County has experienced hundreds of hazardous materials incidents of all types in the past. There are currently 645 Hazardous Waste Generators in Dane County. There is a potential for an incident to occur at any time and virtually any place. Dane County Department of Emergency Management and local police and fire personnel are responsible for coordinating and conducting emergency responses to hazardous material spills and incidents.

Table 26
Hazardous Waste Storage/Transfer Facilities

Facility Name	Location
1. Hydrite Chemical Co.	114 N. Main Street Cottage Grove
2. Budget Lamp Recyclers, Inc.	3224 Kingsley Way Madison
3. Hydrite Chemical C. West	150 Progress Drive Cottage Grove
4. Madison Environmental Resourcing, Inc.	1310 W. Badger Road Madison
5. PKK Lighting, Inc.	7182 USH 14 Middleton
6. Safety–Kleen Systems, Inc.	3715 Lexington Avenue Madison
7. Transwood, Inc.	2733 Hwy N Cottage Grove
8. University of Wisconsin – Madison	30 East Campus Mall Madison

Source: Wisconsin Department of Natural Resources, Bureau of Waste Management, May 2015.

Biosolids Application

Biosolids are organic by-products from municipal wastewater treatment plants. Biosolids are comprised of both water and organic matter, though water is responsible for up to 99 percent of its weight. Biosolids are considered a valuable source of plant nutrients and organic matter for agricultural crops. There are constituents of biosolids, however, which may impact groundwater quality. These can include nitrogen, chloride, pathogenic bacteria and viruses. Hazardous chemicals (e.g., PCBs and pesticides) and metals may also be found in biosolids as a result of concentration and removal in the wastewater treatment process.

Available data from EPA's National Sewage Sludge Survey and from WDNR's database suggests biosolids quality has improved significantly over the last 20 years, particularly with respect to metals. Federal regulations promulgated under 40 CFR Part 503 utilize a comprehensive risk-based approach to identify metal loading limits that are protective of human health and environmental quality. These limits are reflected in state regulations (NR 204), which also includes additional management practices that address such issues as nitrogen management and pathogen control. The EPA National Sewage Sludge Survey also looked at a number of organic compounds and pharmaceuticals. When detected, they were generally found at very low levels. EPA is evaluating the data from this survey to determine whether there is a need to regulate additional potential contaminants.

Biosolids are classified as either Class A or B, based upon how they are managed for three major criteria; namely heavy metal content, pathogen density, and vector attraction (flies, rodents, etc.).[87] Class A biosolids have lower heavy metal levels and no detectable pathogens, making them suitable for horticultural and home use in landscaping, gardens, and lawns. A well known example is the product Milorganite®, a Class A bagged product produced by the Milwaukee Metropolitan Sewerage District since the 1930s, which is distributed nation-wide. Because Class A materials are more expensive to produce, most Wisconsin municipalities produce Class B biosolids that are suitable for application to agricultural land, and can also be used in forestry and other non-agricultural settings.

Class B biosolids are treated to reduce the number of pathogens to a level that significantly reduces the risk to public health. They are handled in bulk and utilized primarily in agriculture as a fertilizer and soil amendment. The risk associated with heavy metals is managed by both adjusting soil pH and the establishment of biosolids metal ceiling concentrations that are somewhat higher than Class A materials or a limit on the lifetime loading of a field of each metal. Fields receiving Class B biosolids must have a soil pH greater than 5.5, which reduces the availability of heavy metals by forming insoluble compounds in the soil. The soil pH of most Wisconsin crop production fields is 6.0 or higher due to liming or calcareous parent material and therefore most fields meet this criterion for application. Municipalities must monitor metal concentrations in their biosolids. Metal levels in domestic wastewater are naturally low, but when the level of a metal increases often from an industrial source, that business may be required to take steps to limit metal discharge to the sewerage system. Applications also must meet numerous site and cropping conditions such as soil depth, slope, and distances from wells, schools, and surface water. The site criteria depend on the method of application (either surface, incorporation by tillage, or injection). Another criterion for limiting the risk of exposure to pathogens in Class B biosolids is the time interval between application and plant harvest. These restrictions effectively direct the majority of Class B biosolids to field crops, with the majority applied for corn production.

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[87] Wolkowski, R. and F. Hegeman. 2010. *Land Applying Municipal Biosolids in Wisconsin*. UW. Madison Extension.

Biosolids are commonly landspread as a recycling practice. This permits utilization of the nutrients and organic content of biosolids, reducing the need for chemical fertilizers. The risk of groundwater pollution from landspreading is dependent upon numerous factors, such as its composition and application rate, depth to water, and the physical and chemical soil properties existing at the application site. Site approval and landspreading of biosolids are regulated by the WDNR. WDNR criteria for determining the suitability of a site are based on soil and product pH, soil permeability and available water capacity, slope, depth to bedrock and water table, soil cation exchange capacity, flooding potential and farming practices. In addition, biosolids application rates are to be in accordance with the nitrogen uptake of crops. This regulatory control helps to minimize the risk of adverse environmental effects. If biosolids are properly applied to suitable sites, the threat of groundwater quality degradation is negligible. Therefore, it is important that biosolids applicators communicate with agricultural producers about the amount of nutrient applied through biosolids so that farmers can account for the nitrogen applied to their fields . This will help avoid the application of unneeded nitrogen through commercial or other organic sources such as manure, which would increase the overall risk of nitrate contamination of groundwater.

MMSD produces a high quality biosolids product which it recycles to agricultural lands through its Metrogro Program. Metals are consistently below the concentrations used by EPA to define an "exceptional quality" biosolid. The District's goal is to diversify its overall biosolids management program by developing a soil-like product called MetroMix. MetroMix will be produced by combining dewatered biosolids with materials such as sand and sawdust to provide bulk and texture. The plan is to upgrade and increase the capacity of the existing solids handling system. It is anticipated that he biosolids produced by the upgraded plant will consistently be of better quality than the current Class B biosolids production. Once fully operational, the plan is to generate 25 percent to Class A quality. This will be reserved for the MetroMix product because the energy cost is very high. It is expected that the land application of Class A and "exceptional" Class B biosolids will have an overall lower impact on water quality than even now.

In Dane County over 45,000 acres of land have been approved by the WDNR for use in the land-spreading of municipal and industrial biosolids. Most of this acreage has been approved for use by the Madison Metropolitan Sewerage District (MMSD), although on an annual basis MMSD only applies biosolids to approximately 4,800 acres. The majority of the MMSD application sites are in the central and south-central part of the county. Approximately 39 million gallons of treated biosolids are recycled each year as part of the MMSD biosolids application program (commonly termed "Metrogro"). Farmer interest in the program is high, with demand exceeding the supply. Many of the other application sites in the county are located near the cities and villages where the product is generated in order to minimize transportation costs. Although the application sites are not shown, most sites fall under the Low to Moderate categories on the Surface Contamination Risk Map.

An analysis of nitrate in shallow wells in the MMSD Service Area associated with Metrogro was conducted in 1993 on the District's behalf by the Department of Civil and Environmental Engineering at UW-Madison. Water samples from about 636 private wells located near biosolids application sites have been collected since 1978. The study included a statistical comparison of background and post-application data from private wells that were sampled as part of the District's monitoring program. It also compared the amount of nitrogen applied by the District through its Metrogro program to the total amount of nitrogen applied to agricultural land in Dane County from traditional commercial fertilizers.

Comparison of background and post-application data indicates that landspreading of biosolids has not adversely affected the water quality of nearby wells. Metrogro applications are based on meeting the nutrient requirements of the crop grown. The annual application rate has been about 725,000 lbs./yr. of available nitrogen between 2008 and 2012. This is roughly three percent of the fertilizer nitrogen applied to corn in Dane County. Any influence on groundwater quality due to the relatively small amount of nitrogen applied as biosolids was found to be negligible in comparison to the much larger effects of commercial fertilizer. Voluntary monitoring is continuing in order to evaluate any possible effects of continued biosolids application.

Septage Application

Septage is a mixture of sludge, fatty materials, and wastewater pumped from septic tanks, holding tanks, grease traps, and portable toilets. Septage is more concentrated than domestic sewage and must be handled carefully to minimize public health hazards and nuisance problems. When properly managed, however, domestic septage is a valuable soil conditioner. Septage contains nutrients that can reduce reliance on chemical fertilizers for agriculture. A good septage management program recognizes the potential benefits of septage and employs practices to maximize these benefits.[88] One of the goals of the Dane County Water Quality Plan is the practice of returning organic waste to the land for the beneficial reuse of the nutrients. Realizing this objective requires careful management to avoid environmental problems and impacts on ground and surface water quality. Management practices need to be followed to ensure that application operations comply with the standards and regulations while maximizing the beneficial use of the organic wastes.

The most important water quality considerations of managing the land application of septage include:

(1) avoiding groundwater contamination from precipitation infiltrating through the waste into groundwater;
(2) preventing the accumulation or buildup of toxic or hazardous materials in soil, water, or plants; and
(3) avoiding contamination of surface waters from runoff from application sites;

About 26 million gallons of septage is disposed in Dane County annually. Septage is hauled and disposed of both at wastewater treatment plants and at landspreading sites. The proportion of septage that is landspread has continued to decline. Septage disposal at wastewater treatment plants has increased from 9 percent in 1983 to 60 percent in 1994 to about 89 percent in 2013, with the remainder being applied to landspreading sites.

It is important to maximize the benefits of land application of organic materials to the greatest extent possible, rather than looking at land application merely as a disposal technique. This means selecting sites and applications where the benefits of the nutrients and organic materials are utilized to the greatest extent in improving soil fertility and productivity, reducing erosion and also chemical fertilizer use.

State regulations have established standards for licensing disposal sites. The rules in effect since 1997 have specified the allowable slopes, soil permeability, minimum separation distances, and rate and manner of application necessary to protect public health and water quality. In addition, Dane County ordinance prohibits the spreading of septage on frozen or snow-covered ground.

While the regulations for landspreading septage under controlled conditions are sufficient to protect public health and water quality, there is not enough information to determine whether or not the

[88] U.S. Environmental Protection Agency. 1994. *Guide to Septage Treatment and Disposal.*

required site conditions and application procedures are being observed. Many of the currently approved septage disposal sites are in close proximity to site conditions that are unsuitable for septage disposal.[89] This underscores the importance of a rigorous monitoring and inspection program for septage disposal sites.

The involvement of County staff in the review and approval of septage landspreading sites would incorporate greater knowledge and familiarity with local site conditions. It would also allow better monitoring and observation of site conditions and landspreading practices. The program should include site location and licensing requirements, application and operating criteria and procedures, surveillance and enforcement procedures, and the revenue necessary to support the program. The use of a geographic information system for record keeping would facilitate the tracking and analysis of the data. The Department of Public Health for Madison & Dane County attempted to gain authority from WDNR to regulate septage spreading in Dane County, but their request was denied because the current county ordinance would hold the land owners responsible for any violations on their land rather than the septage hauler. PHMDC is currently working to incorporate the tracking of septage pumping and disposal into its septic maintenance program. This will help PHMDC and WDNR to track spreading activities and identify any potential problems.

Attachment D in *Private On-Site Wastewater Treatment Systems Management*[90] contains maps showing the general location of WDNR approved septage disposal sites and the disposal site location criteria in NR 113. These maps indicate that many of the currently approved septage disposal sites are in close proximity to site conditions that are unsuitable for septage disposal. **Map 50** shows the location of state approved septage sites and surface contamination risk. This underscores the importance of a rigorous monitoring and inspection program for septage disposal sites. While most haulers conduct landspreading operations conscientiously and with due regard to safe disposal, management measures need to be adopted to ensure that disposal operations follow the standards and regulations.

Table 27 shows the acreage of state licensed septage disposal land area by township in Dane County for 1997 and 2010. The total amount of land approved for septage disposal in Dane County has decreased by almost two-thirds from 5,848 acres to 2,080 acres. This is most likely due to the more stringent land disposal criteria adopted in NR 113 and in effect since 1997, as well as the ability of haulers to more easily dispose of septage at municipal wastewater treatment plants. The proportion of septage disposed at wastewater treatment plants has continued to increase. In 1983 it was only 9 percent. By 1994 it had grown to 60 percent. It is currently estimated to be 89 percent, based on WDNR and wastewater treatment plant records.[91]

Figure 32 shows a 15-year record of the annual septage received at MMSD by type. Septage disposal at MMSD has more than doubled between 2000 and 2010, from about 9.6 million gallons to 22.5 million gallons. The majority of this increase is from septic tanks and holding tanks. Septic tank septage disposal has increased from about 1.2 million gallons in 2000 to 7.2 million gallons in 2010. Holding tank septage disposal has increased from 7.8 million gallons in 2000 to 14.4 million gallons in 2010.

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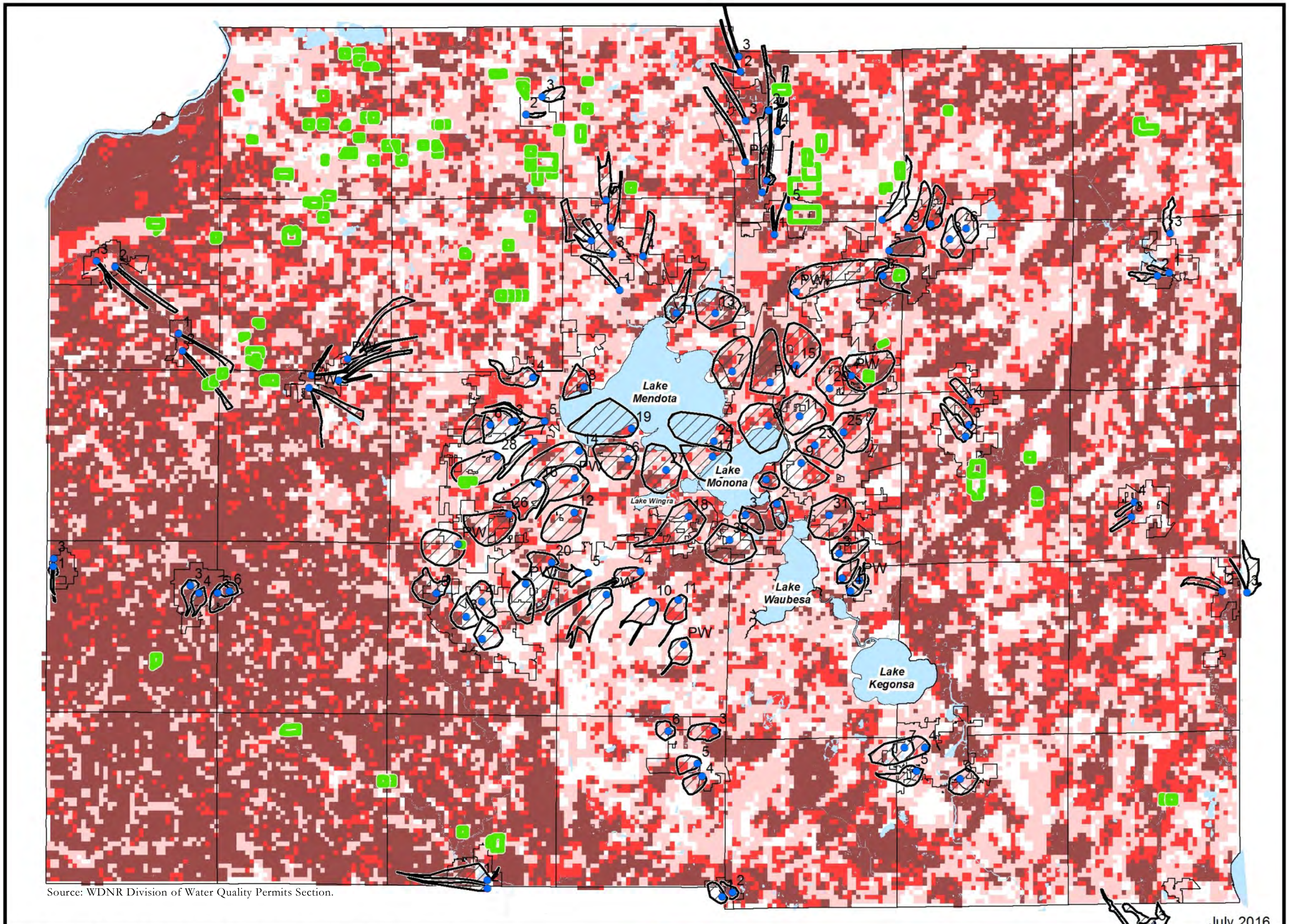
[89] Capital Area Regional Planning Commission. 2013. *Private On-Site Wastewater Treatment Systems Management*.

[90] https://danedocs.countyofdane.com/webdocs/PDF/capd/2013_postings/Publications/Water_Quality_Plan_I_web_08.08.13.pdf Capital Area Regional Planning Commission, 2013.

[91] Capital Area Regional Planning Commission. 2013. *Private On-Site Wastewater Treatment Systems Management*.

The increase in septage disposal at MMSD, and at wastewater treatment plants in general, has been due to a number of factors including: an increase in the number of private on-site wastewater treatment systems, more frequent inspection and pumping requirements for on-site systems, increased standards and regulations for landspreading sites, and Dane County's prohibition on the spreading of septage on frozen or snow covered ground. These factors along with the relatively easy availability of wastewater treatment plants that accept septage at reasonable rates is expected to continue to favor septage disposal at treatment plants in the coming years. In support of this, additional septage receiving sites should be explored at the Belleville, Cross Plains, Stoughton, and Sun Prairie wastewater treatment plants, which do not currently accept septage.

Map 50



State Approved Septage Application Sites and Groundwater Contamination Risk from Surface Activities, Dane County, Wisconsin

Septage Disposal Sites
Well Protection Zone
Municipal Well
Extreme
High
Moderate
Low

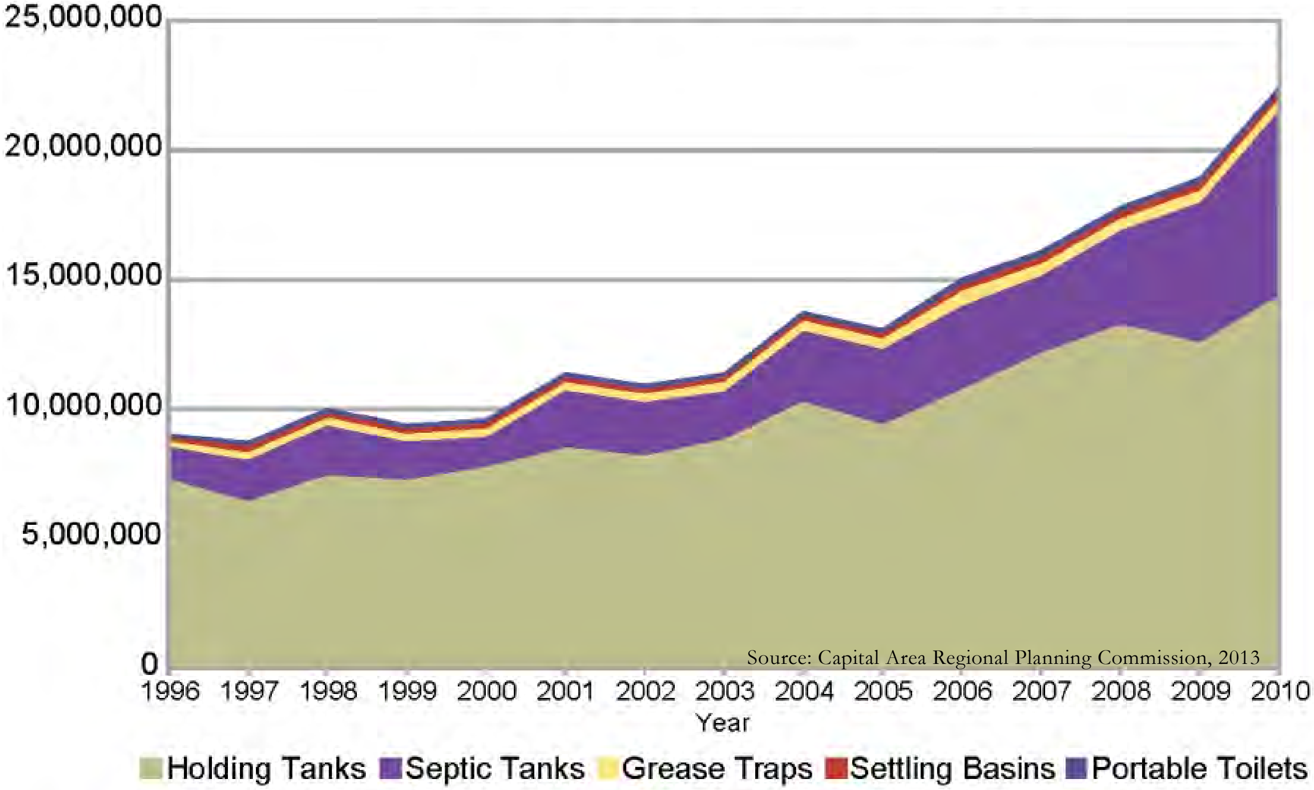
0 1.5 3
Miles

TABLE 27
LAND AREA APPROVED FOR SEPTAGE DISPOSAL BY TOWNSHIP

Township	1997 (acres)	2010 (acres)
Albion	0	30
Berry	580	39
Black Earth	0	0
Blooming Grove	0	0
Blue Mounds	165	50
Bristol	431	10
Burke	442	101
Christiana	0	0
Cottage Grove	359	344
Cross Plains	190	68
Dane	103	306
Deerfield	65	0
Dunkirk	547	0
Dunn	0	0
Madison	0	0
Mazomanie	447	63
Medina	0	0
Middleton	180	30
Montrose	100	150
Oregon	0	0
Perry	15	0
Pleasant Springs	30	0
Primrose	35	52
Roxbury	167	203
Rutland	100	0
Springdale	0	0
Springfield	817	91
Sun Prairie	190	0
Vermont	0	17
Verona	0	17
Vienna	26	113
Westport	272	0
Windsor	543	352
York	44	44
TOTAL	**5,848**	**2,080**

Source: WDNR Records

Figure 32
Septage Received at MMSD



Source: Capital Area Regional Planning Commission, 2013

Wastewater Irrigation and Landspreading

Only a few industries in Dane County discharge processed wastewater to the land surface (**Table 28**). If these land application systems are properly sited and proper application rates adhered to, the pollutants in the discharge will be attenuated in the soil. Currently these discharges do not represent serious sources of groundwater pollution in Dane County, and are regulated under the Wisconsin Pollutant Discharge Elimination System (WPDES) program. In addition, Capital Area Regional Planning Commission staff provide review and comments on proposed permits to better avoid adverse impacts. Wastewater permits contain all the monitoring requirements, special reports, and compliance schedules appropriate to the facility in question. Permits are issued for a five year term.

Table 28
Industrial Surface Wastewater Discharges to Groundwater

Permit Holder	Receiving Water/Watershed	Description	Type of Discharge
Bailey Farms (Karem Inc.) 549 Karem Drive, Marshall, WI WPDES Permit #WI-0046400-03-0	Groundwaters of the Upper Rock River Basin	Processes cattle for various byproducts including hides and ground bones.	Landspread
Clear Horizons Dane LLC 6307 Cuba Valley Road, Dane, WI WPDES Permit #WI-0064530-01-0	Groundwaters of the Six Mile/Pheasant Branch Creek watershed	Three waste digesters to digest manure from local farms and a food processing substrate.	Landspread
Dairyfood USA Inc. 2819 CTH F, Blue Mounds, WI WPDES Permit #WI-0046400	Groundwaters of the Pecatonica River Basin	Cheese processing water	Landspread
GL Dairy Biogas LLC . 1900 S. Ave LaCrosse, WI WPDES Permit #WI-0065099-01-0	Groundwaters of Pheasant Branch Creek	Manure digestate	Landspread
MG&E Compensatory Recharge 4635 Odana Road, Madison, WI WPDES Permit #WI-0063088-02-0	Groundwaters of the Lower Rock River Basin	Filtered pond water	Concentrated infiltration
WI DNR - CWD Processing Facility 4738 Hwy 78, Black Earth, WI WPDES Permit #WI-0063452	Landspreading sites in the Lower Wisconsin River Basin	Wash water and sludge from equipment cleaning	Landspread

Source: Wisconsin Department of Natural Resources 2015.

Irrigation

Irrigation is generally not considered a direct source of groundwater pollution, but it can facilitate leaching of fertilizers or pesticides, whether these are applied directly to crops or through the irrigation system. High capacity irrigation wells, (pumping more than 70 gals./min) are regulated by WDNR. Back-siphoning valves are required on irrigation systems where fertilizers and pesticides are applied through the system. These valves are to be inspected annually.

Although direct groundwater contamination may occur from the malfunction of back-siphoning valves, which can allow backflow of chemicals to the irrigation well, in Dane County few farmers apply pesticides or fertilizers through irrigation systems. Thus back-siphoning failures do not represent a major groundwater quality threat.

Manure Storage and Landspreading

Manure (livestock waste) is a potential source of groundwater pollution. Inadequately controlled animal feedlots, unconfined manure stacks, unlined manure pits and improper manure spreading are the main sources of livestock pollution of groundwater. Primary pollutants from this waste include nitrates, chlorides and pathogenic organisms.

The potential for pollution from manure may be highest during wet or snowy weather conditions. During these times, farmers who normally spread their manure daily may store it in temporary stacks without adequate protection. Precipitation may then leach nutrients and bacteria from the manure into the groundwater. A properly designed and managed manure storage facility reduces the potential for causing groundwater pollution.

Manure Storage

Manure stored or disposed of improperly can seriously affect surface and groundwater. For example, many farm operators do not have adequate manure storage facilities. During the winter months, many farms pile waste until spreading it prior to spring cultivation. Rainfall and snowmelt on unprotected manure stacks can generate runoff that degrades groundwater quality. Potential pollutants from manure include nitrates, chlorides, bacteria, oxygen-demanding materials and phosphorus.

An inventory of manure storage facilities in Dane County has been prepared by the Land Conservation Department (DCLCD), **Map 51.** This effort is associated with the nonpoint source pollution abatement projects conducted by the RPC and DCLCD (e.g., Sixmile–Pheasant Branch, Black Earth Creek, Yahara–Monona, Yahara–Mendota, and Dunlap Creek priority watershed projects), and recently expanded to the rest of the county.

In general, areas in northern and southwestern Dane County are believed to have the greatest number of animal units per square mile. As a result, these areas probably have the greatest concentrations of manure. Both the Surface and Subsurface Contamination Risk Maps were viewed to determine pollutant attenuation and contamination risk for these areas. From the Surface Map, areas in northern Dane County are generally low to moderate risk, while the unglaciated areas of southwestern Dane County present extreme risk conditions. On a large-scale basis, the unglaciated area may be most critical in terms of groundwater pollution due to high animal waste production and more marginal pollutant attenuation conditions, largely the result of thin soils and shallow depths to bedrock.

Also, by comparing the Surface and Subsurface Contamination Risk Maps, the attenuation capacity of the soils in the northern portions of the county appears to be a critical factor between moderate or low risk conditions of surface storage, compared with the largely high or extreme contamination risk associated with manure pits.

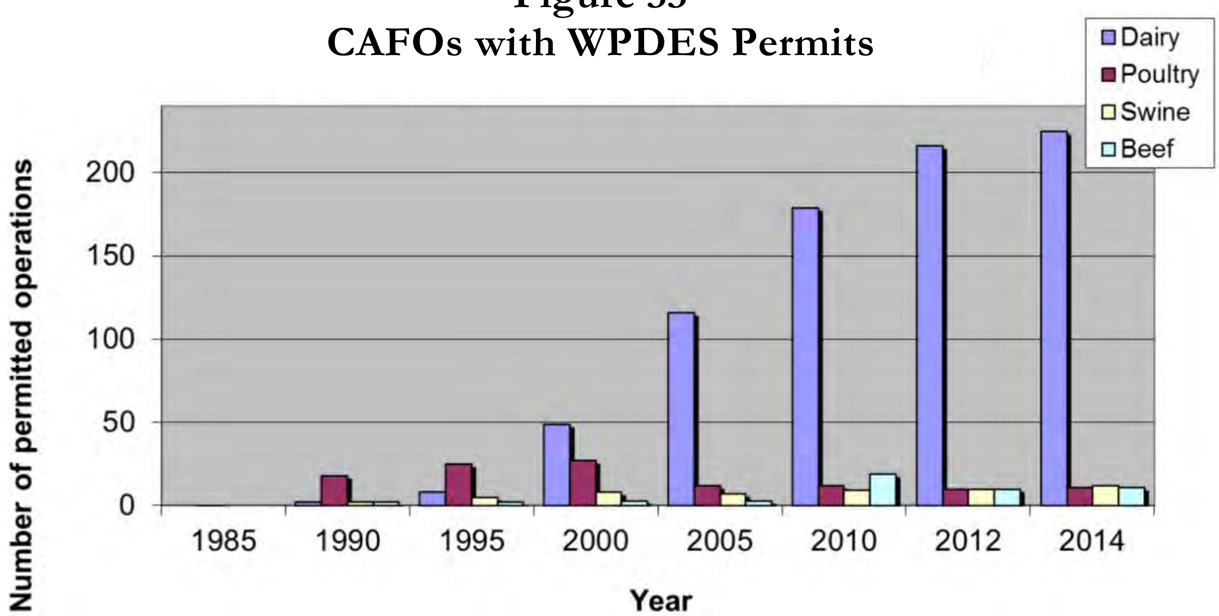
Although regional evaluations are helpful in defining target areas in the county, site-specific factors are most important in determining the threat of groundwater pollution from animal waste. Improperly designed and managed waste storage facilities have the greatest potential for causing groundwater pollution.

Concentrated Animal Feeding Operations (CAFOs)

Feedlots are outdoor areas where animals are concentrated for feeding and other farm management purposes. For large animal feedlots (greater than 1,000 animal units) and smaller operations where pollution problems have been documented, the WDNR requires farm operators to obtain a WPDES permit. In addition, Capital Area Regional Planning Commission staff provides review and comments on proposed permits to better avoid adverse impacts. There are presently 14 farm operations in Dane County that are permitted due to their size (**Map 52**). In 1987 there was one. An overall increasing concentration of livestock in feedlot areas has been occurring in Dane County and Wisconsin overall (**Figure 33**).

Manure production is estimated to be near two million tons per year. Not only is this a large amount of animal waste produced, it is also high relative to most other counties in Wisconsin. Increasing herd sizes may result in additional manure management and associated groundwater quality problems. Water quality protection from large animal feedlots, and manure storage and disposal practices, therefore, should continue to receive state and local emphasis.

Figure 33
CAFOs with WPDES Permits



Source: Wisconsin DNR

Landspreading of Manure

Manure is commonly spread on cropland as a fertilizer. Land application of manure on shallow soils (less than 20 inches over bedrock) represents a major groundwater hazard due to the ease of pollutant leaching. There are four soil series in the county that are less than 20 inches over bedrock: Dunbarton, Edmund, Elkmound, and Sogn. Manure applications on these soils (representing 10 percent of the land area in the county) should be avoided. Spreading of manure should also be limited on highly permeable soils and where a high water table exists.

If manure is applied on cropland in conjunction with commercial fertilizers, care should be given so as not to exceed crop nitrogen needs and induce nitrate-nitrogen leaching. In addition, precautions should be taken to avoid manure application near wells. If well casings are corroded or improperly grouted, groundwater quality can be degraded from pollutants transported by surface runoff

Fertilizer Application

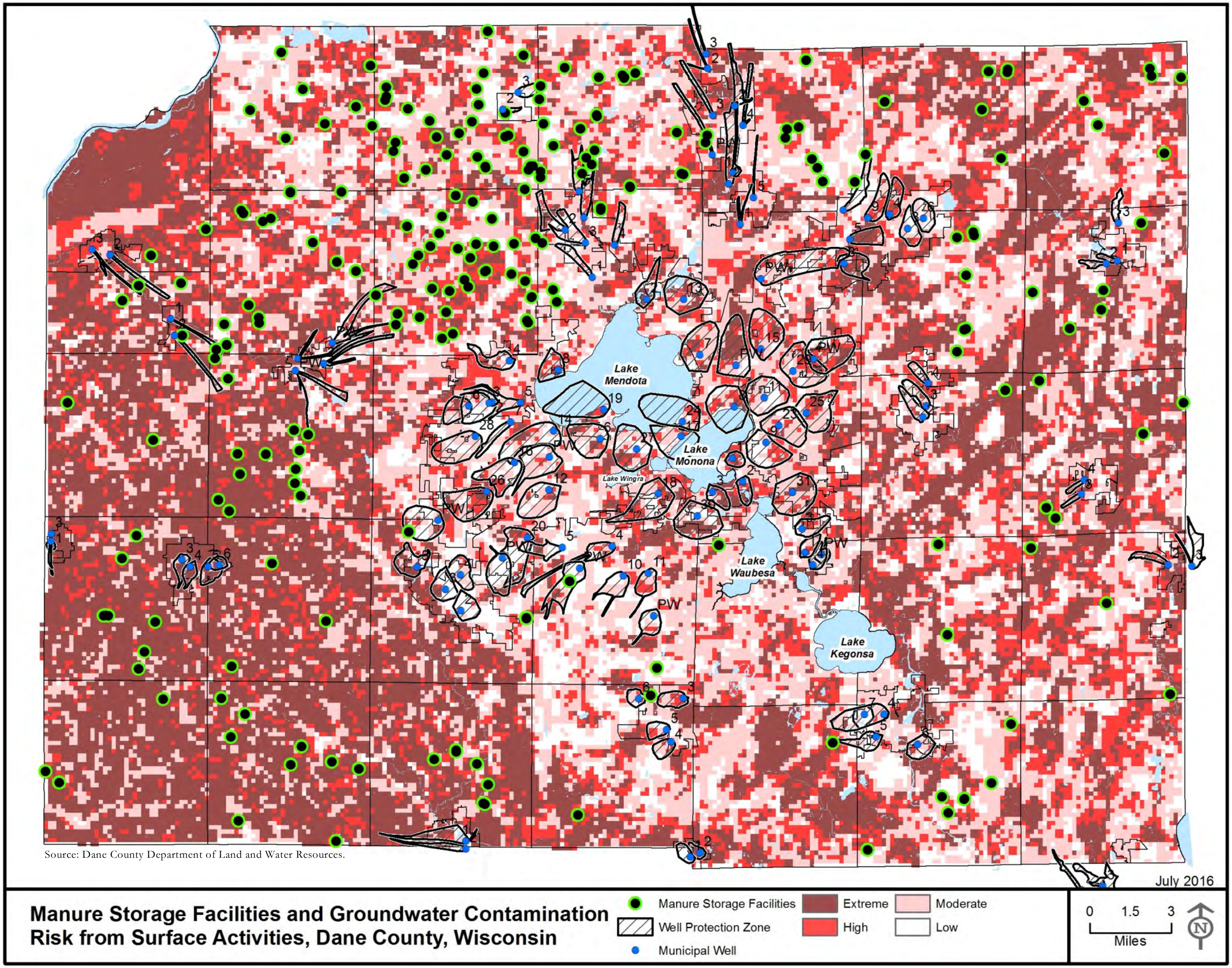
Chemical fertilizers are used to supply plant nutrients for agricultural crops and for urban land uses such as golf courses, lawns, and gardens. The agricultural sector, though, accounts for most fertilizer use. The primary nutrient from fertilizer that may impact groundwater quality is nitrogen. When a nitrogen fertilizer is applied to the soil, it may be oxidized to the nitrate form, which can easily leach through the soil to the groundwater. In Dane County, over-application of nitrogen fertilizer has been associated with elevated nitrate-nitrogen levels in shallow groundwater. High levels of nitrate-nitrogen in groundwater used for drinking purposes represent a human health concern for infants under age six months.

The greatest quantity of nitrogen fertilizer is applied to corn crops in Dane County, and this practice potentially has the most widespread impact on groundwater quality. Lawns, gardens, and other agricultural crops, such as tobacco, also receive nitrogen fertilizer; however, their acreage in the county is much less extensive than that of corn. Groundwater quality impacts from these areas should be localized and over-application is a concern. Lawn fertilizers have also been shown to be a source of nitrogen that can be leached to the groundwater table.

The greatest concentration of land acreage in corn is in eastern Dane County, specifically the towns of Rutland, York, Christiana and Dunkirk. Since these towns probably also have the greatest nitrogen fertilizer use, high nitrate levels in local groundwater supplies may be of particular concern.

Based upon the total corn acreage in Dane County and upon common nitrogen fertilization rates (120-190 lbs./acre), the estimated amount of nitrogen applied to corn in the county is 20 to 35 million pounds per year. About 50 to 70 percent of this quantity can be expected to be utilized by the crop, with much of the unused nitrogen potentially adding to the nitrate content of groundwater. Due to these large nitrogen inputs, fertilizer application represents an important areawide groundwater quality concern. Before fertilizers are applied, a soil test should be performed to determine the nutrient needs of the crop. Fertilizers should also be applied during times of greatest nutrient uptake. Both the University of Wisconsin and Dane County Extension continue to promote the economic and environmental benefits of nutrient management plans, programs and best management practices to control nitrate contamination of groundwater.

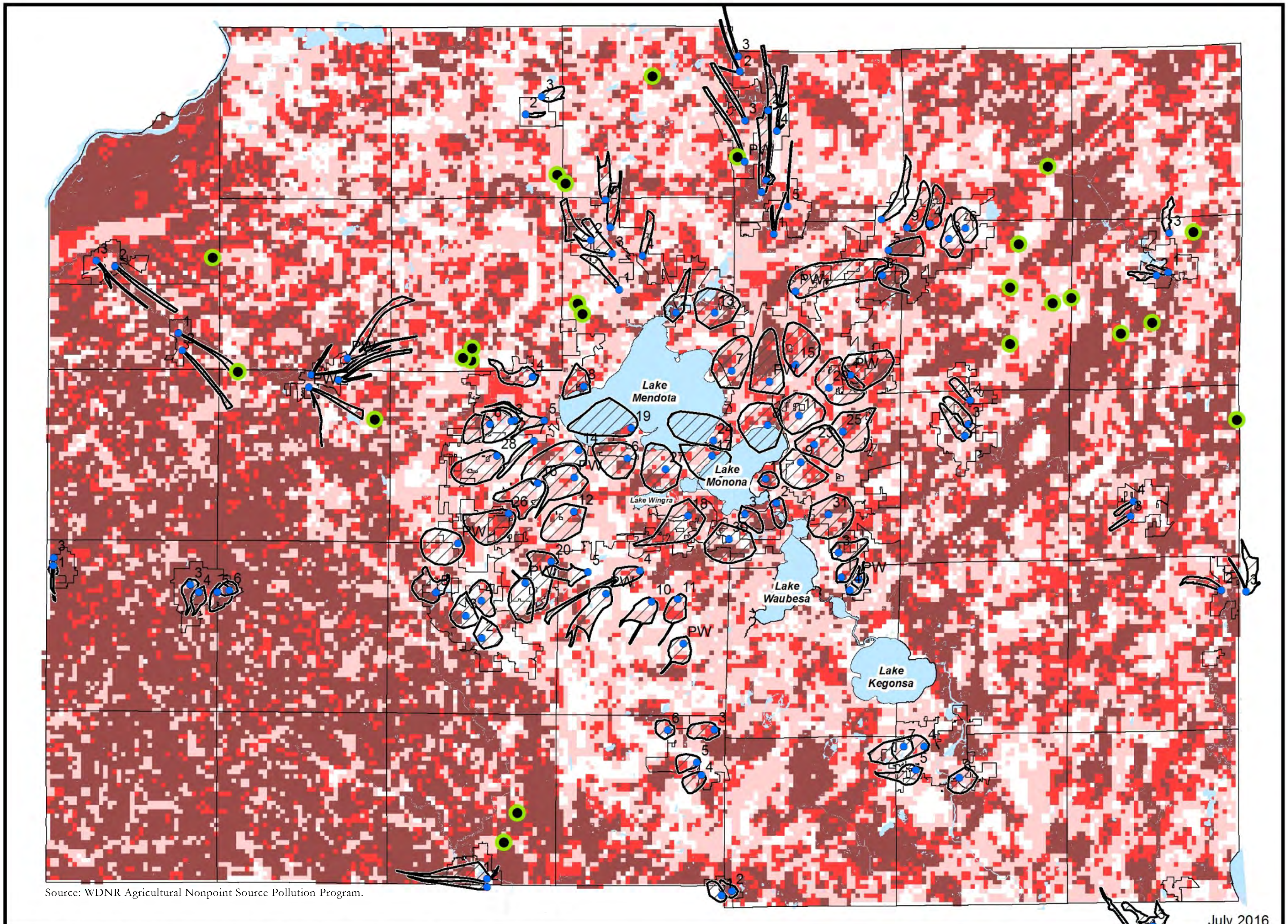
Map 51



Source: Dane County Department of Land and Water Resources.

Manure Storage Facilities and Groundwater Contamination Risk from Surface Activities, Dane County, Wisconsin

Map 52



CAFO (Concentrated Animal Feeding Operation) and Groundwater Contamination Risk from Surface Activities, Dane County, Wisconsin

Pesticide Application

Pesticides are widely applied on agricultural land in Dane County for weed, insect and disease control. Pesticides are also used on roadside ditches, power line right-of-ways, woodlots, lawns and gardens. Pesticides that leach into the groundwater may pose a drinking water health hazard depending on the pesticide's toxicity, concentration and degradation rate. If properly applied, however, most pesticides will be taken up by plants or rapidly broken down by hydrolysis, sunlight, and bacteria or other soil microorganisms. Clay and soil organic matter are also important in binding pesticides and preventing them from leaching into the groundwater. The greatest potential for pesticide contamination of groundwater exists in soils with high permeabilities, thin soils over fractured bedrock, and soils with minimum clay and organic matter.

The principal agricultural pesticide of local concern currently is atrazine. Atrazine prohibition areas have been established under the authority of DATCP under Ch. ATCP 30. This includes the central two-thirds of Dane County as well as along the Wisconsin River. The distribution of wells tainted with atrazine is fairly random and widespread across the county, and generally the concentrations are low. An evaluation of the Atrazine Rule in 1997 shows a significant decline in groundwater atrazine levels between 1994 and 1996, although the percent of contaminated wells, remained about the same. It is believed the limits placed on atrazine use have contributed to its decline in groundwater.

The UW Extension technical bulletin *Nutrient and Best Management Practices for Wisconsin Farms* provides general guidance for pesticide and nutrient management in Wisconsin. However, more research on pesticide transport, degradation pathways and toxicity of metabolites (breakdown products) is needed.

Salt Storage and Use for Deicing

Salt storage and deicing can affect groundwater quality. Precipitation may dissolve salt stored in piles or spread on road surfaces and form a leachate that can seep into the groundwater. Very high chloride concentrations (above 250 mg/l) in drinking water supplies represent a violation of the federal "secondary" drinking water quality standard.

A survey of road salt storage sites in cities, villages, and towns in Dane County indicates that most storage sites in the county are covered and have paved linings. Thus the potential for groundwater contamination from leachate formation and seepage is limited.

Deicing probably has a greater impact on groundwater quality than salt storage in Dane County. This is especially evident in urbanized areas where heavy salting occurs. Even though average chloride concentrations are still significantly below the drinking water standard, sodium and chloride levels in ground and surface waters have been increasing for over the past 30 years (**Figures 24, 25, and 26**).

A road salt reduction program was instituted by the City of Madison in the mid-1970s to minimize adverse environmental effects. Despite gains in application efficiency, however, the use of road salt for winter road maintenance in Madison continues to grow (**Figure 27)**. This indicates that road building has been increasing faster than salt reduction efforts can offset. Also, deicer use is not limited to the city. The state, county, nearly all local units of government, and private property owners and their agents all apply salt, and many are making some effort to reduce or better manage use of salt for deicing.

Two factors that influence the sodium and chloride levels at a well are length of the steel casing and proximity to major roadways (salt routes). A well with a short casing draws proportionally more water from the upper aquifer and water quality is more impacted by surface activities such as road salt application. It should be noted that that reductions in water table levels represented by the cones of depression northeast and southwest of the Yahara Lake chain (**Maps 38a and b**) do not currently indicate a discernable effect or cause of higher chloride levels in drinking water supplies (above and beyond well location, construction, and surrounding land uses). Therefore wellhead protection planning, as currently practiced, and reduced salt usage should continue to be the focus of municipal water utilities and transportation departments. This is less of a problem in rural areas because comparatively less salt is used (per acre), resulting in greater dilution – although, rural homeowners should have their wells tested, particularly if they notice a change in conditions (e.g., cloudiness or taste) or have other reasons to suspect contamination.

It should be noted that contamination potential is a function of several parameters: well location, construction, land use, geology, and pumping rate – so it is not a simple correlation. Pumping by high-capacity wells does increase the potential for contamination because the pumping lowers the potentiometric or apparent surface in the deep aquifer. This increases the downward gradient between the shallow and deep systems so there is increased potential for water and contaminants to move downward, if there is a pathway. Cross-connected (multi-aquifer) wells provide one such pathway. This is why it is recommended that wells be cased past the Eau Claire confining unit, and that old unused wells be plugged and properly abandoned. Chloride is a good water quality indicator because it is soluble and migrates easily through the ground.

But just because the potential exists doesn't mean that contamination is actually happening. Well contamination is spatially variable and depends on the presence of pathways (cross-connected wells, fractures, missing Eau Claire, etc.), along with a contamination source. For example, it is known that viruses reach many of the deep wells, and this would not happen if they were not pumping. Chloride concentrations are increasing in a number of the deep wells, often because they are cross-connected and the chloride would not be moving downward if the wells were not pumping. Cross-connected wells can be a problem, and are not even permitted in some other states. It is therefore recommended that all new municipal wells be cased into the deep Mt. Simon aquifer, and that existing wells be reconditioned where opportunities present themselves.

Another recommendation is to reduce application of salt at the source. Although it has been speculated that the public is intolerant of snow covered roadways and increased travel times, this may not be the case. A 1975 City of Madison-funded UW study found that after two years of reduced salt use in the Wingra basin, more than 90 percent of respondents believed the program was worthwhile and should be continued, while 85 percent supported city wide expansion of the program. Furthermore, the report found little difference in opinion between respondents living within or outside the reduced salt zone.[92],[93]

Municipalities in the region should continue to reevaluate their practices regarding the application of salt for ice and snow control and strive to achieve minimum application rates consistent with safe operation. It is also recommended that municipalities continue to consider alternatives to salt, such as a sand-salt mix (with enhanced street sweeping in the spring), as well as fostering less public expectation for bare pavement conditions, reducing travel speed, and anticipating increased driving

[92] City of Madison 2012 Road Salt Report.
[93] UW-Madison. 1975. *City-University Road Salt Study – Overview Report.* Department of Mechanical Engineering.

times during adverse conditions. This is all part of a public education and awareness campaign being promoted through the Wisconsin Salt Wise Partnership[94]

Other Potential Pollution Sources: Stockpiles, Spills, and Stormwater Management

In addition to salt, unlined and uncovered stockpiles of other materials, such as coal or construction debris, may also pose as a pollution source. If soluble, these materials can dissolve in precipitation and seep into the groundwater. In some instances, silage storage at farms is also a concern. Silage leachate is a liquid which has a high biochemical oxygen demand (BOD) and nitrate concentration. When not properly contained, leachate can be a ground or surface water pollutant.

Spills of hazardous substances occur frequently in Dane County and certain spills may pollute groundwater. Most Dane County communities have documented some spills since state reporting requirements were enacted. Spills can occur from almost any source and take place at any time. Frequent causes of spills are chemical equipment malfunction and deterioration, human errors, and traffic accidents. The quantity of a spill and subsequent cleanup and containment efforts are important in determining the likelihood and extent of groundwater pollution.

The design of stormwater management facilities that involve infiltration of stormwater should also consider the potential impacts on groundwater quality. Such facilities include infiltration trenches, infiltration basins, bioretention facilities, rain gardens, grassed swales, subsurface storage and infiltration galleries, and detention basins. The WDNR has developed post-construction stormwater management technical standards for site-specific evaluation of stormwater facilities.[95] Those standards include provisions intended to protect groundwater quality, and it is recommended that the standards continue to be refined and applied in stormwater management facilities design. In addition to review by WDNR and local municipalities, Capital Area Regional Planning Commission staff also review stormwater facility designs as part of its Water Quality Plan consistency review in urban and limited service areas so that proposed measures are protective of groundwater quality.

94 https://www.wisaltwise.com/
95 http://dnr.wi.gov/topic/Stormwater/standards/index.html

Chapter 6: Groundwater Management

Federal Government

Groundwater protection is a complex issue involving decisions, actions and programs at all levels of government – federal, state, and local. The U.S. Environmental Protection Agency (U.S. EPA) is the principal federal authority concerning groundwater management. The primary responsibility for groundwater management, though, rests with state and local government and these programs are emphasized in this chapter. While there is no comparable federal law to Wisconsin's Groundwater Protection Act, a number of federal regulations do support state and local government in protecting groundwater. Major federal laws with groundwater provisions include:

1. **Safe Drinking Water Act of 1974 (SDWA), as amended in 1986 and 1996**

   The EPA is authorized by this law to set maximum contaminant levels and monitoring requirements for public water systems. The EPA also has authority to designate sole source aquifers, which are the principal sources of drinking water to an area and consequently require special protection.

   The 1986 amendment greatly expanded the number of substances addressed by the primary drinking water standards, and also provided secondary standards relating to the aesthetic qualities of drinking water (e.g., smell and taste). In addition, states are required to adopt wellhead protection programs.

   The 1996 amendment also require states to develop and implement a Source Water Assessment Program (SWAP). In 1999 Wisconsin submitted its SWAP plan for approval by U.S. EPA. States must identify sources of public drinking water, assess water systems' susceptibility to contamination, and inform the public of the results.

2. **Resource Conservation and Recovery Act of 1976 (RCRA), as amended in 1984**

   This act authorizes a hazardous waste program which establishes standards for transportation, treatment, storage and disposal of hazardous material. RCRA establishes EPA's "cradle-to-grave" management system that regulates hazardous wastes from their point of generation to their point of ultimate disposal. The program has a major emphasis on protecting groundwater.

   Amended in 1984, RCRA also created a regulatory program to address leaking underground storage tanks (LUSTs).

3. **Toxic Substances Control Act of 1976 (TOSCA)**

   This law authorizes EPA to restrict or prohibit the manufacture, distribution and use of products presenting an unreasonable risk of injury to health or the environment. Groundwater is included in the definition of "environment."

4. **Clean Water Act of 1972 (CWA), as amended in 1977**

   General references to groundwater protection in municipal wastewater treatment, planning and research programs are made in this law. Its principal regulatory programs, however, focus on surface water.

5. **Federal Insecticide, Fungicide and Rodenticide Act of 1978 (FIFRA)**

   The EPA is given the responsibility in this act to control the use of pesticides, taking environmental impacts into consideration, including those affecting groundwater.

6. **Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA or Superfund), and Superfund Amendments and Reauthorization Act of 1986 (SARA)**

   The act authorizes U.S. EPA to respond directly to environmental threats caused by chemical spills or releases of hazardous materials which may endanger public health safety and welfare. CERCLA regulates a greater number of hazardous substances than does RCRA, and also has lower reporting requirements.

   SARA encourages and supports emergency planning efforts at the state and local levels and provides the public and local governments with information concerning potential chemical hazards in their communities. Although codified as Title III of SARA, it is not part of the Superfund law itself.

7. **Pollution Prevention Act (PPA) of 1990**

   The Pollution Prevention Act established a new national policy for environmental protection: "that pollution should be prevented or reduced at the source whenever feasible..." This deceptively simple statement heralds a profound change in how EPA meets its obligations to protect human health and the environment. The 2010-2014 Pollution Prevention Program Strategic Plan focuses industry, government, and public attention on reducing the amount of pollution through cost-effective changes in production, operation, and raw materials use. Pollution prevention includes practices that increase efficiency in the use of energy, water, or other natural resources as well as protect our resource base through conservation. According to EPA, preventing pollution and conserving our natural resources offers the exciting possibility of reconciling economic growth with environmental protection to enhance the quality of life for everyone.

Summary of Wisconsin Groundwater Management

Wisconsin has a long history of groundwater protection. The first law is the1983 Wisconsin Act 410, Wisconsin's Comprehensive Groundwater Protection Act, which created Chapter 160, Wisconsin Statutes. This law expanded the State's legal, organizational, and financial capacity for controlling groundwater pollution. Chapter 160 provides a multi-agency comprehensive regulatory approach, using two-tiered numerical standards, based on the premise that all groundwater aquifers in Wisconsin are entitled to equal protection. There are a number of major components to Wisconsin's groundwater quality protection program:

Standards

Under chapter 160, Wis. Stats., the Department of Natural Resources (WDNR) must establish state groundwater quality standards based on recommendations from the Department of Health Services. Standard setting is a continuing process based on a priority list of substances detected in groundwater or having a high possibility of being detected, established by the WDNR in conjunction with other state agencies. The state groundwater standards are contained in chapter NR 140, Wisconsin Administrative Code. For each substance there is an enforcement standard (ES) which determines when a violation has occurred and a preventive action limit (PAL) which is set at a percentage of the ES. The PAL serves as a trigger for possible remedial action.

Regulatory Programs

Once groundwater quality standards are established, all state agencies must manage their regulatory programs to comply. Each state regulatory agency must promulgate rules to assure that the groundwater standards are met and to require appropriate responses when the standards are not met. The state regulatory agencies are the WDNR (waste and materials management, industrial and municipal wastewater, wetlands, remediation and redevelopment, and drinking water and groundwater); DSPS (private sewage systems); DATCP (petroleum product storage tanks, pesticide use and storage, fertilizer storage, and agrichemical clean-up program and fund); and DOT (salt storage). A summary of state regulatory controls of pollution sources can be found in **Attachment E** of this report.

Aquifer Classification

One of the most important features of Wisconsin's groundwater law is an item that was intentionally omitted. When Wisconsin was debating the groundwater protection legislation, the U. S. EPA tried to develop a nationwide groundwater approach. A keystone of EPA's proposal was aquifer classification - each aquifer would be classified according to its potential use, value or vulnerability, and then would be protected to that classification level. Some aquifers would not be entitled to protection and might never again be usable for human water supply. Wisconsin opposed aquifer classification. The foundation of Wisconsin's groundwater law is the belief that all groundwater in Wisconsin must be protected equally to assure that it can be used for people to drink today and in the future.

Monitoring and Data Management

At the time the groundwater legislation was created, there was concern that Wisconsin needed a groundwater monitoring program to determine whether the groundwater standards were being met. Therefore, a groundwater monitoring program was created under s. 160.27, Wis. Stats. Money from the Environmental Fund has been used for problem-assessment monitoring, regulatory monitoring, at-risk monitoring, and management-practice monitoring, as well as establishment of a data management system for collection and management of the groundwater data.

Research

Although all state agencies must comply with the groundwater standards, the processes by which groundwater becomes contaminated, the technology for cleanup, the mechanisms to prevent contamination, and the environmental health effects of the contamination are often not well understood. In addition, basic data on geology, soils, and groundwater hydrology is often not available. The University of Wisconsin System (UWS) and the state agencies have recognized that additional efforts in these research areas are badly needed. The Governor and the Legislature included a groundwater research appropriation for the UWS beginning with the 1989-1991 biennial budget. Since 1992, the UWS, DATCP, WDNR, and DSPS have participated in a joint solicitation for groundwater-related research and monitoring proposals.

Coordination

In enacting the Comprehensive Groundwater Protection Act, the Legislature recognized that management of the state's groundwater resources was a responsibility divided among a number of state agencies. Therefore, the Groundwater Coordinating Council (GCC) was created to advise and assist state agencies in the coordination of non-regulatory programs and the exchange of information related to groundwater. The Council has been meeting since 1984.

Wisconsin's Groundwater Protection Act, 2003 Wisconsin Act 310

As the result of a bipartisan legislative effort and support, significant groundwater quantity legislation was enacted - 2003 Wisconsin Act 310. This law expanded Wisconsin's authority to consider environmental impacts of high capacity wells and established a framework for addressing water quantity issues in rapidly growing areas of the state. Act 310 recognizes the link between surface water and groundwater, and the impact wells may have on groundwater quality and quantity. Chapter NR 820, formally defines the extent of Groundwater Management Areas as required by Act 310 and also creates a mechanism for evaluating proposed high capacity wells to determine whether the well will have a significant environmental impact on springs, trout streams, outstanding and exceptional resource waters.

Major components of 2003 Wisconsin Act 310 includes:

1) *Tracking well construction and water use.* The law requires all high capacity well owners to report water use annually, including those with wells approved before enactment of the law. Collection of pumping data assists in evaluating proposed new wells, monitoring approval conditions, calibrating groundwater flow models, improving water use estimates, identifying trends, and contributes to a better understanding and management of groundwater resources throughout the state.

2*) Expanded regulation of high capacity wells.* The Act directs WDNR to consider the environmental impacts associated with high capacity wells in the following situations:

- Wells located in a “groundwater protection area” (an area within 1,200 feet of an Outstanding or Exceptional Resource Water or Trout Stream).
- Wells that may have a significant environmental impact on a spring with a flow of at least one cubic foot per second (cfs) at least 80 percent of the time.
- Wells where more than 95 percent of the amount of water withdrawn will be lost from the basin.

3) *Designation of Groundwater Management Areas (GMA).* The Act directed the WDNR to establish two GMAs: one in Southeastern Wisconsin and another in the Lower Fox River Valley. In these areas the water level of the deep sandstone aquifer has been drawn down more than 150 feet since pre-development. The intention of the groundwater management area is to encourage a coordinated management strategy among state, local government units, regional planning commissions, and public and private users of groundwater to address problems caused by over-pumping of the deep aquifer, including increased levels of radium, arsenic and salinity. The WDNR will assist local government units and regional planning commissions in those areas as they undertake research and planning related to groundwater management.

Groundwater Attention Areas (GAAs) are geographic areas of the state where groundwater management problems are emerging and, if current trends continue, are likely to become a GMA. Dane County has been identified as a GAA. Designation as a GAA is intended to be a proactive mechanism for identifying and managing or mitigating stresses to groundwater and surface water systems *before* the water resources become significantly degraded and *before* significant adverse environmental impacts occur.

4) *Creation of a Groundwater Advisory Committee.* The committee issued a report to the Legislature in December 2006 regarding groundwater management areas. The committee issued a a second report to the Legislature in 2007 that assessed the effectiveness of Act 310 and considered changes to the regulatory framework applicable to high capacity wells. The GAC concluded that Act 310 is working as originally intended as a first step in integrated water management. The GAC, while acknowledging that more work remains to build upon initial improvements in groundwater management provided under Act 310, also recognized that the law has provided an added level of environmental protection for trout streams, outstanding resources waters, exceptional resource waters and springs. The 2007 report contains extensive recommendations and alternatives for enhancing the effectiveness of Act 310. Pursuant to Act 310, the GAC was terminated at the end of 2007 following submittal of its second report to the Legislature.

Great Lakes Compact, 2007 Wisconsin Act 227

The Great Lakes Compact took effect on December 8, 2008 after Wisconsin and the other Great Lakes states' ratification of the Compact and the U.S Congress' subsequent consent. The Compact addresses water quantity management in the Great Lakes – Saint Lawrence River Basin. It sets out requirements for Basin water uses in the areas of registration, reporting, management, and water conservation and efficiency. It also prohibits diversions of Basin water with limited exceptions for straddling communities and intra-basin transfers (from one Great Lake basin to another). Under the Compact, states are required to develop a program for managing Basin withdrawals from groundwater and surface water, that relies on a decision-making standard for new or increased withdrawals. States are also required to develop and implement a Basin water conservation and efficiency program.

Wisconsin's legislation implementing the Great Lakes Compact is extensive. Wisconsin Act 227 calls for statewide registration of existing and new water withdrawals with the capacity to withdraw more than 100,000 gallons per day averaged over 30 days. Withdrawals over 100,000 gallons per day averaged over 30 days must be reported annually (existing state statutes already require this reporting for groundwater withdrawals; however, most surface water withdrawals, other than municipal, were not reported prior to 2010). This requirement applies statewide. Initial withdrawal amounts from 2008 are the basis for determining if a proposed increase in a withdrawal exceeds the threshold for applying a decision-making standard. Act 227 directs that Basin withdrawals over 100,000 gallons per day averaged over 30 days require a permit.

Act 227 requires the WDNR to develop a statewide water resources inventory and publish a State Water Use Report every five years. Act 227 also requires that the WDNR develop and implement a water conservation and efficiency program with voluntary measures to apply across the state. Additional mandatory elements apply in the Great Lakes Basin, with the most stringent requirements for communities applying for diversions or water uses with high rates of water loss.

An additional element of the new legislation is the requirement for water supply service area plans. Act 227 requires all municipalities with water supply systems that supply more than 10,000 people to have an approved water supply plan by 2026. This planning process is modeled after the wastewater planning process and uses a cost-effectiveness analysis that assesses the environmental and economic impacts of alternatives in the plan to determine the approach that maximizes environmental benefits and minimizes total resource costs over the planning period.

High Capacity Wells

High capacity wells are regulated under s. 281.34, Wis. Stats, and are defined as "a well, except for a residential well or fire protection well, that, together with all other wells on the same property, except for residential wells and fire protection wells, has a capacity of more than 100,000 gallons per day." Any well, regardless of pump capacity, on a high capacity property is considered a high capacity well.[96] Section NR 812.09 Wis. Adm. Code requires prior DNR approval for the construction or reconstruction of a high capacity well. Technical review of high capacity wells is limited to what is described in state statute and administrative code. Two components are considered by DNR when reviewing a high capacity well application: construction and water withdrawal.

The proposed well construction is reviewed to ensure that it both meets the specifications of the well construction code (NR 812) and that the proposed well's construction does not contribute to, or worsen any groundwater contamination. Contaminants can be anthropogenic or naturally-occurring, and both are considered when reviewing well construction. For example, there are areas of Wisconsin that have naturally occurring arsenic in aquifer formations. Mobility of this arsenic may have been increased when pumping of large volumes of groundwater altered redox conditions of the aquifer from reducing to oxidized. In these areas applicants may be required to construct wells in such a manner that they do not draw water from formations or intervals that are known to contain arsenic bearing minerals. It is also important that wells be constructed with a good seal around the well casing. A proper seal prevents the well from becoming a pathway for contaminants to migrate from the surface or shallow subsurface to water supply aquifers below.

For the withdrawal portion of the review, the DNR changed its procedures in July 2011 in response to a 2011 Wisconsin Supreme Court decision[97] to review each application for a new high capacity well to determine whether the well, along with other high capacity wells on the contiguous property, would result in significant adverse environmental impacts to waters of the state – which includes all streams, lakes, wetlands, public and private wells. Section NR 820.12(19), Wis. Adm. Code defines significant adverse environmental impact as:

> *Alteration of groundwater levels, groundwater discharge, surface water levels, surface water discharge, groundwater temperature, surface water temperature, groundwater chemistry, surface water chemistry, or other factors to the extent such alterations cause significant degradation of environmental quality including biological and ecological aspects of the affected water resource.*

If the DNR determined the proposed well could directly result in significant adverse environmental impacts, the DNR would either deny the well application or request that an applicant modify their proposed construction or operation of the well to prevent such impacts. DNR based the need to modify or deny an application on the projected impacts to the affected water resource, *e.g.*, estimated reductions in stream flow or lake level, and the resultant impacts to water temperature, the fishery

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[96] 2015 Wis Act 177 granted an exception for wells used for residential or fire protection purposes from being considered high capacity wells effective October 1, 2016. s. 281.34(1)(b) Wis. Stats.

[97] *Lake Beulah Management District v. Department of Natural Resources*, 2011 WI 54, 355 Wis. 2d 47, 799 N.W.2d 73. The Court held that, pursuant to Wis. Stat §281 and the Legislature's delegation of the State's public trust duties, the DNR has the authority and a general duty to consider whether a proposed high capacity well may harm waters o the state. Upon what evidence, and under what circumstances the DNR's general duty is implicated by a proposed high capacity well is a highly fact-specific matter that depends upon what information is presented to the DNR decision makes by the well owner in the well permit application, by citizens, and by other entities regarding that permit application while it is under review by the DNR.

and other ecological aspects of the stream or lake. In conducting these assessments, DNR considered site-specific hydrogeology, separation distance between the well(s) and the water resource, the hydrology and characteristics of potentially-affected surface waters, construction details of nearby wells, characteristics of the proposed wells such as construction, pump capacity, and the water use and pumping schedule for the proposed well and any other existing wells on the property. This version of the technical review methodology was in place from July 2011 through May 2016.

On May 10, 2016 Wisconsin's Attorney General issued a formal opinion (OAG 01 16) on the Department's review authority of high capacity well applications. Two key conclusions from the Attorney General's opinion are:[98]

- DNR may impose conditions or requirements on high capacity well approvals only if the agency has explicit permission or an explicit requirement to do so in statute or rule; and
- DNR does not have explicit authority to consider cumulative impacts or to impose monitoring requirements on high capacity well approvals.

As a result of the opinion, the DNR will review and condition high capacity wells using the same approach applied prior to the 2011 Lake Beulah Supreme Court decision. The DNR will review each high capacity well application to determine whether the proposed high capacity well:

- is within a groundwater protection area (within 1,200 feet of a class 1, 2 or 3 trout stream or a designated outstanding or exceptional resource water);
- may impact springs with flow greater or equal to one cubic foot per second;
- will result in water loss greater than 95 percent;
- will result in 10 or more feet of water level drawdown in the public utility well based on 30 days of continuous pumping from the proposed high capacity well or well system; and
- will degrade safe drinking water and the groundwater resource or impact public safety.

The applications that meet any of the criteria listed above will be subject to an environmental review process and any approval will include conditions to ensure the well does not result in significant adverse environmental impacts and may require preparation of an environmental impact statement. In addition, if any of these conditions is met, the DNR may include specific conditions in the high capacity well approval, which may include conditions as to location, depth, pumping capacity, rate of flow and ultimate use.

State Agencies and Responsibilities

Department of Natural Resources

The WDNR has statutory authority to protect, maintain and improve the quality and management of the waters of the state, ground and surface, public and private (s. 281.11 Wis. Stats.). The WDNR establishes the groundwater quality standards for the state under authority of Chapter 160, Wis. Stats. In addition, the WDNR manages groundwater quantity under provisions of ss. 281.11, 12, 34, and 346, Wis. Stats. The WDNR programs that protect and manage groundwater are as follows:

Drinking Water and Groundwater (DG) – Regulates public water systems, private drinking water supply wells, well abandonment and high capacity wells. DG is responsible for adoption and

[98] http://dnr.wi.gov/topic/wells/highcapacity.html

implementation of groundwater standards contained in chapter NR 140, Wis. Adm. Code, and works closely with other programs and agencies to implement Chapter 160, Wis. Stats., including groundwater monitoring, database management, and staffing the Groundwater Coordinating Council. The provisions under 2003 Wisconsin Act 310 (codified at s. 281.34, Stats., and NR 820) and the Great Lakes Compact (2007 Wisconsin Act 227, codified at ss. 281.343 and 281.346, Stats.) are also being implemented by DG. The program also coordinates the state's Wellhead Protection and Source Water Protection programs. See *http://dnr.wi.gov/topic/DrinkingWater/* and *http://dnr.wi.gov/topic/Groundwater/.*

Remediation and Redevelopment (RR) – Oversees response actions at spills, hazardous substance release sites, abandoned containers, drycleaners, brownfields, high priority leaking underground storage tanks, closed wastewater and solid waste facilities, hazardous waste corrective action and generator closures, and sediment cleanup actions. A significant amount of the RR's work relates to groundwater contamination. In 2013 the authority to fund the removal of underground petroleum storage tanks was transferred from DSPS to the WDNR. In 2015 the State budget no long included any funding for the Petroleum Environmental Cleanup Fund Award (PECFA), Any Wisconsin tank owner who has a release in the future will no longer be able to seek assistance from the State to handle the contamination, yet the environmental clean up requirements remain in place. See *http://dnr.wi.gov/topic/Brownfields/* and *http://dnr.wi.gov/topic/Brownfields/Cleanup.html*.

Waste and Materials Management (WMM) – Regulates and monitors groundwater at proposed, active, and inactive solid waste facilities and landfills. WMM reviews investigations of groundwater contamination and implementation of remedial actions at active solid waste facilities and landfills. WMM also maintains a Groundwater and Environmental Monitoring System (GEMS) database of groundwater quality data from over 600 solid waste facilities and landfills and uses reports from GEMS to evaluate whether sites are impacting groundwater quality. See *http://dnr.wi.gov/topic/Landfills/gems.html*

Water Quality (WQ) – Regulates the discharge of municipal and industrial wastewater, by-product solids and sludge disposal from wastewater treatment systems and wastewater land treatment/disposal systems. WQ also issues permits for discharges associated with clean-up sites regulated by WQ for the RR program. See *http://dnr.wi.gov/topic/Wastewater/* and *http://dnr.wi.gov/topic/TMDLs/*.

Watershed Management (WT) –WT has primary responsibility for regulating stormwater and agricultural runoff as well as managing waste from large animal feeding operations. See *http://dnr.wi.gov/topic/Watersheds/*, *http://dnr.wi.gov/topic/SurfaceWater/*, and *http://dnr.wi.gov/topic/Waterways/*.

Department of Agriculture, Trade and Consumer Protection

DATCP's major activities in this area include management of pesticides and nutrients, research, and funding of local soil and water resource management projects http://www.privacy.wi.gov/Contacts/index.aspx. In compliance with Chapter 160, Wisconsin Statutes, DATCP manages pesticides and pesticide practices to assure that established groundwater standards for contaminants are not exceeded. This may include prohibition of certain activities including pesticide use. DATCP regulates storage, handling, use, and disposal of pesticides, and the storage and handling of bulk quantities of fertilizer. DATCP has authority to develop a statewide nutrient management program through section 92.05 Wis. Stats. The program includes compliance, outreach, and incentive components. Enforcement standards have been established in Wisconsin for many known and potential groundwater contaminants, including over 30 pesticides. DATCP assists landowners with compliance to these standards and the Groundwater Law. DATCP also funds research projects; local development, demonstration, and implementation of improved nutrient and pesticide management practices; as well as collection and disposal of waste pesticides and containers through county Clean Sweep programs. In 2013 the Bureau of Petroleum Products and Tanks was transferred from DSPS to DATCP.

Nonpoint Source Activities

Pesticides

DATCP's primary effort related to nonpoint contamination of groundwater from pesticides continues to involve the herbicide atrazine. In response to concerns about atrazine contamination, DATCP amended administrative rule chapter ATCP 30 in 1992 to manage the use of atrazine in an effort to reduce or eliminate the potential for further groundwater impacts. Rule revisions have been made in several subsequent years in response to additional detections of atrazine in groundwater.

Nutrients

Through its Land and Water Resource Management program, DATCP assists in the protection of water resources through nutrient management and conservation practice implementation. DATCP also tracks fertilizer purchases on a statewide basis via fertilizer tonnage reporting. The WDNR rules on runoff management to protect both groundwater and surface water (NR 151 Wisconsin Administrative Code) lay out the procedures for implementing and enforcing compliance with agricultural performance standards including nutrient management. Through ATCP 50, DATCP identifies the technical standards and practices necessary for agricultural producers to meet WDNR's performance standards including the adoption of the USDA-NRCS 590 nutrient management standard. A nutrient management plan accounts for all N-P-K nutrients applied, and planned to be applied, to each field over the crop rotation as well as all crop management practices utilized. A nutrient management plan manages nutrient applications to maximize farm profitability while minimizing degradation of both surface water and groundwater.

Point Source Activities

Agricultural Chemical Cleanup Program

In August 1993, section 94.73 of the Wis. Stats. was created and established the ACCP to address point sources of contamination and reimburse responsible parties for cleanup costs related to pesticide and fertilizer contamination. To date, more than 520 cases involving soil and/or groundwater remediation related to improper storage and handling of pesticides and fertilizers have been initiated at storage facilities. Over this same time period DATCP has assisted clean ups at over 1,000 acute agrichemical spill locations including applications for more than $40.6 million in reimbursement payments.

Since 1990, the Agricultural Clean Sweep grant program has helped farmers dispose of unwanted pesticides, farm chemicals, and empty pesticide containers. Beginning in 1996, the program extended collection services to small agricultural businesses. In 2004 DATCP began operating and managing the state's household hazardous waste grant program. In 2007 prescription drug collection was added.

Department of Safety and Professional Services

Prior to July 2011, the Wisconsin Department of Commerce was responsible for establishing, maintaining and enforcing uniform statewide standards for plumbing (including on- site waste systems) under Section 145.02, Wisconsin Statutes. Those duties are now part of the Department of

Safety and Professional Services. Chapter SPS 383 of the Wisconsin Administrative Code (previously Comm 83) contains administrative procedures, standards, and specifications to assure the proper siting, design, installation and inspection of private onsite wastewater treatment systems.

Effective July 1, 2013, programs within Department of Safety and Professional Services (DSPS), Division of Industry Services were transferred to other departments. The Bureau of Petroleum Products and Tanks was transferred to DATCP. The authority to fund the removal underground petroleum product storage tanks has been transferred to WDNR

Department of Health Services

Chapter 160, Wis. Stats., directs the Department of Health Services (DHS) to recommend health-based enforcement standards for substances found in groundwater and specifies the protocol for developing the recommended standards. Recommended standards are sent to the WDNR and are submitted through the rule-making process as amendments to chapter NR 140, Wis. Adm. Code.

DHFS staff are the primary resource for information about the health risks posed by drinking water contaminants. The agency provides additional advice to owners of wells that are seriously contaminated with volatile substances such as benzene and vinyl chloride. DHFS is responsible for investigating suspected cases of water-borne illness and has conducted several studies into the health impacts of contaminated groundwater.

Wisconsin State Laboratory of Hygiene

At the Wisconsin State Laboratory of Hygiene (WSLH), a great deal of effort is focused on identifying and monitoring chemical and microbial contaminants in groundwater through testing, emergency response, education and outreach, and specialized research. The activities related to groundwater span several departments at WSLH and, collectively known as the Drinking Water Quality Program. The mission of the WSLH Drinking Water Quality Program is to protect the health of drinking water consumers by providing analytical expertise, research and educational services to the scientific and regulatory communities and the public.

Department of Transportation

The Department of Transportation (DOT) regulates the storage of highway salt (ss. 85.17 and 85.18, Wis. Stats.) to protect the waters of the state from harm due to contamination by dissolved chloride.

Salt Storage

Highway salt is stored statewide by suppliers, counties, cities, villages, and private companies. Annual inspections occur and reports are provided for salt storage sites to insure that storage practices are in accordance with chapter Trans 277, Wis. Adm. Code (Highway Salt Storage Requirements). The intent of the Code is to help prevent entry of highway salts into waters of the state from storage facilities.

Salt Use

The DOT Bureau of Highway Maintenance produces the Annual Winter Maintenance Report describing statewide salt use based on weekly reports from each county. Current policy in the State Highway Maintenance Manual restricts the spreading of deicer salts to a maximum of 400 pounds per lane mile per initial application, and 300 pounds per lane mile for subsequent applications. Electronic controls for salt spreader trucks are continually tested to record and verify application rates and coverage effectiveness. Other technology is used on county highway patrol trucks to keep salt on pavement surfaces (e.g., zero-velocity spreaders, ground speed controllers, and onboard liquid pre-wetting units). Additional efforts to minimize and conserve salt applications include the use of in-situ weather monitoring system. Pavement temperature sensors recorded at 54 locations along major highway routes are used to determine application methods. Annual training for snowplowing and salt spreading techniques is also provided for county snowplow operators.

Salt Usage Tracking

The DOT Bureau of Highway Maintenance is currently in the process of having all of the county trucks that work on the state system equipped with AVL/GPS equipment. This technology will allow the bureau to better track the application of salt usage across the state. It will also help in the optimization of plow routes to make plowing most efficient. In conjunction with the AVL/GPS equipment the bureau is testing out new software called the Maintenance Decision Support System or MDSS. MDSS combines the science of snow removal with weather forecasting. The goal is to only apply the minimum amount of salt necessary given the current weather conditions and forecasts. Many other state who have implemented these technologies are seeing cost savings and salt reductions across their highways.

Wisconsin Public Service Commission

The PSC regulates public utility rates and associated services under Chapter 196 of the *Wisconsin Statutes*. The PSC must approve any proposed changes in water rates before they are implemented. The PSC also has broad authority to review and approve construction projects by public water utilities pursuant to Section 196.49(2) of the *Wisconsin Statutes*. Projects. The PSC has authority to regulate various aspects of water utility operations. Examples of operations regulated under this authority include metering requirements, water accounting and loss control requirements, and standards for pressure management. The PSC also conducts outreach and training programs directed at public utilities and related to rate-setting, improving efficiency of operations, and reducing water loss from distribution systems.

Wisconsin Geological and Natural History Survey

The Wisconsin Geological and Natural History Survey (WGNHS), University of Wisconsin-Extension, performs basic and applied groundwater research and provides technical assistance, maps, and other information and education to aid in the management of Wisconsin's groundwater resources. The WGNHS groundwater program is complemented by the geology and soils programs, which provide maps and research-based information essential to the understanding of groundwater recharge, occurrence, quality, movement, and protection of this vital resource.
WGNHS maintains a statewide groundwater-level monitoring network and data management system that provides the basic information for conducting groundwater research in the county and throughout the state. For example, water levels collected from the network help scientists and managers evaluate the effects of well pumping, the response of groundwater levels to drought and climate change, and the effects of land-use change on groundwater resources. These data are also routinely used in the development and calibration of sophisticated regional groundwater flow models, such as the one developed for Dane County as well as other parts of the state. WGNHS also conducts geologic and groundwater studies on important and emerging topics of interest. Viruses in groundwater, cross-connection of aquifers due to multi-aquifer wells, groundwater recharge, and investigation of unsewered rural subdivisions are just some of the topics being investigated. WGNHS also provides significant education and outreach to both professionals and

the general public on the technical aspects of well hydraulics, wellhead protection, waste disposal, comprehensive planning, etc.

University of Wisconsin System

The University of Wisconsin System (UWS) has research, teaching and outreach responsibilities. These three missions are integrated through cooperation and joint appointments of teaching, research and Extension personnel who work on groundwater issues. UWS staff members work with state and federal agencies and other partners to solve groundwater resource issues. Citizen outreach is accomplished through publications, video and audio podcasts, social media, media relations, public meetings, teleconferences, and water testing and satellite programs. Activities of several specific programs are described below.

UW Water Resources Institute (WRI)

The UW Water Resources Institute (WRI) is one of 54 water resources institutes located at Land Grant universities across the nation with core funding provided and administered by the U.S. Department of the Interior through the U.S. Geological Survey. It promotes research, training and information dissemination focused on Wisconsin's and the nation's water resources problems. The WRI research portfolio includes interdisciplinary projects in four broad areas: groundwater, surface water, groundwater-surface water interactions, and drinking water. Groundwater is a top priority and an area of particular strength at the WRI.

UW-Extension's Central Wisconsin Groundwater Center

The Central Wisconsin Groundwater Center provides groundwater education, research and technical assistance to the citizens and governments of Wisconsin. Assistance includes answering citizen questions, helping communities with groundwater protection, describing the extent and causes of groundwater pollution, assessing drinking water quality, and working on groundwater policy. Recent policy work focuses on groundwater pumping and impacts on surface waters.

UW Environmental Resources Center (ERC)

The UW Environmental Resources Center (ERC) hosts UWEX state specialists addressing water resources, land and water conservation, forestry, conservation professional training, citizen engagement, and volunteer monitoring. ERC also coordinates a number of regional and national programs addressing water resources and water education initiatives related to groundwater.

UW Nutrient and Pest Management (NPM) program

In 1989 a broad coalition of agricultural organizations, environmentalists, and the University sought funding for a water quality program for farmers and the agricultural community. The NPM outreach program has conducted on-farm demonstrations and education throughout Wisconsin to promote management practices that reduce groundwater and surface water contamination from agriculture while maintaining or improving farm profitability.

UW Soil Science Department

The UW Soil Science Department provides greater understanding of the practical application of biology, chemistry, physics, and earth science principles to integrate land use and environmental protection. Research is conducted with local farmers, agriculture agents, and university specialists on working farms across the state each year to collect data and find answers and solutions to Wisconsin crop fertility questions and problems. Notable examples include SnapPlus software, Nutrient Recycling and Upcycling (NRU) studies, crop nutrient application guidelines, field trials, among other leading topics of research.

Groundwater Coordinating Council

In 1984, the Legislature enacted Wisconsin Act 410 to improve the management of the state's groundwater. This act required establishment of a Groundwater Coordinating Council (GCC) to be made up of representatives of state agencies with groundwater protection responsibilities.

The GCC is directed by s. 160.50, Wis. Stats., to serve as a means of increasing the efficiency and facilitating the effective functioning of state agencies in activities related to groundwater management. The GCC advises and assists state agencies in the coordination of nonregulatory programs and the exchange of information related to groundwater, including, but not limited to, agency budgets for groundwater programs, groundwater monitoring, data management, public information and education, laboratory analysis and facilities, research activities, and the appropriation and allocation of state funds for research.

The GCC consists of high-level administrators of all state agencies with some responsibility for groundwater management plus a Governor's representative. The GCC also has five subcommittees to assist in its work. Additionally, the WDNR has one permanent position with half-time responsibilities related to coordination of the GCC. The GCC meets quarterly to discuss issues of interest and make decisions regarding groundwater issues of concern such as:

- Coordinating a joint solicitation for groundwater research and monitoring proposals among four state agencies.
- Promoting efforts to enhance the utility of groundwater monitoring and research funded by the state.
- Ensuring consistency in groundwater education, data management, and mapping efforts.
- Working with representatives of federal and local agencies to promote communication and coordination with state groundwater activities.
- Preparing an annual Report to the Legislature due each August.
- Sponsoring and participating in forums and other outreach events to promote discussion of groundwater issues.

Table 29. State Agencies with Responsibilities for Groundwater Management	
Wisconsin Department of Natural Resources	Protects, maintains, and improves state's water quality and management; monitoring groundwater, setting state groundwater quality standards
Wisconsin Department of Agriculture, Trade, and Consumer Protection	Regulates pesticide use and cleanup, oversees farm nutrient management, research where pesticides have entered groundwater. Approves and inspects underground storage tanks
Wisconsin Department of Safety and Professional Services	Enforces septic system regulations
Wisconsin Department of Health Services	Recommends enforcement standards for substances of health concern, investigates health effects from contamination
Wisconsin State Lab of Hygiene	Conducts research on virus and pathogen occurrence in groundwater
Wisconsin Department of Transportation	Conducts research on road salt and groundwater
Wisconsin Public Service Commission	Approves expenditures of new public water/electrical utilities, regulates setting of rates
Wisconsin Geological and Natural History Survey; University of Wisconsin-Extension	Assesses, characterizes, and maps groundwater resources; provides information and education on hydrology and groundwater resources
Groundwater Coordinating Council	Improves management of state's groundwater by sharing information and improving interagency cooperation
	Source: Modified after Lindorff et al. (1997) and Chern et al. (1999).

Local Groundwater Management

The Groundwater Protection Act also clarified the powers and responsibilities of local governments to protect groundwater in partnership and consistent with state law.

a. Zoning authority for cities, villages, towns and counties was expanded to "encourage the protection of groundwater."
b. Counties can adopt ordinances regulating disposal of septage on land, consistent with WDNR requirements. Cities, villages or towns may do so if the county does not. There is limited authority under NR 151 for adoption of local restrictions on land application of manure and waste.
c. Counties can regulate, under WDNR supervision, well construction and pump installation for certain private wells.
d. Property assessors must consider the time and expense of repairing or replacing a contaminated well or water supply when assessing the market value of real property. They must also consider the "environmental impairment" of the property value due to the presence of a solid or hazardous waste disposal facility.

Local units of government possess a variety of controls (regulatory and non-regulatory) which may be used to manage and protect groundwater. Some of the most powerful regulatory tools available to local governments for groundwater management are those that control land uses. For instance, local zoning provisions which determine the location and, in some cases, density of various land use practices are important in the siting of potential groundwater pollution sources. By enforcing county sanitary codes, such as the permitting of on-site wastewater systems, local government has further regulatory responsibility for protecting groundwater. Authorization for carrying out certain state regulatory programs, such as state private well code and septage disposal programs, may also be more effectively handled at the local level.

Local government can also have substantial influence in promoting non-regulatory approaches that protect groundwater. These approaches include public education and information on groundwater, promotion of best management practices for fertilizer and pesticide use, and establishment of recycling programs and household hazardous waste disposal programs.

Local and state groundwater management controls, both regulatory and non-regulatory, are described in the following pages for each major pollution source. Brief assessments of the effectiveness of these controls are also presented. Due to the nature of this report, county roles are emphasized in the local control section; however, the county must coordinate regulatory and non-regulatory activities with cities, villages and towns. In many instances this is essential because the county may not be authorized by statute to adopt particular regulations, whereas cities and villages have home-rule powers allowing them to have more extensive regulatory authority. Thus, involvement and cooperation by all local units of government is imperative for carrying out an effective countywide groundwater protection program.

Chapter 7: Management Controls for Potential Pollution Sources

Land Disposal of Solid Waste

State Controls

WDNR licenses all solid waste disposal sites and regulates their construction, operation, monitoring and closure (chapter NR 500). In 1984, WDNR performed an exhaustive search for abandoned waste disposal sites in Wisconsin, as mandated by the Environmental Repair Law of 1983. In 1990, the list was updated and published as *The Registry of Waste Disposal Sites in Wisconsin*. The Registry includes about 200 sites in Dane County. The Registry is WDNR's "master list" of known solid and hazardous waste disposal sites in Wisconsin. WDNR has also established a hazard ranking system, under NR 710, and criteria for determining necessary remedial actions. The inclusion of a site on the Registry does not mean that environmental contamination has occurred, is occurring, or will occur. The Registry is intended to serve as a general information source for the public and state and local officials as to the location of waste disposal sites in Wisconsin.

Local Controls

Solid waste management planning is undertaken by the county in meeting the criteria of chapter NR 185. The Dane County Zoning Ordinance (Chap. 10) sets conditional use provisions for landfills in certain land use districts; however, the state can override local zoning in the siting of a landfill through the Waste Facility Siting Board. State solid waste management rules preempt local controls.

Impact/Effectiveness

Strict regulatory controls help to minimize groundwater quality impacts at new landfill sites. However, numerous landfills constructed before these controls were enacted exist in Dane County, and some may be polluting groundwater. Groundwater monitoring is required for only a small number of landfills in the county and the effect of most inactive or closed landfills on groundwater quality is largely unknown.

Land Disposal of Wastewater

State Controls

Land disposal of municipal wastewater is regulated by the WDNR (chapters NR 110 and NR 206). Industrial wastewater disposal is regulated under chapter NR 214. Design and construction criteria, discharge limitations and effluent monitoring requirements are set forth in these regulations. A Wisconsin Discharge Elimination System (WPDES) permit is required by the WDNR for all pollutant dischargers.

Local Controls

No local regulatory controls are in effect in Dane County. The Capital Area Regional Planning Commission provides review and comments on permits, facilities plans, and disposal sites.

Impact/Effectiveness

State controls for municipal and industrial wastewater dischargers are stringent. Dane County has few facilities that discharge large quantities of wastewater through land application systems. To date, monitoring has not revealed any detrimental groundwater quality impacts. Currently, these discharges are regulated under the WPDES program and do not represent serious sources of groundwater pollution in Dane County.

Sanitary Sewers

State Controls

Interceptor and collector sewers are regulated by the WDNR (chapter NR 110). The WDNR code contains sewer design and leakage criteria. It also establishes well-separation distances from sewers. DSPS regulates all lateral sewer connections (SPS 382) and requires non-leakage design adherence.

Local Controls

The Capital Area Regional Planning Commission in conjunction with local governmental units, maps planned sewer service areas and sensitive environmental areas or corridors. This mapping reflects groundwater protection concerns, along with other factors. Proposed sanitary sewer extensions are reviewed to ensure that sewered development is directed to the areas where it is best suited while minimizing environmental impacts, including groundwater impacts.

Impact/Effectiveness

The extent of sewage leakage or exfiltration from sanitary sewers in Dane County is not known. Design regulations are probably sufficient to minimize substantial leakage; however, exfiltration may still occur from pipeline breakage by tree roots or rupture by superimposed heavy loads. Ground-water infiltration rather than sewage exfiltration is a more common problem. Evidence of viruses in deep municipal wells is a growing concern. Breaks or leaks in pressure sewers or force mains are subject to WDNR enforcement.

Mapping sewer service areas and reviewing sanitary sewer extensions for consistency with plans is an effective tool in reducing the environmental impacts of expanding urban development and protecting sensitive areas and resources.

On-Site Wastewater Systems

State Controls

The Department of Safety and Professional Services (DSPS) regulates the siting, design, installation, and inspection of private on-site sewage systems. (chapters SPS 383 and SPS 385). SPS 383 contains administrative procedures, standards, and specifications to assure the proper siting, design, installation, and inspection of private onsite wastewater treatment systems. SPS 385 contains standards and procedures for soil and site evaluations conducted for the treatment or dispersal of wastewater, treated wastewater, final effluent or human wastes into soil. DSPS also administers the Wisconsin Fund for the replacement or rehabilitation of failing private onsite systems serving a principal residence or small commercial business. For large-scale (cluster or small community) on-site wastewater systems having a discharge capacity of over 12,000 gallons per day, state review and inspection is mandated prior to installation. A Wisconsin Pollutant Discharge Elimination System (WPDES) permit is required for these systems by the WDNR (NR 200.03[3][d]). In addition, the Regional Planning Commission staff provides review and comments on proposed permits to better avoid adverse impacts.

WDNR may also prohibit septic tanks where they could cause a water quality problem under NR 113. Every governmental unit responsible for the regulation of private sewage systems is required to adopt a private sewage system ordinance that conforms to the state plumbing code (Wis. Stat.s Chap. 145).

Local Controls

The Department of Public Health for Madison and Dane County (PHMD) administers the private sewage system ordinance. The ordinance and administrative procedures are included in Chapter 46, Dane County Code of Ordinances. The ordinance and all systems installed in Dane County must conform to the State Plumbing Code with respect to siting, design, installation and inspection. The county issues state sanitary permits which are required before any septic tank or other on-site system may be installed. The ordinance also requires owners of all septic systems to have the systems inspected and, if necessary, pumped every three years. The county also administers a state grant program (the Wisconsin Fund) to repair septic systems against which enforcement orders have been issued. The Dane County Zoning and Subdivision Regulations (Chaps. 10, 11, 17, and 75) set design standards for subdivisions (minimum lot area of 20,000 ft^2.) and control on-site system placement in floodplain and shoreland districts.

Impact/Effectiveness

Nitrate-nitrogen data from private well water analyses indicate that high nitrate levels (above the drinking water standard) exist for wells in some rural subdivisions. On-site wastewater systems are suspected as a likely, but not the primary, nitrate source. Since on-site systems do not generally remove nitrate, and nitrates in groundwater are not transformed by flowing through soil or rock, the general assumption is that nitrate levels in groundwater are related to nitrogen loading at the surface. Proper maintenance and placement of private wastewater systems is important to avoid detrimental groundwater impacts from system failures or other contaminants, but the only effective way to reduce nitrates in groundwater is to reduce nitrogen loading to groundwater, either by using alternative on-site systems which remove nitrogen, or by reducing the density of on-site systems. Research and information from Wisconsin and other states is fairly consistent that there is a low probability of significant problems where housing densities are less than one house per two acres, and a higher probability of problems at densities greater than one house per 1-1.5 acres, based on the gross acreage of the development. These developments should include an evaluation to ensure that drinking water supplies are protected.

Land Application of Biosolids (Sludge) and Septage

State Controls

Biosolids recycling practices are regulated by both U.S. EPA and WDNR. These regulations are designed to ensure biosolids recycling is conducted in a manner protective of human and animal health and environmental quality. U.S. EPA has established comprehensive risk-based regulations for recycling programs (Part 503 Regulations) including potential pathways, maximum soil concentrations and loading rates for trace elements, such as copper, zinc, selenium, etc. WDNR regulates biosolids, applications under NR 204, which contain the same risk-based limits as U.S. EPA, with additional site management requirements such as setbacks from wells and homes. Landspreading of industrial sludge is regulated under NR 214. Biosolids handling and storage requirements are also covered by NR 110, and NR 113, which establishes licensing and site criteria. WDNR has the authority to prohibit landspreading of biosolids at any site where groundwater quality may be adversely affected.

Local Controls

Although WDNR has exclusive authority to regulate the landspreading of biosolids, the Groundwater Law (Wis. Act 410) provides concurrent authorization for county regulation of land application of septage. Site criteria and septage application procedures contained in a county regulatory program must be identical to WDNR statewide rules. If a program is adopted, the county can establish a license fee for each septage application site to offset the costs of program operation.

Dane County Chapter 46 prohibits the spreading of septage on frozen or snow-covered ground. *Private On-Site Wastewater Treatment Systems* Management (Appendix I of the Dane County Water Quality Plan) includes township maps showing the general location of WDNR approved septage disposal sites and the disposal site location criteria in NR 113. These maps indicate that many of the currently approved septage disposal sites are in close proximity to site conditions that are unsuitable for septage disposal. This underscores the importance of a rigorous monitoring and inspection program for septage disposal sites in Dane County. The Department of Public Health for Madison and Dane County attempted to gain authority from WDNR to regulate septage spreading in Dane County, but their request was denied because the current county ordinance would hold the landowners responsible for any violations on their land rather than the septage hauler. PHMDC is currently working to incorporate the tracking of septage pumping and disposal into its septic maintenance program, which should include a monitoring component. This will help PHMDC and WDNR to track spreading activities and identify any potential problems.

Impact/Effectiveness

Biosolids are a byproduct of our modern society and the need to manage their use will continue in the future. They provide an excellent source of plant nutrients and organic matter for agriculture, which should not be wasted by landfilling or incineration. Their creation is carefully managed to reduce the health risks associated with pathogens and heavy metals. Their use is closely monitored by both the USEPA and the WDNR. Research on biosolids process and management has been conducted at the University of Wisconsin for over 80 years and continues to this day. The land application of biosolids should be incorporated into a farm's nutrient management plan to reduce the risk of water quality degradation. Private well water analyses adjacent to biosolids application sites have not indicated adverse groundwater quality impacts in Dane County. An active site inspection and permitting program by the WDNR has helped minimize detrimental environmental effects.

Septage application and siting, on the other hand, have not been as actively regulated by WDNR. WDNR does not currently have adequate staff to effectively implement the septage program. Although there is limited documentation of pollution incidents resulting from septage application in Dane County, this may be due to the lack of surveillance and monitoring of land application sites. Even though standards for landspreading are outlined in NR 113, WDNR staff resources are currently too limited to provide routine field inspections, stringent surveillance or enforcement.

The involvement of County and Regional Planning Commission staff in the review and approval of septage landspreading sites would incorporate greater knowledge and familiarity with local site conditions. It would also allow better monitoring and observation of site conditions and landspreading practices. The program should include site location and licensing requirements, application and operating criteria and procedures, surveillance and enforcement procedures, and the revenue to support the program.

Provisions for receiving septage at municipal wastewater treatment plants at a reasonable cost are important to provide waste haulers flexibility and to avoid the need to landspread under adverse conditions (such as on frozen ground in winter). This recommendation has largely been implemented. Opportunities for disposing of septage at treatment plants have expanded considerably; about 89 percent of septage is currently disposed of at wastewater treatment plants. The relative ease and availability of wastewater treatment plants that accept septage is expected to continue to favor septage disposal at treatment plants in the coming years.

Manure Management

State Controls

Regulatory authority over manure management rests with the WDNR (chapter NR 243). A WPDES permit is required for large animal feedlot operations, (more than 1,000 animal units) and smaller operations where pollution problems are evident. The placement of wells in relation to animal feedlot operations is regulated under chapter NR 812.

In 1997 Wis. Act 27 and 1999 Wis. Act 9, the legislature directed the WDNR and DATCP to redesign state programs related to non-point source pollution. To meet this legislative mandate the DATCP adopted ATCP 50 that identifies conservation practices a farmer must follow to meet WDNR's Agricultural Performance Standards and Prohibitions in NR 151 Subchapter II. ATCP 50 also reflects DATCP's lead responsibility for nutrient management. DATCP administers the program in cooperation with County Land Conservation Committees and Departments.

As part of the redesign of the nonpoint source pollution program, Wisconsin Act 27 modified Chap. 92.10 Wis. Stats. to enable County Land and Water Conservation Committees and Departments to develop Land and Water Resource Management Plans. More specifically, Wis. Stat. 92.15 extends beyond manure storage and provides new authority for local governments to regulate livestock operations through local ordinances. Generally, local ordinances may not be more restrictive than state minimum performance standards. The Livestock Facility Siting Law, Wis. Stat. 93.30 and Adm. Rule ATCP 51 established state standards and procedures local governments must use if they choose to require conditional use or other permits for siting new and expanded livestock operations.

Local Controls

In 2005 Dane County's Manure Storage and Utilization Ordinance was updated (Chapter 14, Sub. I). The purpose of the amended ordinance is to regulate the design, construction, maintenance and proper abandonment of animal waste storage facilities and manure stacks; including the transfer of wastes into storage facilities; provide for adequate disposal of animal waste in order to prevent water pollution, and comply with provisions in NR 151 Agricultural Performance Standards as outlined in the Dane County Land and Water Resource Management Plan and ATCP 50.56. The Regional Planning Commission staff also provides review and comment on proposed WPDES permit applications. Existing animal waste storage facilities are not subject to regulation under this ordinance unless the facility is not maintained, leaking, reconstructed, enlarged or altered in some way. Emergency repairs to a manure storage facility, such as repairing a broken pipe or equipment, repairing leaking dikes, or the removal of stoppages also do not require a permit.

Impact/Effectiveness

The WPDES program has had increasing impact in Dane County, due to the growing numbers of larger farming operations. Currently, 14 farms are regulated under this program in Dane County (compared to only one in 1987). There are currently 278 large farms statewide. Smaller operations have been exempt from manure management controls, although they may be cited under NR 243 for discharge of significant amounts of pollutants to waters of the state (including groundwater). Cost-sharing/technical assistance is available to help farmers remedy discharge citations.

The Wisconsin Soil and Water Resources Management Program and other cost-sharing programs have been historically based on voluntary participation by state farmers. Typically, however, there was low participation in such voluntary programs – although the state Priority Watershed Program had provided some funding in priority project areas. In 2002 the WDNR rule NR 151 went into effect. This rule set performance standards and prohibitions for agricultural facilities, operations, and practices. The Dane County Land Conservation Division (LCD) developed an implementation strategy and accompanying checklist document as part of the 2003 Land and Water Resource Management Plan. Ordinance amendments to manure storage and utilization requirements located within Chapter 14, Dane County Code of Ordinances went into effect on January 31, 2006. These amendments provided the necessary mechanisms for Dane County to administer and enforce NR 151 agricultural performance standards at the local level.

Pesticide and Fertilizer Applications

State Controls

Under the Wisconsin Groundwater Law, DATCP manages pesticides and pesticide practices to assure that established groundwater standards for contaminants are not exceeded. This may include prohibition of certain activities including pesticide use. DATCP regulates storage, handling, use and disposal of pesticides, and the storage of bulk quantities of fertilizer. Under chapter ATCP 29, applicators of restricted-use pesticides are required to be properly trained and certified. Use of a pesticide by an applicator in a manner inconsistent with its labeling is illegal.

DATCP's primary effort related to nonpoint contamination of groundwater continues to involve the herbicide atrazine. In response to concerns about atrazine contamination, DATCP amended administrative rule chapter ATCP 30 in 1992 to manage the use of atrazine in an effort to reduce or eliminate the potential for further groundwater impacts. Rule revisions since then have increased the number of atrazine use prohibition areas. Information suggests that atrazine use has declined as a result of the atrazine management rule and concern about groundwater contamination.

DATCP is also responsible for identifying pesticides that have the greatest potential for polluting groundwater, and for compliance with groundwater standards by adopting administrative rules to be taken if standards are exceeded (ATCP 31). Requirements for proper labeling of pesticide containers by manufacturers are also set forth. In addition, ATCP 33 regulates fertilizer and pesticide bulk storage. ATCP also establishes the Agricultural Chemical Cleanup Program. The program identifies and help manage the clean up of pesticide and fertilizer spills to prevent these products from reaching groundwater. Once a site has been identified as needing a clean up, the ACCP provides re-imbursement for eligible costs by the responsible parties.

In 2007, the department updated Wisconsin Administrative Code ATCP 50. This code incorporates the phosphorus and nitrogen based NRCS 590 standard. This standard provides the technical guide to how Nutrient Management Plans (NMPs) should be development, what they must include, and what risk reduction factors must be met. It includes a number of practices specifically directed toward reducing the potential for groundwater contamination. Incorporating this nutrient management standard is intended to meet the water quality performance standard requirements outlined in NR 151.07.

While the rules require all farms to have an NMP, the state cannot enforce on this requirement without offering 70 percent cost-share. On the other hand, many cross-compliance mechanisms exist; such as county manure storage ordinances, WPDES permits for the state's largest CAFOs, and the Farmland Protection Program (FPP) that require an NMP without the cost-share requirement. The FPP in particular is driving a significant increase in NMP acreage across the state. In 2013, 26 percent, or 2.3 million acres of the state's cropland was covered by an NMP, this is up approximately 600,000 acres in 2003.

Also, DATCP's Manure Advisory System[100] includes interactive maps and other information to help farmers identify the sensitive areas on their farms, such as shallow depth to bedrock or water table, highly permeable soils, etc., and help reduce groundwater contamination risk.

Local Controls

Local controls are limited. County and UW-Extension have the responsibility for training pesticide applicators within Dane County and providing information regarding proper application of fertilizers. County-approved waste management plans are required for all new manure structures.

Historically, there has been increasing documentation of groundwater quality degradation attributable to agricultural inputs. Moreover, the costs of overapplication of agricultural fertilizers and pesticides may reduce the profitability of farming operations in the county. The UW Nutrient and Pesticide Management program has documented this extensively. More recently, County-approved waste management plans and other conservation practices appear to be working. After 4 decades of increasing nitrates in area streams, baseflow concentrations are beginning to show early signs of improvement. This is supported by more recent analysis of historic nitrate sample results obtained from shallow wells across the region.

Impact/Effectiveness

While historically there has been documentation of increased groundwater quality degradation attributed to agricultural inputs, more recent results indicate improvements in some areas of the county – likely associated with the programs and practices being conducted to reduce contamination. This is particularly evident in baseflow nitrate concentrations in streams and atrazine concentrations in shallow private wells. While significant progress has been made, more work needs to be done to protect and improve this vital resource. More funding needs to be provided to assist farmers in developing NMPs for their farms.

[100] http://www.manureadvisorysystem.wi.gov/

Underground and Aboveground Storage Tanks

State Controls

As part of the 2013-2015 biennial budget, the responsibility for administering the state's storage tank regulations, including the tank registry, has been transferred from the Department of Safety and Professional Services (DSPS) to the Department of Agriculture, Trade and Consumer Protection (DATCP). Aboveground and underground storage tanks containing flammable and combustible liquids are regulated under ATCP 93. In addition, the WDNR oversees investigation and cleanup of petroleum tank discharges and other hazardous wastes through its Remediation and Redevelopment Program (see Spills of Hazardous Materials, NR 700 series). WDNR also administers the Petroleum Environmental Cleanup Fund Award (PECFA), which reimburses responsible parties for eligible cleanup costs. The PECFA program was created in response to federal regulations requiring release prevention from underground storage tanks and cleanup of existing contamination from those tanks. However, the 2015-2017 Wisconsin budget does not include any funding for PECFA and effectively sunsets the program for releases after July 2017 and any claims after July 2020. According to the Governor's office, the program has existed for a sufficient time and that its primary purpose has been completed. According to the WDNR, any Wisconsin tank owner who has a release in the future will no longer be able to seek assistance from the State to handle the contamination, yet the environmental cleanup requirements remain in place. Program initiatives have resulted in identifying a large population of underground tanks, reducing the number of underground tanks in use, and upgrading those in use to meet federal requirements. Educational outreach efforts and annual inspections by the Department and its agents has resulted in a high level of regulatory compliance, and a reduction of system failures and environmental contamination.

Bulk storage of pesticides and fertilizers are regulated by DATCP (chapters ATCP 29 and ATCP 32, respectively). Standards are established for storage containers, loading areas and secondary containment. On-site inspection, tank maintenance and contingency plans are also required. On-farm storage tanks are excluded from these regulations.

Local Controls

On-site tank inspection responsibilities (excluding bulk storage of fertilizers and pesticides) can be conducted by city, village, and town fire chiefs who are DATCP designated deputies. If a local fire department elects not to perform the inspections, DATCP will have this responsibility.

Impact/Effectiveness

Substantial progress has been made in attempting to prevent leaks and spill from storage tanks and in reducing associated environmental impacts. Of the 1319 identified leaking underground storage tanks, 94 percent have been officially "closed," where investigation and clean-up of the contamination has been completed and the state has approved all cleanup actions. Many underground storage tanks have also been removed where no action was required. Frequent testing is especially important for older tanks near public wells, as is vigorous long-term enforcement of existing regulations. The end of the PECFA fund will likely affect individuals and small business owners who lack the resources to respond adequately on their own to a leaking tank.

Spills of Hazardous Materials

State Controls

The WDNR (chapter series NR 600 and NR 700) has authority regarding hazardous waste management and response to hazardous spills. The Bureau of Remediation and Redevelopment oversees clean-up actions at spills, abandoned containers, state funded responses, closed wastewater and solid waste facilities, hazardous waste corrective actions and generator closures, and sediment clean-up actions.

The Hazardous Substance Spill Law, Wis. Stat. Chap. 292, requires immediate notification when hazardous substances are discharged, as well as taking necessary actions to restore the environment to the extent practicable. NR 700-726 specifies the required response (clean-up actions). Approximately 850 discharges are reported annually to the WDNR, and of those, approximately 65 percent are petroleum-related, with another 5 percent being agri-chemicals. Groundwater monitoring is performed when necessary to delineate the extent of contamination.

DATCP also has rules (chapter ATCP 29) which govern the transport of pesticides and call for the preparation of contingency plans at pesticide storage facilities. Preventive spill measures are also included in transportation regulations regarding hazardous materials. DATCP also administers the Agricultural Chemical Cleanup Program (ATCP 35). The program identifies and helps manage the clean up of pesticides and fertilizer spills to prevent those substances from reaching groundwater.

Local Controls

Local government can monitor spill sites. Under its regulatory authority, the county can also require contingency plans for facilities handling hazardous materials. The Dane County Department of Emergency Management updates its *Dane County Strategic Plan for Emergency Response to Hazardous Materials Releases* annually. The plan identifies the potential for hazardous materials emergencies and develops policies and procedures for responding to hazardous materials incidents in the county. The plan also defines the roles, responsibilities, and inter/intra-organizational relations of government and private organizations in response to a hazardous materials incident.

Impact/Effectiveness

Reporting of hazardous spills, contingency plans and proper storage of hazardous materials has received increasing emphasis at the state and local level. The threat of groundwater pollution from spills clearly exists. The Dane County Emergency Response Plan provides an efficient and effective organizational structure for assessing, coordinating and addressing the threats associated with hazardous materials. Effective March of 1997, all discharges of hazardous substances that adversely impact, or threaten to adversely impact public health, welfare or the environment must be immediately reported to WDNR.

Junkyards/Salvage Yards

State Controls

Junkyards are no longer licensed by the WDNR. This authority was removed in 1981 because environmental hazards from junkyards were not documented. The WDNR does regulate the disposal of solid and hazardous waste generated at salvage yards through laws and rules which are intended to prevent contamination of the land, surface, and groundwater. In addition, auto salvage yards must have a Stormwater Discharge Permit issued by the WDNR's Watershed Program. The WDNR may inspect and monitor activities involving hazardous substances at salvage and junk yards.

Local Controls

A conditional use permit and an annual license is required by Dane County before a salvage or junk yard can be operated (Chap. 10, Dane County Code of Ordinances).

Impact/Effectiveness

Groundwater impacts from salvage and junkyards are not documented in the county. Attention has not been focused on these areas for inspection or monitoring.

Well Construction and Abandonment

State Controls

The operation and design of public water systems is regulated by the WDNR under Chapter NR 811. This chapter requires the proper abandonment of all unused or unsafe private wells within municipal water service areas. Well construction, siting and abandonment is further regulated by the WDNR (chapter NR 812). This code prohibits the use of any well for disposal of sewage or for surface discharge drainage. Drillers of potable wells and pump installers need to be licensed, and well construction reports must be sent to the WDNR. Chapter. NR 141 establishes standards for designing, installation, construction and abandonment of groundwater monitoring wells.

Local Controls

Chapter NR 845, Wis. Adm. Code, was developed to allow for county administration of the private well construction and abandonment program. Dane County ordinance Chap. 45 details the county well construction and abandonment code. Improperly abandoned wells represent a real threat to groundwater that can be removed at relatively low cost. PHMD typically issues 60 to 70 abandonment orders each year.

The City of Madison has a local ordinance (Madison General Ordinance Sec. 13.21) which addresses well abandonment and operation permits within the Madison Water Utility service area. The ordinance provides that all unused and unsafe wells be properly abandoned. Owners of all other wells are required to obtain an operating permit from the utility which requires the owner to show that the well meets code and produces safe water. Well operating permits must be renewed every five years.

Impact/Effectiveness

Abandoned or unused wells pose a great threat to the safety and quality of groundwater drinking water supplies. An unused well provides a direct path for contaminants and pollutants to the underground aquifers that supply working wells. The WDNR considers a well to be permanently abandoned when it has been completely filled and sealed by a licensed well driller or pump installer using materials and methods as prescribed in section NR 812.26 of the Wisconsin Administrative

Code. This generally means that the pump and any piping inside of the well casing have been removed and the well has been filled from bottom to top with proper filling materials, such as cement grout, concrete grout, concrete, a clay/sand slurry mix or, in some cases, bentonite chips. Some unsafe or unused wells are identified through complaints and are required to be abandoned as appropriate, but many wells may go undetected.

Unused wells are a direct line for contamination into clean ground water. The WDNR provides financial assistance for low income well owners to properly abandon unused private wells. The WDNR also provides Well Compensation grants for replacing, reconstructing or treating contaminated private water supplies that serve a residence or used for watering livestock. Well construction work must be done according to WDNR specifications and the contaminated well properly abandoned.

Salt Storage and Use for Highway Deicing

State Controls

The Department of Transportation (DOT) has established standards for salt storage (Ch. Trans. 277). Standards apply to all persons who store bulk quantities (more than 1,000 pounds) of highway salt. The DOT must conduct periodic inspections, at least annually, of salt storage facilities. This chapter does not restrict the actual use of salt on highways.

Local Controls

Local units of government can voluntarily attempt to minimize the amount of salt applied to roadways. Many have evaluated and begun implementing various options to address this, such as purchasing new equipment (e.g., automated spreaders) and/or using alternative materials (e.g., sand).

Impact/Effectiveness

A survey of salt storage sites in the county revealed that most sites are protected by coverings and linings. Salt use is probably a greater threat to groundwater quality than salt storage in Dane County. Increasing chloride and sodium concentrations in Madison wells are associated with deicer use. Many communities have begun instituting salt reducing measures, but these do not appear to be keeping up with the increase in lane miles being traveled. Increasing salt concentrations in wells and surface water is cause for concern. Additional efforts are needed to reverse this disturbing trend including support for additional research and demonstration projects to provide safe winter driving conditions while also reducing chloride and sodium application.

Stormwater Management

State Controls

Proper infiltration of stormwater has many benefits, including maintaining groundwater recharge and reducing stormwater runoff and pollutant loads. In order to ensure safe drinking water, contaminants must be removed from stormwater before it reaches groundwater aquifers. Although soil is a tremendous natural filter, it cannot treat contaminated stormwater runoff beyond its limits. Pretreatment practices have a wide range of removal rates for different contaminants. This why it is important to design and implement practices to remove pollutants that take into account the potential contaminants in stormwater, site specific conditions, and maintenance needs.

Under NR 151.124 and 151.244, a construction site landowner must meet the performance standard for infiltration of runoff taking into account site restrictions. A technical standard has been developed to assist site designers in the assessment of the site and its adequacy in providing infiltration that is both protective of groundwater and practical to implement. The intent of the infiltration standard is to encourage infiltration of runoff. This requirement is tempered by a series of prohibitions and exemptions for the purpose of minimizing the risk of groundwater contamination and to address the practicality of implementation.

Local Controls

In 1989 the Legislature created the Dane County Lakes and Watershed Commission to serve as a coordinating and advisory agency for water quality issues within Dane County government (Wisconsin Act 324). Under the Act, the Commission may propose to the county board minimum standards for local regulations and ordinances for municipalities and the county to protect and rehabilitate the water quality of the surface waters and groundwater. In addition, the Regional Planning Commission provides review and approval of stormwater practices through its Urban Service Area amendment process. Dane County, local municipalities, and the Regional Planning Commission encourage and promote development practices that minimize surface water runoff and maximize infiltration and groundwater recharge. Several researchers have pointed out that stormwater infiltration practices that have been designed correctly pose little threat to the groundwater.[101,102,103] Current stormwater regulations and technical standards require pretreatment to remove contaminants prior to infiltration.

Impact/Effectiveness

With the emphasis on volume control BMPs in recent years, the issue of soil and groundwater contamination is gaining more attention. Recent research has improved the outlook on the risks of soil and groundwater contamination. Long-term (20 year or more) studies of groundwater below infiltration basins have shown no adverse effects from infiltrating stormwater.[104] Pretreatment of stormwater runoff from critical pollutant sources areas is required. The WDNR has developed program guidance and technical standards for best management practices for meeting the infiltration performance standard of NR 151.[105,106] By standard, no stormwater is infiltrated without treatment unless it is clean rooftop runoff. With the increased emphasis on infiltration, the potential for groundwater table rise or "mounding" should also be considered in planning extensive infiltration facilities.

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[101] Pitt, R. et al. 1999. *Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration.*
[102] Mikkelsen, P. et al. 1997. *Pollution of Soil and Groundwater from Infiltration of Highly Contaminated Stormwater.*
[103] Barraud, S. et al. 1999. *The Impact of Intentional Stormwater Infiltration on Soil and Groundwater.*
[104] Emmons and Oliver Resources. 2012. *Update on the Science of Volume Control BMPs.*
[105] http://dnr.wi.gov/topic/Stormwater/standards/postconst_standards.html
[106] http://dnr.wi.gov/topic/stormwater/documents/InfiltrationPerformanceStandardGuidance.pdf

Groundwater Quantity

State Controls

The Groundwater Quantity Act (2003 Wisconsin Act 310) expanded the State's authority to consider environmental impacts resulting from certain high capacity wells. Under that law, proposed high capacity wells that are within 1200 feet of trout streams and other designated high quality waters, wells that could have significant impacts on a spring, and wells with a high water loss are subject to more rigorous evaluation.

In terms of current administrative code, NR 860 and NR 820 establishes the process, requirements, and criteria for water use permitting. NR 856 establishes requirements for registering water withdrawals and accurate reporting to support management efforts. NR 852 establishes a statewide water conservation and efficiency program, specifying mandatory measures in the Great Lakes Basin. In other areas of the state, the regulation applies to wells that would result in an average water loss greater than 2,000,000 gals./day over a 30 day period (although, relatively few wells exceed this amount).

Wisconsin law also requires a statewide water supply service area planning process for public water supply systems (Wis. Stats. 281.348). This is being promulgated through proposed rule NR 854. This rule would apply to water supply systems that serve a population of 10,000 or more. These systems would be required to be covered by an approved water supply service area plan by December 31, 2025.

The goal of the planning process is to help sustainably manage the state's waters to provide an adequate quantity and quality of water to customers; to prepare for increasing demands on the state's groundwater and surface water resources; and to protect springs, streams, wetlands, and other natural features. The law requires that communities assess the quantity and quality of available water supply through a practical planning process to ensure dependable, safe, and cost-effective water delivery to customers. Since groundwater doesn't recognize municipal boundaries, a regional planning process is the best approach to addressing water demand issues associated with urban development. Some municipalities in Dane County, in collaboration with the Regional Planning Commission, WGNHS, and USGS, have begun this work on an ad hoc basis as outlined in this planning framework.

Local Controls

Local units of government in Dane County can voluntarily manage their water supplies to help minimize impacts to their environment and promote more sustainable water use. Significant collaborative efforts have been made among federal, state, and local entities to conduct groundwater modeling and planning activities in the region coordinated by the Regional Planning Commission. While much has been accomplished, more can be done in this regard.

Impact/Effectiveness

In Dane County significant state-of-the-art scientific tools have been developed (presented in this report) that can help inform communities and aid the WDNR in its decisions and approvals. Furthermore, continued regional collaboration will be needed among municipalities to minimize and mitigate the impacts of high capacity well withdrawals on the region's ground and surface waters, and promote more sustainable plans and practices in the future. Therefore, cooperative groundwater management policy in the region should include:

- a regional/watershed approach
- up-to-date hydrologic science
- increased focus on addressing cumulative impacts
- opportunities for water conservation and reuse
- monitoring and reporting
- adequate funding
- widespread participation and collaborative support

Public Information and Education

A well-developed educational program concerning groundwater protection should continue to be pursued in Dane County. Only through an informed public will groundwater be adequately protected. Public education on the occurrence and movement of groundwater, potential pollution sources and groundwater protection strategies is necessary to maintain the high quality of groundwater in the county. Also, in many instances, public knowledge is imperative for complying with state and local regulatory programs pertaining to groundwater management.

Particular emphasis in groundwater educational programs should be placed on how land use activities affect drinking water quality. This is especially relevant in Dane County because all residents obtain their drinking water from groundwater supplies. If individuals understand that their drinking water supply may be at risk, they will probably be more inclined to prevent water pollution. General as well as detailed groundwater educational programs should be promoted to the public. Various federal and state agencies have all developed general educational and resource materials that are available to Dane County residents. A good place to begin with groundwater education is in the school systems of the county, where environmental awareness may be instilled at an early age. The Groundwater Coordinating Council publishes the *Wisconsin Groundwater Education Resource Directory,* which is a compendium of the agencies, people and resource materials available for use in groundwater education.

In addition to general educational efforts, specific programs should be developed (or intensified) and targeted at groups that have a direct land use impact on groundwater. In many instances, this means the agricultural community. Thus, educational programs concerning agricultural best management practices should receive emphasis. Best management practices that minimize detrimental groundwater impacts include pest control strategies that limit pesticide use (e.g., crop rotation), proper pesticide container and rinse water disposal, fertility and manure management, and irrigation. County and UW-Extension promote many of these practices, and educational outreach programs are needed to reach more farmers. Renewed staff and resource commitments to Extension are necessary to expand existing educational efforts. The Regional Planning Commission also has a role in water service area planning.

Waste Recovery Programs

Waste recovery programs reduce the overall quantity of refuse to be disposed of in the county. As a result, a reduction in the need for landfill space can occur along with a reduction in associated environmental concerns. In addition, the need to use raw materials is diminished and an economic cost savings may be realized. The Dane County Solid Waste and Recycling Plan, adopted by Dane

County and the RPC as a specific element of the *Dane County Water Quality Plan*, sets the policy framework for each segment of the solid waste system. The Dane County Solid Waste Division is responsible for the siting, construction, operation, maintenance, closure, and post-closure care of Dane County's landfills, compost sites, and landfill gas-to-energy systems. This Division also coordinates and manages the County's recycling and Clean Sweep programs and activities, for example:

Recycling

Recycling consists of the separation of waste into components that are later converted into new products. This is now required for many common materials. All local units of government in Dane County have developed recycling programs to various levels. There is always room for improvement to further the amount of waste being landfilled.

Clean Sweep

Household hazardous materials (e.g., paint, cleaning compounds, pesticides, wood preservatives) have become an increasing concern in waste collection and disposal. Such waste is often disposed of by residents along with other household refuse. A community or countywide educational program promoting the safe collection and disposal of household hazardous waste is a non-regulatory approach that can be used to lessen disposal problems.

Dane County and the City of Madison have joined in establishing a successful household hazardous waste collection and disposal program (Operation Clean Sweep and the Product Exchange Program). The Product Exchange is a program where customers are encouraged to reuse quality waste products left by others (about 15 percent of material that comes into the facility), including paint, solvents, cleaning products, etc.

Waste Oil Collection

Waste oil collection is another waste recovery method which helps to safeguard the environment. Individuals who sell motor oil are now required by law to either post a sign directing consumers to the nearest waste oil collection site or set up a collection center themselves. Design and locational criteria for such sites are set forth in NR 679. Numerous waste oil collection sites exist in Dane County.

Pharmaceuticals and Personal Care Products (PPCPs)

Scientific evidence shows that a growing number of drugs and chemicals found in personal care products are ending up in waterways across the country. The potential for harm to human health is not known at this time, but because drinking water is drawn from these same sources, there is a growing concern about how these drugs and other substances may be affecting people, especially with long-term exposure. To protect out drinking water and our health, it makes sense to reduce the amount of these PPCPs in our wastewater as much as possible. In Dane County, MedDrop is the best way to dispose of medicines or pharmaceuticals. Lotions, soaps, sunscreen, shampoo, and perfume also wash off easily when we shower, bathe, or go swimming. These chemicals end up in our waterways and little is known about the effect they may have. We can make conscientious choices to reduce these products or buy those that contain only biodegradable or natural ingredients.

Groundwater Quality Monitoring

Monitoring of groundwater through public, private and observation wells provides needed information on existing water quality conditions. Such monitoring is essential in determining the existence and extent of groundwater pollution. If monitoring is maintained over an extended period, water quality changes may also be observed. Monitoring is routinely done for public water supply wells and near groundwater pollution sources.

Since it is impossible to monitor all sources of potential pollution, monitoring programs focus on identifying the most important ones. The importance of a potential pollution source is related to the magnitude of potential pollution (volume, degree of toxicity, etc.), the risk associated with such pollution (population exposed, seriousness of effects, etc.) and the probability or likelihood of pollution occurring.

Public Well Water Monitoring

Monitoring of public water supply systems is particularly important because of the large population at risk if a well is polluted. The federal Safe Drinking Water Act requires periodic monitoring of all public wells. Monitoring requirements and frequency for various organic and inorganic contaminants are detailed in chapter NR 809.

Since 1999, public water suppliers have been required to publish Consumer Confidence Reports, plainly worded reports which raise general awareness about drinking water and help consumers make informed decisions about their health. The reports include information such as the source of water, drinking water standards, regulated and unregulated contaminant levels, health concerns, and who to call for more information. The reports are sent to all customers by mail and efforts also made to reach those not billed, such as through local newspapers.

In addition, the 1996 Safe Drinking Water Act Amendments require states to develop and implement a Source Water Assessment Program (SWAP). Source water assessments are documents produced by WDNR staff during the period between 1999 and 2003 intended to provide basic information to public water suppliers. This program: 1) Delineates source water assessment boundaries for all public water systems in the state; 2) Inventories existing and potential sources of contamination within those boundaries; 3) Analyzes the susceptibility of the water systems to the contaminants; and 4) Makes the results of the assessments available to the public. The goal of the program is to use the assessments to protect public water supplies through prevention strategies, especially those most vulnerable to contamination.

Private Well Water Monitoring

The Department of Public Health for Madison and Dane County has been delegated state authority to administer and enforce well siting and abandonment permits and requirements. For new wells drilled or new pumps installed only a test for bacterial contamination is required. Testing for nitrates is recommended. Some mortgage lenders may require testing be conducted associated with property transfers. Also, any private well owner in the Madison Water Utility service area is required to obtain an operating permit which requires the well to be tested every five years. Outside of these requirements, private well owners are not compelled to have their wells tested, usually because of cost and inconvenience. Private well owners are recommended to test their water for bacteria and nitrates on a yearly basis, or whenever there are changes in taste, color or odor. Nitrate levels greater than 20 mg/l indicate a pathway connection to the surface and pesticides should also be tested.

WDNR performs private well water monitoring for VOCs and pesticides on a risk assessment basis, and also publishes brochures which recommends various tests for drinking water from private wells.

Observation Well Monitoring

Observation well monitoring is required by the WDNR at several waste disposal sites in Dane County. The degree of monitoring varies with each site.

Groundwater Data Management

The collection, coordination, and exchange of groundwater data within the WDNR and with outside agencies continue to be an important issue. WDNR places priority on coordinating the collection and retrieval of all groundwater data to meet inter-agency responsibilities and cooperative agreements.

Groundwater data from WDNR's consolidated Groundwater Retrieval Network (GRN) system is available on the following website http://prodoasext.dnr.wi.gov/inter1/grn$.startup. GRN accesses groundwater data from database systems in the Waste and Materials Management, Drinking Water and Groundwater, and Watershed Management programs including information on approximately 300,000 wells in the state and nearly 15,000 wells in Dane County. These wells represent public and private water supply wells, piezometers, monitoring wells, non-potable wells, and groundwater extraction sites. Data from the Bureau of Remediation and Redevelopment (LUST, spills, or remediation sites) is not currently retrievable through the GRN system. Rather, the Contaminated Lands Environmental Action Network (CLEAN), http://dnr.wi.gov/topic/Brownfields/clean.html, is an inter-linked system providing information on different contaminated land activities in Wisconsin, to assist with the investigation, cleanup and eventual re-use of those lands.

DATCP also needs up-to-date, reliable data about pesticide and nitrate contamination of groundwater. DATCP uses these data to develop substance specific rules about pesticide use, to respond to citizen requests on groundwater quality data for specific locations, and to investigate pesticide contamination of groundwater. DATCP's groundwater database currently contains information for over 62,000 wells (about 811,000 data records). DATCP is also the primary agency responsible for administration and regulation of the petroleum and hazardous materials storage tanks http://datcp.wi.gov/Consumer/Hazardous_Materials_Storage_Tanks/. Program initiatives have resulted in identifying a larger population of underground storage tanks

WGNHS has responsibility for geologic mapping, collection and analysis of basic data, survey and research on Wisconsin's groundwater resources. Products from the geologic mapping program support land-use planning, county-wide inventories of groundwater resources, and groundwater quality management and protection.

The UWS Central Wisconsin Groundwater Center maintains a database of private well testing data for nearly 228,000 test results from samples covering the state for various inorganic chemical and biological parameters. In addition, the Wisconsin Well Water Quality Interactive Viewer (http://www.uwsp.edu/cnr-ap/watershed/Pages/WellWaterViewer.aspx) was created as an educational tool to help people better understand Wisconsin's groundwater resources that we rely on for our drinking water.

DOT maintains records of hazardous material investigations associated with highway projects, including groundwater contamination.

In 1998, The Wisconsin Groundwater Coordinating Council updated the *Directory of Groundwater Databases*, which cross-references agency databases and principal contacts. The directory describes the agencies which have responsibilities or conduct activities related to groundwater protection, and principal contacts, as well as internet sites for retrieving groundwater or related information.

Chapter 8: Groundwater Protection Recommendations

This chapter presents groundwater protection recommendations for each potential groundwater pollution source. They incorporate and expand upon much of the work and findings from previous plans and studies, as well as information from the supporting sections of this plan. These proposals provide a range of both regulatory and non-regulatory approaches to groundwater protection that should be promoted and implemented by various state and local organizations as early as opportunity and circumstance allow. Chapter 9 follows with selected short-range priority actions recommended for immediate management agency consideration.

Siting and Land Use Decisions Affecting Groundwater

Assessment of Conditions and Management Controls:

Sources of groundwater pollution are many and varied. Many activities that contribute to groundwater pollution are closely integrated into our economic and cultural way of life. The type, duration, and intensity of our use of the land will largely determine the risk posed to groundwater.

Thus, siting and land use decisions made by state agencies, and by county and local governments and private landowners, can have a significant effect on drinking water supplies. In addition, wellhead protection programs are an important approach to drinking water supply protection. Although these programs are being required by federal and state regulations, given the catastrophic impacts on a community resulting from contamination of their water supply, the costs of replacing a contaminated well, the near impossibility of cleaning up a contaminated aquifer, and the importance of citizen confidence in the safety of their drinking water, this preventive approach has been strongly supported by communities – basically giving them local control and responsibility for their drinking water supplies. Some aspects of wellhead protection programs, such as protecting important recharge or source areas, may need to extend beyond municipal boundaries, and will therefore require intergovernmental cooperation. Communities may want to consider extraterritorial zoning, intergovernmental agreements, open space plans, etc. Such an approach can reduce the risk of drinking water contamination and may avoid future infrastructure costs such as new wells or treatment.

Much of the information and analytical capacity for incorporating groundwater protection concerns into land use planning and decisionmaking processes exists (e.g., hydrogeologic model, contamination risk maps, guidelines and criteria in **Table 20,** etc.). Greater efforts are needed to ensure that impacts on groundwater quality are routinely and adequately considered in siting and land use decisions.

Recommendations:

1. Local units of government and other responsible agencies, including the Regional Planning Commission should collaborate to develop processes and standards for the evaluation of potential groundwater and hydrologic impacts.
2. Local units of government should assess, consider, and incorporate potential groundwater impacts and protections in the development and updates of local comprehensive and water supply plans. The Regional Planning Commission staff can provide technical assistance in this regard.
3. Local units of government should collaborate with the county and other responsible agencies to formally develop and incorporate groundwater impact assessment procedures and standards into their wellhead protection plans and ordinances. Also consider alternative options for plan implementation such as intergovernmental agreements and open space plans. The Regional Planning Commision staff can provide technical assistance in this regard.
4. The Regional Planning Commission staff should continue to provide assistance, through the Regional Hydrologic Modeling and Management Program, to local units of government and water supply agencies in Dane County, to maximize participation in the state Wellhead Protection Program and develop groundwater protection programs to protect all major water supply wells and aquifers in the region.

Solid Waste Disposal Sites

Assessment of Conditions and Management Controls:

A deterioration in groundwater quality has occurred near several closed landfills in Dane County. Strict regulatory requirements have been established for landfills since the 1980s; however, most closed landfills in the county were developed before these requirements were enacted. Groundwater quality is being monitored near only a small number of landfills, thus the extent of groundwater pollution may not be realized.

Recommendations:

1. The WDNR in conjunction with the Regional Planning Commission should establish a priority list for monitoring closed or inactive landfills.

   Highest priority for monitoring should be closed or inactive landfills located in areas of high or extreme contamination risk in municipal well protection zones. Subsequent priority should be for landfills in areas of moderate risk in well protection zones.

2. New solid waste disposal sites and landfills should continue to be located and designed to protect surface and groundwater. Proposed landfills should be located outside of municipal well protection zones and in areas of low to moderate groundwater contamination risk. WDNR and other responsible state agencies should seek Regional Planning Commission staff participation, technical review and comment on proposed locations.
3. Dane County should continue to support and promote recycling and waste-reduction programs to decrease waste loads going to landfills – ultimately reducing the need for additional landfills. The county should continue to support and expand Clean Sweep programs to collect household hazard wastes for proper disposal

Land Application of Wastewater

Assessment of Conditions and Management Controls:

A few industries in Dane County discharge wastewater through land application systems, mainly organic food processing and canning wastewaters. State controls for wastewater dischargers are stringent, but groundwater monitoring is limited. No detrimental impacts have been reported.

Recommendation:

1. Sites for land application of wastewater should be carefully located and designed to avoid groundwater contamination, and should not be located in areas of extreme contamination risk or municipal well protection zones. All significant land application sites should be subject to groundwater monitoring. WDNR and other responsible state agencies should continue to request Regional Planning Commission staff technical review and comment on proposed application sites and permit renewals.

Sanitary Sewers

Assessment of Conditions and Management Controls:

Recently, viruses and other microbial pathogens have been found in municipal wells, challenging previous assumptions about their occurrence. Virus serotypes detected in sewage and groundwater were temporally correlated, suggesting very rapid virus transport, on the order of weeks, from the source(s) to wells. Virus levels in the wells were associated with precipitation events. The most likely source of the viruses in the wells is leakage of untreated sewage from sanitary sewer pipes. As older, failing infrastructure is replaced, emphasis should continue to be focused on adequate construction, testing, and disinfection of public drinking water supplies.

Recommendation:

1 Continued emphasis should be placed on municipal sanitary sewer inspection and repair programs to reduce infiltration of groundwater into sewers and also sewage leaking into groundwater.

2 Municipal wells should be properly constructed and cased to discourage contamination. Testing and retrofitting existing wells should be conducted where opportunities present themselves.

3 Continued disinfection of municipal drinking water supplies is necessary to protect and maintain human health.

On-Site Wastewater Management

Assessment of Conditions and Management Controls:

Over 23,000 homes in rural Dane County are served by on-site wastewater systems. Private well samples indicate that a significant proportion (approximately 25 percent) of domestic wells have nitrate levels exceeding the drinking water standards. While it does not appear that on-site systems are a major source of nitrates on an areawide basis, localized well contamination can result from high loading from clusters of on-site systems (rural subdivisions). Although the impacts on groundwater of septic systems in all the soil-geologic-hydrogeologic settings in the county are not clearly understood, systems which: a) have failed hydraulically or b) are not treating and purifying wastes as they are designed to, are probably adversely impacting groundwater. Implementation of the triennial inspection and required maintenance program for all on-site systems has helped the continued proper functioning of those systems which have not failed, and identifying those that have.

Recommendations:

1. Governmental units responsible for the regulation of private on-site wastewater treatment systems should continue to implement an effective inspection and required maintenance program for all on-site wastewater disposal systems.
2. Local management and planning agencies should cooperate in investigating and developing community water systems for existing concentrations of rural development experiencing on-site wastewater system problems and/or nitrate contamination issues.
3. Large on-site wastewater systems and clusters of more than 20 systems with an average density of 1.0- to 1.5-acre lot size should be planned and evaluated to ensure that wells and water supplies are protected from excessive nitrate levels.
4. Holding tanks should continue to be used for wastewater disposal only in instances when adequate servicing and

pumping can be assured, and when suitable disposal methods (well-regulated land disposal sites or wastewater treatment plants) are specifically available for receiving the wastes.

5. Explore innovative methods for improving waste disposal and groundwater quality through site design and new technologies.
6. Local units of government and Public Health Madison and Dane County should encourage all residents with private wells to have their water tested for nitrates, especially those with infants.
7. State and local funding for on-site wastewater management and septage disposal programs should be increased to adequate levels.

Biosolids Applications

Assessment of Conditions and Management Controls:

Biosolids are a byproduct of our modern society and the need to manage their use will continue in the future. They provide an excellent source of plant nutrients and organic matter for agriculture, which should not be wasted by landfilling or incineration. Their creation is carefully managed to reduce the health risks associated with pathogens and heavy metals. Their use is closely monitored by both the USEPA and the WDNR. Research on biosolids process and management has been conducted at the University of Wisconsin for over 80 years and continues to this day. The land application of biosolids should be incorporated into a farm's nutrient management plan to reduce the risk of water quality degradation. In Dane County no detrimental groundwater quality changes have been indicated from private well water monitoring near biosolids application sites. The current state regulatory program has been effective and should continue.

Recommendations:

1. Organic biosolids should continue to be recycled as a fertilizer and soil conditioner for agricultural cropland, nurseries, and sod farms.
2. The location and operation of biosolids land application sites should continue to be regulated by WDNR. Criteria for sites should be expanded to reflect groundwater protection, and sites should not be located in areas of extreme groundwater contamination risk. WDNR and other responsible agencies should seek Regional Planning Commision staff participation, technical review and comment on proposed locations.
3. Wastewater treatment plants should continue to maintain adequate biosolids storage capacity (180 days) to avoid the need to apply biosolids to land during winter months or

under saturated soil conditions.

4. Increase communication between biosolids applicators and landowners to ensure biosolids nutrient applications are being accounted for in nutrient management plans.

Septage Applications

Assessment of Conditions and Management Controls:

About 26 million gallons of septage, a high-strength organic waste, is handled in Dane County annually, with about 90 percent of the total discharged to wastewater treatment plants and the remainder applied to landspreading sites. Landspreading septage under controlled and monitored conditions would be consistent with the *Dane County Water Quality Plan.* However, there is much less routine monitoring and supervision of application sites and procedures than other similar waste management programs, such as land application of wastewater treatment plant sludge or biosolids. Consequently, there is not enough information to determine whether or not the required site conditions and application procedures are being observed, or whether any significant problems are occurring.

Recommendations:

1. Public Health-Madison and Dane County should assume responsibility for or participate in the approval and inspection of landspreading sites for the disposal of septage.
2. Land application sites for septage should be carefully located and designed to avoid groundwater contamination, and should not be located in areas of extreme groundwater contamination risk or well protection zones. Existing sites located in these areas should be monitored and subjected to stringent design and operating requirements, and eventually phased out. WDNR and other responsible agencies should seek Regional Planning Commission staff participation, technical review and comment on proposed locations.
3. Municipal wastewater treatment plants should include provisions for receiving and treating septage generated within a reasonable distance. This recommendation has largely been implemented. Additional sites should be explored that do not currently accept septage.

Manure Storage

Assessment of Conditions and Management Controls:

Animal waste (manure) handling and management is an integral part of much of the agriculture in the county. Manure storage pits and manure-spreading can pose a threat to groundwater quality. Chapter 14 of the County Zoning Ordinance has been modified to include the proper design and construction of manure storage facilities. A state permit system exists for the few large feedlot operations in the county.

Recommendations:

1. Manure storage pits or lagoons should be located and designed in accordance with specifications necessary to protect groundwater. Large storage pits should not be located in areas of high or extreme groundwater contamination risk. WDNR and other responsible agencies should seek Regional Planning Commission staff participation, technical review and comment on proposed locations.

Fertilizer and Manure Spreading

Assessment of Conditions and Management Controls:

A high level of nitrate-nitrogen is evident in Dane County's shallow groundwater system. Excessive fertilizer application in excess of crop uptake is believed to be increasing groundwater nitrogen concentrations on an areawide basis. Limited regulatory controls over fertilizer application exist.

Recommendations:

1. Further educational programs and best management practices aimed at reducing nitrogen fertilization should be stressed to county farmers as well as to residential and commercial applicators of fertilizers. Emphasis should be placed on the vulnerability of groundwater to contamination and the difficulty/expense of restoring drinking water supplies. This should be a collaborative effort among local partners including the county Land Conservation Division, Madison and Dane County Public Health, the Regional Planning Commission, the Clean Lakes Alliance, Yahara Pride Farms, among other groups.

Pesticide Applications

Assessment of Conditions and Management Controls:

Atrazine was the most widely used herbicide in Wisconsin for more than 40 years because it is effective and inexpensive. According to DATCP, 40 percent of private wells tested across the state have atrazine detections, while about 1 percent of wells contain atrazine over the groundwater enforcement standard. Limited groundwater monitoring for pesticides has occurred in Dane County. Approximately two-thirds of central Dane County is designated an atrazine prohibition area. Applicators of restricted use pesticides are required to be trained and certified, while applicators of general use pesticides have no training requirements.

In 1997 and 2007 DATCP conducted an *Atrazine Rule Evaluation Survey* to evaluate the restrictions on the use of atrazine in Wisconsin. The results showed a significant decline in atrazine concentrations in Wisconsin. However, while the average atrazine concentrations in wells with detections declined 44 percent (from 0.96 to 0.54 *u*g/l) the percent of contaminated wells did not show a significant decline. The results of a DATCP *Weed Management Survey in Atrazine Prohibition Areas* survey suggests that although many corn growers would like the option to use atrazine in a prohibition area, they have adapted well to growing corn without it.

Recommendations:

1. Increased monitoring for pesticides in groundwater should be conducted in areas of extreme contamination risk where pesticides are commonly used. This should be done by the Department of Agriculture and the WDNR.
2. Support should be provided for the state Atrazine Management Program, which currently bans the use of atrazine in a major portion of the county and allows only for reduced usage in other areas.
3. Adoption by county farmers of Integrated Pest Management (IPM) strategies, which direct pesticide application only when needed, should be encouraged and supported by Dane County Land Conservation Division and Dane County UW Extension.
4. Educational efforts aimed at farmers, homeowners and commercial applications of pesticides by Dane County UW Extension should be expanded and continue to emphasize the vulnerability of groundwater to contamination and the tremendous difficulty of restoring groundwater once it has been contaminated.
5. Stimulate innovation at the local/farmer level; Dane County Land Conservation Division and Dane County Extension should encourage farmers to apply for grants that support innovation in the development of sustainable practices (such as the U.S. Department of Agriculture's Sustainable Agriculture, Research, and Education (SARE) program).

Irrigation

Assessment of Conditions and Management Controls:

Irrigation can facilitate the leaching of fertilizers and pesticides to the groundwater. Irrigation, though, is not widespread in the county. High-capacity irrigation wells are regulated by the state.

Recommendation:

1. Continue registration and monthly reporting of high capacity wells and withdrawals.

Household Hazardous Materials

Assessment of Conditions and Management Controls:

Household hazardous materials (e.g., cleaning agents, paint products) are commonly used by residents and ultimate disposal of these materials often means landfilling or improper dumping. If not safely disposed, hazardous materials can degrade groundwater quality. Dane County and the City of Madison have established the Clean Sweep and Product Exchange programs for proper collection and disposal of hazardous wastes.

Recommendation:

1. A countywide information and education program concerning the safe collection and disposal of household hazardous materials, along with the use of alternative products to these materials, should continue to be promoted through the Clean Sweep and Product Exchange programs. Emphasis should be made on the vulnerability of groundwater to contamination, and the tremendous difficulty/expense of restoring groundwater once it has been contaminated.
2. Local units of government should continue to promote public information and education programs concerning pharmaceuticals, personal care products, and endocrine disrupting compounds in groundwater, along with continued support for the MedDrop program for expired and unused medications.

Aboveground Storage Tanks

Assessment of Conditions and Management Controls:

Chemicals leaking from aboveground storage tanks may infiltrate the soil and pollute groundwater. The threat of pollution, though, is less than from underground tanks. The Department of Agriculture, Trade and Consumer Protection has an ongoing program to regulate above and underground tanks. The program requires registration and inspection. Inspection responsibilities can be conducted by city, village, and town fire chiefs, who serve as the state agency's designated deputies.

Regulations for large aboveground tanks storing petroleum products should help minimize adverse impacts from leaks or spills. Requirements for the bulk storage of pesticides and fertilizers should also minimize groundwater quality threats from these sites.

Recommendation:

1. There are information gaps regarding smaller (1,100 gals. or less) fuel and chemical tanks in rural parts of the county. Proper on-farm storage of fuel, pesticides, and fertilizers should receive greater emphasis, including education, increased security and safety/containment.

Underground Storage Tanks

Assessment of Conditions and Management Controls:

Leaking underground tanks have a significant potential to contaminate groundwater and threaten municipal and private water supplies.

State regulations for underground tanks contain permitting, testing and on-site inspection requirements have significantly reduced the threat of groundwater quality degradation. While the responsibility for this program rests largely with state government, the county should continue to encourage on-site inspection to prevent discharge of contaminants to groundwater due to tank failure. Pollution prevention costs are substantially less than remediation.

Recommendations:

1. Although tank testing is required on a five-year basis, this may not be of sufficient frequency to adequately detect and respond to leaks, particularly in municipal well protection zones. More frequent monitoring and testing requirements should be considered in wellhead protection plans for tanks in these areas, as well as other areas of high or extreme contamination risk. Existing tanks not providing adequate corrosion protection or leak containment should be replaced or properly abandoned.
2. The State should consider reinstating the Petroleum Environmental Cleanup Fund Award (PECFA) to help individuals and small business owners who lack the resources to respond adequately to a leaking tank on their own.

Transmission Pipelines

Assessment of Conditions and Management Controls:

Groundwater quality problems have not been documented from the major petroleum pipelines in Dane County. Leaks from these pipelines, though, could pose a serious groundwater hazard due to the amount and type of pollutant released. The federal government has regulatory authority over petroleum pipelines. No local management proposals are suggested.

Hazardous Spills

Assessment of Conditions and Management Controls:

In Dane County, numerous hazardous spills have been reported to the WDNR. Some of these spills have reached the groundwater table. Strict state requirements pertaining to hazardous substance handling, spill contingency plans and spill reporting assist in preventing harmful impacts.

Recommendation:

1. Dane County should continue to provide funding to allow the City of Madison to provide response assistance for local fire departments and emergency response personnel throughout the county. This will allow spill response equipment and emergency efforts to be more cost-effective and readily available on a countywide basis.

Junkyards/Salvage Yards

Assessment of Conditions and Management Controls:

Although groundwater quality problems have not been identified at many of these sites, leakage of hazardous materials from improperly managed junkyards and salvage yards can represent a pollution threat. A conditional use permit and an annual license are required by Dane County before a salvage or junkyard can be operated.

Recommendation:

1. Active local and state oversight of hazardous materials at junkyards/salvage yards should be continued.

Well Construction and Abandonment

Assessment of Conditions and Management Controls:

High-capacity wells serve most communities and many industries in Dane County. These wells are generally deeper and of larger diameter than private domestic wells. Although many of these wells produce water from the deep sandstone aquifer, such wells are sometimes constructed with well casings extending only into the shallower bedrock units. High-capacity wells with shallow casings create a vertical conduit that can allow groundwater to move rapidly between the shallow and deep bedrock aquifers. Contamination in the deep bedrock is extremely expensive and difficult to remediate. In addition, viruses found in deep municipal wells indicate that *all* aquifers are potentially vulnerable to microbial contamination.

Recommendation:

1. Municipalities and industries in Dane county designing new high-capacity wells should design the wells (e.g., adequate casing depth, etc.) to be sure to avoid cross-connecting the shallow and deep aquifers across the Eau Claire aquitard . Older wells with inadequate casings should be reconstructed with deeper casings or properly abandoned as they go out of service. The Wisconsin Geological and Natural History Survey and WDNR can assist in designing new wells and abandoning old wells.

Salt Storage and Deicing

Assessment of Conditions and Management Controls:

Sodium and chloride concentrations have been increasing in the water of Madison wells. These increases are associated with salt use. Generally, salt storage sites are not a problem in the county due to adequate containment and state regulatory controls. Temporary snow storage sites should be located and managed to avoid groundwater pollution.

Recommendation:

1. Municipalities in the region should re-evaluate their practices regarding the application of road salt for snow and ice control and strive to achieve minimum application rates consistent with safe operation. This includes alternatives to salt, such as sand-salt mix with enhanced street sweeping, metered application, and promoting less expectations by the public for clean pavement conditions and anticipating increased driving time and slower speeds during winter events.
2. Continue to promote the public information and education efforts of the SaltWise Partnership directed to municipalities, homeowners, motorists, and commercial applicators.

Stormwater Infiltration

Assessment of Conditions and Management Controls:

Significant progress has been made in Dane County and around the state to reduce or mitigate the potential increase in flood peaks through stormwater volume control ordinances. Maintaining pre-development infiltration promotes additional benefits as well, including maintaining stream baseflow, water temperatures, and also water quality considerations (since pollutant loading is a function of runoff volume).

Both NR 151 and Dane County Chapter 14 require development projects to maintain some level of pre-development stay-on volumes. Dane County's ordinance (mirrored by other municipalities in the county) is more stringent, requiring 90 percent of pre-development stay-on for all development types. Additional requirements common to both regulations effectively protect groundwater quality. Municipalities should consider maintaining 100 percent pre-development stay-on volumes, where opportunities exist, as well as enhanced recharge above natural rates to help make up for well water withdrawals in a community.

Recommendations:

1. Stormwater Best Management Practice designers should consult state and local ordinances, technical standards, and current research for design guidance and acceptability of infiltration practices and performance.
2. Municipalities should consider enhanced infiltration (above required levels) to help offset well water withdrawals in appropriate areas and where potential groundwater mounding/flooding will not negatively impact existing development or property.
3. Municipalities should actively encourage, promote, and track demonstration infiltration practices and also retrofit projects as part of current urban development in the region. Opportunities for public and private partnerships to undertake and assess new and innovative options for infiltration should be actively sought in partnership with the Regional Planning Commission. Practices such as porous pavement, roof gutters connected to infiltration trenches, and channeling of residual runoff to an infiltration pond could be installed and their effectiveness monitored.

Groundwater Quality Monitoring

Assessment of Conditions and Management Controls:

Easy access to available geologic and groundwater information is essential if this information is to be useful for day-to-day management decisions. In the long term, it is likely that land planning and resource management will continue to evolve toward a total system/network based on computerized geographic information systems (GIS) storing a wide array of data and information for specific locations and small geographic areas, including geologic and groundwater data. It is important that appropriate information be gathered that is suitable for such a system, and can be linked with other databases and systems.

Recommendation:

1. Additional groundwater quality monitoring and testing should be conducted in Dane County by WDNR and DATCP, with specific needs related to the impacts of closed landfills, underground and aboveground storage tanks, barnyards and manure storage, agricultural fertilizer and pesticide use, and the impacts of on-site wastewater systems. The groundwater contamination risk maps and well protection zones can be used to prioritize geographic areas needing more urgent attention.
2. Public Health Madison and Dane County and Dane County UW Extension should provide rural homeowners with information and guidelines for testing their wells.

Groundwater Quantity Management

Assessment of Conditions and Management Controls:

Groundwater Quantity Management is currently a work in progress in Wisconsin. Under current law, a person may not construct a high capacity well without an approval from WDNR Current law also requires WDNR to administer a planning process for public water supply systems that serve a population of 10,000 or more. A water supply plan specifies the area for which a public supply system will provide water and how the system will provide the water.

Significant research and progress has been initiated in the region to address the impacts of well water withdrawals through the Regional Planning Commission's Regional Hydrologic Modeling and Management Program. These efforts need to continue to be supported and expanded throughout the region. Efforts should be focused on coordinated and comprehensive strategic implementation of plans among communities, using the information and tools detailed in this plan, to arrive at the least cost alternatives for each community addressing reliability, sustainability, and resource-based issues.

Recommendations:

1. In cooperation with local management agencies, the Regional Planning Commission should conduct proactive and collaborative regional groundwater planning among communities to address water availability and sustainability issues related to ground and surface water resources.
2. In cooperation with local management agencies, the Regional Planning Commission should maintain an inventory of information on the location, quantity, and uses of the region's groundwater.
3. In cooperation with local management agencies, the Regional Planning Commission should conduct targeted research and modeling of the impact of groundwater withdrawals on surface waters.

Groundwater Data and Information Management

Assessment of Conditions and Management Controls:

Much of the current groundwater data is being gathered by separate agencies and filed in such a manner that it is difficult to extract and utilize. Easy access to available geologic and groundwater information is essential if this information is to be useful in day-to-day management decisions.

The first step in improving the accessibility and utility of available groundwater data is to develop an organizational framework by which this information may be collected, analyzed and shared among resource management agencies and decision-makers in Dane County. The interagency Regional Hydrologic Modeling and Management Program is part of an ongoing collaborative effort between the Regional Planning Commission, WGNHS, WDNR, and USGS in cooperation with participating state and local governments to establish an information management program and provide analytical tools to promote better management of Dane County's water resources. The Regional Planning Commission also coordinates an ongoing Cooperative Water Resource Monitoring Program which includes water quality baseflow sampling on representative streams throughout the county, to better assess problem areas and groundwater quality improvements to surface waters.

In the long term, resource and land planning and management will continue to evolve using computer tools, technologies, and geographic information management systems that store a wide variety of data and information for specific locations and small geographic areas, including geologic and groundwater data. It is important that comprehensive groundwater quantity and quality data be collected that is available for use at the local level that is also useful at a regional scale for evaluating groundwater conditions and trends.

Recommendation:

1. Dane County, the Regional Planning Commission, and other federal, state and local agencies should continue to develop and use a cooperative and comprehensive groundwater data and information management system for more effective and groundwater protection, planning, and management in the region overall through the ongoing Regional Hydrologic Modeling and Management Program.

Chapter 9: State and Local Government Priority Actions

In this section, those actions and programs which need priority attention in the near future are presented for each level of government. These proposals are limited to the most important areas of immediate concern based on the review of present programs and deficiencies presented at the end of Chapter 8.

State Government

Department of Natural Resources

1. Consider and utilize the information, tools, criteria and guidelines identified in this planning framework in site approvals, or permits that could impact groundwater in Dane County. These include high-capacity well approvals, WPDES permits for wastewater facilities discharging to groundwater, site approval for biosolids and septage landspreading sites, stormwater infiltration practices, sanitary landfills, large manure storage lagoons or feedlots, and prioritizing remediation sites and monitoring. WDNR and other responsible agencies should seek Regional Planning Commission staff participation, technical review and comment on proposed projects and locations.

2. Work with local governments, Dane County and the Regional Planning Commission to develop effective wellhead protection programs and source protection plans for all municipal wells in Dane County. Also, provide information, guidelines and contacts to rural homeowners for testing drinking water quality in cooperation with the Department of Public Health – Madison and Dane County.

3. Support increased groundwater monitoring directed at priority concerns: closed or inactive landfills; leaking underground storage tanks; barnyards and manure storage practices; fertilizer and pesticide use; and land application of biosolids, septage and wastewater.

Department of Agriculture, Trade and Consumer Protection

1. Consider and utilize the information, tools, criteria and guidelines outlined in this planning framework in site approvals, or permits that could impact groundwater in Dane County. These include large manure storage lagoons and feedlots, and targeting pesticide monitoring and control efforts. DATCP and other responsible agencies should seek Regional Planning Commission staff participation, technical review and comment on proposed projects and locations.

2. Support increased promotional and educational efforts directed at expanding development of farm nutrient management plans and integrated pesticide management programs in order to reduce pesticide and fertilizer applications.

3. Increase emphasis on proper on-farm storage of fuel, pesticides, and fertilizers.

4. Support increased groundwater monitoring directed at priority concerns: closed or inactive landfills; leaking underground storage tanks; barnyards and manure storage practices; fertilizer and pesticide use.

Department of Safety and Professional Services

1. Consider and utilize the information, tools, criteria and guidelines identified in this plan in site approvals, or permits that could impact groundwater in Dane County. DSPS and other responsible agencies should seek Regional Planning Commission staff participation, technical review and comment on proposed projects and locations.

2. Support and work with Dane County in implementing a program for tracking and ensuring that required inspection and maintenance is provided for all on-site wastewater systems in Dane County.

3. Increase support of monitoring and research directed at the groundwater impacts of on-site wastewater systems, and the development of practical and economical nitrogen-removing on-site systems.

Local Government

Dane County

1. Incorporate and utilize the information, tools, criteria and guidelines identified in this planning framework to develop processes and standards to address potential groundwater impacts. Support and participate in the cooperative Regional Hydrologic Modeling and Management Program. Dane County should seek Regional Planning Commission staff participation, technical review and comment on proposed projects and locations.

2. Assess, consider, and incorporate potential groundwater impacts and protections in the development and updates of local comprehensive plans. The Regional Planning Commission staff can provide technical assistance in this regard.

3. Work with WDNR, the Regional Planning Commission, and local units of government to develop effective wellhead protection programs and source protection plans for all municipal wells in Dane County, particularly where protection programs need to extend beyond local jurisdictional boundaries.

4. Maintain an inventory of livestock, feedlots, and manure storage facilities in Dane County.

5. Increase promotional and educational efforts directed at developing farm nutrient management plans and integrated pesticide management programs.

6. Continue implementation of the triennial inspection and required maintenance tracking system for all on-site wastewater systems in Dane County. Expand distribution of public informational materials on proper use and maintenance of on-site wastewater systems and private wells, including safe use and storage, collection and disposal of household hazardous materials and personal care products. Provide information, guidelines and contacts to rural homeowners for testing drinking water quality.

7. Continue to seek to assume responsibility for, or participate in, approval of septage landspreading sites.

8. Continue to expand and improve household hazardous waste programs, and emergency response capability for hazardous material spills.

Cities, Villages, Towns, and Local Water Supply Agencies

1. Conduct water supply service area planning in the region as required by Wis. Stats. 281.348 with assistance provided by the Regional Planning Commission and in collaboration with local management agencies.

2. Incorporate and utilize the information, tools, criteria and guidelines identified in this planning framework to develop processes and standards to address potential groundwater impacts. Support and participate in the cooperative Dane County Regional Hydrologic Modeling and Management Program. Municipalities and water supply agencies should seek Regional Planning Commission staff participation, technical review and comment on proposed projects and locations.

3. Assess, consider, and incorporate potential groundwater impacts and protections in the development and updates of local comprehensive and water supply plans. The Regional Planning Commission staff can provide technical assistance in this regard.

4. Work with WDNR, Dane County and the Regional Planning Commission to develop effective wellhead protection programs and source protection plans for all municipal water supplies. Fix wells with faulty casing separating deep and shallow aquifers to help prevent downward movement of contaminants.

5. Work with DATCP and WDNR to expand monitoring and testing of older underground tanks in municipal well protection zones and areas of high or extreme contamination risk.

6. Continue and expand efforts to reduce the groundwater impacts of salt storage and use and snow removal practices.

7. Cooperate with WDNR and utilize the information and criteria in this plan and through the Regional Planning Commission's Regional Hydrologic Modeling and Management Program in locating and designing new high-capacity wells, in order to minimize adverse groundwater impacts.

8. Continue to work with WDNR, Dane County and the Regional Planning Commission to incorporate stormwater infiltration practices into local erosion/stormwater control ordinances that will protect groundwater.

9. Cooperate in expanding and improving household hazardous waste collection and public information programs, and in improving emergency response to hazardous materials spills.

Capital Area Regional Planning Commission

1. Conduct water supply service area planning efforts in the region as required by Wis. Stats. 281.348. More specifically, promote proactive and collaborative regional groundwater management planning among communities to address water availability and sustainability issues related to both ground and surface water resources.

2. Assist municipalities and resource management agencies consider and utilize the information, tools, criteria and guidelines outlined in this planning framework in all land use decisions, site approvals, or permits that could impact groundwater. These include high-capacity well proposals, WPDES permits for wastewater facilities discharging to groundwater, biosolids and septage land spreading sites, stormwater infiltration practices, sanitary landfills, large manure storage lagoons or feedlots, large unsewered subdivisions, prioritizing remediation sites and monitoring, etc.

3. Assist municipalities and resource management agencies in providing public information, education, and technical resources to citizens and landowners concerning groundwater quality protection and management throughout the region.

Presented as such, the Dane County Groundwater Protection Planning Framework is intended to provide the basis for and foster more detailed evaluations and strategic planning at the local level.

Summary of Groundwater Protection Roles and Responsibilities

Table 30 summarizes the governmental roles and responsibilities for the various regulatory, non-regulatory and other program activities for the array of potential groundwater pollution sources. This table indicates the level of government (local, state or federal) having significant responsibility for each area of program activity for each potential pollution source.

Table 30 has been used to indicate the entire array of existing groundwater protection programs and strategies and areas needing substantial improvement, or requiring priority attention or action because of the importance of the pollution source or shortcomings in existing protection programs. These priority areas are indicated by shaded boxes in **Table 30,** and highlight the short-term priority actions for state and local government.

Table 30
Groundwater Protection Roles and Responsibilities

Potential Pollution Sources \ Groundwater Management Controls		Regulatory						Non-Regulatory					Other				
		Permits	Site Approval	Land Use Controls	Construction Standards	Use Restrictions	Inspection & Testing	Guidelines/Criteria	Minimizing Input of Pollutants	Education	Voluntary BMP	Governmental Coordination	Training & Demonstration	Monitoring	Research & Inventory	Remedial Action	Emergency Response
Waste Disposal	Solid Waste Disposal Sites	S	S	L	S		Sl	Sl	L			SL		Sl	Sl	SL	
	Land Application of Wastewater	S	S		S		SL	S						Sl	Sl	L	
	Sanitary Sewers	S		SL	SL		S	S				SL				L	SL
	On-Site Wastewater Systems	SL	SL	sL	S		L	L		L		SL			SL		
	Sludge/Biosolids Application	S	S	S			S	S				SL		L	SL		
	Septage Applications	S(L)	S(L)	S(L)			S(L)	S(L)				SL			S(L)		
Agriculture	Manure Storage	L			SL			sL		sL	L				L		
	Fertilizer & Manure Spreading							sL		sL	L		SL				
	Pesticide Application					S		SL	L	SL	L		SL	S			
	Irrigation	S			S		S			sL	L						
Hazardous Materials	Household Hazardous Materials								L	sL							
	Above-ground Storage	S			S		L	S		SL		SL				SL	SL
	Underground Storage	S			S		Sl	S		SL		SL		SL	S	SL	SL
	Transmission Pipelines	F			F		F	F								S	S
	Spills											SL	SL	SL	S	SL	SL
	Junkyards/Salvage Yards	L		L			L										
Other	Well Construction & Abandonment	SL	SL		SL		SL	S		SL		L			L		
	Salt Storage & Deicing					S	L	S	L	L	L	L			SL		
	Stormwater Infiltration	SL	sL		SL		L	SL		L	sL	L	SL		SL		
	Groundwater Quality and Quantity Management	Sl	Sl	L			S	sL		sL		SL		S	SL	FSL	

F = Federal Role
S = State Role
L = Local Role (including CARPC)
▢ = Priority Action Needed

L or S = Primary Role
l or s = Assisting or Advisory Role
(L) = Possible Future Regulatory Program

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Attachment A

Chemical Analyses for Public Water Supplies in Dane County																							
Municipality	Well #	Alkalinity ($CaCO_3$) (mg/l)	Arsenic (ug/l)	Barium (ug/l)	Cadmium (ug/l)	Calcium (mg/l)	Chloride (mg/l)	Chromium (ug/l)	Copper (ug/l)	Fluoride (mg/l)	Hardness ($CaCO_3$) (mg/l)	Iron (mg/l)	Lead (ug/l)	Magnesium (mg/l)	Manganese (ug/l)	Mercury (ug/l)	$N0_3$,$N0_2$ (as N.) (mg/l)	pH (SU)	Selenium (ug/l)	Silver (ug/l)	Sodium (mg/l)	Sulfate (mg/l)	Zinc (ug/l)
MCL			10	2000	5			100	1300	4			15			2	10		50				
Belleville	D								200	0.52			5.30										
	1	310	ND	10	ND	61	ND	0.2		0.05	330	ND		44	ND	ND	0.06	7.7	ND	ND	2.4		22
	2	270	ND	10	ND	59	4.8	ND		ND	320	ND		43	ND	ND	1.10	7.7	ND	ND	4.4		19
Black Earth	D								298	0.84			7.80										
	1	310	ND	27	ND	59	0.9	ND		0.29	291	0.16		36	4	0.03	0.17	7.5	ND	ND	1.8		ND
	2	310	ND	20	ND	58	1.4	ND		0.29	285	0.08		36	2	0.03	0.41	7.6	ND	ND	2.1		ND
Blue Mounds	D								140	0.73			2.80				ND						
	1	296	3.1	39	0.17	80	58.4	ND		0.14	391	0.10		47	11	ND	1.72	7.7	ND	ND	27.5		447
	3	266	ND	18	0.20	59	2.7	ND	ND	0.15	295	0.40	ND	36	14	ND	ND	7.7	ND	0.10	2.5	21.0	2
Cambridge	D								172	0.65			3.30										
	2	310	2.0	24	ND	65	ND	ND		0.11	320	0.72		37	33	ND	ND	7.6	ND	ND	4.0		15
	3	320	3.1	62	ND	71	2.6	1.4		0.50	310	5.50		33	110	ND	ND	7.9	ND	ND	4.7		32
Cottage Grove	D								118	0.72			1.80										
	1		ND	15	ND			ND		0.16						ND	5.05		ND		7.9		
	2	345	ND	8	ND	69	1.5	ND	6	0.09	374	ND	ND	49	11	ND	ND	7.6	ND	ND	3.2	6.7	ND
	3	346	ND	7	ND	71	1.5	ND		0.10	377	ND		48	18	ND	ND	7.5	ND	0.10	3.6		ND
	4	341	ND	13	ND	77	1.4	ND		0.09	368	0.30		43	49	ND	ND	7.5	ND	ND	3.2		9
Cross Plains	D								30	0.81			ND										
	1	310	ND	34	ND	75	16.0	1.6		0.10	362	ND		42	ND	ND	5.20	7.5	ND	ND	6.6		4
	2	308	ND	35	ND	76	27.4	1.4		0.09	366	ND		43	ND	ND	4.60	7.5	ND	ND	13.0		ND
Dane	D								72				1.30										
	1	327	ND	56	ND	110	100.0	ND		ND	470	ND		52	ND	ND	8.19	7.4	ND	ND	54.0		26
	2	253	ND	14	ND	55	ND	ND		ND	260	ND		30	ND	ND	4.65	7.4	ND	ND	4.9		8
Deerfield	D	327				51			392	1.39			4.39										
	3	321	ND	7	ND	58	1.6	ND	340	0.11	336	0.10	13.50	52	9	ND	ND	7.6	ND	0.10	3.1		4
	4	327	ND	18	ND	48	ND	ND	ND	0.11	330	0.27	ND	46	12	ND	ND	7.5	ND	ND	3.4	8.8	
DeForest	D (N)								271	0.80			2.20										
	D (S)								1300				0.92										
	1	239	ND	84	ND	61	1.7	ND		0.12	272	ND		29	21	ND	ND	7.5	ND	ND	3.2		ND
	2	248	ND	12	ND	58	5.6	1.4		1.07	276	ND		32	ND	ND	0.46	7.5	ND	ND	5.5		2
	3	258	ND	17	ND	59	1.2	2.2		0.13	278	ND		32	ND	ND	ND	7.5	ND	0.10	3.2		ND
	4	284	ND	38	ND	80	37.4	ND		0.11	389	ND		46	ND	ND	3.36	7.6	ND	ND	9.6		ND
	5	280	ND	71	0.33	66	45.0	ND	ND	ND	303	0.14	ND	33	13	ND	1.80	7.4	ND	ND	19.5	30.0	

MCL = Maximum Contaminant Level (NR 809.11)
D = Distribution system sample.
ND = Not detected.
Source: Wisconsin Department of Natural Resources, Bureau of Drinking Water and Groundwater (2014).

Chemical Analyses for Public Water Supplies in Dane County

Municipality	Well #	Alkalinity ($CaCO_3$) (mg/l)	Arsenic (ug/l)	Barium (ug/l)	Cadmium (ug/l)	Calcium (mg/l)	Chloride (mg/l)	Chromium (ug/l)	Copper (ug/l)	Fluoride (mg/l)	Hardness ($CaCO_3$) (mg/l)	Iron (mg/l)	Lead (ug/l)	Magnesium (mg/l)	Manganese (ug/l)	Mercury (ug/l)	NO_3,NO_2 (as N.) (mg/l)	pH (SU)	Selenium (ug/l)	Silver (ug/l)	Sodium (mg/l)	Sulfate (mg/l)	Zinc (ug/l)
MCL			10	2000	5			100	1300	4			15			2	10		50				
Fitchburg	D (N)								70	0.80		ND	0.73										
	D (S)								74	0.72			1.70										
	4	280	ND	18	ND	57	2.2	ND		0.10	278	0.22		33	16	0.08	ND	7.4	2.30	ND	3.0	16.0	9
	5	280	ND	11	ND	59	2.9	ND		0.11	283	ND		33	4	ND	0.09	7.5	2.80	ND	2.8	14.0	1
	7	310	ND	22	ND	68	7.3	1.6		0.10	318	ND		36	ND	ND	2.50	7.3	3.20	ND	3.7		19
	8	300	ND	63	ND	73	12.0	1.0		0.10	339	ND		38	ND	ND	4.70	7.4	2.30	ND	4.9		3
	10	280	ND	17	ND	54	1.3	ND		0.10	267	0.98		32	25	ND	ND	7.4	2.20	ND	2.9	16.0	7
	11	260	ND	14	ND	54	2.4	ND		0.10	258	0.21		30	14	ND	ND	7.7	2.00	ND	2.3	17.0	ND
Madison	D		ND	55	ND	72		ND	90	0.75	329	0.40	1.01	36	179	ND			ND	ND	3.3		ND
	6	315	0.2	22	ND	81	30.7	2.2		0.83	383	0.01	ND	44	1	ND	3.21	7.5	1.03	ND	14.7	28.5	26
	7	314	0.5	38	ND	79	5.9	ND		0.71	387	0.35	ND	46	26	ND	ND	7.6	ND	ND	6.8	37.2	4
	8	300	0.8	33	ND	68	22.3	ND		0.93	334	0.61	ND	40	53	ND	ND	7.9	0.50	ND	9.3	16.5	27
	9	340	ND	26	ND	83	30.9	1.3		0.76	401	0.01	ND	47	1	ND	1.81	7.6	0.49	ND	14.8	16.7	27
	10		1.7	22	ND			0.4		1.32		0.60	ND		70000	ND	1.06		ND		2.7	11.8	
	11	336	ND	19	ND	83	45.2	1.3		0.84	421	0.02	ND	52	14	ND	2.98	7.5	0.63	ND	19.4	28.4	23
	12	283	ND	13	ND	62	2.6	0.9		0.83	295	ND	ND	34	0	ND	0.77	7.7	ND	ND	2.3	10.2	23
	13	304	ND	30	ND	66	8.5	1.1		0.88	334	0.05	ND	41	12	ND	1.89	7.7	0.42	ND	5.1	13.6	17
	14	343	0.2	53	ND	97	88.1	2.1		0.88	456	ND	ND	52	ND	ND	3.70	7.6	0.89	ND	35.9	24.3	ND
	15	290	ND	9	ND	85	44.6	1.0		0.88	380	0.01	ND	47	7	ND	2.20	7.6	0.65	ND	19.5	31.0	14
	16	291	ND	18	ND	70	34.3	1.4		0.78	344	0.00	ND	41	4	ND	2.83	7.6	0.49	ND	17.5	10.3	26
	17	285	0.3	26	ND	71	38.4	0.4		0.89	371	0.10	ND	47	31	ND	ND	7.7	ND	ND	19.3	55.6	27
	18	280	ND	15	ND	67	16.6	1.1		0.82	332	ND	ND	40	1	ND	1.19	7.7	ND	ND	6.7	16.8	18
	19	289	0.4	17	ND	63	5.9	0.5		0.77	297	0.19	ND	34	41	ND	ND	7.7	ND	ND	3.9	7.7	25
	20	275	ND	9	ND	56	2.3	9.4		0.72	280	ND	ND	34	1	ND	0.41	7.7	0.48	ND	2.1	7.5	24
	23	345	0.6	53	ND	96	62.6	1.4		0.97	454	0.07	ND	52	3	ND	3.56	7.6	0.94	ND	23.0	26.2	35
	24	275	0.2	13	ND	58	5.7	ND		0.82	293	0.18	ND	36	30	ND	ND	7.7	ND	ND	5.0	14.2	18
	25	327	ND	8	ND	64	2.9	0.9		0.81	345	0.09	ND	45	11	ND	0.65	7.6	0.56	ND	3.3	7.1	16
	26	292	ND	17	ND	66	15.3	0.7		0.75	313	0.03	ND	36	4	ND	1.31	7.8	ND	ND	5.4	12.8	38
	27	325	0.3	26	ND	92	64.5	0.5		0.88	436	0.10	ND	50	44	ND	0.36	7.5	ND	ND	16.1	39.7	21
	28	286	0.2	15	ND	63	2.6	ND		0.44	301	0.19	ND	35	24	ND	ND	7.5	ND	ND	2.4	20.0	23
	29	335	ND	52	ND	71	2.9	0.5	ND	0.87	321	0.14	ND	35	74	ND	0.83	7.6	ND	ND	3.1	7.3	6
	30	273	0.2	17	ND	58	4.4	ND	ND	0.82	289	0.20	ND	35	14	ND	ND	7.7	ND	ND	3.8	18.5	20
	31	342	ND	24	ND	63	2.5	ND	ND	ND	348	0.24	0.50	46	10600	ND	ND	7.6	ND	ND	3.4	9.2	31200

MCL = Maximum Contaminant Level (NR 809.11)
D = Distribution system sample.
ND = Not detected.
Source: Wisconsin Department of Natural Resources, Bureau of Drinking Water and Groundwater (2014).

Chemical Analyses for Public Water Supplies in Dane County

Municipality	Well #	Alkalinity ($CaCO_3$) (mg/l)	Arsenic (ug/l)	Barium (ug/l)	Cadmium (ug/l)	Calcium (mg/l)	Chloride (mg/l)	Chromium (ug/l)	Copper (ug/l)	Fluoride (mg/l)	Hardness ($CaC0_3$) (mg/l)	Iron (mg/l)	Lead (ug/l)	Magnesium (mg/l)	Manganese (ug/l)	Mercury (ug/l)	$N0_3N0_2$ (as N.) (mg/l)	pH (SU)	Selenium (ug/l)	Silver (ug/l)	Sodium (mg/l)	Sulfate (mg/l)	Zinc (ug/l)
MCL			10	2000	5			100	1300	4			15			2	10		50				
Marshall	D								1030	0.69			2.40										
	1	283	ND	4	ND	55	1.2	ND		0.09	285	0.10		36	85	ND	ND	7.7	ND	ND	3.1		3
	2	272	ND	54	ND	55	2.9	ND		1.84	277	0.10		34	190	ND	ND	7.6	ND	ND	4.2		8
	3	310	1.2	86	ND	57	ND	ND	4	0.11	300	0.09	0.14	39	50	ND	ND	7.3	ND	ND	2.5	11.0	
Mazomanie	D								308	0.72			3.85										
	2	275	ND	37	ND	62	2.8	ND		ND	300	0.42		34	18	0.20	ND	7.0	0.20	ND	2.4		19
	3	275	0.6	37	ND	72	67.3	ND		ND	331	0.34		36	51	0.20	1.55	7.0	0.40	ND	30.4		5
McFarland	D								1460	0.69			8.90										
	1	319	ND	12	ND	78	22.2	ND		0.13	373	ND		44	ND	ND	2.68	7.4	ND	ND	8.3		55
	3	325	ND	7	ND	63	2.1	ND		0.14	348	ND		46	7	ND	0.64	7.5	ND	ND	2.7		9
	4	319	ND	24	ND	80	14.9	ND		0.13	379	ND		43	3	ND	3.53	7.5	ND	ND	6.3		5
Middleton	D								200	0.88			11.00										
	2		ND																				
	3		ND																				
	4	293	1.4	70	ND	67	1.4	ND		0.13	313	ND		35	42	ND	0.17	7.6	ND	ND	3.5	2.7	ND
	5	290	ND	31	ND	68	4.2	ND		0.07	313	ND		35	34	ND	0.10	7.7	ND	ND	3.6	16.0	ND
	6	278	ND	20	ND	72	22.0	1.2		0.77	343	ND		40	1	ND	3.50	7.6	ND	ND	18.0	14.0	10
	8	380	ND	4	ND	59	ND	ND	6	0.77	320	0.04	0.49	41	58	ND	ND	7.5	ND	0.11	2.8	7.4	
Monona	D								152	0.81			6.90										
	1	344	ND	55	ND	105	117.0	1.7		0.11	477	ND		52	ND	ND	4.16	7.3	ND	ND	45.0		1
	2	359	ND	50	ND	101	89.6	1.5		0.11	474	ND		54	ND	ND	2.19	7.3	ND	ND	30.2		ND
	3	289	ND	11	ND	60	2.9	ND		0.10	303	0.30		37	25	ND	ND	7.6	ND	ND	3.7		ND
Morrisonville	D								229	0.80			11.60										
	1	305	ND	108	0.42	99	94.4	ND		0.05	456	0.80		50	2110	ND	9.13	7.4	ND	ND	27.2		36
	2	238	ND	4	ND	58	3.4	2.1		0.11	275	ND		32	ND	ND	3.09	7.9	ND	ND	3.1		2
Mount Horeb	D	311				69			1160	0.59			24.60										
	3	313	ND	22	ND	70	41.1	ND	ND	0.41	375	ND	ND	45	2	ND	2.29	7.5	ND	ND	27.3		9
	4	293	ND	25	ND	69	48.5	ND	ND	0.79	376	ND	ND	44	4	ND	3.08	7.6	ND	ND	23.5		752
	5	288	ND	5	ND	61	1.3	ND	2	0.59	317	ND	ND	39	8	ND	ND	7.6	ND	0.10	2.6		ND
	6	264	ND	24	ND	53	3.4	ND	45	0.64	276	0.20	ND	34	14	ND	ND	7.8	ND	ND	3.6	13.0	1470
Oregon	D								182	0.75			53.40										
	3	275	ND	13	ND	64	3.4	1.4		0.82	298	ND		34	ND	ND	1.83	7.7	ND	ND	2.8		ND
	4	274	ND	25	ND	67	8.9	1.4		0.97	315	ND		36	ND	ND	3.47	7.8	ND	ND	4.0		ND
	5	277	ND	16	ND	62	3.6	1.8		0.10	295	ND		34	ND	ND	2.06	7.7	ND	ND	3.0		2

MCL = Maximum Contaminant Level (NR 809.11)
D = Distribution system sample.
ND = Not detected.
Source: Wisconsin Department of Natural Resources, Bureau of Drinking Water and Groundwater (2014).

Chemical Analyses for Public Water Supplies in Dane County

Municipality	Well #	Alkalinity ($CaCO_3$) (mg/l)	Arsenic (ug/l)	Barium (ug/l)	Cadmium (ug/l)	Calcium (mg/l)	Chloride (mg/l)	Chromium (ug/l)	Copper (ug/l)	Fluoride (mg/l)	Hardness ($CaC0_3$) (mg/l)	Iron (mg/l)	Lead (ug/l)	Magnesium (mg/l)	Manganese (ug/l)	Mercury (ug/l)	$N0_3$,$N0_2$ (as N.) (mg/l)	pH (SU)	Selenium (ug/l)	Silver (ug/l)	Sodium (mg/l)	Sulfate (mg/l)	Zinc (ug/l)
MCL			10	2000	5			100	1300	4			15			2	10		50				
Stoughton	D								150	0.80			2.50										
	4	320	ND	41	ND	80	37.0	0.9		0.13	360	ND		40	ND	ND	5.00	7.7	ND	ND	15.0	22.0	4
	5	280	ND	20	ND	52	2.6	ND		0.60	270	0.19		34	13	ND	0.08	8.0	ND	ND	2.8	15.0	4
	6	320	ND	32	ND	62	2.6	ND		0.08	320	0.28		40	14	ND	0.03	7.9	ND	ND	3.0	14.0	12
	7	270	0.7	21	ND	56	3.6	ND		2.70	270	0.28		32	16	ND	ND	8.0	ND	ND	9.0	13.0	2
Sun Prairie	D								41	0.69			5.60										
	3	290	ND	16	ND	65	13.0	ND		0.68	310	ND		35	ND	ND	3.80	7.9	ND	ND	6.7	14.0	4
	4	310	ND	33	ND	80	65.0	0.2	ND	0.16	380	ND	0.10	44	ND	ND	5.60	7.3	ND	ND	22.0	24.0	3
	5	310	ND	27	ND	67	10.0	ND		0.10	320	ND		37	ND	ND	4.00	8.0	ND	ND	8.7	13.0	4
	6	300	ND	19	ND	64	9.3	0.4		0.10	310	ND		36	ND	ND	3.30	8.0	ND	ND	5.6	12.0	2
	7	320	ND	12	ND	65	8.1	ND		0.09	320	ND		39	3	ND	2.60	7.5	ND	ND	4.1	8.4	4
	8	280	ND	12	ND	56	6.6	ND	ND	0.10	270	ND	ND	33	ND	ND	0.08	7.9	ND	ND	3.0	5.8	4
	9	300	ND	21	ND	65	5.1	ND	20	0.11	316	0.01	1.00	34	ND	ND	1.90	7.4	ND	ND	5.2	8.8	16
Verona	D								188	0.76			4.50										
	1	307	ND	47	ND	81	42.0	1.7		0.12	379	ND		43	ND	ND	5.29	7.5	ND	ND	12.8		ND
	2	294	ND	15	ND	61	9.4	ND		0.09	320	ND		41	5	ND	5.91	7.8	ND	ND	5.5		ND
	3	316	ND	44	ND	79	29.2	1.4		0.10	375	ND		44	ND	ND	6.49	7.5	ND	ND	19.1		1
	4	287	ND	41	ND	74	39.2	2.0		0.10	345	ND		39	ND	ND	4.18	7.6	ND	ND	10.7		ND
	5																0.35						
Waunakee	D								134	0.83			0.90										
	1	260	ND	11	ND	54	3.9	1.7		0.09	260	ND		31	ND	ND	3.00	7.9	ND	0.11	3.4	6.3	ND
	2	280	0.9	23	ND	63	14.0	0.8		0.20	300	ND		36	18	ND	3.90	8.0	2.50	ND	8.1	10.0	3
	3	270	ND	7	ND	54	2.5	1.5		0.10	260	ND		31	ND	ND	1.40	8.0	ND	ND	2.9	5.7	ND
	4	240	ND	8	ND	51	ND	1.0		0.07	240	ND		28	ND	ND	0.60	8.1	ND	ND	2.1	ND	3
	5	130	ND	9	ND	51	ND	1.7	ND	0.07	250	ND	0.64	29	ND	ND	0.19	7.6	ND	0.45	2.6	ND	
Westport	D								275	0.90			1.80										
	1	252	ND	7	ND	52	1.3	2.1		0.19	254	ND		30	ND	ND	ND	7.7	ND	ND	2.9		ND
	2	259	ND	11	ND	55	1.6	1.6		0.07	270	0.50		32	8	ND	ND	7.6	ND	ND	3.0		3
Windsor	D								150	0.80			3.50										
	1	270	ND	24	ND	63	7.6	0.7		1.10	290	0.03		32	3	ND	1.80	8.1	ND	ND	4.7		3
	2	260	ND	140	ND	60	ND	ND		0.13	280	0.07		30	6	ND	0.05	8.1	ND	ND	3.5		3

MCL = Maximum Contaminant Level (NR 809.11)
D = Distribution system sample.
ND = Not detected.
Source: Wisconsin Department of Natural Resources, Bureau of Drinking Water and Groundwater (2014).

Attachment B

Description of Factors Used to Determine Groundwater Contamination Risk

The conceptual model for the groundwater contamination risk maps is based on two premises. First, it is assumed that the sediments in the unsaturated zone have the potential to attenuate contaminants. The thickness of these sediments is an important factor in determining the susceptibility of the aquifer to contamination. Secondly, it is assumed that position of an area in the groundwater flow system is equally important in determining the contamination risk.

There are three factors that were used to determine the groundwater contamination risk. The first factor evaluates the soil's ability to attenuate contaminants. The second factor, the hydrogeologic setting, combines attributes of the topography, hydrogeology, and geology. The groundwater flow system, the third factor, is the distribution of recharge and non-recharge areas. These three factors were represented as three GIS data layers. It is the combination of the soil, the hydrogeologic setting and the groundwater flow system factors that determine the risk of groundwater contamination.

Attenuation Potential of the Soil

Soil properties are important in determining whether a contaminant breaks down quickly, is complexed with soil particles, or if it leaches into the groundwater. Because most attenuation and degradation of contaminants occurs in the soil, there is a greater potential for groundwater contamination to occur in areas where soil is thin or permeable. Water and contaminants can move quickly through sandy soils due to the large pore spaces between particles. Sand particles also provide little surface area for sorption of contaminants.

Clay soils have smaller pore sizes and proportionally more mineral surface area and therefore can attenuate contaminates more readily. As the clay content increases, the water-holding capacity and exchange capacity increase. Thus, if a layer containing a large amount of clay exists in the subsurface, it will act as a retarding layer to the vertical flux of contaminants. While held in the soil, contaminants can be degraded by soil bacteria or other microorganisms in the soil. Organic matter generally has exchange properties and proportionally more surface area which make it ideal for adsorption of contaminants. Thus, soil high in organic matter provides an environment for chemical and biological degradation of contaminants.

The soil properties used in the method are listed in Table B–1. Properties for each soil map unit in Dane County were rated from 1 to 10. The ratings for the soil properties within a soil map unit were then added, resulting in a total score.

Table B–1
Ranking System for Evaluating the Attenuation Potential of Soils in Dane County
(from Bridson & Others, 1994)

Physical/Chemical Characteristics	Classes	Weighted Values
Texture of Surface (A or O) Horizon[1]	l, sil, scl, si	9
	c, sic, cl, sicl, sc	8
	lvfs, vfsl, lfs, fsl	4
	s, ls, sl, organic materials, and all textural classes with coarse fragment class modifiers	1
Texture of Subsoil (B) Horizon[1]	c, sic, sc, sl	10
	scl, l, sil, cl, sicl	7
	lvfs, vfsl, lfs, fsl	4
	s, fs, ls, sl, o	1
Organic Matter Content[2] of Surface Horizon	Mollisol	8
	Alfisol (Mollisol, eroded)	5
	Inceptisol, Entisol, Spodosol (Alfisol, eroded)	3
	Inceptisol, Entisol, Spodosol (eroded)	1
	Histosols; Aquic suborder; and Lithic, Aquollic, and Aquic subgroups	1
pH of Surface (A or O) Horizon	≥ 6.6	6
	< 6.6	4
Depth of Soil Solum (O, A + B horizons)	≥ 60	10
	40–59	8
	30–39	5
	<30	1
Permeability of Subsoil Horizon[3]	moderately low, low to very low	10
	moderate	8
	moderate/high	5
	high	3
	very high	1
Soil Drainage	well-drained	10
	well- to moderately well-drained	7
	moderately well-drained	4
	somewhat poorly, poorly, and very poorly drained; and excessively well-drained	1

[1]Soil textural classes: 1 = loam, sil = silt loam, scl = sandy clay loam, si = silt, c = clay, sic = silty clay, cl = clay loam, sicl = silty clay loam, sc = sandy clay, lvfs = loamy very fine sand, vfsl = very fine sandy loam, lfs = loamy fine sand, fsl = fine sandy loam, fs = fine sand, s = sand, ls = loamy sand, sl = sandy loam, o = organic material.

[2]Based on the ordinal level of the soil classification system; soils are penalized if they are wet or less than 20 inches thick over bedrock.

[3]Based on the particle-size class at the family level of the soil classification system, type and grade of structure, and consistence. Use 3 if bedrock is found at 20-40 inches, or 1 if bedrock is <20 inches.

Based on the total score, soil map units were divided into three categories: good, fair, and poor potential to attenuate contaminants (Table B–2). Soils in the "good" category have properties that contribute to attenuation. Soils in the "poor" category have little potential to attenuate potential contaminants. The numeric categories (1, 2, or 3) shown in Table B–2 were used to identify the attenuation potential of the soil in the final risk classification and included in the first digit of the 3-digit subclass code (Table B–4). Contaminant attenuation of Dane County soils is listed in Table B–3.

Table B–2
Total Scores and Category Number of a Soil's Potential to Attenuate Contaminants

Soil's Potential to Attenuate Contaminants	Total Score	Category
Good	≥45	3
Fair	≥35 and <44	2
Poor	<34	1

Hydrogeologic Setting

Groundwater contamination risk also depends on the hydrogeologic setting and the groundwater flow system. The second data layer, the hydrogeologic setting, evaluates the contamination risk based on the thickness of materials below the soil but above the water table as well as presence (or absence) of an unlithified aquifer. The soil information described above is accurate to approximately five feet below the ground surface. However, the unsaturated zone extends greater than five feet below the ground surface in more than 75% of Dane County. Consequently, an evaluation of the remaining materials in the unsaturated zone had to be developed. The hydrogeologic setting data layer was a combination of the depth to bedrock (or thickness of unlithified materials), depth to the water table and presence of an unlithified aquifer.

The hydrogeologic setting categories were based on the thickness of the unsaturated zone and presence of an unlithified aquifer. Hydrogeologic settings that met the qualifications for category 1 are areas where bedrock is within five feet of the surface, or if an unlithified aquifer is present and the water table is within ten feet of the surface. If bedrock is at or very near the surface there is a possible direct connection between the surface and the underlying aquifer. If bedrock is near the surface, there is also little or no soil layer in which natural degradation of contaminants can occur.

Hydrogeologic settings that did not meet the qualifications for category 1 were then considered for inclusion in category 2, the next most restrictive category. The process continued for categories 3 and 4. Category 4, the least restrictive category, included those settings that were not included in categories 1, 2 or 3. If the water table surface or bedrock surface is greater than 50 feet below the ground surface, travel time is longer and the potential for attenuation and biodegradation is increased. As a result, the potential for groundwater contamination is decreased. The category numbers (1 through 4) used in the hydrogeologic setting data layer were used to identify the hydrogeologic setting in the final risk classification and included as the second digit of the subclass code (Table B–4).

Table B–3
Contaminant Attenuation Potential of Dane County Soils

Poor Attenuation (<34 points)	Fair Attenuation (≥35 and <44)	Good Attenuation (≥45)
Adrian	Basco	Ashdale
Alluvial land	Chaseburg	Batavia
Boyer	Colwood	Del Ray
Brems	Derinda	Dodge
Cut and fill land	Dodgeville (12–20% slopes)	Dodgeville (2–12% slopes)
Dells	Dresden (6–30% slopes)	Dresden (2–6% slopes)
Dickenson	Dunbarton	Gale (2–6% slopes)
Dickenson (sandy variant)	Edmund	Grays (0–6% slopes)
Eleva	Elburn	Griswold
Elkmound	Elvers	Huntsville
Granby	Gale	Kegonsa
Gravel pit	Grays (6–12% slopes)	Kidder
Hayfield	Hixton	McHenry (2–6% slopes)
Houghton	Kickapoo	Meridian
Made land	McHenry (6–20% slopes)	New Glarus
Marsh	Military	Pecatonica
Marshan	Montgomery	Plano
Palms	Orion	Port Byron
Plainfield	Otter	Radford
Quarry	Rockton (6–30% slopes)	Ringwood
Rodman	Sable	Rockton (2–6% slopes)
Salter (2–12% slopes)	Salter	St. Charles
Salter (wet variant)	Seaton	Seaton
Sogn	Virgil	Troxel
Spinks	Whalan	Warsaw
Stony and rocky land		Westville
Wacousta		
Watseka		

Groundwater Flow System

Based on the results of Bridson and others (1994), a map depicting groundwater contamination risk would potentially be more accurate if the groundwater flow system were incorporated into the methodology. Percolating water has a much greater potential of reaching the water table in shallow water table areas, which are often discharge areas, than in deeper water table areas, which are often recharge areas. Discharge areas, though, have upward hydraulic gradients that would impede the downward migration of contaminants. Contaminants would then be contained near the water table and eventually could enter surface water. Recharge areas are more problematic because the contaminant would enter the water table and move within the groundwater flow system.

The groundwater recharge distribution in the county was estimated by Swanson (1996) using a modular three-dimensional finite difference groundwater flow model, known as MODFLOW (McDonald & Harbaugh, 1988).

The groundwater flow system data layer had two attribute categories: recharge and non-recharge. Category numbers (0 and 1, respectively) were used for identification purposes in the final risk classification and include as the third digit of the subclass code (Table B–4).

Final Groundwater Contamination Risk Classification for Surface and Subsurface Maps

The three-digit subclass code was used to arrive at a final risk classification for the Surface and Subsurface Groundwater Contamination Risk Maps. Table B–4 represents a summary of possible risk classifications, with the subclass representing numerical expressions of data layers 1, 2, and 3 combined to arrive at a final risk classification code. By assuming a poor soil attenuation layer (category 1), a Subsurface Contamination Risk Map was similarly developed. This results in shifting some areas with either fair or good soils to the next lower risk classification, taking into account the importance of soil attenuation for reducing pollutants. Removing the soil layer changes the first subclass digit to one, resulting in a modified subclass as well as its associated final risk classification.

Extreme

An area is considered to be of extreme groundwater contamination risk if the aquifer materials (unlithified sediments or bedrock) are close to the land surface irrespective of position in the groundwater flow system and attenuation potential of the soil.

Areas in Dane County that are rated by extreme risk of groundwater contamination are located, for example, in the Driftless Area. Another example of areas that are considered to present extreme groundwater contamination risk are the northeast to southwest trending pre-glacial valleys in the eastern part of the county. The saturated sediments in the valleys are considered to be an unconfined unlithified surficial aquifer. The water table is close to the surface and the soil is poorly drained muck. These valleys are considered areas of extreme contamination risk. The Wisconsin River Valley is also considered to be of extreme risk. The soils in the Wisconsin River Valley are sandy and excessively to moderately well-drained, resulting in a low attenuation potential. These examples are not an exhaustive description; rather, they demonstrate the main characteristics of areas considered to be of extreme groundwater contamination risk

High

The influence of the attenuation potential of the soil and the thickness of the unsaturated zone is evident in areas that are considered to be of high contamination risk. The combination of the proximity of the aquifer materials to the land surface (bedrock or the water table within 25 feet of the land surface) and the poor attenuation potential of the soil result in a high risk classification, even if an area is considered to be in a non-recharge zone.

Areas that are considered high groundwater contamination risk are located throughout Dane County, either in low-lying areas of the Yahara River Basin, along the moderate to steep slopes in the Driftless Area, or in the glaciated region of Dane County. A large area of former Glacial Lake Middleton in northern Middleton township, for example, is also considered to have a high contamination risk because the soils have a poor attenuation potential and the majority of the area is in a recharge zone.

Moderate

Areas considered as moderate contamination risk are located in either recharge or non-recharge areas, depending on the attenuation potential of the soil and the thickness of the unsaturated zone. Bedrock or water table depths range from 5 feet below the land surface to greater than 50 feet below land surface in non-recharge areas. In recharge areas, a greater thickness of unsaturated materials and soils that have a good or fair attenuation potential are necessary for an area to be considered as moderate risk.

Deep, well-drained silt loam soil on gently sloping land or low hills are some of the areas that are considered as moderate contamination risk. In the hummocky moraine zone in Middleton township or drumlinized ground moraine in Cottage Grove township, the depth to bedrock or depth to the water table may be greater than 25 feet. In Middleton township, the depth to bedrock or depth to water table is sometimes greater than 50 feet. Stream valleys in the Driftless Area are considered discharge areas and commonly have deep, poorly drained silt loam soils and are considered, in some places, to be of moderate risk. Portions of Pleasant Valley, Syftestad Creek Valley and Kittleson Valley in southern Perry township, for example, are moderate contamination risk. The model depth to bedrock in these valleys is typically greater than five feet, although there are areas where it is closer to the surface.

Low

Only non-recharge areas are considered to have a low groundwater contamination risk relative to other regions in Dane County. Areas have a low risk classification because the attenuation potential of the soil is considered to be fair or good. These soils have physical and chemical characteristics that would be beneficial for attenuation of contaminants. The depth to the bedrock and depth to water table ranges from 25 feet to greater than 50 feet below the land surface.

Low risk areas are located on the hummocky moraine zone, or in places where there are thick accumulations of silt or clay, such as in the Yahara River basin. Although the potential for groundwater contamination is considered to be low in these areas relative to other areas of Dane County, if groundwater contamination were to occur, the low contamination risk areas would be the most difficult to remediate.

Table B–4
Summary of Possible Groundwater Contamination Risk Classifications

Subclass	Attenuation Potential of Soil (Data Layer 1)	Hydrogeologic setting (Data Layer 2)*	Groundwater Flow System (Data Layer 3)*	Final Risk Classification
110	Poor	dol or ss <= 5 ft or WT <= 10 ft in unconfined unlithified aquifer	Recharge	Extreme
111	Poor	dol or ss <= 5 ft or WT <= 10 ft in unconfined unlithified aquifer	Non-recharge	Extreme
120	Poor	dol or ss 5-25 ft or WT 10-25 ft in unconfined unlithified aquifer	Recharge	Extreme
210	Fair	dol or ss <= 5 ft or WT <= 10 ft in unconfined unlithified aquifer	Recharge	Extreme
211	Fair	dol or ss <= 5 ft or WT <= 10 ft in unconfined unlithified aquifer	Non-recharge	Extreme
220	Fair	dol or ss 5-25 ft or WT 10-25 ft in unconfined unlithified aquifer	Recharge	Extreme
310	Good	dol or ss <= 5 ft or WT <= 10 ft in unconfined unlithified aquifer	Recharge	Extreme
311	Good	dol or ss <= 5 ft or WT <= 10 ft in unconfined unlithified aquifer	Non-recharge	Extreme
121	Poor	dol or ss 5-25 ft or WT 10-25 ft in unconfined unlithified aquifer	Non-recharge	High
130	Poor	dol or ss 25-50 ft or WT 25-50 ft in any unlithified aquifer	Recharge	High
140	Poor	dol or ss > 50 ft or WT > 50 ft	Recharge	High
230	Fair	dol or ss 25-50 ft or WT 25-50 ft in any unlithified aquifer	Recharge	High
320	Good	dol or ss 5-25 ft or WT 10-25 ft in unconfined unlithified aquifer	Recharge	High
131	Poor	dol or ss 25-50 ft or WT 25-50 ft in any unlithified aquifer	Non-recharge	Moderate
141	Poor	dol or ss > 50 ft or WT > 50 ft	Non-recharge	Moderate
221	Fair	dol or ss 5-25 ft or WT 10-25 ft in unconfined unlithified aquifer	Non-recharge	Moderate
231	Fair	dol or ss 25-50 ft or WT 25-50 ft in any unlithified aquifer	Non-recharge	Moderate
240	Fair	dol or ss > 50 ft or WT > 50 ft	Recharge	Moderate
321	Good	dol or ss 5-25 ft or WT 10-25 ft in unconfined unlithified aquifer	Non-recharge	Moderate
330	Good	dol or ss 25-50 ft or WT 25-50 ft in any unlithified aquifer	Recharge	Moderate
340	Good	dol or ss > 50 ft or WT > 50 ft	Recharge	Moderate
241	Fair	dol or ss > 50 ft or WT > 50 ft	Non-recharge	Low
331	Good	dol or ss 25-50 ft or WT 25-50 ft in any unlithified aquifer	Non-recharge	Low
341	Good	dol or ss > 50 ft or WT > 50 ft	Non-recharge	Low

*dol = dolomite, ss = sandstone, WT = water table.

Attachment C

Solid Waste Disposal Sites in Dane County

Map No.	Site Name	PLSS	Township	Years of Operation	Type of Waste[1]	DNR Assessment Date	Source of Information[2]
1	AUGUST SHEMANEK	S S22 09N 06E	Mazomanie	?	U	1/24/2001	Post-Reg.
2	PRAIRIE DU SAC VIL	NW SE S13 09N 06E	Mazomanie	?	?	6/5/2008	Public
3	ROXBURY TN	NW SW S16 09N 07E	Roxbury	pre-1970-1991	T,G,M	4/14/2004	113114870
4	DANE TN LF	NE S04 09N 08E	Dane	1965-1969	U	1/29/2004	Pre-Reg.
5	DANE TN	NW SE S35 09N 08E	Dane	1970-1992	G	11/22/2000	113113660
6	DANE VIL OLD LF	SE SW S13 09N 08E	Dane	1958-1974	W,T,G	10/13/2005	DCRPC Solid Waste Plan
7	DANE VIL	SE NW S24 09N 08E	Dane	? - 1990	W,T,G	12/13/2000	113117180
8	VIENNA TN	NW NW S23 09N 09E	Vienna	1970-1986	D,W,T,G	3/11/2004	113115530
9	DEFOREST VIL	SW SW S01 09N 09E	Vienna	1971-1991	W,T,G	6/9/2004	113117510
10	DEFOREST VIL	S18 09N 10E	Windsor	?	?	11/23/2005	Post-Reg.
11	WINDSOR TN	SW SW S08 09N 10E	Windsor	1971-1972	W,T,G	11/23/2005	DCRPC Solid Waste Plan
12	DEFOREST VIL	NW NW S17 09N 10E	Windsor	?-1971	W,T,G	11/23/2005	DCRPC Solid Waste Plan
13	WINDSOR TN	SW NE S16 09N 10E	Windsor	1972-1991	W,T,G	3/11/2004	113115750
14	BRISTOL TN	NE SW S05 09N 11E	Bristol	1968-1991	T,G	6/1/2000	113113110
15	ECKEL SANITARY SERVICE 69-70	NE S34 09N 11E	Bristol	1969-1970	T,G	3/10/2011	Pre-Reg.
16	YORK TN	NW SW S14 09N 12E	York	pre-1969-1990	W,T,G	4/20/2004	113115860
17	MAZOMANIE TN LF	SE SE S06 08N 06E	Mazomanie	1949-1971	W,T,G	3/22/2004	113343450
18	MAZOMANIE VIL	SE NE S18 08N 06E	Mazomanie	?	W	10/14/2005	Post-Reg.
19	WICK BLD SYSTEMS (DEMO)	NE NE S17 08N 06E	Mazomanie	1967-1973	W, D	8/9/2005	113186700
20	MAZO LAND DISPOSAL	SE SE S03 08N 06E	Mazomanie	1971-1983	H,D,W,T,G	8/14/2000	113111130
21	BLACK EARTH VIL	NE SE S26 08N 06E	Black Earth	?	?	11/23/2005	Pre-Reg.
22	BERRY TN	SE SE S22 08N 07E	Berry	1971-1992	W,T,G	6/28/2000	113113000
23	CROSS PLAINS VIL	NE SW S26 08N 07E	Berry	1968-1990	D,W,T,G	6/28/2000	113116960
24	CROSS PLAINS VIL	SE SE 26 S26 08N 07E	Berry	1956-1968	W,T		Pre-Reg. DCRPC
25	BERRY TN	SW SW S25 08N 07E	Berry	?-1971	D,W,T,G	10/13/2005	Temp. 285
26	GEORGE PULVERMACHER	NW SE S07 08N 08E	Springfield	?	U	3/23/2004	Post-Reg.
27	JEROME DEDRICH	SE NW S04 08N 08E	Springfield	?-1972	T	10/21/2005	113110360
28	FRED DUHR	SW NE S04 08N 08E	Springfield	1969-1973	U	9/8/2005	DNR Madison Area Files
29	SPRINGFIELD TN	SW NW S02 08N 08E	Springfield	1972-1988	T	6/22/2005	113115200
30	SPRINGFIELD TN	SW SW S35 08N 08E	Springfield	?-1972	T,G	6/15/2005	DCRPC Solid Waste Plan
31	WAUNAKEE VIL	NE S12 08N 08E	Springfield	?-1953	U		Pre-Reg. DCRPC
32	WAUNAKEE CTY 1950'S	NE S05 08N 09E	Westport	1950s	U	6/18/2008	Pre-Reg.
33	SCIENTIFIC PROTEIN LAB	NW NW S04 08N 09E	Westport	1976-1977	U	3/14/2004	DNR Madison Area Files
34	DANE COUNTY (PROPOSED) WESTPORT LF #3	S02 08N 09E	Westport			11/14/2005	113175590
35	WESTPORT TN	SE SE S10 08N 09E	Westport	1966-1987	D,W,T,G	8/24/2000	113115640
36	HAROLD ZEIGLER	SW NE S22 08N 09E	Westport	1976	D	4/11/2006	Post-Reg.
37	METROPOLITAN REFUSE DIST, INC	W1/2 S30 08N 09E	Westport	1961-	W,T,G	11/30/2005	113111240
38	HERBRAND SAND & GRAVEL	SW NE S31 08N 09E	Westport	1972-1978	H,W	9/10/2004	113109810
39	U W MADISON BURNING PIT	NE NE S31 08N 09E	Westport	1972-1981	H	6/23/2005	Post-Reg.
40	WESTPORT SAND & GRAV (DEMO)	NW SW S29 08N 09E	Westport	?	D	8/26/2010	Post-Reg.

Solid Waste Disposal Sites in Dane County							
Map No.	Site Name	PLSS	Township	Years of Operation	Type of Waste[1]	DNR Assessment Date	Source of Information[2]
41	RAMESH PIT (DEMO)	W1/2 NW S29 08N 09E	Westport	?	D		Post-Reg. Dane Co.Files
42	UNNAMED SITE	NE S32 08N 09E	Westport	?	?		Gr.Mad. Board Realtrs
43	WESTPORT TN	SW SW S28 08N 09E	Westport	1960s	T,G		Pre-Reg. DCRPC
44	WESTPORT TN 1940'S	SE S28 08N 09E	Westport	1940s	T,G	7/24/2007	Pre-Reg.
45	MENDOTA STATE HOSPITAL	NE S32 08N 09E	Westport	?	U	10/8/2004	113023570
46	MADISON CTY - LAKEVIEW SAN	NE SW S25 08N 09E	Westport	1920-1960?	U	5/26/2005	Pre-Reg.
47	MAPLE BLUFF VIL	SW SE S18 08N 10E	Burke	1954-1993	W	6/28/2005	113117730
48	FINDORFF DEMO LF	NE S19 08N 10E	Burke	?	D,W	11/16/2004	113339380
49	DANE CNTY TRUAX FIELD (FMLY CTY MAD)	NE S31 08N 10E	Burke	1948-1972	W,T,G,H	4/21/2004	113183620
50	C. MADISON-OSCAR MAYER RDF RECEIVING FACILITY	SE SW S31 08N 10E	Burke	1977-	T		DNR 2872?
51	MADISON CRUSHING & EXCAVATION	SE SW S33 08N 10E	Burke	pre-1972	D	6/28/2005	113110580
52	GILOMEN TRUCK & EQUIPMENT	SW SE S33 08N 10E	Burke	?	D,T	2/3/2004	Post-Reg.
53	MADISON CTY - SYCAMORE SITE	NW SW S34 08N 10E	Burke	1972-1977	D,W,T,G	7/6/2004	113108710
54	H SAMUELS-MIDWEST STEEL	SE NE S33 08N 10E	Burke	?	Auto shredder	4/13/2006	113111460
55	MADISON CTY - SYCAMORE BRUSH	SW NW S34 08N 10E	Burke	1963-1975	W	9/8/2004	113108600
56	RUSS DARROW INC	SW SE S28 08N 10E	Burke	1976-1977	F	8/1/2005	113112450
57	RTRV PARTNERSHIP LANDFILL	SE S28 08N 10E	Burke	1977-1992	F	5/9/2001	113112340
58	MRS LEONA GERKE	SE SE S27 08N 10E	Burke	?	D	6/28/2005	113111680
59	BURKE TN	NE SE S23 08N 10E	Burke	1975-1991	D,W,T,G	5/4/2000	113113220
60	OTTO ZERWICK	NW NE S21 08N 10E	Burke	?	?	4/10/2006	Post-Reg.
61	MADISON PRAIRIE LF - BFI	NW NE S23 08N 10E	Burke	1981-	D, W, T, G, F	11/15/2005	113195280
62	MADISON PRAIRIE DEMOLITION LF	NE NE S23 08N 10E	NEW	1981-2001	Demo	11/15/2005	113110910
63	J P WEST (EARLY 1950'S)	SW S18 08N 11E	Sun Prairie	Early 1950s	Organic wastes	5/22/2008	Pre-Reg.
64	HERBERT HELLENBRAND	SE SE S07 08N 11E	Sun Prairie	?	D	6/13/2006	113109700
65	MARVIN STARKS	SE SE S07 08N 11E	Sun Prairie	?-1975	D	7/10/2006	113111020
66	SUN PRAIRIE CTY - BIRD ST SITE	SW SW S08 08N 11E	Sun Prairie	?-1992	D,W	8/18/2010	133006390
67	SUN PRAIRIE CTY	SW NE S08 08N 11E	Sun Prairie	1971-1974	W	4/22/2004	133006060
68	SUN PRAIRIE CTY - ANGEL PK	NE S08 08N 11E	Sun Prairie	?	U	4/22/2004	Post-Reg.
69	C. SUN PRAIRIE-TRANSFER RECEIVING FACILITY	SW SE S05 08N 11E	Sun Prairie	1980-	W,T,G		DNR 2823?
70	WISCONSIN CHEESEMAN INCINERATOR	SW S06 08N 11E	Sun Prairie	1972-	T		DNR 1856?
71	DON SIMON REALTORS	NW NW S06 08N 11E	Sun Prairie	?	U	3/17/2004	Post-Reg.
72	SUN PRAIRIE TN	SW NE S13 08N 11E	Sun Prairie	1970-1990	W,T,G	3/11/2004	113115310
73	PHILLIP FREIDEL	NE SE S10 08N 12E	Medina	?	?	11/8/2004	Post-Reg.
74	MARSHALL VIL	SW SE S13 08N 12E	Medina	1970-1988	W,T,G	3/11/2004	113117950
75	MEDINA TN	NW SW S24 08N 12E	Medina	1970-1990	W,T	6/6/2001	113114100

Solid Waste Disposal Sites in Dane County							
Map No.	Site Name	PLSS	Township	Years of Operation	Type of Waste[1]	DNR Assessment Date	Source of Information[2]
76	CROSS PLAINS TN	NE SW S20 07N 07E	Cross Plains	?	D,W,T	5/4/2000	113113550
77	TRANSPORT GAS STATION		Cross Plains	1956-1963	T,G	1/29/2004	Pre-Reg.
78	VALLEY ST BREWERY	NE S03 07N 07E	Cross Plains	?	?	3/21/2004	Pre-Reg.
79	REFUSE HIDEAWAY LANDFILL	SW NW S08 07N 08E	Middleton	1973-1988	D,W,T,G,H	11/16/2000	113112010
80	HEATHERCREST FARMS	NW NW S21 07N 08E	Middleton	?-1973	T	11/14/2005	Post-Reg.
81	RAY WEITZEL	SE S28 08N 09E	Middleton	?	?	1/21/2004	Post-Reg.
82	PLEASANT VIEW GOLF	NW NW S15 07N 08E	Middleton	?	T	5/18/2005	DNR Southern District Files
83	PREFINISHED MILLWORK CORP	NE SE S10 07N 08E	Middleton	?	?	11/8/2000	113124550
84	MIDDLETON CTY ?-1967	NW S11 07N 08E	Middleton	?	?	6/11/2008	Pre-Reg.
85	DENNIS HOWARD	SW SE S14 07N 08E	Middleton	?-1977	W,T	10/11/2004	Post-Reg.
86	MADISON CTY (MINERAL PT)	NE SW S24 07N 08E	Middleton	1965-1971	H,T,G	7/6/2004	113185050
87	HERMAN SCHNOOR	NW SE S25 07N 08E	Middleton	?-1973	D	2/4/2004	DNR Southern District Files
88	MADISON CTY - GREENTREE HILLS	SE NE S36 07N 08E	Middleton	1973-1982	W,T,G	9/8/2004	113108160
89	MADISON CTY - Odana Golf Course	NE NE S31 07N 09E	Madison	?	?	9/9/2004	Public
90	MADISON CTY - OLD BRICKYARD	SW SE S17 07N 09E	Madison	1938-1941	U	9/9/2004	113339490
91	SHOREWOOD VIL	SE SW S17 07N 09E	Madison	?	?	11/28/2000	113063610
92	SHOREWOOD VIL - DOCTORS PK	SE SW S16 07N 09E	Madison	?	W	7/12/2006	Pre-Reg.
93	UNIV WISC-UNIV BAY 1968-71	SW NE S16 07N 09E	Madison	1968(?)-1971	D, Ash	6/1/2004	DCRPC Solid Waste Plan
94	UNIV OF WISC-PICNIC PT	NE NE S16 13N 09E	Madison	?	D,W	3/17/2004	Pre-Reg.
95	MADISON CTY - ST MARY'S PK LOT	NE S27 07N 09E	Madison	?	U	10/5/2004	113339600
96	MADISON CTY FIORE PLAT	NW SW S26 07N 09E	Madison	1932-1935	U	9/22/2004	113340260
97	MADISON CTY - BOWMAN FIELD	NW NW S35 07N 09E	Madison	?	U	5/30/2001	113125980
98	ICKE CONST. (ASH SITE)	NW SW S36 07N 09E	Madison	?-1983	D, Ash	12/6/2000	113119380
99	COYLE INC	NE NW S36 07N 09E	Madison	?	U	1/26/2004	Post-Reg.
100	LENNES SCHLOBOHM (DEMO)	NE NW S36 07N 09E	Madison	?	D	1/22/2004	Post-Reg.
101	MADISON CTY - OLIN AV LF	NW SW S25 07N 09E	Madison	1945-1976	U	6/13/2000	113108380
102	MADISON CTY LAKESIDE	NW NW S25 07N 09E	Madison	1937-1939	U	9/23/2004	Pre-Reg.
103	MADISON CTY LAW PK 41-46	NW S24 07N 09E	Madison	1941-1946	U	9/9/2004	113340150
104	MADISON CTY 1953-69	SW SW S13 07N 09E	Madison	1953-1969	?	9/13/2004	Pre-Reg.
105	MADISON GAS & ELECTRIC RDF STORAGE FACILITY	S 1/2 S13 07N 09E	Madison	?	T,RDF		DNR 2769?
106	MADISON GAS & E 1941-44	SE SE S12 07N 09E	Madison	1941(?)-1944	U	12/2/2004	113339160
107	MADISON CTY BURR JONES FIELD	NW NW S07 07N 10E	Blooming Grove	1927-1930	U	6/30/2000	113317160
108	MADISON CTY (DEMETRAL 1952-67)	NE NW S06 07N 10E	Blooming Grove	1952-1967	T,G	9/8/2004	113189560
109	GARVER SUPPLY LF	NW SE S05 07N 10E	Blooming Grove	?	D	9/14/2004	DNR Southern District Files
110	MADISON CTY OLBRICH PK	SW SE S05 07N 10E	Blooming Grove	1946-1951	U	6/5/2000	113068120

Solid Waste Disposal Sites in Dane County							
Map No.	Site Name	PLSS	Township	Years of Operation	Type of Waste[1]	DNR Assessment Date	Source of Information[2]
111	NUTRI-FEED CORP	SW S31 07N 10E	Blooming Grove	?	?	3/10/2011	113111790
112	MADISON CTY	S31 07N 10E	Blooming Grove	?	?	9/8/2004	Temp. 306
113	CRVI-LIBBY PROPOSED LF	NE SE S31 07N 10E	Blooming Grove			11/14/2005	113175920
114	MADISON METROPOLITAN SEWERAGE DIST LAGOONS	SE S30 07N 10E	Blooming Grove	—	Sludge	9/10/2004	113192970
115	GISHOLT FOUNDRY 1971-72	NE NW S29 07N 10E	Blooming Grove	1971-1972	F	6/28/2005	DNR Madison Area Files
116	MONONA CTY	NW NW S28 07N 10E	Blooming Grove	1963-1972	W,G	5/30/2001	113236200
117	HARP & KETTLE CHEESEHOUSE	NW S28 07N 10E	Blooming Grove	?	D	10/6/2004	Post-Reg.
118	L S LUNDER CONST CO	NW NE S28 07N 10E	Blooming Grove	?	?	8/3/2005	Temp. 407
119	GOBEN CARS INC	SW SE S21 07N 10E	Blooming Grove	?	D,W	10/6/2004	113339710
120	L. A. O. MACHINE SHOP	SE SW S22 07N 10E	Blooming Grove	?	?	5/26/2005	Post-Reg.
121	CRVI-VONDRON PROPOSED LF	E NE S22 07N 10E	Blooming Grove			11/14/2005	113193960
122	HY-HO SILVER INC	NW NW S22 07N 10E	Blooming Grove	?	?	10/7/2004	WID980610596
123	MIDWEST STEEL DIVISION	NE SW S15 07N 10E	Blooming Grove	1976-1980	Auto Shredder	7/30/2005	113111570
124	TERRA ENGR & CONSTR CORP	SE SE S15 07N 10E	Blooming Grove	1972-	D,W	12/2/2004	113112890
125	MONONA CTY	S26 07N 10E	Blooming Grove	?	?	10/4/2010	Post-Reg.
126	BLOOMING GROVE TN	NE SW S12 07N 10E	Blooming Grove	1961-1991	W,T,G	11/21/2000	113114650
127	BLOOMING GROVE TN 1954-60	NW NW S13 07N 10E	Blooming Grove	1954-1960	U	3/8/2004	113343230
128	D & M CONSTRUCTION	NW S13 07N 12E	Blooming Grove	?	D,G	5/28/2008	Post-Reg.
129	MADISON CTY - Yahara Hills Golf Crse	NE SW S25 07N 10E	Blooming Grove	?	?	9/9/2004	Public
130	DANE CNTYLANDFILL #2-RODEFELD	NE S25 07N 10E	Blooming Grove	1985-	D,W,T,G	4/21/2004	113127300
131	LLOYD DOWNING	SW SW S31 07N 11E	Pleasant Springs	?-1973	T	4/11/2006	DNR Southern District Files
132	COTTAGE GROVE TN	NW NE S28 07N 11E	Cottage Grove	1969-1988	D,W,T,G	5/4/2000	113113440
133	FRED SCHROEDER	SW SW S16 07N 11E	Cottage Grove	?-1974	T,F	3/8/2011	Post-Reg.
134	HYDRITE CHEM CO	NW NE S16 07N 11E	Cottage Grove	?	?	3/15/2004	WID000808824
135	IRVING SMITH FILL	NW NE S04 07N 11E	Cottage Grove	?	D,W	11/10/2004	Pre-Reg.
136	TALIAFERRE TIRE STORAGE SITE	NE S24 07N 11E	Cottage Grove	?-1973	Tires		DNR Madison Area Files
137	DEERFIELD VIL	SW SW S22 07N 12E	Deerfield	?-1981	D,W	6/25/2001	113117290
138	DEERFIELD TN	SW SE S27 07N 12E	Deerfield	1970-1991	W,T,G	6/7/2001	113119710
139	THOMPSON STATE CAMP	SE SW S35 07N 12E	Deerfield	1969-1970	T,G	8/12/2003	Temp. 492
140	ZICKERT FARM	NE SW S14 07N 12E	Deerfield	?	?	3/17/2011	Post-Reg.
141	UNAMMED SITE	NW S13 07N 12E	Deerfield	?	?		Gr.Mad. Board Realtrs
142	BLUE MOUNDS STATE PARK	SE NE S01 06N 05E	Blue Mounds	?	?	11/23/2005	Pre-Reg.
143	BRIGHAM FARM	SW SW S05 06N 06E	Blue Mounds	?-1976	D,W	11/8/2004	Post-Reg.
144	MT HOREB VIL	SW S10 06N 06E	Blue Mounds	Pre-1943	U	4/14/2004	Pre-Reg.
145	MOUNT HOREB VIL	SE SE S14 06N 06E	Blue Mounds	1943-1975	D,W,T,G	4/14/2004	113118280
146	EDGAR MARKWARDT PROPERTY	SW NW S01 06N 07E	Springdale	1960s	H	11/22/2000	113151830
147	SPRINGDALE TN (EARLY 1960'S)	SE SE S25 06N 07E	NEW	?	?	10/6/2005	Pre-Reg.
148	VERONA TN	SW SW S09 06N 08E	Verona	pre-1968-1990	W,T,G	3/22/2004	113115420
149	VERONA CTY 1968-71	NE SE S16 06N 08E	Verona	1968-1971	W,T	10/4/2010	DCRPC Solid Waste Plan
150	VERONA VIL	NW SW S22 06N 08E	Verona	1940-1950	T,G	6/27/2000	313005110

Solid Waste Disposal Sites in Dane County							
Map No.	Site Name	PLSS	Township	Years of Operation	Type of Waste[1]	DNR Assessment Date	Source of Information[2]
151	DANE CNTY LANDFILL #1-VERONA	NE NE S14 06N 08E	Verona	1977-1986	D,W,T,G	7/30/2004	113097930
152	FITCHBURG CTY	NE SW S18 06N 09E	Fitchburg	?	U	11/30/2005	Pre-Reg.
153	KIETH HAMMERSLEY JR	SW SW S07 06N 09E	Fitchburg	1970-1980	D,W,T	7/27/2010	113109480
154	WISC BRICK & BLOCK (DEMO)	NE SW S07 06N 09E	Fitchburg	?	D,W,T,G,Tires	8/9/2005	113134450
155	HAMMERSLY STONE DEMO	NE NE S07 06N 09E	Fitchburg		D	2/5/2004	Demo
156	OREGON STATE FARM	NE SW S35 06N 09E	Fitchburg	?-1972	G	12/11/2000	113064710
157	WISC SCHOOL FOR GIRLS	NE SE S26 06N 09E	Fitchburg	1969-1971	T,G	12/11/2000	113233780
158	NEVIN HATCHERY DNR	SE NE S10 06N 09E	Fitchburg	1974	D	4/14/2004	113339270
159	HAMMERSELY CONST CO	SE SW S02 06N 09E	Fitchburg	1977	D	8/3/2010	One-Time
160	STEWART WATSON (DEMO)	NW S02 06N 09E	Fitchburg	?	D	3/8/2011	Post-Reg.
161	SCHUEPBACH LF	SE NW S01 06N 09E	Fitchburg	?-1973	D,W	12/13/2000	113151720
162	MADISON CRUSHING CO.	SE NW S01 06N 09E	Fitchburg	1971-1973	D,F	8/3/2005	Post-Reg.
163	HOLTZMAN CO	SE SE S06 06N 10E	Dunn	pre-1971-1992	Lab animals	8/9/2005	113109920
164	WASTE MGT OF WI-CITY DISPOSAL	SE NE S30 06N 10E	Dunn	1966-1977	H,D,W,T,G	3/31/2000	113118830
165	ARLO LADELL (T & H)	NW NW S29 06N 10E	Dunn	?	?	10/19/2005	WID980610125
166	DUNN TN	NW NE S21 06N 10E	Dunn	1970-1991	T,G	4/14/2004	113113880
167	CRESENT DRIVE SITE	SW S9 06N 10E	Dunn	?	?		Gr.Mad. Board Realtrs
168	MCFARLAND VIL	SW SW S02 06N 10E	Dunn	1972-1975	W	5/30/2001	113118170
169	DONALD BARBER LF	SW NW S26 06N 10E	Dunn	?	?	5/29/2001	Post-Reg.
170	PLEASANT SPRINGS TN	E 1/2 NW S31 05N 09E	Pleasant Springs	1940-1966	?		Gr.Mad. Board Realtrs
171	CLIFFORD SAGEN	SW S17 05N 09E	Pleasant Springs	?	D	3/8/2011	Post-Reg.
172	OLD TIME AUTO PARTS - I90 RUBBLE	NE SW S09 07N 11E	Pleasant Springs	?	?		Gr.Mad. Board Realtrs
173	PLEASANT SPRINGS TN	SW NW S36 06N 11E	Pleasant Springs	1972-1989	D,W,T,G	10/13/2005	113114320
174	PLEASANT SPRINGS TN	NE SW S25 06N 11E	Pleasant Springs	1967-1972	W,T,G	9/27/2005	Temp. 7
175	CAMBRIDGE TN OLD DUMP	NW S29 06N 12E	Christiana	?-1970	U	10/26/2005	Pre-Reg.
176	CHRISTIANA TN	SW NE S08 06N 12E	Christiana	?-1986	W,T	1/5/2004	113113330
177	BOB BIRKREM	NE SE S05 06N 12E	Christiana	?	D,G	3/8/2011	Post-Reg.
178	MELSTER CANDY KITCHENS LF	NW NE S12 06N 12E	Christiana	?	U	8/12/2010	Post-Reg.
179	PERRY TN	NE NE S18 05N 06E	Perry	1970-1991	D,W,T	6/6/2001	113114210
180	PRIMROSE TN	NE SW S09 05N 07E	Primrose	1970-1974	T,G	3/10/2004	113343340
181	BELLEVILLE VIL	SE SE S34 05N 08E	Montrose	1972-1988	D,W	4/14/2004	113116410
182	MONTROSE TN	SE SW S01 05N 08E	Montrose	?-1973	D,W,G	3/10/2004	113343890
183	OREGON TN	NE NW S17 05N 09E	Oregon	?-1974	W	9/13/2000	113114430
184	DANE CNTY HWY DEPT-ACES' PIT	SE NW S17 05N 09E	Oregon	?-1974	D,W,T	7/31/2004	113107060
185	OREGON VIL - SENIOR CITZEN CENTER	NW S12 05N 09E	Oregon	?	?		Pre-Reg.
186	OREGON VIL	NE NW S12 05N 09E	Oregon	?	?	7/6/2005	Pre-Reg.
187	OREGON KAR BODY	NW S07 05N 10E	Rutland	?-1973	D	1/16/2003	113334760
188	DUMP SITE	SW NW S31 05N 10E	Rutland	?	?	8/30/2007	Pre-Reg.
189	BROOKLYN VIL	SW SW S31 05N 10E	Rutland	1969-1988	D,W	5/30/2001	113116630
190	RUTLAND TN	SE NE S17 05N 10E	Rutland	1974-1992	W,T,G	1/9/2002	113115090

Map No.	Site Name	PLSS	Township	Years of Operation	Type of Waste[1]	DNR Assessment Date	Source of Information[2]
191	OREGON RACE TRACK	SW SW S09 05N 10E	Rutland	?-1973	T	7/8/2005	Post-Reg.
192	RUTLAND TN	NW NW S02 05N 10E	Rutland	1970-1974	W,T,G	9/12/2005	113114980
193	EVERY FARM	SE NE S02 05N 10E	Rutland	1963-1966	H	5/18/2007	113179330
194	RUTLAND TN	S36 05N 10E	Rutland	1950s	U	8/16/2005	Pre-Reg.
195	PETTY REALTY	NE NE S06 05N 11E	Dunkirk	?	?	1/22/2004	Post-Reg.
196	STOUGHTON CTY	SW SW S05 05N 11E	Dunkirk	?	U	8/5/2005	Pre-Reg.
197	STOUGHTON CTY	SW NE S08 05N 11E	Dunkirk	?	U	8/5/2005	Pre-Reg.
198	STOUGHTON CTY (AMUNDSON PK)	NW SW S04 05N 11E	Dunkirk	1953-1978	H	8/5/2005	113005950
199	DUNKIRK TN	SE SE S9 05N 11E	Dunkirk	?-1986	W,T,G	6/7/2001	113113770
200	THOMAS MATSON (DEMO)	NW SW S10 05N 11E	Dunkirk	?	U,D	1/13/2003	113334870
201	ORRIN HAGEN FARM	NE SW S10 05N 11E	Dunkirk	Late 1950s-early '60s	H	9/14/2004	113176030
202	ALBION TN OLD DUMP	NE NE S23 05N 12E	Albion	1967-1972	G	11/29/2005	Pre-Reg.
203	GUS OBERG'S BAR	NW SE S25 05N 12E	Albion	?	D,W,T	8/24/2005	113109370
204	ALBION TN	SE 1/2 S35 05N 12E	Albion	1973-1986	D,W,T	12/1/2000	113114540

Solid Waste Disposal Sites in Dane County

Note: All landfills are closed or inactive, except for Map #61 and #130

[1]Type of Waste

- U = Undifferentiated
- W = Wood and brush
- T = Trash
- G = Garbage (discarded materials from food processing and consumption)
- D = Construction and demolition waste
- F = Foundry waste
- H = Hazardous waste

[2]Source of Information:

DNR Solid and Hazardous Waste Information System (SHWIMS) database, unless otherwise noted.

Temp: Indicates that a temporary permit or license has been issued.

Post-Reg or Pre-Reg: Indicates whether disposal occurred previous to or following the 1969 requirements that landfills be licensed by the state.

Demo: Demolition sites requiring permits are noted by “one-time” or “Demo.”

WID: EPA Comprehensive Environmental Response, Compensation, and Liability Information System (CERLIS) archive.

This table and associated map indicate the general location of waste disposal sites identified by the DNR and other governmental units and private entities. In many cases, the exact boundaries and precise contents of the sites are not known.

Attachment D

State and Federal Groundwater Agencies

The following summarizes Wisconsin state and federal agencies that have groundwater databases and conduct groundwater protection activities.

Department Of Agriculture, Trade, And Consumer Protection

Agrichemical Resources Management Division

- Regulate pesticide use
- Regulate bulk pesticide and fertilizer storage
- Conduct groundwater studies and testing
- Certify pesticide applicators
- Track agrichemical spills and remediation
- Regulate installation and maintenance of underground storage tanks
- Testing of petroleum products

Food Safety Division

- Conduct inspections of food processors (including water bottlers)
- Conduct sampling of Grade A dairy wells

Department Of Health Services (DHS)

Bureau of Community Health and Prevention

- Recommend enforcement standards for substances related to health concerns
- Investigate health effects from contamination incidents
- Develop groundwater standards
- Develop groundwater public health policy

Bureau of Environmental Health

- Inspect restaurant, hotel, motel and campground water supplies

Department Of Safety and Professional Services (DSPS)

Division of Safety and Buildings

- Regulate private sewage systems
- Approve home water treatment devices
- Approve plats for unsewered subdivisions

Department Of Natural Resources (DNR)

Bureau of Watershed Management

- Approve sewage lagoons, municipal and industrial wastewater systems
- License large-scale on-site waste disposal systems
- License wastewater sludge disposal
- License septage disposal

Bureau of Waste Management

- Track operating and abandoned landfill
- Monitor hazardous waste treatment, storage, and disposal
- Administer recycling program
- Administer pollution prevention
- Approve mining operation
- Approve environmental restoration and response program

Bureau for Remediation and Redevelopment

- Remediate environmental contamination (soil, groundwater, etc.)
- Administer Brownfields program
- Redevelopment of contaminated areas
- Respond to spill incidents
- Administer Leaking Underground Storage Tanks program
- Administer Superfund program
- Administer state-funded response actions
- Administer the Petroleum Environmental Cleanup Fund Award (FECFA)

Bureau of Drinking Water and Groundwater

- Set and enforce public and private drinking water standards
- Monitor public drinking water wells
- Approve public and high-capacity wells
- License well drillers and pump installers
- Conduct well driller education
- Implement the Safe Drinking Water Act
- Administer the Wellhead protection
- Administer Injection Well program
- Conduct water quality planning and education/Wellhead protection
- Facilitate groundwater coordination
- Set and enforce groundwater quality standards
- Monitor groundwater quality and quantity

University Of Wisconsin (UW)

Central Wisconsin Groundwater Center
University of Wisconsin-Extension

- Conduct drinking water and groundwater education programs
- Provide technical assistance to local governments
- Develop materials regarding groundwater Best Management Practices
- Collect and analyze groundwater resource data
- Produce educational materials and county groundwater reports
- Conduct research

Wisconsin Geological and Natural History Survey

- Map and inventory groundwater resources and geologic conditions
- Write technical reports and assist regulating agencies

- Monitor groundwater levels and water quality
- Provide education and public information
- Conduct research

UW Water Resources Center

- Coordinate and administer water resources research in UW system
- Operate designated federal water resource center
- Develop curriculum for children
- Produce research publications

United States Geological Survey (USGS)

- Collect data and conduct studies regarding:
  - streamflow at gaging stations and other sites
  - stage and contents of lakes and reservoirs
  - chemical, physical and biological characteristics of surface water
  - groundwater levels in observation wells
- Conduct geologic mapping
- Conduct research

United States Department Of Agriculture (USDA)

Natural Resources Conservation Service

- Maintain and interpret soil property databases
- Produce digital soil maps
- Rate soils for potential pesticide leaching and runoff
- Provide technical assistance for soil and water
- Provide resource planning and management
- Develop farming practice standards for groundwater protection
- Rate soils for potential nitrogen and phosphorus leaching

Attachment E

Summary of State Regulatory Controls of Groundwater Pollution Sources and Withdrawals

Activity	Regulator	Adm. Code	Focus of Regulation
WASTE DISPOSAL			
Municipal & Industrial Landfills	DNR	185 500	Licensing of all sites; standards for location, design, operation, construction, monitoring and abandonment.
Environmental Repair Fund (ERF)	DNR	710	Focuses on development of an environmental response plan; inventory sites that might pollute; develops a hazard ranking system; identifies remedial actions to be taken. Also applies to hazardous waste disposal facilities.
Municipal & Industrial Wastewater	DNR	110 206 214	DNR regulates through WPDES permit process. NR 110 sets design standards for municipal sewerage systems; NR 206 land disposal of municipal and domestic wastewater; and NR 214 land disposal of industrial wastewater.
Sanitary Sewers	DSPS	382	DSPS regulates laterals.
	DNR	110	Sets design standards for municipal pumping, interceptors and collector systems.
Private Wastewater Systems	DSPS	383 385	DSPS regulates siting, design, installation, and inspection of systems and licensing of installers and evaluators. Large-scale systems (>12,000 gals/day) requires a DNR WPDES permit. DNR can also prohibit tanks in areas where they could cause a water quality problem.
Municipal Sludge	DNR	204	Regulates sewage sludge disposal and recycling.
		214	Regulates landspreading of industrial sludge.
		518	Regulates landspreading of solid waste
Septage	DNR	113	Regulates septage disposal, recycling and licenses septage pumping businesses.
AGRICULTURE			
Animal Waste Management	DNR	243	Require operators to obtain WPDES permit and require monitoring wells in situations to achieve compliance with livestock performance standards and prohibitions.
	DNR	812	DNR regulates the distance of wells from concentrated feeding operations.
	DATCP	151	Establishes Agricultural Performance Standards and Prohibitions
		51	Establishes state standards and procedures local governments must use if they choose to require conditional use permits for siting new and expanded livestock operations
Nonpoint Source Pollution	DNR	120	Sets up Nonpoint Source Pollution Program cost/share funding for best management practices including storage manure facility requirements, critical site designation, BMPs, etc.
	DATCP	50	Implements Wisconsin's Soil and Water Resource Management Program.

Summary of State Regulatory Controls of Groundwater Pollution Sources and Withdrawals

Activity	Regulator	Adm. Code	Focus of Regulation
Pesticide Use & Control	DATCP	29	Rules require good handling practices and prohibit direct (or possible indirect) entry of pesticides into the groundwater; also has aldicarb restrictions and groundwater sampling requirements.
Pesticide Product Restrictions	DATCP	30	Rules restrict the use of specific pesticide products, including the Atrazine Rule (ATCP 30.31)
Groundwater Protection Program	DATCP	31	Establishes standards for groundwater test reporting and the regulatory and enforcement actions to prevent and control groundwater pollution from agricultural activities.
Fertilizer Bulk Storage	DATCP	33	Rules apply to fertilizer and pesticide bulk storage by manufacturers and distributors.
Agricultural Chemical Cleanup Program	DATCP	35	Rules for administering the Agricultural Chemical Cleanup Program
HAZARDOUS MATERIALS & WASTE			
Hazardous Waste Requirements	DNR	600+	State regulatory program exceeds minimum RCRA Federal standards.
		700+	Comprehensive code: procedures and standards for cleaning up hazardous waste contamination sites including leaking underground storage tanks, environmental repair sites, and hazardous substance discharges.
PCBs	DNR	157	Establishes procedures for collection, storage, transport, and disposal of PCBs and products containing PCBs.
Chemical Storage Tanks	DATCP	93	Leak detection program, plan review, tank inspection and approval, design and construction standards, and recordkeeping.
Used Oil	DNR	679	Creates comprehensive rule for management of used oil, including standards for burning, storage, transportation and reporting.
WATER QUALITY & OTHER ACTIVITIES			
Groundwater Standards	DNR	140	Sets up a two-tiered system of numerical standards for polluting substances enforced by DNR, and establishes groundwater quality standards for harmful substances.
Drinking Water Standards	DNR	809	DNR sets drinking water standards and public water supply monitoring requirements.
Well Construction & Abandonment	DNR	141	Rule establishes requirements for groundwater monitoring, well construction and abandonment.
		811 812	Specifies well design and construction, sets minimum separating distances between wells and potential pollution sources, and requires proper abandonment of all wells. DNR licenses well drillers and pump installers.
		845	Provides for county administration of NR 812.
Well Compensation	DNR	123	Program lets DNR provide partial reimbursement to replace contaminated wells.
	DATCP	31	DATCP rule establishes the regulatory and enforcement actions which the DATCP will take to protect groundwater against pollution from agricultural activities.

Summary of State Regulatory Controls of Groundwater Pollution Sources and Withdrawals

Activity	Regulator	Adm. Code	Focus of Regulation
Highway Salt Storage	DOT	277	TRANS 277: Provides DOT response when preventative action limit for chloride has been exceeded at a storage facility and sets requirements for remedial action.
GROUNDWATER QUANTITY			
Water Supply and Environmental Protection	DNR	800+	Comprehensive code addressing water use, permitting, well construction, water supply systems, and groundwater quantity protection.
		820	Establishes review criteria applicable to high capacity well applications involving wells situated near springs, trout streams, outstanding and exceptional resource waters, and also groundwater withdrawals involving high water loss. Also establishes special protection efforts in two Groundwater Management Areas in the state experiencing water level drawdowns in excess of 150 feet (Lower Fox River Valley and Southeast Wisconsin).
		852	Establishes a statewide water conservation and efficiency program for withdrawals in the Great Lakes Basin and water loss approvals statewide.
		854	(proposed) Establishes a statewide water supply service area planning process for public water supply systems.
		856	Establishes requirements for registering water withdrawals and collecting and reporting accurate water withdrawal data to support management efforts.
		860	Establishes the process, requirements, and criteria for water use permitting.
		142	Wisconsin Water Management and Conservation, established to protect and promote the conservation of the waters of the state.