

Wisconsin Groundwater Coordinating Council

Fiscal Year 2015

REPORT TO THE LEGISLATURE



2015 GROUNDWATER COORDINATING COUNCIL MEMBERS

Department of Natural Resources – **Patrick Stevens, Chair**
Department of Agriculture, Trade & Consumer Protection – **John Petty**
Department of Safety & Professional Services – **Awaiting appointment**
Department of Health Services - **Henry Anderson, MD**
Department of Transportation - **Dan Scudder**
Geological and Natural History Survey (State Geologist) – **Kenneth Bradbury**
Governor's Representative – **Steve Diercks**
University of Wisconsin System – **James Hurley**

SUBCOMMITTEES

Research & Monitoring

Geological and Natural History Survey - **Ken Bradbury** (Co-Chair) *, **Madeline Gotkowitz***, and **Bill Bristoll**
Department of Natural Resources –**Bill Phelps***(Co-Chair), and **Shaili Pfeiffer**
Department of Agriculture, Trade and Consumer Protection - **Jeff Postle*** and **Rick Graham***
Department of Safety and Professional Services – **Ross Fugill*** and **Jon Heberer***
Department of Health Services - **Robert Thiboldeaux***and **Ryan Wozniak***
University of Wisconsin System - **Paul McGinley***, **Maureen Muldoon***, **Tim Grundl***, and **Trina McMahon***
U. S. Geological Survey - **Randy Hunt***, **Mike Fienen***, and **Cheryl Buchwald**
Center for Watershed Science and Education - **George Kraft*** and **Dave Mechenich**
Natural Resources Conservation Service - **Tim Weissbrod***

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Department of Natural Resources – **Mary Ellen Vollbrecht** (Co-Chair)
University of Wisconsin System –**Maira Harrington**
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Department of Transportation - **Bob Pearson**
State Laboratory of Hygiene –**Jeremy Olstad**
U. S. Geological Survey – **Marie Peppler**
Natural Resources Conservation Service - **Tim Weissbrod**
Association of Wisconsin Regional Planning Commissions – **Eric Fowle**
Wisconsin Rural Water Association – **Andrew Aslesen**
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Wisconsin Water Well Association – **Cindy Denman**



State of Wisconsin \ GROUNDWATER COORDINATING COUNCIL

Scott Walker, Governor

101 South Webster Street
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Patrick Stevens,
Council Chair
DNR

August 28, 2015

To: The Citizens of Wisconsin

Kenneth Bradbury
WGNHS

The Honorable Governor Scott Walker

Senate Chief Clerk

John Petty
DATCP

Assembly Chief Clerk

Secretary Mark Gottlieb - Department of Transportation

Secretary Dave Ross - Department of Safety and Professional Services

Henry Anderson, MD
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Secretary Ben Brancel - Department of Agriculture, Trade & Consumer Protection

Secretary Kitty Rhoades - Department of Health Services

James Hurley
UWS

Secretary Cathy Stepp - Department of Natural Resources

President Ray Cross - University of Wisconsin System

Dan Scudder
DOT

State Geologist James Robertson - Geological and Natural History Survey

Steve Diercks
Governor's Rep.

The Groundwater Coordinating Council (GCC) is pleased to provide its 2015 Report to the Legislature. The GCC was formed in 1984 to help state agencies coordinate non-regulatory activities and exchange information for efficient management of groundwater. For 30 years, the GCC has been a model for interagency coordination and collaboration among state agencies, local and federal government, and the university. It is one of very few examples of effective statewide coordination of groundwater efforts from an advisory position.

The level of coordinating effort and investment in groundwater is particularly appropriate as Wisconsin depends so heavily on groundwater for its drinking water. Wisconsin also relies on groundwater to irrigate crops, water cattle, and process a wide variety of foods, as well as feed trout streams and spring-fed lakes - all of which are vital to our state economy. New challenges and new ideas continue to warrant the GCC's collaborative approach.

This on-line report summarizes and links to information on the GCC and agency activities related to groundwater protection and management in FY15 (July 1, 2014 to June 30, 2015). Search "GCC" on dnr.wi.gov to find the full report. Click on the rotating cover graphics to see indicators of the condition of Wisconsin groundwater, our current uses and the state of our groundwater information. Click on the picture tabs for chapters of the report, beginning with the GCC's recommendations titled *Directions for Future Groundwater Protection*. The Executive Summary is attached.

We hope you will find this report to be a useful reference in protecting Wisconsin's priceless groundwater supply.

Sincerely,

Patrick Stevens, Chair
Groundwater Coordinating Council

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EXECUTIVE SUMMARY

PURPOSE OF THE GCC AND ANNUAL REPORT

In 1984, the Legislature enacted Wisconsin's Comprehensive Groundwater Protection Act, to improve the management of the state's groundwater. The Groundwater Coordinating Council (GCC) was created and 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 Groundwater Coordinating Council shall advise and assist state agencies in the coordination of non-regulatory 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 is required by s. 15.347, Wis. Stats., to prepare a report which "summarizes the operations and activities of the council..., describes the state of the groundwater resource and its management and sets forth the recommendations of the council. The annual report shall include a description of the current groundwater quality of the state, an assessment of groundwater management programs, information on the implementation of ch. 160, Wis. Stats., and a list and description of current and anticipated groundwater problems." This report is due each August. The purpose of this report is to fulfill this requirement for fiscal year 2014 (FY14). The report is an interactive web-page with links to extensive supporting information.

The GCC's role in facilitating inter-agency coordination includes the exchange of information regarding Wisconsin's Comprehensive Groundwater Protection (Act 1983 Wisconsin Act 410), Wisconsin's Groundwater Protection Act (2003 Wisconsin Act 310), the Great Lakes Compact (2007 Wisconsin Act 227), the federal Safe Drinking Water Act's Wellhead and Source Water Protection provisions, and many other programs.

GROUNDWATER COORDINATION ACTIVITIES

In addition to the council of agency leaders, the GCC is authorized to create subcommittees on "the subjects within the scope of its general duties...and other subjects deemed appropriate by the Council." See a list of GCC members and subcommittees on the inside cover of this executive summary.

The GCC and its subcommittees regularly bring together staff from over 15 different agencies, institutions and organizations to communicate and work together on a variety of research, monitoring and data management, educational, and planning issues. A strong network among GCC and subcommittee members leads to coordination across agency lines on a variety of groundwater-related issues. These activities regularly avoid duplication, create efficiencies, and provide numerous benefits to Wisconsin's taxpayers.

Coordination of Groundwater Research and Monitoring Program

The GCC is directed to "advise the Secretary of Administration on the allocation of funds appropriated to the Board of Regents of the University of Wisconsin under s. 20.285(1)(a) for groundwater research." Since 1992, a joint solicitation process has facilitated selection and funding of sound scientific research and monitoring to answer state priority needs.

The GCC, the UWS, DNR and the Groundwater Research Advisory Council (GRAC) again collaborated on the annual solicitation for groundwater research and monitoring proposals as specified in the Memorandum of

Understanding. After a multi-agency effort spearheaded by the UW Water Resources Institute, the GCC approved selected projects for the annual program of research to answer current groundwater management questions.

A comprehensive review process including the GRAC, the GCC's Monitoring & Research Subcommittee, and outside technical experts resulted in recommendations that were used by the UWS and DNR in deciding which groundwater-related proposals to fund. From 17 proposals, seven new projects were selected for funding in FY16, five by UWS and two by DNR. The GCC approved the proposed UWS groundwater research plan as required by s. 160.50(1m), Wis. Stats., and a letter to this effect was sent to the UWS President and the Department of Administration. [Current groundwater research and monitoring projects](#), are listed in the report as well as all Wisconsin Joint Solicitation groundwater research and monitoring projects.

The UW Water Resources Institute (WRI) provides access to [summaries and reports](#) of GCC-facilitated groundwater research, as well as cataloging all WRI research reports into WorldCat and MadCat, two library indexing tools that provide both worldwide and statewide access to this research. The Water Resources Library has partnered with UW Libraries' Digital Collections Center to digitize and post UWS and DNR final project reports. As a result of this partnership, full-text reports are also available through the [UW Ecology and Natural Resources Digital Collection](#). Progress continues in making older final reports and summaries accessible on-line.

Information and Outreach Activities

For the 15th year in a row, groundwater workshops for teachers were taught jointly by GCC Outreach and Partnership Subcommittee members from the DNR, WGNHS and the Center for Watershed Science and Education (CWSE) at Stevens Point. Teacher applications to participate continue to fill all available workshop space and equipment. The workshop leaders instructed teachers on using a groundwater sand-tank model and provided additional resources to incorporate groundwater concepts into their classroom. Educators who attended the workshops received a free model. With funding from a U.S. Environmental Protection Agency (EPA) wellhead protection grant, over 275 groundwater models have been given to schools and nature centers since 2001 and over 550 educators have received hands-on training in using the model effectively. Educators are regularly surveyed to promote continued use and evaluate educational benefits.

At the direction of the GCC, the Outreach and Planning Subcommittee inventoried all ongoing agency outreach efforts and developed recommendations for improved on-line support to well owners as a precursor to outreach efforts to health service providers.

Other Coordination Activities

The GCC continued to promote communication, coordination, and cooperation between the state agencies through its quarterly meetings. In addition to identifying collaboration opportunities, making decisions about research, and guiding report development, the GCC received briefings and discussed a variety of current topics at its FY15 meetings:

- US Geological Survey monitoring and analysis in Wisconsin for the National Water Quality Assessment
- Wisconsin water use trends
- Research results from UWS on best designs for managing silage leachate to minimize groundwater risk
- Natural Resources Conservation Service nutrient management technical standards update process
- WGNHS analysis of groundwater quality a decade after land use change from row crop to subdivision
- WGNHS analysis of groundwater nitrate sources from more than 80,000 well tests from Dane County

More information on these topics and the coordinating efforts of the GCC can be found in the FY15 GCC meeting minutes. Through these activities, the GCC plays an important role in ensuring agency coordination, increasing efficiency, avoiding duplication, and facilitating the effective functioning of state agencies in activities related to groundwater protection and management. As a result, groundwater is better protected, which benefits public health, sustains our economy, and preserves Wisconsin's natural resources for future generations.

SUMMARY OF AGENCY GROUNDWATER ACTIVITIES

State agencies and the University of Wisconsin System addressed numerous issues related to groundwater protection and management in FY15. Detailed discussions of the groundwater activities of each agency can be found at the agency activities tab in the [on-line report](#).

CONDITION OF THE RESOURCE: Groundwater Quality

Major groundwater quality concerns in Wisconsin are summarized below and detailed in the [on-line report](#).

Nitrate

Nitrate is Wisconsin's most widespread groundwater contaminant and is increasing in extent and severity. Nitrate levels in groundwater above 2 milligrams per liter (mg/L) indicate a source of contamination such as agricultural or turf fertilizers, animal waste, septic systems, and wastewater. While nitrate in agricultural use has benefits such as larger crop yields, high concentrations in groundwater lead to public health concerns. Approximately 90% of total nitrate inputs into our groundwater originate from agricultural sources.

Up slightly from last year, 57 public water supply systems exceeded the nitrate drinking water standard of 10 mg/L in 2014 requiring them to post notices, provide bottled water, replace wells, install treatment, or take other corrective actions. Concentrations of nitrate in private water wells have also been found to exceed the standard. A 2007 DATCP survey estimated that 9 % of private wells exceeded the 10 mg/L enforcement standard for nitrate. GCC member agencies are working on multiple initiatives related to reducing the risk of high nitrate levels in groundwater and drinking water.

Bacteria, viruses and other pathogens

Bacteria, viruses, and other pathogens often occur in areas where the depth to groundwater is shallow, in areas where soils are thin, or in areas of fractured bedrock. These agents can cause acute illness and result in life-threatening conditions for young children, the elderly, and those with chronic illnesses. In one assessment (Warzecha et.al., 1994), approximately 23% of private well water samples statewide tested positive for total coliform bacteria, an indicator species of other biological agents. Approximately 3% of these wells tested positive for *E. coli*, an indicator of water borne disease that originates in the mammalian intestinal tract.

Viruses in groundwater are increasingly a 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% of private wells contain detectable viruses. Other studies showed virus presence in four La Crosse municipal wells, in the municipal wells in Madison, and in five shallow municipal wells serving smaller communities.

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. GCC member agencies are involved with research and risk reduction measures as well as emergency response on this issue.

Pesticides

Pesticide contamination in groundwater results from field applications, pesticide spills, misuse, or improper storage and disposal. Pesticide metabolites are related chemical compounds that form when the parent pesticide compounds break down in the soil and groundwater. The most commonly detected pesticide compounds in Wisconsin groundwater are atrazine and metabolites of atrazine, alachlor, and metolachlor.

In 2011, DATCP reported on the results of its [2010 Survey of Weed Management Practices in Wisconsin's Atrazine Prohibition Areas \(PA\)](#). The main purpose of this survey was to identify differences in herbicide use and other weed control practices inside and outside of Wisconsin's atrazine prohibition areas. Survey results suggest that although many corn growers would like the option to use atrazine in a prohibition area, they have adapted to growing corn without it. Half of the respondents indicated that they do not find it more difficult to control weeds in a PA without atrazine.

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 2013, DATCP produced a map showing locations and atrazine levels of private drinking water wells tested for atrazine in the state. 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% of the wells and levels over the enforcement standard in about 8% of the wells. The enforcement standard for atrazine includes atrazine and three of its metabolites.

Arsenic

Naturally occurring arsenic has been detected in wells throughout Wisconsin. DNR historical data show that about 4,000 public wells and over 3,000 private wells have detectable levels of arsenic. About 10% of these wells exceed the federal drinking water standard of 10 µg/L. Although arsenic has been detected in well water samples in every county in Wisconsin, the problem is especially prevalent in northeastern Wisconsin where increased water use has likely released arsenic from rocks and unconsolidated material into the groundwater. GCC member agencies and partners continue to proactively address arsenic concerns through well drilling advisories, health studies, well testing campaigns, and studies aimed at improving geological understanding and developing practical treatment technologies.

Volatile Organic Compounds (VOCs)

Sources of VOCs in Wisconsin's groundwater include landfills, underground storage tanks, and hazardous substance spills. Thousands of wells have been sampled for VOCs and about 60 different VOCs have been found in Wisconsin groundwater. Trichloroethylene is the VOC found most often in Wisconsin's groundwater.

Radionuclides

Naturally-occurring radionuclides, including uranium, radium, and radon, are an increasing concern for groundwater quality, particularly in the Cambrian-Ordovician aquifer system in eastern Wisconsin. The water produced from this aquifer often contains combined radium activity in excess of 5 pCi/L and in some cases in excess of 30 pCi/L. Historically, about 80 public water systems exceeded a radionuclide drinking water standard, causing these communities to search for alternative water supplies or treatment options. The vast majority of

these systems are now serving water that meets the radium standard. The DNR continues to work with the remaining water systems to ensure that they develop a compliance strategy and take corrective actions.

CONDITION OF THE RESOURCE: Groundwater Quantity

Groundwater quantity conditions are summarized below and detailed in the [on-line report](#) .

Groundwater is available in sufficient amounts throughout most of Wisconsin to provide adequate water supplies for most municipal, industrial, agricultural, and domestic uses. What is frequently missed is that groundwater pumping lowers water levels in aquifers and connected lakes, wetlands, and streams; and diverts flow to surface waters where groundwater would have discharged naturally. The amount of water level lowering and flow diversion is a matter of degree. At certain amounts of pumping in an area, streams, lakes, and wetlands can dry up and aquifers can be perilously lowered.

Groundwater pumping shows a continued long term increase. Numbers of high capacity wells, especially in the Central Sands region of the state (parts of Portage, Waushara, Waupaca, Adams, and Marquette Counties), indicates pumping amounts will continue to expand.

Groundwater pumping issues have arisen in multiple regions of Wisconsin. Large scale drawdowns of the confined aquifer have been documented in the Lower Fox River Valley and southeastern Wisconsin. Surface water impacts have been well-documented in the Wisconsin Central Sands and Dane County. These impacts have included the drying of lakes and streams.

BENEFITS OF MONITORING AND RESEARCH PROJECTS

The GCC provides consistency and coordination among state agencies in funding Wisconsin's Groundwater Research and Monitoring Program to meet state agency needs. Approximately \$17 million has been spent over 22 years by DNR, UWS, DATCP, and Commerce more than 400 different projects selected to answer essential management questions and advance understanding of groundwater in Wisconsin.

Projects funded have helped evaluate existing programs, increased the knowledge of the movement of contaminants in the subsurface, and developed new methods for groundwater protection. While the application of the results is broad, a few examples where the results of state-funded groundwater research and monitoring projects are successfully applied to groundwater problems in Wisconsin include:

- Detection and characterization of sources of microbial pathogens
- Groundwater movement in shallow carbonate rocks
- Extent of arsenic in Northeastern Wisconsin
- Best practices for minimizing risk of groundwater contamination
- Methods for diagnosing causes of bacterial contamination in public water systems
- Understanding barriers to private well testing
- Groundwater monitoring at solid waste disposal sites

See the “Benefits from Projects” tab in the [on-line report](#) for more information on how project results are used to improve management of the state's groundwater resources.

RECOMMENDATIONS: DIRECTIONS FOR FUTURE GROUNDWATER PROTECTION

The GCC is directed by statute to include in its annual report a "list and description of current and anticipated groundwater problems" and to "set forth the recommendations of the Council" (s. 15.347(13)(g), Wis. Stats.). In this section, the GCC identifies its recommendations for future groundwater protection and management. These recommendations include top priorities of immediate concern, on-going efforts that require continued support, and emerging issues that will need to be addressed in the near future.

Priority Recommendations

Evaluate the occurrence of viruses and other pathogens in groundwater and groundwater-sourced water supplies, and develop appropriate response tools. Viruses and other microbial pathogens have been found in municipal and domestic wells, challenging previous assumptions about their persistence and transport. Monitoring and assessment should focus on refining our understanding of pathogens in groundwater, in particular where and when they pose threats to human health. Agencies should also work with partners to increase awareness of waste disposal choices, their risks and costs.

Implement practices that protect groundwater from nitrate and other agricultural contaminants (microbial agents, pesticides and their degradates). Nitrate that approaches and exceeds unsafe levels in drinking water is one of the top drinking water contaminants in Wisconsin, posing an acute risk to infants and women who are pregnant, a possible risk to the developing fetus during very early stages of pregnancy, and a chronic risk of serious disease in adults. In addition, pesticides are estimated to be present in one-third of private drinking water wells in Wisconsin. Areas of the state with a higher intensity of agriculture generally have higher frequencies of detections of pesticides and nitrate. Agencies should develop and evaluate a strategy to promote practices that lead to efficient use of nitrogen and careful or reduced use of pesticides in order to protect drinking water sources. Implementation of these practices should be supported with appropriate technical tools and incentives.

Support the sustainable management of groundwater quantity and quality in the state to ensure that water is available to be used, which will protect and improve our health, economy, and environment now and into the future. This includes:

- Supporting an inventory of information on the location, quantity, and uses of the state's groundwater
- Supporting targeted monitoring and modeling of the impact of groundwater withdrawals on other waters of the state
- Supporting identification and evaluation of options for areas with limited groundwater resources

Ongoing Recommendations

Without ongoing attention to the following needs, Wisconsin cannot address the priority recommendations (see above) or begin to understand emerging issues (see below).

Support implementation of the Statewide Groundwater Monitoring Strategy. Chapter 160 of the Wisconsin Statutes requires the DNR to work with other agencies and the GCC to develop and operate a system for monitoring and sampling groundwater to determine whether harmful substances are present (s. 160.27, Wis. Stats.). The strategy has been incorporated into the DNR Water Monitoring Strategy, but needs are constantly evolving as new problems emerge. For example, food processors, homeowners, municipalities, and well drilling

contractors need more information about the origin and extent of naturally occurring contaminants such as arsenic, other heavy metals, acidic conditions, sulfate, total dissolved solids, radium, and uranium. Wisconsin should improve the accessibility of current data and continue to encourage research efforts that will provide information for addressing these issues. State agencies, the university, and federal and local partners should continue to implement and modify this strategy to efficiently meet monitoring objectives.

Continue to catalog Wisconsin's groundwater resources. Management and protection of Wisconsin's groundwater resources requires publically-accessible and up-to-date data in order to foster informed decisions, not only on state policy matters but also for sound business decisions on siting or technology investments. State agencies and the University should continue to collect, catalog, share, and interpret new data about Wisconsin's groundwater so that it can be used by health care providers and people seeking business locations, as well as homeowners and local governments.

Continue to support applied groundwater research. Focus on investments to identify and test cost-effective groundwater protection strategies that can prevent groundwater problems before they need to be remediated at a much greater cost. State agencies should work to maximize collaboration to answer the key groundwater questions facing Wisconsin water suppliers. To maintain adequate levels of support, agencies should seek leveraging partnerships for applied analysis and innovation.

Emerging Issues

Industrial sand mining. Since 2010, unprecedented growth of industrial sand mining and processing has occurred in West-Central Wisconsin and is expected to continue growing for another decade. The potential impact of this industry on groundwater resources has not been comprehensively evaluated, which would be the first step to avoid problems and plan for restoration. Wisconsin should support data analysis and field investigations to understand how this industry might impact groundwater. Agencies should partner with industry and local governments to develop and adapt site analysis and best-management practices for this industry.

Livestock industry expansion. Since 2010, many animal feeding operations that house thousands of animals have been sited or proposed in Wisconsin. These operations require large quantities of groundwater for both animals and animal food crops, and must also dispose of large amounts of animal waste. Wisconsin agencies should develop efficient and effective ways for measuring groundwater quality and quantity conditions in and around these operations. Agencies, industry and local governments should partner to develop policies and innovations that allow for effective siting and efficient operation of these facilities, while still protecting groundwater quality and quantity.

Effects of extreme weather. More prolonged drought or heat waves can increase groundwater demand at the same time as reducing supply. Groundwater quality may be affected by large fluctuations in water table elevation that can occur with extreme weather. More severe flooding can affect groundwater quality, wells and water system operations. Public drinking water supplies as well as water-dependent industries need reliable estimates of these effects in order to develop practical emergency response and adaptation strategies. To understand and predict the impact of these changes on the state's groundwater, agencies should develop the data and provide analyses of likely scenarios for quantity and quality of Wisconsin's groundwater supply.

Metallic mining. Lead, zinc, iron and copper deposits exist around Wisconsin. These deposits may be mined in the future and are located in sparsely-populated regions where background information on groundwater resources is often incomplete. The state should support background data collection and groundwater assessments so that future decisions about potential mining operations can be made most efficiently.

DEPARTMENT OF NATURAL RESOURCES

The Department of Natural Resources (DNR) 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 DNR establishes the groundwater quality standards for the state under authority of ch. 160, Wis. Stats. In addition, the DNR manages groundwater quantity under provisions of ss. 281.11, 12, 34, and 346, Wis. Stats. The DNR 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 implementation of groundwater quality standards contained in ch. NR 140, Wis. Adm. Code, and works closely with other programs and agencies to implement Chapter 160, Wis. Stats., including groundwater monitoring, data management, hydrogeologic advice, and staffing the Groundwater Coordinating Council. Groundwater quantity provisions (2003 Wisconsin Act 310, codified at s. 281.34, Stats. and ch. NR 820) and the Great Lakes Compact (2007 Wisconsin Act 227, codified at ss. 281.343 and 281.346, Stats.) are also 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 (including the Site Assessment Grant program through 2010), “high priority” leaking underground storage tanks, closed wastewater and solid waste facilities, hazardous waste corrective action and generator closures, and sediment cleanup actions, all of which are closely related to groundwater issues. 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/>.

Drinking Water and Groundwater Program

Groundwater Quality Standards Implementation

Chapter 160, Wis. Stats., requires the DNR to develop numerical groundwater quality standards which consists of enforcement standards and preventive action limits for substances detected in, or having a reasonable probability of entering, the groundwater resources of the state. Chapter NR 140, Wis. Adm. Code (<http://legis.wisconsin.gov/rsb/code/nr/nr140.pdf>), establishes these groundwater standards and

creates a framework for their implementation. Groundwater quality standards are set for 138 substances of public health concern, 8 substances of public welfare concern and 15 indicator parameter substances in ch. NR 140.

Revisions to ch. NR 140 groundwater quality standards were last adopted by the Legislature in 2010. Following the required schedule, DNR is currently canvassing agencies for any new substances that have been detected in or have a reasonable probability of entering groundwater to start the process of determining whether any new or revised standards are needed.

To help ensure awareness of known health risks, DNR updated its [table](#) listing health and welfare based enforcement standards (ch. NR 140), state public drinking water standards (ch. NR 809), and established health advisory levels (HALs) for substances in water reflect new or revised health advisory levels set this year. This table of regulatory standards and advisory levels provides a useful source of information to members of the public concerned about the safety of their drinking water, and it is also a valuable resource for agency staff and consultants involved with groundwater contamination and remediation actions. Links to resource web sites allows users to obtain additional toxicological and health related information on many of the substances listed in the table.

DNR staff from several programs worked together in 2014 to identify policy issues, to develop guidance, and to provide training related to the implementation of groundwater quality standards, including training for landspreading discharge permit writing and animal waste drinking water well contamination response. Groundwater and runoff program staffs regularly consult on groundwater quality issues that arise in agricultural and urban runoff programs. Such coordination is critical in obtaining statewide consistency on how the DNR evaluates and reduces risk of groundwater contamination associated with regulated activities.

DNR staff actively participated in the technical work group on Wisconsin-specific provisions to the NRCS conservation practice standard for agricultural nutrient management ([NRCS Code 590](#)). All states are updating their provisions to be consistent with updated federal standards, including revisions related to nitrogen. Participants in federal and some state farm programs, as well as some state permit holders, must comply with the federal conservation practice standards.

Groundwater Quantity Program Implementation

The DNR is authorized under ch. 283, Wisc. Stat. to regulate wells on any property where the combined capacity of all wells on the property, pumped or flowing, exceeds 70 gallons per minute (100,000 gallons per day). Such wells are defined as high capacity wells. Since 1945, the DNR has reviewed proposed high capacity wells for compliance with applicable well construction rules and to determine whether the well would impair the water supply of a public utility well. The DNR review of high capacity wells has been evolving over the last decade as described in the paragraphs below. To improve efficiency and consistency of review, DNR implemented a ‘lean’ project in 2013 to address the broadened scope and increased complexity of the high capacity review process for non-potable wells. The project increased efficiency by streamlining high capacity application and approval forms and eliminated duplication within the review process.

In May of 2004, the statutes regarding high capacity wells were expanded through 2003 Wisconsin Act 310 to give the DNR additional authority to consider environmental impacts of proposed wells on critical surface water resources and springs. DNR may deny or limit an approval to assure that proposed high capacity wells do not cause significant adverse environmental impacts to these valuable water resources. The Act 310 changes are implemented primarily through ch. NR 820, Wis. Adm. Code. NR 820 provides a mechanism for evaluating proposed high capacity wells to determine whether the well will have a significant adverse environmental impact on large springs, trout streams, or outstanding and exceptional

resource waters. DNR water use section staff implement the programs created by Act 310 including reviewing applications, managing data, and collecting water withdrawal reports.

The Wisconsin Supreme Court's July 2011 decision in [*Lake Beulah Management District v. State, 2011 WI 54 \(2011\)*](#) has further modified DNR high capacity well application reviews. The *Lake Beulah* case involved approval of a high capacity well for the Village of East Troy and the extent of possible impacts to nearby Lake Beulah. The Court concluded that "the DNR has the authority and a general duty to consider whether a proposed high capacity well may harm waters of the state".

Given the Wisconsin Supreme Court's affirmation of DNR authority in the *Lake Beulah* decision, the DNR has broadened the scope of its high capacity well application review beyond the specific considerations of Wis. Stat. s. 281.34 and Ch. NR 820. DNR's scope of review for high capacity well applications now includes potential impacts to all waters of the state, including all surface waters, wetlands, and public and private wells.

Great Lakes Compact and Implementation of 2007 Act 227

The Great Lakes—St. Lawrence River Basin Water Resources Compact (Compact) took effect on December 8, 2008 following ratification in each of the eight Great Lakes States and Congress' consent. DNR water use section staff implements Compact-related programs including authorizing permits, implementing the water conservation and efficiency program, reviewing diversion applications, and working in conjunction with groundwater quantity staff to collect annual water withdrawal reports.

The DNR has promulgated four administrative rules to implement the Compact and associated statewide water use legislation. Three of these rules took effect January 1, 2011: Water Use Registration and Reporting (ch. NR 856); Water Use Fees (ch. NR 850); and Water Conservation and Water Use Efficiency (ch. NR 852). The Water Use Permitting rule (ch. NR 860) took effect in December 2011. Three additional rules are still in the drafting stage. These rules include Water Supply Service Area Planning, Water Loss and Consumptive Use, and Water Use Public Participation.

Water Use Registration and Reporting

Following implementation of the Compact, all new or increased withdrawers that have the capacity on their property to withdraw 100,000 gallons per day (gpd) or more for 30 days must register with the WDNR prior to withdrawing groundwater or surface water. This is typically done in conjunction with other approval or permitting procedures.

WDNR continues to upgrade water use data management systems, improve existing registration data, and expand data collection methods. These efforts resulted in an increase in withdrawal report response rates from below 50 percent in 2008 to 79 percent in 2010. These improvements continued so that the reporting response rate for 2013 reached 95 percent.

Water Withdrawal Registrations by Source Type and Major Basin (2013)

	Great Lakes Basin	Mississippi River Basin	Total
Groundwater	3,496	9,467	12,963
Surface Water	356	636	992
Total	3,852	10,103	13,955

Persons with registered withdrawals must measure or estimate their monthly withdrawal volumes and report the previous calendar years' monthly water use by March 1 of each year. These reports are

collected and analyzed for errors and inconsistencies. Summary analysis is conducted on reported withdrawals and an annual water withdrawal reporting summary is made publicly available on the [WDNR website](#). Individual reports are also provided upon request to governmental partners, researchers, businesses and private individuals.

Water Conservation and Water Use Efficiency

Ch. NR 852, Wis. Adm. Code establishes a mandatory water conservation and water use efficiency program for new or increased Great Lakes Basin surface water and groundwater withdrawals. In addition, mandatory conservation is required for any new or increased diversions of Great Lakes water and water withdrawals statewide that would result in a water loss of two million gallons per day or more. The rule identifies conservation and efficiency measures that withdrawals subject to the mandatory program must meet.

The rule helps guide a statewide voluntary water conservation and efficiency program which focuses on providing information and education, identifying and disseminating information on new conservation and efficiency measures, and identifying water conservation and efficiency research needs. The program is coordinated with the Public Service Commission and the Department of Safety and Professional Services. Education and outreach programs include an annual promotion of Fix-a-Leak Week, geared towards encouraging homeowners to check and fix toilet leaks. Other activities include participation in the DNR's State Fair with an exhibit on high efficiency plumbing fixtures.

Water Use Permits

Water Use Permits are required for Great Lakes Basin groundwater or surface water withdrawals averaging 100,000 gallons per day or more in any 30-day period. General permits (valid until 2036) are required for withdrawals of 100,000 gallons per day averaged over 30 days up to 1,000,000 gallons of water for 30 consecutive days. Individual permits (valid for 10-years) are required for withdrawals of 1,000,000 gallons per day or more for 30 consecutive days. Chapter NR 860, Wis. Adm. Code prescribes a review process for the individual permits requires an additional environmental review. Since December 8, 2011, 192 permits have been issued to new or increased withdrawals in the Great Lakes Basin.

Water Use Fees

Wisconsin Act 28 contained statutory language directing the DNR to collect water use fees to fund Great Lakes Compact implementation and water use program development in Wisconsin. The statute directs that all persons with water supply systems with the capacity to withdraw 100,000 gallons per day or more must pay an annual \$125 fee per property. Act 28 also directed the DNR to promulgate a rule imposing an additional fee on Great Lakes Basin water users withdrawing more than 50 million gallons per year. That rule, ch. NR 850, Wis. Adm. Code, prescribes a tiered system for additional Great Lakes Basin fees on withdrawals exceeding 50 million gallons per year. Water use fee revenue is used to: document and monitor water use through the new registration and reporting requirements; implement the Great Lakes Compact through water use permitting and regulate diversion of Great Lakes Basin waters; help communities plan water supply needs; build a statewide water conservation and efficiency program; and to develop and maintain a statewide water resources inventory.

Frac Sand Mining

The rapid growth of industrial frac sand mining has created economic opportunity, but requires the state to address a variety of potential side-effects. The locations of sand deposits, hence many of the mines, are near trout streams and other sensitive resources and require more comprehensive high capacity well reviews, often including analysis of pumping tests or numerical groundwater models. Concerns have been raised over potential for contamination from flocculants used during sand processing. DG has been working with Chippewa County as they evaluate potential risks associated with these chemicals.

Prospecting boreholes have often been left unfilled or improperly filled and sealed which creates conduits for contaminants to reach groundwater. DG is assisting in a sampling program to investigate the potential for acid mine drainage caused by sulfide oxidation. DG is working with Chippewa County, the WGNHS, and the USGS to model groundwater impacts from mine and irrigation wells.

Well Construction and Private Wells

Well Construction and Private Wells

DG sets and enforces minimum standards for well construction, pump installation, and well filling and sealing through ch. NR 812, Wis. Adm. Code. The standards are intended not only to provide health protection, but also to protect groundwater. DG licenses and educates well drillers and pump installers under ch. NR 146, Wis. Adm. Code so that they are qualified to construct wells in a way that meets standards and won't contaminate groundwater.

Advance notification to DNR is required for all new and replacement well construction. After construction, drillers submit Well Construction Reports to the DNR describing the construction of each well drilled. Private Water Supply staff enforce minimum well construction standards by conducting compliance inspections to observe wells during construction, and reviewing well construction reports and associated sampling. During the past year violations have included: failure to fill and seal exploratory boreholes, failing to obtain well water quality samples, failure to notify well owners of unsafe water test results, and well drilling or pump installing by unlicensed contractors.

DNR worked with water well and heat exchange drillers and industry groups to complete rule revisions to NR 146 and NR 812, Wis. Adm. Code. Revisions went into effect on October 1, 2014. Key changes include:

- new heat exchange drilling license
- on-line notification for most heat exchange drillholes
- additional nitrate and arsenic sampling requirements for pump work and property transfer well inspections
- consistent process for voluntary well inspections at the time of a real estate transfer

DNR Private Water Supply staff offered eight Continuing Education sessions for well drillers and pump installers, in conjunction with the Wisconsin Water Well Association. 2015 Continuing Education focused on rule revisions, including new requirements for well and pressure system inspections associated with property transfer. DNR will conduct a customer survey in mid-2016 to identify ways to improve the Continuing Education process to provide quality, cost-effective training.

A team led by Private Water staff conducted a "Lean" project in 2015 to identify improvements the Well Driller and Pump Installer License Renewal process. Team recommendations include consolidating forms to reduce mailing costs, eliminating unnecessary questions on the form, and automating to allow on-line renewal. Recommendations will be implemented in two phases, beginning in fall 2015.

Private Water Supply staff is the first-responders to complaints regarding the contamination of private wells. Well contamination by manure has been an increasing problem in recent years. Heavy rains and farm equipment failure in fall of 2014 resulted in several well contamination events in northeastern Wisconsin. Using the results of analytical tools for tracking the source of microbial contamination – known as MST sampling - staff were able to determine that fecal contamination was due to grazing animal manure rather than human sources. Agency news releases to both the agricultural community and general media emphasize ways to avoid contamination and encourage regular testing by private well owners. Joint training for DG staff and DNR animal waste specialists is held each year to increase staff efficiency and effectiveness in responding to manure contamination emergencies.

DG encourages private well owners to test their wells annually for bacteria, and other contaminants they may be concerned about. Private Water staff continues to maintain the popular web page titled “[What’s Wrong with My Water?](#)” to help answer commonly-asked questions about private well water quantity, helps well owners diagnose their aesthetic water quality problems, and provide DNR water supply institutional knowledge.

DG continues to promote electronic management of well construction, well abandonment, and other information. Private Water staff recently developed an on-line Well Abandonment Report system, which allows licensed individuals to submit required well filling and sealing reports electronically. The new on-line system will be promoted during 2015, and electronically filing will be required by July 1, 2016. DG is working to provide drillers with internet-based access to the most current data needed to make sound well siting decisions, including well construction reports, location of waste disposal and remediation sites, and many other related maps.

Public water systems

DG’s Public Water Supply (PWS) program oversees monitoring of public water systems through ch. NR 809 (Safe Drinking Water), Wis. Adm. Code to ensure all public water systems are safe to drink and use. Working in cooperation with owners and operators of water systems, the PWS program ensures that samples are collected and analyses completed to determine if the water meets federal Safe Drinking Water Act (SDWA) standards. The PWS program regulates the operation of public water systems through ch. NR 810 and the general design and construction of community water systems through ch. NR 811. The PWS program also works to educate water system owners and operators concerning proper operation and maintenance of water systems to ensure safe drinking water for Wisconsin consumers.

The PWS program developed and continues to maintain data about Wisconsin’s drinking water and groundwater quality through the [Drinking Water System database](#). The Drinking Water System is an important tool used to efficiently enforce SDWA regulations for public water systems. It contains the monitoring and reporting requirements for each public water system and their drinking water sampling results. It also includes violations for any missing requirements and exceedances of the maximum contaminant levels (MCLs).

In 2013, DG implemented a new data system to accept and store monthly operating report (MOR) data from public drinking water systems. MORs contain required documentation of a system’s operations such as monthly pumpage, chlorine residual, turbidity, and temperature. Previously, MORs were submitted in various types of electronic spreadsheets or paper formatted reports. The Electronic Monthly Operating Report (EMOR) is a web-based application that began accepting data in 2012. EMOR uses a standard format and has the ability to generate data reports to make water quality and quantity management decisions.

This past year, DG saw an increase in transient non-community (TN) public water systems exceed the nitrate MCL of 10 mg/L. 21 additional TN systems exceeded the standard compared to the previous year. These systems, which include taverns, restaurants, churches, and campgrounds, were required to post notices warning customers of the exceedance and to provide bottled water to infants and pregnant women. The higher nitrate concentrations were a result of increasing concentrations in groundwater caused by land use activities and weather patterns. The public water supply program continues to work with other DNR programs and external partners to reduce nitrate in groundwater and surface water. For additional information about the Public Water Supply Program you can review the current [Annual Compliance Report](#).

Wellhead protection

The goal of Wisconsin's Wellhead Protection (WHP) program is to reduce the risk of groundwater contamination in areas contributing groundwater recharge to public water supply wells, consistent with the state's overall goal of groundwater protection. A WHP plan is required for new municipal wells and must be approved by the DNR before the new well can be used. A WHP plan is voluntary for any public water supply well approved prior to May 1, 1992; the DNR promotes and encourages but does not require wellhead protection planning for these older wells.

DNR and Wisconsin Rural Water Association (WRWA) are working together on pro-active strategic interventions to support wellhead protection actions in selected communities with wells susceptible to contamination. In particular, DNR, WRWA and other partners are developing groundwater monitoring, modelling and related tools to demonstrate a community-based preventive approach to rising nitrate levels.

DNR continues to measure and report to US EPA on the percent of public water systems that are protected by substantial implementation of wellhead protection. In 2014, 15% of Wisconsin public water systems were protected by implementation of a WHP plan. In FY14, approximately 20 communities submitted wellhead protection plans to the DNR. Over 400 communities now have a WHP plan for at least one of their wells.

DNR maintains a [web page](#) with a variety of information aimed at encouraging and supporting water utilities in protecting their water supplies from potential sources of contamination.

DNR staff from a variety of water programs completed several collaborative projects to more effectively align management of both phosphorus and nitrogen losses to lakes, streams and groundwater. Different chemical behavior and separate Clean Water and Drinking Water federal laws make coordination somewhat challenging. Wisconsin's Nutrient Reduction Strategy and its newly-revised Nonpoint Source Program Plan now more thoroughly address both groundwater and surface water.

For the fourteenth year in a row, DNR staff worked with the Groundwater Center at the Center for Watershed Science and Education (CWSE) and the Wisconsin Geological and Natural History Survey (WGNHS) to sponsor three groundwater workshops for teachers in January and February. Educators from 24 schools centers took part in the workshops and were able to take a free groundwater model back to their school. Besides learning how to use the groundwater model, the educators received groundwater resources to incorporate groundwater concepts into their classroom. The intent of the workshops is to provide information for teachers to educate students – and their parents – on the importance of protecting groundwater in their own communities. With funding from an EPA WHP grant, groundwater models have been given to over 300 schools or nature centers since 2001 and nearly 600 educators have received hands-on training in using the model effectively.

DNR and WRWA staff continues to coordinate their assistance to local protection efforts. WRWA staff work on plans for individual communities and area wide plans for multiple water supply systems. DNR staff reviewed draft plans and ordinances and provided technical advice to local officials responsible for carrying out wellhead protection.

Groundwater Information and Education

In 2014, the Groundwater Coordinating Council Report to the Legislature went on-line in interactive format. Web visits and time spent at the site increased substantially. Phone inquiries about the subject matter in the report were received for the first time in over five years.

Well drillers and pump installers, water testing providers, local health and conservation departments, health care providers and many individuals requested and received hundreds of thousands printed

publications on groundwater. Among the most-frequently requested items were: Nitrate, *Groundwater: Wisconsin's Buried Treasure* publication, and the *Groundwater Study Guide* packet.

Groundwater Monitoring and Research

Chapter 160 of the Wisconsin Statutes requires the DNR to work with other agencies and the Groundwater Coordinating Council (GCC) to develop and operate a program for monitoring and sampling groundwater to determine whether harmful substances are present (s. 160.27, Wis. Stats.). The DNR has also supported groundwater monitoring studies evaluating existing design and/or management practices associated with potential sources of groundwater contamination. The intent of these studies is to reduce the impacts of potential sources of contamination by changing the way land activities that may impact groundwater are conducted. See the “Benefits” tab on the [GCC website](#) for more information on the benefits from DNR’s monitoring studies.

Four [projects](#) began in FY14 for a total investment of \$364,332 and seven [new projects](#) were selected through the Joint Solicitation process for funding in FY15. Final reports and 2-page research summaries are available for many projects from the [Water Resources Institute website](#).

DNR has committed \$80,000 annually to the ongoing maintenance of the statewide groundwater monitoring network. Groundwater level monitoring is one part of the overall groundwater monitoring strategy. The objective of the strategy is to coordinate groundwater monitoring between all agencies that assess groundwater quality and quantity in the state and work to include all key monitoring components, including:

- A fixed network of groundwater level monitoring locations
- A statewide assessment of groundwater quality
- A fixed network of groundwater quality monitoring sites
- Surface water monitoring stations
- Water use reporting

The groundwater monitoring strategy is integrated into DNR’s overall water monitoring plan.

Groundwater Data Management

DNR’s consolidated Groundwater Retrieval Network ([GRN](#)) accesses groundwater data from database systems in the Waste & Materials Management, Drinking Water & Groundwater, and Watershed Management programs, including information on approximately 300,000 wells. These wells represent public and private water supply wells, piezometers, monitoring wells, non-potable wells, and groundwater extraction wells. DG staff continued to improve the locational data associated with GRN’s wells and the ease with which the data can be accessed.

The DNR’s high capacity well and surface water intake data continues to improve. Since the database was developed in 2007, much of the previously existing locational and ownership information has been verified or updated to improve data quality. The improved data quality has helped increase response rates on annual water withdrawal reporting. Between 2008 and 2013, reporting response rates increased from 60% to over 95%. The online reporting system has increased reporting accessibility and improved communication with the user community.

The DNR continued to make progress on several other groundwater-related data initiatives in FY14. DG continued to improve its public water supply well data and coordinated efforts with the RR, WMM, and WT programs to improve the DNR’s data on significant potential sources of contamination that may contaminate these wells. With DNR financial support, WGNHS has developed a map-based application to access a varied catalog of hydrogeologic data and related information.

DNR staff updated the DG Mapping Application which is a geographic information system that maps locations of high-capacity wells, trout streams, springs, outstanding water resources and exceptional water resources, public wells, source water areas, and potential contaminant sources within source water areas in a format consistent with high-capacity well approval, public water system vulnerability assessment, wellhead protection, and related drinking water and groundwater needs. Update work began on related applications that use maps of potential contaminant sources along with well construction, monitoring, and geologic information to help determine the susceptibility of public wells to contamination. Design work began on an application to provide on-line, real-time maps that well drillers and realty professionals can use to ensure the safest possible drinking water well location and construction. These applications are at the leading edge of DNR's efforts in integrating spatial and tabular data toward the goal of public health and resource protection.

Remediation and Redevelopment Program

The Remediation and Redevelopment (RR) program has primary responsibility for implementing and aiding cleanups under the Spill Law, the Environmental Repair Law, federal programs (Superfund, Hazardous Waste Corrective Action and Closure, Leaking Underground Storage Tanks (LUST), and Brownfields), , the Drycleaner Environmental Response Fund, Petroleum Environmental Compensation Fund Act, and at closed landfills. The RR program provides technical assistance, helps to clarify legal liability, provides financial assistance primarily to local governmental units, and provides technical project oversight of cleanup projects.

All cleanups are conducted according to the ch. NR 700 rule series, Wis. Adm. Code, Investigation and Remediation of Environmental Contamination, and ch. NR 140, Groundwater Quality. The majority of cleanups are done by persons responsible under the laws, or persons or groups involved in the redevelopment of potentially contaminated properties. Program staff provide technical assistance on cleanups conducted by consultants at the direction of responsible parties. In addition, RR staff contract and direct consultants on state-funded cleanups. The RR Program also provides assistance for spill response, sometimes with the aid of a contractor; and works with other agencies, particularly the U.S. EPA Removals Program, for conducting major spill response actions and removal of hazardous substances when the responsible party is unable or unwilling to do so and there is a risk to public health, welfare, or to the environment.

Cleanup Of Groundwater Contamination

As of mid-June, in FY15, the program spent over \$800,000 in Environmental Fund dollars and over \$200,000 in bonding to initiate or continue environmental cleanup actions at over 28 locations where groundwater contamination is known or suspected. The Environmental Fund is used when contamination is significant but no identifiable private party has legal responsibility for the contamination, the person(s) legally responsible do not have the financial ability to proceed, or the responsible person simply refuses to proceed. Private contractors conduct these cleanups with oversight by DNR staff. Whenever feasible, the RR program and legal staff attempt to recover costs from responsible persons after the cleanups are undertaken.

Investigation, Cleanup and Redevelopment of Brownfields

Brownfields are abandoned, idle, or underused industrial or commercial facilities or sites whose expansion or development is adversely affected by actual or perceived environmental contamination. The RR program coordinates several efforts to encourage local governments and private businesses to cleanup and redevelop brownfield properties. At many brownfields sites, the release of hazardous substances threatens groundwater quality.

The RR Program also provides redevelopment assistance at brownfield sites with groundwater contamination. Program staff assists local governments and private businesses with the cleanup and redevelopment of brownfields by providing technical assistance. In many cases, these properties have groundwater contamination or soil contamination that poses a threat to groundwater.

The RR program also provides a number of different types of assurance, comfort, or general liability clarification letters related to properties with groundwater contamination. Collectively, these letters facilitate the reuse and development of properties. Since 1994, the RR program provided 3000 redevelopment assistant reviews – which can include liability clarification letters, off-site exemption letters, cleanup agreements for tax delinquent properties, building on abandoned landfill approvals, etc. – at Brownfield properties throughout the state.

The RR program also continues to provide technical assistance and assist parties with voluntary investigations and cleanups of Brownfield properties through the Voluntary Party Liability Exemption (VPLE) process. Many sites that follow the VPLE process have contaminated groundwater.

After a person has conducted an environmental investigation of the property and cleaned up soil and groundwater contamination, the DNR will issue a "Certificate of Completion" which provides a release from future liability for any contamination that occurred on the property prior to issuance of the certificate. Since 1994, the DNR issued 145 certificates of completion.

Dry Cleaner Environmental Response Fund (DERF) Program

The DERF program reimburses dry cleaner owners and operators for eligible costs associated with the cleanup of soil and groundwater at sites contaminated by dry-cleaning solvents. Fees paid by the dry-cleaning industry provide program funding. Environmental cleanups at dry cleaner sites are conducted following the ch. NR 700 rule series. There are 230 sites in the program, with 156 at various stages of investigation and cleanup and 74 sites closed. The program is implemented through ch. NR 169, Wis. Adm. Code.

Tracking System and GIS Applications

The program's main database on the status of sites undergoing investigation and/or cleanup is the Bureau of Remediation and Redevelopment Tracking System ([BRRTS](#)).

In 2001, revisions to ch. NR 726, 716, 749, 811, and 812 implemented a Geographic Information System (GIS) Registry of Closed Remediation Sites to replace the requirement to record groundwater use restrictions at the County Register of Deeds Office. In 2002, additional rule revisions required the inclusion of sites with residual soil contamination on the GIS Registry. The GIS Registry currently includes locational information on sites closed with residual groundwater contamination above the ch. NR 140 enforcement standards and sites closed with soil contamination above ch. NR 720 soil standards, as well as site specific information pertaining to where the contamination is on the property in question and at what concentration it was found at the time the closure decision was made. In 2006, the spill law was amended (see s. 292.12, Wis. Stats.) to expand the use of DNR's databases to track sites with residual contamination left in place at the time of case closure.

Inclusion of the [GIS Registry](#) on the Internet provides a means of notifying future owners or users of the property of the existence of soil and/or groundwater contamination, as well as any responsibilities of the property owner (or occupant in some cases) to comply with any conditions of closure. The site specific information is attached to each site by a link to a .pdf.

The GIS Registry is to be used with well construction requirements for private wells, and with a setback distance for new municipal wells. Beginning in July 2004, the DNR made the GIS Registry information available to well drillers through a Well Construction CD that is updated twice a year. Before drilling, well drillers are asked to consult the CD to determine if a well is proposed for a property listed on the

Registry. If the proposed well is located on a closed remediation site, then the driller must contact regional Drinking Water and Groundwater staff prior to any well construction activities to determine if additional casing or other construction techniques may be required.

In 2005, an expanded GIS application was made available, called the [RR Sites Map](#). This application shows the locations of the majority of sites available on BRRTS (open and closed), or provides an address for those sites for which geolocal coordinates have not yet been obtained. In 2008, additional data regarding financial tools and liability clarification actions were added, so RR Sites Map now provides even more information on redevelopment and cleanup activities. In June of 2013, RR Sites Map was migrated to Geocortex where it obtained a new look, but kept the same functionality.

The GIS applications are linked to BRRTS on the Web and are all useful for locating potential contamination sites when evaluating new municipal well placement or for property transactions. These databases make site specific information on open and closed remediation sites much more available and accessible to the public and specific interested groups, particularly those wanting to install or replace a potable well on an affected property, as well as those buying properties. Sites regulated by the Department of Agriculture and the Trade and Consumer Protection are also included in BRRTS on the Web, the GIS Registry, and RR Sites Map.

The RR Program continues to make improvements to both BRRTS and the GIS applications. In addition to the ongoing programming efforts, work continues on quality assurance and quality control (QA/QC) of existing data.

Waste and Materials Management Program

Monitoring Groundwater Quality Around Landfills

Waste and Materials Management Program (WMM) implements the DNR's Groundwater Standards Program in several ways during the life of a landfill. When staff review an applicant's "Feasibility Report," which proposes to site a landfill at a particular location, they review baseline groundwater data submitted by the applicant to determine whether exemptions and alternative concentration limits (ACLs) to the established ch. NR 140 groundwater standards are needed for the public health and welfare parameters, based on the concentrations of those substances present in the groundwater before landfill development. In addition, reviewers establish preventive action limits (PALs) for indicator parameters based on statistical calculations of the baseline concentrations.

During the active life of a landfill and after closure, staff review routine groundwater detection monitoring data, collected and submitted by the landfill owner at sites where monitoring is required to determine compliance with ch. NR 140 standards and site-specific ACLs and PALs. Ch. NR 140 provides a list of response actions that the DNR may require a facility to take after a groundwater standard exceedance is confirmed. Should conditions warrant, staff require groundwater investigation reports that include proposals for further evaluations and recommendations for remediation at landfills that exceed groundwater standards. Staff review results of site investigations triggered by the exceedances of groundwater standards and evaluate the effectiveness of remedial actions at active solid waste facilities and closed landfills by comparing results to groundwater standards and by looking at concentration trends over time.

WMM accepts only electronic submittal of environmental monitoring data from landfill owners, labs, and consultants. The electronic data submittals are currently uploaded by DNR to the WMM Groundwater and Environmental Monitoring System (GEMS) database. In the future, a web interface, possibly using the Department's Data Portal and/or Web Access Management System, will allow facilities to upload

environmental monitoring data into GEMS. Currently, funding is not available to do the necessary programming. In 2006, WMM began providing facilities and the public access to the environmental monitoring data contained in GEMS by using “GEMS on the web.” “GEMS on the web” was updated in 2013 to allow more flexibility in choosing a specific date range and particular monitoring points.

In late 2014, the WMM Program finalized updating its guidance document on reducing or terminating groundwater monitoring at landfills, which places stronger emphasis on having facilities collect water samples for VOC analysis rather than for indicator parameters, in exchange for a reduced sampling frequency.

Monitoring Groundwater Quality Around Metallic Mines

The Waste and Materials Management Program regulates metallic mining activity in the state. Issues related to groundwater quantity and groundwater quality are critical in determining whether a proposed mining project receives necessary approvals. State statutes have created separate approval processes for non-ferrous mining projects (Chapter 293, Stats.) and ferrous mining projects (Chapter 295, Stats.). The regulatory framework for ferrous mining projects was recently created through enactment of 2013 Wisconsin Act 1 in March of 2013. The law created a process by which iron mining projects are evaluated and includes provisions related to groundwater withdrawals, mining waste site design and operation and protection of groundwater quality. The law requires compliance with existing groundwater quality standards but establishes point of standards application and evaluation processes and criteria that are unique to ferrous mining projects.

On March 24, 2015, the Department received notification from Gogebic Taconite, LLC that they are withdrawing their pre-application for the proposed ferrous mining project in Iron and Ashland Counties.

Water Quality Program

The Bureau of Water Quality (WQ) is responsible for statewide implementation of DNR’s groundwater standards primarily through the issuance of discharge permits to facilities, operations, and activities that discharge treated wastewater and residuals to groundwater.

Wastewater Discharges

WQ issues Wisconsin Pollutant Discharge Elimination System (WPDES) permits to all communities, industrial facilities, and large privately owned wastewater systems which discharge treated domestic or industrial wastewater to groundwater through land treatment/disposal systems. These systems are primarily spray irrigation, seepage cell, subsurface absorption systems, and ridge & furrow treatment systems regulated under ch. NR 206, Wis. Adm. Code (domestic wastewater) and ch. NR 214, Wis. Adm. Code (industrial wastewater). WPDES permits issued to these facilities contain groundwater monitoring and data submittal requirements that are used to evaluate facility compliance with ch. NR 140, Wis. Adm. Code (groundwater quality standards). Groundwater monitoring systems at existing facilities are evaluated and upgraded as necessary at permit re-issuance. In 2015, DNR issued 10 new permits for municipal and industrial facilities that discharge directly to land disposal (groundwater), bringing the total number of such permits to 214.

DNR also regulates the land application of organic industrial wastes, municipal biosolids and septage (chapters NR 214, 113, and 206) through approval of land spreading sites and requirements on locations, loading rates, nutrient levels, and time of year. In recent years, as the quantities of these materials and agricultural manure have increased, competition for acceptable land spreading sites has increased,

particularly in some areas of the state. Some instances of unacceptable impacts to groundwater have occurred associated with these activities. In addition, DNR has pushed land spreading entities to provide for more storage capacity to minimize winter and spring runoff to surface water. As a result, wastewater generators and haulers have sought to utilize existing tanks and lagoons, and in some cases, substandard earthen manure pits or substandard storage tanks. The industrial wastewater program has affirmed code requirements to insure older structures meet the standards needed to assure storage is environmentally sound, protective of both groundwater and surface water.

WQ maintains a database, designated the System for Wastewater Applications, Monitoring, and Permits (SWAMP), for holders of specific WPDES and general permits. This database system stores facility-specific information such as address, contacts, location, permit requirements, monitoring results, and violations of permit requirements for private and municipal wastewater treatment facilities. The system contains current information on groundwater, wastewater, and biosolids treatment/management. Historical sampling data from groundwater monitoring wells is available through the system and current sample results are added on a monthly basis. Sampling results and site loading information are also available for land application of municipal biosolids, septage and industrial sludge, by-product solids, and wastewater.

WQ assists and participates in local planning efforts for existing developed areas (served by onsite wastewater treatment systems) that are investigating the possibility of providing a public sewerage system.

DNR continues to monitor the Nondomestic Wastewater to a Subsurface Soil Absorption System general permit it reissued in 2011; the general permit is in use at 25 sites. The requirements for requesting a permit, and for renewing permit coverage, revisit the setback requirements for changes due to new water supply wells during the previous permit period. The general permit is renewed every five years. The renewal process provides for identifying land use changes that may have occurred. This will serve as a check on groundwater and public health protection, and could also identify future concerns and permit needs.

Septage and Sludge Management

WQ implements the regulations in chapters NR 113, NR 204, and NR 214, Wis. Adm. Code. NR 113 relates to septage management and ch. NR 204 governs the treatment quality, use, and disposition of municipal wastewater treatment plant sludge. ch. NR 113 and ch. NR 204 incorporate federal septage and sludge standards. WQ regulates the land application of industrial sludge, liquid wastes, and by-product solids through ch. NR 214. Chapters NR 113, NR 204, and NR 214 contain treatment quality standards and land application site requirements and restrictions that are designed to prevent runoff to surface water or leaching of nutrients and pollutants to groundwater.

Results of federal and state septage audits identified the need for compliance training in the area of septage management. Cooperation with U.S. EPA led to the on-going creation of better training tools and implementation of numerous compliance classes. Recent septage operator certification code changes in ch. NR 114 now require minimum compliance training of all certified septage operators in their continuing education requirements cycles to ensure a compliance focus. New classes and training segments are currently offered through various associations, county updates, and stand-alone classes.

Inter-division work with the Bureau of Law Enforcement will continue to be necessary and likely increase as industry continues to explore more economical options for waste disposal and re-use during these difficult economic times and “green” transformation. Unfortunately, many of these options can cause significant harm to waters of the state. Continued enforcement efforts are necessary to deter further significant environmental harm. Increasing the number of audits is proposed to preempt significant

operations that create long-term harm of the environment. Also, efforts are underway to systemize audits to minimize the intrusion to the permitted community, but allow ample discussion to provide educational opportunities if needed.

Proposed efforts to modify the multiple land application codes (NR 113, NR 204, and NR 214) have been stalled for the time being to focus on streamlining issues. However, these code changes are only temporarily stalled as the following need to be addressed: creating consistency within these land application codes and between other related codes such as runoff management; providing a clearer understanding of code requirements; implementing best management practices consistent with total maximum daily loadings (TMDLs) of phosphorus; and modifying code language to be consistent with current practices employed by industry and contractors.

WQ continues to implement a statewide computer system that records and monitors treatment and disposal of municipal sludge, septage, and industrial land-applied wastes. This system includes an inventory and a history of all sites used for land application. Wisconsin became the fourth state delegated authority by U.S. EPA to implement municipal sludge regulations, through its delegated NPDES (WPDES) permit program, in July of 2000.

Wisconsin Act 347 provides incentives for more wastewater treatment plants to accept and treat septage. This is accomplished through the offer of a zero percent Clean Water Fund loan for the planning and construction of receiving facilities, and additional capacity provided for septage. Facilities which are upgrading capacity by more than 20% must evaluate septage generation and available disposal options in their planning area during facility planning. Although they are not mandated to provide such capacity, they are offered the zero percent loan if they do so. Structures are provided by which publicly owned treatment works establish costs for receipt of septage and a process is laid out for dispute resolution when such costs are questioned. Land application also remains a viable option when appropriate and Act 347 provides explicit pre-emptive authority to the state by disallowing restrictive local ordinances if they are not identical to state regulations.

Watershed Management Program

The Bureau of Watershed Management (WT) is responsible for statewide implementation of DNR's groundwater standards primarily through the issuance of discharge permits to concentrated animal feeding operations (CAFO) and dischargers of contaminated storm water. Field staff carries out compliance and enforcement activities using policies, codes, and guidelines intended to meet groundwater quality standards. Integrated basin planning carried out in the field under guidelines developed by WT assess and evaluate groundwater (as well as surface water) and provide general and specific recommendations for the protection and enhancement of the basin's groundwater.

Agricultural runoff and groundwater quality

Chapter NR 243 Wis. Adm. Code covers Wisconsin Pollutant Discharge Elimination System (WPDES) permit requirements for livestock operations and contains provisions to protect surface water, groundwater and wetlands in Wisconsin. Revisions made to ch. NR 243 have improved groundwater protection associated with CAFO land application practices by increasing setback requirements from community/non-community public wells and karst features and by further restricting winter applications of manure. Nutrient management plans submitted as part of the issuance of WPDES permits to CAFOs address how, when, where, and in what amounts CAFOs apply manure, process wastewater, and associated nutrients to cropped fields to protect surface waters and groundwater. Groundwater monitoring has been conducted voluntarily and as a requirement at selected sites. In response to monitoring, significant groundwater contamination is being addressed in 2014 by renovation of a feedlot through DNR compliance processes. The DNR also promotes groundwater protection through the implementation of agricultural performance standards in ch. NR 151, Wis. Adm. Code, the issuance of

Notices of Discharge under ch. NR 243, and response to acute manure related groundwater impacts (e.g., well contaminations).

Currently 248 livestock operations are covered under discharge permits issued (87% dairy; 4% poultry; 5% swine; 4% beef). Regional and central office staff have successfully maintained the permit backlog at less than 15%. The trend of growing numbers of permit applications for larger-scale livestock operations is expected to continue.

Sections ch. NR 151.07 and ATCP 50.04(3) require all crop and livestock producers to develop and implement nutrient management plans. Technical Standard NRCS 590 contains planning and implementation requirements for all nutrient management plans. DNR staff are participating in the NRCS effort to update its technical standard for nutrient management plans to reflect new federal water quality protection criteria, including a nitrogen loss risk assessment.’

Federal, state, and local agencies maintain technical resources and expertise to implement NRCS Standard 590, including development and dissemination of the field-based Soil Nutrient Application Program (www.snapplus.net) in cooperation with the University of Wisconsin. Implementation of the ch. NR 151 performance standard cannot be required without cost sharing in many situations. A multi-partner conservation consortium was effective in securing cost share resources from the Legislature to help farmers meet nutrient management plan requirements. DATCP administers these funds through its Soil and Water Resource Management Program. In addition, the NRCS provides cost sharing for development and implementation of comprehensive nutrient management plans, including 590 compliant planning and implementation. In other situations, cost sharing does not have to be provided to require compliance. This includes compliance for farms operating under a WPDES Animal Feeding Operation Permit, farms receiving state farmland preservation tax credits under the state’s Working Lands Program, livestock operations obtaining local permits under the state Livestock Siting Law, and livestock operations that voluntarily apply for new or altered manure storage facilities when the local regulation requires development and implementation of a nutrient management plan.

DNR promulgated a revised ch. NR 151 performance standard, which will require DATCP to amend ATCP 50 and 51, via rulemaking. Changes included in the ch. NR 151 revisions may impact nutrient management plan development and implementation. These changes include: TMDL’s; soil erosion and pastures; tillage setback; phosphorus index; process-wastewater discharge prohibitions; nutrient management plan clarifications on municipal sludge, industrial waste or septage; and an explanation on how these sources may impact nutrient management plans. The DNR has also provided comments to DATCP to help make implementation of ch. NR 151 more consistent across the state.

Storm Water and groundwater quality

Storm water discharges are regulated as required under the federal Clean Water Act under Chapter NR 216, Wis. Adm. Code. Chapter NR 216 requirements include: 1) permits for nearly 220 municipalities in Wisconsin to control polluted runoff that may enter their municipal separate storm sewer systems (MS4s); 2) permits for owners of construction sites with one or more acre of land disturbance to control erosion during construction and to install practices to limit post-construction pollutant discharge after construction is completed; and 3) permits for certain industrial facilities to address potential contamination of storm water from outside activities and outdoor storage of materials.

In addition, under Chapter NR 151, Wis. Adm. Code, the DNR has developed runoff performance standards for MS4s and construction sites that are implemented through the storm water permit program. Chapter NR 151 was updated and those changes became effective on January 1, 2011.

Provisions to implement Chapter NR 216 and the performance standards in Chapter NR 151 are included in several general permits. The MS4 general permit for municipal storm water discharges was first issued on in January 2006. . The MS4 general permit was reissued in May 2014. The general permit to regulate storm water discharges from construction sites was reissued on September 30, 2011. There are 5 general permits that cover industrial activity, including heavy manufacturing, light manufacturing, scrap recycling, vehicle dismantling, and non-metallic mining.

DEPARTMENT OF AGRICULTURE, TRADE AND CONSUMER PROTECTION

Protecting Wisconsin's groundwater is a priority for the Department of Agriculture, Trade and Consumer Protection (DATCP). DATCP's major activities in this area include management of pesticides and nutrients, research, and funding of local soil and water resource management projects.

In compliance with Chapter 160, Wisconsin Statutes, DATCP manages pesticides and pesticide practices to ensure 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, as well as 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 incentives.

Enforcement standards have been established in Wisconsin for many known and potential groundwater contaminants, including over 30 pesticides. DATCP helps landowners comply with these standards and the Groundwater Law.

Nonpoint Source Activities

Pesticides

DATCP's primary effort related to nonpoint contamination of groundwater from pesticides continues to involve the herbicide atrazine. Several rule revisions have been made in response to additional detections of atrazine in groundwater with the latest revision being put into effect in April 2011. A set of maps for 101 prohibition areas is available from the Environmental Quality Section covering 1.2 million acres that have been incorporated into the rule. The maps were updated with new base mapping software in 2012 to 1) update roadway names and other manmade features that have changed over the years, and 2) provide a consistent look for maps that had been created using different map software since the early 1990s. Pesticide use surveys indicate that atrazine use has declined from peak levels in the late 1980's and is now holding roughly constant. The decline in use may have been a result of the atrazine management rule and concern about groundwater contamination.

In 2008, DATCP prohibited the use of a simazine, a triazine herbicide related to atrazine, in a small area of the Lower Wisconsin River Valley near Spring Green. DATCP continues to perform routine testing of private wells for simazine both inside and outside of atrazine prohibition areas to determine if additional actions are needed to protect groundwater from simazine.

Nutrients

Through its Land and Water Resource Management program, DATCP assists in the protection of water resources through nutrient management. The DNR 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. DATCP has adopted the USDA- NRCS 590 nutrient management standard via administrative rule, ATCP 50, to meet DNR's performance standards.

A Wisconsin nutrient management (NM) plan is an annually updated record that follows NRCS's 590 Nutrient Management Standard. A NM plan accounts for all nitrogen, phosphorus, or potassium (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. Soils need to be tested by a DATCP certified laboratory every 4 years, with each field sampled every 5 acres. A NM plan manages nutrient applications to maximize farm profitability while minimizing degradation of both surface water and groundwater.

The nutrient management rules apply to all Wisconsin farmers who engage in agriculture and mechanically apply N-P-K nutrients from manures or fertilizers to cropped fields. Under Wisconsin Statutes, cost-share funds must be made available to producers to compel compliance. However, as many as half of Wisconsin farms may be compelled to comply with nutrient management standards and other performance standards without cost-sharing because they are either: Concentrated Animal Feeding Operations (operations with 1,000 animal units or greater); farms regulated by local manure storage or livestock siting ordinances; or participants in Wisconsin's Farmland Preservation Program.

The 590 NM Standard contains criteria for surface and groundwater protection that manages the amount and timing of all nutrient sources. Nutrients are managed according to:

- Soil nutrient reserves (soil test)
- Current crop and yield
- Previous crops and yields
- Soil types (e.g. sand, loam, clay)
- Current and previous manure and fertilizer applications
- Location of potential surface or groundwater conduits
- Soil temperature
- Irrigation practices
- Draining/tiling practices
- Field slope
- Season (e.g., winter)
- The Phosphorus Index
- UW's recommendations for each crop and soil type

The objective of the 590 NM Standard is to decrease the opportunity for losses to occur, decrease the total residual amount of nutrients in the soil and to keep those residual nutrients within the soil-crop system by limiting the processes (leaching, runoff, erosion, and gaseous losses) that carry nutrients out of the system. The 2005 NRCS 590 Nutrient Management Standard focuses on reducing the P losses to surface water systems and is currently being revised to focus more closely on nitrogen management techniques and practices.

NRCS's nutrient management standard includes a number of practices to protect groundwater from the impacts of nutrient applications such as:

- Nutrient and manure application setbacks from karst features and other conduits to groundwater
- Combinations of reduced nutrient application rates, timing, and nutrient sources to mitigate movement of nutrients and manure when they are applied to highly permeable or thin soils
- Nutrient applications must meet University of Wisconsin recommendations for crop production
- Application prohibitions or restrictions in waterways, Surface Water Quality Management Areas (SWQMA's), slopes in winter, buffers, fields exceeding tolerable soil loss, and non-cropped fields
- Irrigation management (inhibitors and split applications)

Like other agricultural performance standards, the nutrient management standard is "designed to achieve water quality standards by limiting nonpoint source water pollution" (Ch. 281.16 (3), Wis. Stats 'Nonpoint sources that are agricultural'). Requiring applications of nitrogen to meet University of Wisconsin recommendations for crop production, in conjunction with the other practices listed above, is meant to limit non-point pollution of groundwater. Currently, 26.4 percent of agricultural land in Wisconsin is covered by an approved nutrient management plan.

Statewide estimates by DATCP indicate that in 2007, over 200 million pounds of nitrogen (from all sources) were applied *in excess* of UW recommendations. Clearly, if Wisconsin's agricultural lands are to meet University recommendations for crop production, and comply with the other required nutrient management practices, significant reductions in nitrogen loading to groundwater would be occurring.

Research conducted by John Norman on silt loam soils in Columbia County at Arlington indicates that applications of nitrogen consistent with UW recommendations on continuous corn would, on average, roughly comply with the nitrate water quality standard of 10 parts per million. Other research cited later in this report, on other soils and cropping systems, indicate that applications consistent with UW recommendations for nitrogen would result in leaching of nitrogen to groundwater that would exceed the nitrate standard. Additional research, and importantly, monitoring of actual in-field practices are needed to illuminate the effectiveness of the nutrient management standard to protect groundwater under various conditions. DATCP has advocated that approach through its priority recommendations to the GCC. There is a committee currently meeting to assess what, if any, changes need to be made to the 590 Standard to better address water quality protection; specifically addressing the need for additional groundwater protection provisions.

Increasing attention on the role of land use practices in achieving water quality goals was recognized in the 2008-2009 state budget. Funding for the land and water resource management program's cost-share allocation increased from \$520,000 to \$6.5 million in the second year of the 2008-2009 biennium. A portion of those funds were directed to provide support for nutrient management implementation, including farmer training, outreach, and education, Snap-Plus Nutrient Management Planning Software support, and program evaluation activities. For the 2008 allocation, DATCP elected to use part of this increased appropriation to allocate \$2,996,483 in cost-sharing grants for nutrient management plans and \$403,000 in implementation support grants. However, during the years since 2008, lapses and other spending reductions have significantly reduced the funds available for DATCP to allocate for cost-sharing and implementation support. Beginning in 2009, budget shortfalls forced DATCP to reduce its allocation of cost-share funding to \$735,544, and reduce its allocation of implementation support grants to \$518,745. The 2011-13 budget contained an annual appropriation of \$5.36 million in SEG funds for nutrient management cost-sharing and for activities to support nutrient management. However, as a result of shortfalls in the Wisconsin Environmental Fund, DATCP was directed not to spend \$3.5 million of these funds, and as a result, it allocated \$1,317,333 for cost-sharing and \$591,399 for contracts to support nutrient management implementation in FY 2012.

The allocation of DATCP's annual appropriation in the 2013-15 budget of \$2.5 million in SEG funds "for cost-sharing grants and contracts under the soil and water resource management program under s 92.14" with an increase of \$210,000, providing \$2,710,000 available for allocation, \$2,012,000 will be provided to counties for landowner cost-sharing, \$175,000 will be set up in a reserve to fund grants for farmer training (Nutrient Management Farmer Education grant program), and the remainder of the \$523,000 will be awarded to supporting partners, including UWEX/CALS, which includes SnapPlus software support in addition to outreach and education support. The majority of grant funding directly benefits farmers by providing either cost-sharing or training. By dedicating a small portion of the SEG funds for support of projects focusing on training, outreach, and other DATCP priorities, DATCP is enhancing the statewide infrastructure fundamental to implementing state conservation activities, most importantly nutrient management planning. Total requests from counties exceed available funds by \$3,534,292. The lack of sufficient funds has practical implications for our capacity to implement state and local priorities, including newly added farm runoff standards, and may impact conservation compliance efforts for farmers' participation in the Farmland Preservation Program.

DATCP nutrient management program staff train farmers, consultants, and local agencies on the principles of sound nutrient management, how to comply with performance standards, and how to use

available tools to create and evaluate an ATPC 50-compliant nutrient management plan. The 2008-2009 state budget first allocated funds to DATCP for the creation of a Manure Management Advisory System (MMAS). This system is currently focused on helping farmers develop a clear understanding of field-specific soils and their ability to accept nutrients and manure for optimal crop production while protecting water quality. In order to accomplish this goal, new web-accessible tools have been developed, including: WI "590" Nutrient and Manure Application Restriction Maps, a map service for geographic information system (GIS) users, and the Runoff Risk Advisory Forecast (RRAF) model.

The 590 Restriction maps are available at the section level to assist farmers in making sound decisions about how and where to apply nutrients to their cropland. The mapped data used to create the restriction maps are also available for GIS-users to download into their own mapping applications. The RRAF provides Wisconsin's farmers with an innovative decision support tool which communicates the threat of undesirable conditions for manure and nutrient spreading for up to 10 days in advance. Developed with inter-agency collaboration, the RRAF model was validated against both edge-of-field observed runoff as well as small USGS gauged basin response. The model is updated three times daily and is hosted on the DATCP website. The encouraging results from this first generation tool are aiding State of Wisconsin officials in increasing awareness of risky spreading conditions to help minimize contaminated agriculture runoff from entering the State's water bodies.

Through these combined efforts, the total number of acres covered by over 5,000 nutrient management plans statewide in the 2013 crop year rose to over 2.3 million acres. In just six years, since the 2006 crop season (852,000 acres), this is an increase of almost 1.5 million acres, see Figure 1.

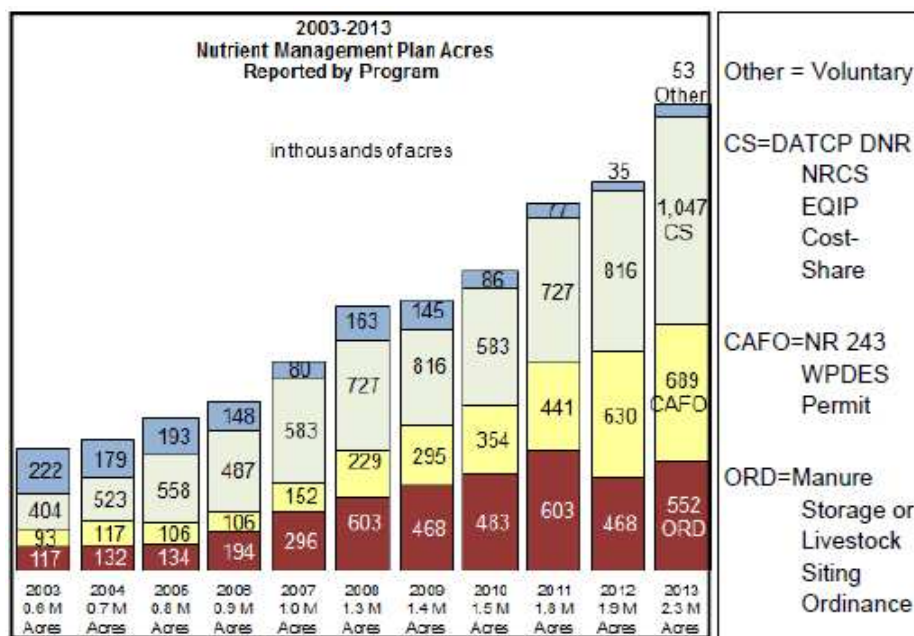


Figure 1. Acreage trends in nutrient management as reported to DATCP. Taken from DATCP's annual nutrient management report:

<http://datcp.wi.gov/uploads/Farms/pdf/2013NutrientMgmtNews.pdf>

While resources available to assist farmers and agronomists with NM implementation have been significantly improving over the past few years, the price of commodities is presenting new challenges. More land is being taken out of programs such as the Conservation Reserve Program and annual crops requiring N inputs, such as corn, are replacing crops that take up a lot of N, such as alfalfa and other perennial deep rooted legumes. For example, Wisconsin Agricultural Statistics Service reports that in 2006 there were 3,650,000 acres of corn planted with the number rising to 4,150,000 acres in 2011.

DATCP will continue to provide staff and technical resources to train farmers and agronomists on writing and implementing NMPs, to work with county staff to develop NM programs, and to review NMPs to ensure program integrity.

Point Source Activities

Previous work by DATCP identified pesticide and fertilizer operations as possible point sources of groundwater contamination. Past problems included improper disposal of unwanted agricultural chemicals, lack of containment for spills, outdated product handling methods, and poor understanding by workers in the industry of how small actions, when continued over time, lead to large problems. DATCP has worked to address these problems through point source prevention. In cases where environmental degradation has already occurred, DATCP oversees environmental cleanup of contaminated soil and groundwater.

Since 1990, the Agricultural Clean Sweep grant program has helped farmers dispose of unwanted pesticides, farm chemicals, and empty pesticide containers. In 2004, DATCP began operating and managing the state's household hazardous waste grant program. In fall 2007, prescription drug collection was added to the grant and the annual program budget expanded to \$1 million. In 2009 the program budget was reduced to \$750,000 annually and program management reduced to 75 percent FTE.

In 2013, 59 grants were issued: 16 for agricultural waste, 24 for household hazardous waste and 19 for the collection of unwanted pharmaceutical wastes. There were 1,094 farmers and 11 agricultural businesses that brought in more than 118,000 pounds of agricultural wastes, a 13 percent increase from 2012, most likely due to the increased number of participating agricultural businesses. Farm participation seems to be holding steady overall, but many counties have been reporting declining collections as more farmers are using custom application and products are becoming more concentrated. Much of the old stockpiled pesticides from years ago have been collected during the early years of the program, although Clean Sweeps are still seeing old, banned or cancelled pesticides like DDT and chlordane. The amount of household hazardous waste collected continues to increase. More than 2 million pounds were collected in 2013 from more than 55,000 residents. Please note that in the previously published 2012 figures, more than 1 million pounds of latex paint were collected and included in the total. For 2013, latex paint totals are not included. This is to reflect that although some Clean Sweep events collect latex paint, it is not a hazardous waste and collection figures will be listed separately. Drug collections netted nearly 41,000 pounds of unwanted pharmaceuticals. Collections occurred through collection events or through permanent drug drop boxes located in police stations throughout Wisconsin.

Fourteen local DATCP specialists work with facilities across the state to keep them in compliance with the ATCP rules designed to protect the environment. Agency staff also educates facility managers and employees about how routine practices may affect the environment.

The Agricultural Chemical Cleanup Program (ACCP) addresses point sources of contamination and reimburses responsible parties for a portion of 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. The ACCP has received more than 1,400 reimbursement applications for more than \$41.3 million in reimbursement payments.

Groundwater Sampling Surveys

DATCP has conducted a number of annual surveys to investigate the occurrence of pesticides in groundwater resulting from nonpoint sources. Results of these surveys are at:

<http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuality/Pesticides.pdf>

Research Funding

Due to budget constraints, DATCP did not have funding for new pesticide research projects in FY 2013. DATCP currently funds fertilizer research at approximately \$200,000 per year.

Groundwater Data Management

In 2011, DATCP received a grant from Department of Health Services (DHS) to merge two groundwater sample databases into one database. The new system combined data from the former drinking water well and monitoring well databases. DATCP also created a geographic information system (GIS) web-mapping application that allows the user to search the database and plot maps that show data located within a user-defined geographic area. The new database was placed on-line in early 2012. It contains contact and location information, well characteristics, and pesticide and nitrate sample results for private and public drinking water wells and combines that data with monitoring well data collected from hundreds of agricultural chemical cleanup cases. The database includes samples analyzed by DATCP, Wisconsin State Lab of Hygiene (WSLH), as well as other public and private laboratories. DATCP's groundwater database currently contains information for over 62,000 wells and nearly 800,000 pesticide and nitrate-N sample analytical results.

DATCP uses GIS tools to analyze groundwater data and prepare maps for public hearings, DATCP board meetings, presentations, and other uses. DATCP prepares and maintains data in GIS of well locations, atrazine concentrations, atrazine prohibition areas, and other pesticide and nitrate-N data. This database information located in GIS is used to generate maps of statewide pesticide and nitrate-N detections in wells, as well as maps for chapter ATCP 30, Wis. Adm. Code (Pesticide Product Restrictions). For example, see Figure 1, "Private Wells Tested for Atrazine in Wisconsin", on page 3 of this report (<http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuality/Pesticides.pdf>). Other GIS analyses involve identifying groundwater wells that may be impacted by point sources of pesticide and nitrate-N contamination. DATCP also uses global positioning system receivers to locate and map wells and other features, such as agrichemical facilities and spill sites that may affect groundwater quality.

For further information

Visit the following web site (<http://www.datcp.state.wi.us/>)

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DEPARTMENT OF HEALTH SERVICES

Chapter 160, Wisc. 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 recommendations. Recommended standards are sent to the DNR and are submitted through the rule-making process as amendments to ch. NR 140, Wisc. Adm. Code. When requested, DHS develops health-based drinking water advisories for substances that do not have an enforcement standard.

DHS serves as a primary resource for information about the health risks posed by drinking water contaminants, and is charged with investigating suspected cases of water-borne illness. Toxicologists, public health educators, and epidemiologists employed in the Department's Division of Public Health present water quality information to the public at town meetings and conferences, and provide direct assistance to families via home visits, letters to well owners, and telephone consultations. DHS prepares and distributes a wide variety of informational materials for the public on groundwater and drinking water issues related to human health. DHS staff members also work with DNR representatives on correspondence sent to well owners. Follow-up letters sent by DHS explain the health effects of specific contaminants and suggest strategies for reducing exposure until a safe water supply can be established. The agency frequently provides supplemental advice and assistance to families whose drinking water is highly contaminated with volatile substances such as benzene and vinyl chloride, especially in cases where the contaminants may pose concerns from inhalation of vapors from contaminated water that partitions to indoor air.

DHS programs work to improve understanding of current and potential groundwater and drinking water issues related to human health in Wisconsin. To accomplish this, DHS programs, in collaboration with local, state, and federal partners, employ exposure biomonitoring, disease surveillance, health assessment, and capacity and vulnerability assessment. Information from these activities assists project development, focus area prioritization, and research project support for academic work. This information also aids local and state agency work on groundwater-related public health issues. For example, DHS is frequently called upon to review the toxicity of constituents from well construction and rehabilitation products to ensure that products approved for use in Wisconsin can be used safely without risk of chemical overexposure.

Providing Public Health Support for Manure Contamination Events that Impact Drinking Water

Every year, there are a number of cases in Wisconsin that involve microbial contamination of drinking water wells following the agricultural landspreading or accidental discharge of animal waste. Problems can occur when there are spills of stored or transported waste, when there is waste runoff due to excessive rain or snowmelt, or when waste is improperly applied. Such incidents can generate a lot of public interest, especially with respect to the immediate local public health response.

Responding to problems related to landspreading waste is a focus area for federal, state, and local agencies that have a regulatory role in agricultural practices. DHS does not have a defined regulatory role for agricultural activities, but environmental health experts from DHS are frequently invited participants on multi-stakeholder workgroups that examine agricultural practices related to manure storage, handling, and landspreading. These include the University of Wisconsin-Extension Understanding Manure Irrigation workgroup, the Department of Agriculture, Trade, and Consumer Protection (DATCP) Livestock Siting Review Committee, and several DNR ad hoc groups. As a participant, DHS contributes public health expertise and perspectives during workgroup discussions.

In addition, through its Groundwater Standards Development program and On-call Chemical and Natural Disasters Emergency Response Team, DHS provides support to local public health agencies (LPHAs)

responding to a broad range of groundwater contamination events, including those related to manure contamination. Such responses may include:

- facilitating communications between LPHAs and various state partners (e.g., DNR and DATCP)
- providing technical assistance for determining appropriate public health recommendations for users of affected drinking water wells
- developing and implementing health outreach efforts (through advisory letters, public meetings, fact sheets, etc.)
- providing well water testing capacity through the Basic Agreement with the Wisconsin State Laboratory of Hygiene for LPHAs conducting public health investigations in affected communities

Response to Private Citizen Calls, Questions, Concerns, and Complaints

DHS receives hundreds of inquiries each year regarding various environmental health concerns; many of these calls from the public are specifically about groundwater and drinking water concerns. Some of the drinking water/groundwater inquiries are related to concerns at individual residences. Others are related to concerns regarding active environmental cleanup projects, which can result in DHS conducting (or supporting) a comprehensive public health response for the site. These responses are often carried out by the DHS APPLETREE program, which provides site-specific technical assistance to state and local agencies for testing, health assessment, and outreach on groundwater and drinking water contamination from present or past commercial or industrial practices and/or accidents.

As an example, DHS was involved in a comprehensive public health response when an investigation in a small community in central Wisconsin found that approximately 20 drinking water wells were affected by groundwater contamination, most likely from a former dry cleaning establishment. Based on contaminant levels found in the wells, most residents whose water was affected were advised to not drink the water from their wells. However, for six wells, contaminants levels were high enough that DHS recommended that the water should not be used for anything other than flushing toilets, because of concerns from dermal and inhalational exposures from contaminated water. Throughout the response, DHS served as a technical resource for DNR and the two LPHAs that were involved, helping state and local agencies determine and implement appropriate public health response actions. Recommendations from DHS also provided support for DNR actions to prevent future short-term residential exposures to groundwater contaminants from well water use. Actions included communicating public health recommendations and providing bottled water to all residents whose water was affected, and bringing in a shower trailer for those who were no longer able to bathe in their household water.

DHS also served as a source of health information for community members who had health-related questions and concerns. Staff helped plan and conduct outreach to the community and directly contacted all affected residences by phone (or by mail) to ensure that any health questions were being addressed. DHS, in partnership with DNR and LPHAs, also participated in a public meeting to discuss residents' health-related concerns about the groundwater contamination.

DHS outreach to the community provided multiple opportunities for health questions to be addressed. At this time, residents no longer appear to be concerned about possible health effects from the water contamination. In addition, DHS recommendations provided support for DNR partnering with EPA to pursue further investigation of groundwater contamination in the town. Recommendations are also helping to guide the community as it works with DNR and EPA to consider long-term options for obtaining safe drinking water.

Increasing the Availability and Accessibility of Data and Information on Private Well Water Quality

As a state partner in the Centers for Disease Control (CDC) and Prevention's Environmental Public Health Tracking (EPHT) network, DHS continually seeks to expand the availability and accessibility of data on environmental exposures and the chronic diseases for which they are risk factors. To this end, DHS' EPHT program has worked with the University of Wisconsin–Stevens Point (UWSP) and the Wisconsin Association of Local Health Departments and Boards (WALHDAB) to support expansion of UWSP's Private Well Water Viewer to summarize and visualize data from LPHA water testing laboratories. Partnership with UWSP and WALHDAB has resulted in the addition of data from the Eau Claire City-County Health Department on the UWSP data portal. It is anticipated that other local laboratories will make their data available on this platform to support interventions such as well testing and community health assessment.

Climate and Extreme Weather Vulnerability Assessment

The DHS Building Resilience Against Climate Effects (BRACE) Program, funded by CDC, works to enhance DHS statewide capacity to prepare for and respond to the public health impacts of extreme weather events, such as impacts to private wells from heavy rainfall events. Through this program, DHS developed a Wisconsin Climate and Health Profile Report. This is a qualitative assessment created from a collaborative data collection process to summarize and explain potential climate and extreme weather impacts on Wisconsin's physical environment and on the health of Wisconsin's citizens.

Gaps identified by the Climate and Health Profile Report assessment have already led to the development of several flood-related projects, with the goal of improving understanding of flood risk in specific watersheds and flood-related vulnerable populations. Flooding events can have profoundly negative effects on groundwater quality and public health, such as well contamination issues, impacts to aquifers from flood runoff, and chemical releases. These projects involve partnerships between DHS, the University of Wisconsin Center for Climatic Research, Wisconsin Emergency Management (WEM), and a number of LPHAs. The findings from these flood-related projects will help inform the BRACE Statewide Strategic Adaptation plan, WEM's Wisconsin Hazard Mitigation plan, as well as LPHA and local emergency management planning processes.

The BRACE Program also continues to investigate climate and extreme weather impacts on groundwater resources, including changes to groundwater quality and quantity, climate indicators related to water supplies, and climate-related health impacts on residents who rely on groundwater resources for drinking water.

For more information

Visit <http://www.dhs.wisconsin.gov/water/>

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WISCONSIN GEOLOGICAL & NATURAL HISTORY SURVEY

The Wisconsin Geological & 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. The Director of the WGNHS is a permanent member of the Wisconsin Groundwater Coordinating Council (GCC) and several WGNHS staff members serve on GCC subcommittees.

Groundwater-Level Monitoring Network

Wisconsin's statewide groundwater-level monitoring network has been operated jointly by the WGNHS and the U.S. Geological Survey (USGS) since 1946. As of June of 2014, this network consists of 103 long-term monitoring wells, two spring gaging stations and 57 project-specific, limited-term monitoring wells. The 103 permanent wells and 2 spring gaging stations are located in 49 of Wisconsin's 72 counties. This network provides a consistent, long-term record of fluctuations in water levels in shallow and deep aquifers. In addition, project-specific wells are managed as well as supported with funding from various groundwater studies across the state. While these project-specific wells are only operational over the lifetime of an active groundwater study, they provide substantial cost savings for the network.

Water levels collected from the network help scientists and managers evaluate effects of well pumping, the response of groundwater levels to drought or increased precipitation, and effects of land-use change on groundwater resources. These data are routinely used in the development of regional groundwater flow models. The WGNHS continues to support the maintenance of the monitoring network, aids in data interpretation, and provides information to public and private clients at: <http://wgnhs.uwex.edu/water-environment/groundwater-monitoring-network/>.

The WGNHS, in consultation with DNR and USGS, has recently completed several improvements to the monitoring network. In FY15, these improvements included bringing a number of new and existing wells into the long-term network and investigating several other wells for addition to the network in future years. Some of the highlights include the addition of a new well in Manitowoc County, an existing well in Brown County, a shallow piezometer in Waukesha County, and a new well in Price County completed within the Precambrian crystalline aquifer system. During FY16 we will continue ongoing monitoring activities and apply statistical techniques to help better determine the ideal distribution of wells within the network.

County Groundwater Studies

Geologic and groundwater studies at the county scale continue to be an important part of WGNHS programs. With funding from the federal STATEMAP program or local sources, WGNHS scientists initiated or carried out geologic and/or groundwater studies during FY15 in twelve different counties. Many of these studies will generate or have generated [water-table maps](#). Lists of current projects are maintained at: <http://wgnhs.uwex.edu/research/water-resources/>.

Regional Groundwater Studies

Regional groundwater studies usually span multiple counties. During FY15 the WGNHS was involved in several regional projects, including the following:

- a. *Hydrogeology of the Chequamegon-Nicolet National Forest.* In cooperation with the USGS, and with funding from the US Forest Service, the WGNHS is conducting a multi-year study of the hydrogeology of Wisconsin's National Forests. Following completion of studies in the Park Falls Unit in Price County the study moved into the Washburn-Great Divide Unit (Bayfield, Ashland, and Sawyer Counties), and Medford Unit (Taylor County) during FY13. During FY16 the study will focus on the Medford Unit and begin work on the Nicolet Unit in Forest, Florence, and Oconto Counties.
- b. *Hydrogeology of the frac-sand mining district in western Chippewa County.* This five-year [study](#), commissioned by the Chippewa County Department of Land Conservation and Forest Management in 2012, is a cooperative effort between the USGS and WGNHS. The goal of the study is to evaluate impacts to groundwater resources from land use and water use changes associated with frac-sand mining and irrigated agriculture. This effort includes development of a groundwater flow model and a series of informational meetings to update the public about study results and water resources in this region of Wisconsin.
- c. *Geothermal resources.* In anticipation of increased interest in geothermal heating and cooling in Wisconsin, the Survey is participating in a Department of Energy-funded effort to evaluate geothermal resources of the state. We have measured the thermal conductivity of Wisconsin's bedrock formations and measured the geothermal gradients in deep test wells at sites across the state. The information gained from this work is useful to engineers and heat pump installers for improved design of ground source heat pump systems.

Groundwater Research Activities

The WGNHS carries out specific groundwater research projects focused on understanding topics important to groundwater use and management in Wisconsin and elsewhere. Active research areas during FY15 included the following:

- a. *A new model of the Little Plover River basin and surrounding areas, Portage County.* This [project](#) addresses continuing concerns over the potential effects of irrigation on groundwater levels in Wisconsin's Central Sands region. The project is developing a new computerized groundwater flow and optimization model for the region that can help people understand the groundwater system and inform management decisions.
- b. *Hydrogeology of the Cedarburg Bog, southeastern Wisconsin.* This natural area is home to endangered species such as the Heinz emerald dragonfly and the prairie fringe orchid. The study results provide data useful to land use management in the vicinity of the Bog. The results and database are being used by a UW-Milwaukee researcher and students to model groundwater flows in the Bog.
- c. *Viruses in groundwater.* WGNHS scientists are nearing completion of a two-year [study](#) addressing the impacts to groundwater quality from leaky sewers. Funded by the US EPA, this work uses the presence of human enteric viruses in groundwater wells to trace pollutants from sewers to water supply wells. A [fact sheet](#) related to this project describes important implications for Wisconsin's groundwater quality and municipal drinking water supplies.

- d. *Groundwater recharge.* Groundwater recharge is critical to maintaining the supply of Wisconsin's groundwater, but mapping and quantifying recharge areas and rates can be a difficult process. The WGNHS has developed a computerized technique for rapidly delineating recharge areas for use in regional groundwater models. Currently, the WGNHS is incorporating the recharge delineation methodology into new projects and is cooperating with the USGS in using it in other areas of Wisconsin. In FY15, recharge delineations were completed for Columbia County, National Forest Units in parts of Florence, Vilas, Oneida, and Forest Counties as part of the Nicolet Forest project, as well as parts of Portage County in conjunction with our Little Plover River project.
- e. *Fluid flow in fractured rocks.* Fractured rocks (limestone, dolomite, crystalline rocks, and even some sandstone formations) underlie much of Wisconsin and form important aquifers over large parts of the state. Groundwater in carbonate rocks can move through fractures and solution features. Groundwater movement in such rocks can be quite rapid, and the rocks usually have very low ability to attenuate contaminants. WGNHS FY15 projects in carbonate terrain include a study of springs in the Mink River Estuary (Door County). WGNHS research in FY13-15 also addresses fracture flow and heterogeneity in the Cambrian sandstone aquifer in southern Wisconsin. Data and improved understanding of this significant regional aquifer are incorporated in the Dane County regional flow model and a Columbia County groundwater model currently under construction. We also studied fracture flow in granitic rock from central Wisconsin and compared fracture transmissivities before and after hydrofracturing.

Karst features, such as sinkholes, cavities, solution openings, cracks, and fractures, are commonly found in carbonate rock. WGNHS staff respond to questions about karst and sinkholes on a regular basis. They also prepared a statewide [fact sheet](#) on karst. In related work, WGNHS researchers have studied the Rountree Formation in southwest Wisconsin. This formation might protect underlying aquifers from contamination. This work focused on mapping the extent and thickness of the Rountree using well records and electrical resistivity imaging of the shallow subsurface. Electrical resistivity imaging was compared to exposures on quarry walls. A report is currently in preparation.
- f. *Investigation of unsewered rural subdivisions.* Population growth and urban expansion in many areas have resulted in residential development on what was formerly agricultural land. However, there have been few studies of the impacts of such developments on groundwater quality. To document the effects of this land-use conversion on groundwater quality, the WGNHS initiated a monitoring program to collect water-quality data before, during, and after construction of a new, unsewered subdivision located on agricultural land several miles outside of Madison, Wisconsin.

Groundwater Data Management

In FY15 the WGNHS continued to collect geologic and groundwater data and provide this data to a variety of users. Significant databases and data efforts include the following:

- a. *Data viewer construction.* The WGNHS continues to develop and support the Hydrogeologic Data Viewer, a map-based application to access a statewide catalog of hydrogeologic data. The application provides DNR staff with efficient and timely access to statewide hydrogeologic data, and includes several methods to search by area for data

of interest, such as geologic and geophysical logs or well construction reports. DNR and WGNHS are in discussions related to public accessibility for this application.

- b. *wiscLITH database*. The Survey provides annual updates of the digital database, [wiscLITH](#), which contains lithologic and stratigraphic descriptions of geologic samples collected in Wisconsin. This is a publicly available database, and current work efforts focus on including more data for areas of the state with active geologic and hydrogeologic projects.
- c. *Well construction reports*. The WGNHS serves as the repository for well constructor's reports (WCRs) from wells installed between 1936 and 1995. These reports were usually submitted to the DNR by a well driller within a few months of a well's completion. The [database](#) and scanned images are now available to state agencies, consulting firms, and private well owners on CD-ROM and paper copies.
- d. *Tillpro Database*. TILLPRO is primarily a [database](#) of grain-size analyses performed on unlithified sediment samples collected from Wisconsin and analyzed in the Quaternary Laboratory at the Department of Geoscience, University of Wisconsin-Madison. The data are available for public distribution on CD-ROM.
- e. *WGNHS Research Collections and Education Center (RCEC)*. The WGNHS archives geologic records, rock samples, core samples, and other materials in Mount Horeb, Wisconsin. Currently the [RCEC](#) contains over 2.5 million feet worth of drillhole cuttings, more than 600,000 feet of drill core, and more than 51,000 individual hand samples of rock from across the State. Examination tables and basic laboratory facilities at the RCEC allow convenient analysis and study of these materials by qualified individuals.
- f. *Physical properties of Wisconsin's bedrock aquifers and aquitards*. This [database](#) contains porosity and density of core samples collected from across the state. Data include high-resolution images of core taken from various depths along with a summary table.

In FY16, this database is being expanded to include porosity and hydraulic conductivity of samples from the mid-continent rift as well as thermal conductivity and specific heat of representative rocks from across Wisconsin. We expect to post the newer data on the WGNHS website.

Groundwater Education

WGNHS groundwater education programs for the general public are usually coordinated with the DNR or the Central Wisconsin Groundwater Center at UW-Stevens Point. The WGNHS also produces and serves as a distributor of many groundwater educational publications. More recently, we have expanded our outreach efforts to reach different audiences through a variety of social media tools, including:

- ☐ Facebook - <https://www.facebook.com/WGNHS>
- ☐ Twitter - <https://twitter.com/wgnhs>
- Pinterest – <http://www.pinterest.com/WGNHS/>
- YouTube – <https://www.youtube.com/channel/UCwwucf9-W1qocovGx-uzs7w>

WGNHS presents groundwater educational activities at the Wisconsin State Fair, at various children's museums and schools, at UW-Madison events (such as Saturday Science at the Wisconsin Institutes for Discovery or UW-Day in Marinette), and at afterschool programs.

In FY15, WGNHS staff members participated in groundwater educational meetings in counties where mapping and/or hydrogeologic studies are in progress, particularly in Chippewa and Columbia Counties. Staff members will continue to work with the DNR and the Central Wisconsin Groundwater Center on teacher-education programs connected to the distribution of groundwater sand tank models.

The WGNHS maintains a long commitment to the continuing education of water well drillers, pump installers, and plumbing contractors through participation in the programs of the DNR and the Wisconsin Water Well Association. Geologic and hydrogeologic field trips and presentations for DNR water staff and new DNR employees have been held in the past and will continue as requested.

Multiple WGNHS staff members gave presentations at the Wisconsin Society of Science Teachers conference helping to increase our efforts to reach teachers in FY15. Additionally, our Research Collections and Education Center is providing a locale for various groups, such as the Wisconsin Rural Water Association, to conduct related educational programs.

For more information

Visit <http://wgnhs.uwex.edu/>

Contact Ken Bradbury, Wisconsin Geological & Natural History Survey
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DEPARTMENT OF TRANSPORTATION

As a result of the 1983 Wisconsin Groundwater Law, 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. DOT is also responsible for potable well sampling at 69 rest area and seasonal waysides. Other DOT groundwater related activities or assistance include: hazardous material investigation or remediation; wetland compensation; storm water management; and groundwater level monitoring points for the Wisconsin Groundwater-Level Monitoring Network at 16 locations.

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 ch. 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. All salt must be covered and stored on an impermeable base. The base for stockpiles is required to function as a holding basin and to prevent runoff. The covers must consist of impermeable materials or structures to prevent contact with precipitation. State funded facilities are being added to the DOT salt storage program to provide greater capacity of indoor storage. This will improve groundwater protection and create greater flexibility for scheduling salt purchase at optimal prices.

The DOT annually updates salt storage facility records into a database and assists the DNR Wellhead and Source Water Protection program in locating salt storage facilities for GIS mapping applications. There are currently 1,295 salt storage sites listed in the database and 2,483 sub-sites. Each county keeps detailed inventories of salt which are updated monthly. Facility inventories, inspections, repairs and improvements are included in the database.

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 64 locations along major highway routes are used to determine application methods. Annual training for snowplowing and salt spreading techniques is 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 with the optimization of plow routes to make plowing most efficient. In conjunction with the AVL/GPS equipment the bureau is using 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 states who have implemented these technologies are seeing cost savings and salt reductions across their highways.

For more information***Visit the following web site (<http://www.dot.state.wi.us>)******Contact Bob Pearson, Environmental Services Section******Room 451, 4802 Sheboygan Ave.******P. O. Box 7965******Madison, Wisconsin 53707-7965******Phone: 608-266-7980, e-mail robert.pearson@wisconsin.gov***

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 with 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.

The 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.

Research

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. Key areas of emphasis in FY15 included hydrology and research focused on groundwater-surface water interactions and various groundwater contaminants, including arsenic and manganese, as well as viruses.

During FY15 (July 1, 2014–June 30, 2015), the WRI directed a wide-ranging program of priority groundwater research consisting of three new projects and two continuation projects. These included short- and long-term studies both applied and fundamental in nature. They provide a balanced program of laboratory, field, and computer-modeling studies and applications aimed at preserving or improving groundwater quality. These five projects, funded by the UWS, provided training in several disciplines for several graduate student research assistants and undergraduate students at UW-Madison and UW-Milwaukee. Groundwater issues investigated during the past year included:

- Assessment of environmental impacts of geothermal source heat exchangers
- Hydrologic impacts of the loss of Wisconsin's winter on surface water - groundwater interactions
- Effect of source chemistry on Mn-bearing solid dissolution and reactivity in municipal water systems
- Microbial community diversity as a predictor of virus survival in groundwater
- Assessing the effect of riverbank inducement on groundwater quality

For FY16 (July 1, 2015–June 30, 2016), the UWS selected five new groundwater research projects from proposals submitted in response to the Joint Solicitation. The new projects are based at University of Wisconsin-Extension, University of Wisconsin-Oshkosh, and University of Wisconsin-Madison. Three projects, selected from the previous year's solicitation, will receive continuation. These projects include:

- The Wonewoc and Tunnel City: A potential natural source of groundwater contamination in western and central Wisconsin (new project)
- Long-term alterations in groundwater chemistry induced by municipal well pumping (new project)

- Phosphorus and arsenic sensors for real-time environmental monitoring (new project)
- Engaging stakeholders to improve the use of groundwater flow models for decision making (new project)
- Predicting the locations of nitrate removal hotspots at the groundwater-surface water interface in Wisconsin streams (new project)
- Assessment of environmental impacts of geothermal source heat exchangers (continued project)
- Hydrologic impacts of the loss of Wisconsin's winter on surface water - groundwater interactions (continued project)
- Effect of source chemistry on Mn-bearing solid dissolution and reactivity in municipal water systems (continued project)

Beginning with FY11, the WRI's annual 104(B) allocation was used to expand the scope of the Joint Solicitation to include research on the effects of a changing climate on Wisconsin's water resources. Priorities for research were established through a partnership with the Wisconsin Initiative on Climate Change Impacts (WICCI). Established in 2007, WICCI is a university-state partnership created to: (a) assess and anticipate the effects of climate change on specific Wisconsin natural resources, ecosystems, and regions; (b) evaluate potential effects on industry, agriculture, tourism, and other human activities; and (c) develop and recommend adaptation strategies that can be implemented by businesses, farmers, public health officials, municipalities, resource managers, and other stakeholders. Two projects received continuation funding during FY15 and included:

- Establishing the Long-Term Range of Variability in Drought Conditions for Southwest Wisconsin
- Impacts of Climatic and Land Use Changes on Streamflow and Water Quality in the Milwaukee River Basin

Additionally, a portion of FY15 WRI's annual 104 (B) allocation was used to plan a workshop to advance the monitoring and analysis of trace metals and address applications in the upper Great Lakes. In FY16, funding will be allocated to establish a new Wisconsin Water Resources Fellowship to fund a student project assistant to work half time at the Wisconsin Department of Natural Resources Bureau of Drinking and Groundwater.

Teaching

Institutions within the UWS continue to offer undergraduate- and graduate-level courses and programs focusing on diverse issues regarding groundwater resources. Additionally, several campuses offer for-credit, field-oriented water curriculum courses for middle- and high-school teachers during summer sessions. The WRI views continuing education for P-12 teachers as an important component of its outreach and training effort. The Wisconsin Water Library, housed on the UW-Madison campus and a service of the WRI, maintains an extensive curriculum collection of guides with innovative approaches and other educational materials for teaching water-related science in P-12 classrooms. The curricula are available for checkout by all teachers and residents in Wisconsin. The librarian also has extensive experience in working with Pre-K children. She is putting that experience to use in developing already field-tested science, technology, engineering, art, and math curriculum kits. The kits will eventually number 27 on topics such as the water cycle, art and water, and pond science. In this reporting period, a kit related to frogs has been completed and two additional ones—on winter and on buoyancy—are nearly ready for circulation to age-appropriate audiences. The kits contain several books, tips on a guided water-science experiment and other themed activities. Finally, the library also provides checkout of an aquatic invasive species elementary- and middle-school-aged curriculum collection known as an attack pack.

Since September 2013, five packs have been checked out more than 20 times to formal and nonformal educators (the maximum checkout period is two months). The packs have been used to educate more than 10,900 people about aquatic invasive species in the waters of Wisconsin. What is also unique about this tool is that in the past it was a problem to circulate packs designed like this. Now, the WRI has devised a distribution system through the public interlibrary loan system.

Grants Administration

WRI conducts the annual outside peer-review of proposals submitted to the State of Wisconsin Joint Solicitation for Groundwater Research and Monitoring (WGRMP). A website called [*iPROPOSE*](#) was developed by WRI staff members in FY07-09. The website enables seamless online submission and review of proposals. At the site, prospective investigators submit a proposal by filling out a series of forms and uploading their full proposal and budget. Assigned reviewers then complete their reviews through *iPROPOSE* by answering a series of questions online. Once all of the reviews are completed, the UW Groundwater Research Advisory Council is given access to anonymous reviews and original proposals to help decide which proposals to recommend for funding. The website provides a framework for consistently capturing the same information from all of the prospective investigators and reviewers, thus helping to ensure that each proposal is treated equally.

Information and Outreach Activities

The [*University of Wisconsin Water Resources Institute website*](#) is a portal to information about WRI research projects and publications. One of the site's main audiences is researchers. To that end, the site provides a clear navigational path to the WRI project listings, project reports, a groundwater research data base, funding opportunities and conference information sections. The site is also integrated with the UW Aquatic Sciences Center's interactive [*Project Reporting Online*](#) system, an online tool that allows principal investigators to report on the progress of their projects. All of these areas are updated on a regular basis to ensure currency of information transfer. In this reporting period, the WRI website received 146,239 visitors. Additionally, WRI has a presence on Twitter, Facebook, Tumblr, Pinterest, Sound Cloud and Flickr.

WRI's video catalog includes "What is a spring?," "Streams neutralize nitrates in groundwater," "A new measure of groundwater flow," "Got oaks" and one of the most popular videos on our [*YouTube channel*](#), "Testing well water for microorganisms." To date it has nearly 8,400 views, which is a large number for a scientific topic. Additionally, WRI continued work on a video to explain Wisconsin's Groundwater-Level Monitoring Network, partnering with the Wisconsin Geological and Natural History Survey.

The program is also reaching audiences through an informative and entertaining seven-part audio podcast about mercury in aquatic environments. The series is offered through the WRI site, as well as through the University of Wisconsin-Madison iTunes university site. At the iTunes university site, WRI has been able to claim an artist's page. Pages such as these are reserved only for those who provide a deep array of content. The special pages allow a richer display of water-related content. Moreover, they provide a so-called "sticky" experience where users are attracted to the page for a specific need, but then stick around for additional, related information. "Aquifers and Watersheds" is a second podcast series. It demystifies these geological formations and the geoscience involved in studying them for the general public. It features eight chapters.

During this reporting period, WRI staff were also integral to the content-population of [*http://www.water.wisc.edu*](http://www.water.wisc.edu). The site is a portal to the breadth and depth of water-related work on the state's flagship campus, the University of Wisconsin-Madison, and serves as the first stop for anyone interested in water research. Additionally, graduate students can search for departments offering courses and degrees that fit their interests, and staff and faculty can search for colleagues working on topics complementary to their own to facilitate greater interdisciplinary collaboration and exploration. The site

had 174,508 visitors in this reporting period. Building off of this website, this year, WRI staff provided leadership in launching Water@UWMadison – A Wisconsin Idea Symposium, an event designed to bring water researchers and faculty from around the UW campus together to build awareness and collaboration.

Water Resources Publications

The program offers easily accessible publications through an online store with free information or information available for a nominal cost. Topics include nitrates in groundwater, siting rain gardens and arsenic. The program also produces the “[*Aquatic Sciences Chronicle*](#)” on a quarterly basis. It circulates to roughly 5,700 online and print subscribers with an interest in WRI projects and related topics. The newsletters are also posted online. There were nearly 283,000 online visitors to the newsletter.

Traveling Photography Exhibit

Photography is a powerful way to communicate and in this reporting period, WRI coordinated a traveling photography exhibit along with its sister organization, the University of Wisconsin Sea Grant Institute. Four 24” x 36” double-sided panels depict stunning scenes of Wisconsin’s water assets and highlight work that WRI and Sea Grant are doing to promote their sustainable use. The exhibit has traveled to public libraries in all corners of the state, with more visits scheduled for the remainder of 2015 and throughout 2016. At each stop, a news release is distributed to local media and local residents are invited to view the exhibit. There are also accompanying handouts to encourage further interaction through websites and tools such as the aquatic invasive species attack pack. WRI staff are offered as speakers for events in conjunction with the exhibit’s run at a specific venue.

AWRA Annual Conference

The WRI was once again integral to the planning and staging of the American Water Resources Association-Wisconsin Section’s annual conference. The theme of the 39th conference was agriculture and water. General areas covered included groundwater modeling, water quality, and agricultural hydrology and management. The Wisconsin Section is also dedicated to mentoring future leaders in water resources and offers a student workshop and an opportunity for students to showcase their academic work. The meeting was supported by other academic and governmental partners, including the American Water Resources Association, Wisconsin Section; Center for Watershed Science and Education, UW–Stevens Point Wisconsin; Department of Natural Resources; U.S. Geological Survey, Wisconsin Water Science Center; and Wisconsin Geological and Natural History Survey. WRI also provided materials for distribution from a booth at the conference.

Wisconsin’s Water Library Outreach Activities

Wisconsin’s Water Library is a unique resource for Wisconsin citizens. It contains more than 30,000 volumes of water-related information about the Great Lakes and the waters of Wisconsin. The library includes a curriculum collection, dozens of educational videos, a children’s collection, and more than 20 journals, and 100 newsletters. In the reporting period, about 1,400 publications circulated among interested users.

In addition to archival benefits, the library provides outreach by answering many in-depth reference questions on a wide range of water-related topics. Some examples of reference queries answered in this reporting period include: the economic valuation of cleaning up Green Bay, assistance to a northern Wisconsin lakefront property owner who wondered how to dispose of questionable water that had accumulated in an old boat, and assistance to the statewide Master Naturalist Program.

In partnership with the Wisconsin Department of Natural Resources and the Wisconsin Wastewater Operator’s Association (WWOA), the library continued its outreach to current and future wastewater operators of Wisconsin. The library catalogs the essential technical manuals and loans them to WWOA

members around the state in support of required state license examinations as well as in support of the educational needs of daily work.

Wisconsin's Water Library continues to catalog all groundwater research reports from projects funded by the Water Resources Institute into WorldCat and MadCat, two library indexing tools that provide both worldwide and statewide access to WRI research. By having this information permanently indexed, the research results are easily available to other scientists throughout the University of Wisconsin System as well as across the nation and the world.

The library also maintains a digital archive of the entire collection of [Groundwater Research and Monitoring Program reports](#). The archive was created in partnership with the UW Digital Collections Center, and ensures a permanent and accessible electronic record of Wisconsin groundwater-related activities since 1984. Paper copies of the reports continue to be a part of the Wisconsin Water Library. The library is also working to digitize and make more readily available the scripts and some audio from EarthWatch radio. The program was syndicated to more than 100 radio stations around the country in the latter half of the last century to make water science more accessible to broad audiences.

To build water literacy, staff reached approximately 2,060 Wisconsin residents through nearly 70 events conducted as public libraries, Head Start and other early-childhood programs, at the Wisconsin State Fair and in venues sponsored by the Girl Scouts or as part of other informal learning setups.

Library Websites

The library maintains several information transfer tools to reach library patrons and the most frequently accessed is the [library's robust website](#). The library's site serves as an outreach tool for those who want to know more about the state's water resources. The site's design ensures books and other materials in the library are easily accessible to any Wisconsin resident. There are three areas of the Web site, each set up to address the needs of distinct library user groups: UW system faculty, staff and students; a section just for Wisconsin residents; and an area dedicated to children, and their guardians and parents. Library staff continually update the site with new topical reading lists, new links to useful water-related Web sites, and pages with the library's new books. These frequent updates encourage users to return to the site often. The overall goal is to build water literacy among target audiences. The site is currently undergoing upgrades to make it more graphically appealing as well as functional, including responsive design. That means that the site will display in an optimal way regardless of the user's device. For example, a person logging on from a tablet or a smart phone will see content in an appealing and easy-to-navigate manner. During the past 12 months, the library site had 210,604 visitors, a growth of nearly 36,000 visitors over the last report.

In addition to its website, Wisconsin's Water Library uses other technology tools to reach library patrons. Using email, the library sends out a bimonthly *Recent Acquisitions List* to about 600 contacts. The message also includes recent updates to the library website and contact information for users to ask any water-related question. The library also supports an email at askwater@aqua.wisc.edu, which is monitored daily. Anyone with a water-related query can pose a question and receive a response in a timely manner.

The library has been using social media tools to reach new library users and to raise visibility of the library. The library has a blog, [AquaLog](#), where library staff reports on news, publications, and resources about water and the Great Lakes.

The library is also using social media tools, Facebook and Twitter. Users of both technologies can become followers of both and get the latest on water-related information instantly. [Facebook](#) is used often to announce events and display interesting links to its "fans." The library's Facebook page currently has

more than 420 “fans. [Twitter](#) is an excellent way to communicate in a timely manner. The Library’s Twitter tool has been in use since June of 2009 and now has more than 1,620 followers.

Both tools have seen increased use by library patrons and both have loyal and increasing numbers of followers.

UWS Publications Resulting from Recent WRI Groundwater Research and Monitoring Program-Sponsored Projects

Water Resources Institute Reports

Feriancikova, L., and S. Xu. 2013. Transport of manure-derived, tetracycline resistant *Escherichia coli* in unsaturated soil. Final report, Water Resources Institute, University of Wisconsin-Madison. WR11R007.

Gorski, P., M. Shafer, J. Hurley, S. Zana, and J. Swarthout. 2015. Hexavalent Chromium (Cr(VI)) in WI Groundwater: identifying factors controlling the natural concentration and geochemical cycling in a diverse set of aquifers. Final report, Water Resources Institute, University of Wisconsin-Madison. WR12R005.

Larson, R., and M. Holly. 2015. Silage Storage Runoff Water Quality Assessment and Design Recommendations to Limit Environmental Impacts. Final report, Water Resources Institute, University of Wisconsin-Madison. WR11R007.

Li, Z. 2013. Influence of adsorbed antibiotics on water quality and soil microbes. Final report, Water Resources Institute, University of Wisconsin-Madison. WR10R006.

Loheide, S., and C.B. Voter. 2015. Effects of Nuanced Changes in Lot Layout and Impervious Area Connectivity on Urban Recharge. Final report, Water Resources Institute, University of Wisconsin-Madison. WR12R002.

Luczaj, J.A., M. Zorn, and J. Baeten. 2013. An Evaluation of the Distribution and Sources of Dissolved Strontium in the Groundwater of Eastern Wisconsin, with a Focus on Brown and Outagamie Counties. Final report, Water Resources Institute, University of Wisconsin-Madison. WR12R004.

Sellwood, S.M., D.J. Hart, M.B. Gotkowitz, and J.M. Bahr. 2015. Identifying the controls on flow and contaminant distribution in siliciclastic bedrock aquifer systems. Final report, Water Resources Institute, University of Wisconsin-Madison. WR12R001.

Thompson, A., K.G. Karthikeyan, and R. Jackson. 2013. Groundwater recharge characteristics and subsurface nutrient dynamics under alternate biofuel cropping systems in Wisconsin. Final report, Water Resources Institute, University of Wisconsin-Madison. WR10R003.

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For more information on the WRI:**Visit the WRI website (wri.wisc.edu)****Contact Dr. Jennifer Hauxwell, Assistant Director for Research and Student Engagement of the University of Wisconsin Water Resources Institute****1975 Willow Drive****Madison, WI 53706****Phone (608) 262-0905, fax (608) 262-0591, email jennifer.hauxwell@aqu.wisc.edu****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. The center is part of the Center for Watershed Science and Education, an office of UW-Extension Cooperative Extension Service, and the UW-Stevens Point College of Natural Resources. More information can be found at <http://www.uwsp.edu/cnr-ap/watershed/>.

Well Water Testing

In calendar year 2014, the Center assisted 3,344 households in having their water tested in conjunction with county Extension offices and the Watershed Center's Water and Environmental Analysis Laboratory. Fourteen Drinking Water Education Programs helped 1,260 well users in 13 counties understand potential remedies for these problems and the relationship of land-use practices to groundwater quality. Nitrate screening and information on well water testing was provided at Wisconsin Farm Technology Days.

Water Quality Database

The Groundwater Center maintains a database of private well testing data from the Water and Environmental Analysis Regional Laboratory at UW-Stevens Point, and drinking water education programs conducted through the Center. There are currently 742,085 individual test results for approximately 89,278 samples covering the state, including 25 counties with 100 to 500 samples and 37 counties with 500 or more samples. Chemistry data includes pH, conductivity, alkalinity, total hardness, nitrate-nitrogen, chloride, saturation index, and coliform bacteria. The database primarily covers the period 1985 to the present. The database is PC-based and can be easily queried to be a significant source of information for local communities and groundwater managers.

Interactive Wisconsin Well Water Quality Viewer

In July 2012, the Groundwater Center made publically available an online mapping tool that allows people to search for groundwater quality information. The tool incorporates private well water data from the Center's database, the Wisconsin Department of Natural Resources (DNR) Groundwater Retrieval Network, and the Department of Agriculture, Trade and Consumer Protection. In 2014, data from the Eau Claire County Health Department was also integrated. [Summary maps](#) are available for 14 different water quality parameters and can be viewed or summarized into a table at a county, town, or section level detail. In 2014, 3,428 people used the viewer.

Central Wisconsin county-based volunteer streamflow monitoring

In a joint project with five county conservation offices and DNR, the Center launched a program that provides citizen volunteers with professional grade streamflow monitoring equipment. This is part of an effort to better understand water conditions in the pumping stressed region of the central sands. Staff has

worked with county staff to recruit and train volunteers. Currently, staff are coordinating with 10 citizen volunteers to measure baseflow at 70 sites throughout the Central Sands region. A quality/control procedure is in place by Center staff to independently verify a percentage of each citizen volunteer's measurements to ensure consistency and accuracy; results are extremely encouraging. These volunteers fill a large gap in the ability to collect baseline monitoring data of stream flow in the Central Sands region.

Chemical Tracers for Identifying Sources of Groundwater Nitrate-Nitrogen

Chemical analysis methods for a suite of human wastewater tracers and agricultural pesticide metabolites were developed and then used to analyze water from a group of private wells with elevated nitrate concentrations. This study will assist in identifying compounds useful for tracking sources of nitrate contamination and increase our understanding of the occurrence of these "emerging" compounds in private drinking water. Center staff worked with the DNR and the Wisconsin Department of Health Services to develop drinking water advisory levels for some of the compounds detected. Preliminary results from this study have been presented at the Wisconsin American Water Resources Association meeting.

Groundwater Phosphorus

Phosphorus analysis of groundwater collected through water education programs has been used to better understand the distribution, concentration, and sources of groundwater phosphorus in Wisconsin. This is one of the largest sources of groundwater phosphorus information available in the state and helps fill an important gap in understanding the sources of phosphorus to surface water resources. Results have been presented at several Wisconsin meetings and workshops and are being summarized in a scientific publication.

Policy

The Center continues to play pivotal roles in a number of state groundwater issues. Working with partners in the private and public sectors on groundwater quantity policy and law has been a continuing priority for the Center. Director George Kraft has been called upon to provide testimony to legislative committees related to groundwater quantity issues and routinely presents to local and state government officials on the science of groundwater pumping and associated impacts. Research Scientist Paul McGinley participated in a recent DNR workshop on estimating groundwater phosphorus loads to surface waters.

Partnerships

Center staff works with agencies and private organizations including:

- Little Plover River Working Group
- DATCP Atrazine Technical Advisory Committee
- Wisconsin Standards Oversight Council: Nutrient Management

The Center continues to work closely with local governments, land conservation departments, UW-Extension county faculty and natural resource educators, and many local watershed-based groups.

Recent Publications and Reports

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Bussan, A.J., G. Kraft, and J.D. Isherwood, eds. 2011. Walking on water: essays for the central sands. Publication A3961, University of Wisconsin – Extension, Madison WI

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**For more information on the UW-Extension's Central Wisconsin Groundwater Center:
Contact George Kraft, Center for Watershed Science and Education
College of Natural Resources, UW-Stevens Point
Stevens Point, WI 54481
Phone (715) 346-4270, email gndwater@uwsp.edu**

UW Environmental Resources Center (ERC)

The UW Environmental Resources Center ([ERC](#)) hosts UW-Extension (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.

ERC Regional Water Programs and Conservation Professional Development

As a successor to the 12-year [Great Lakes Regional Water Program](#), ERC hosts the [North Central Regional Water Network \(NCRWN\)](#), a 12-state collaboration among Land Grant universities including partnerships with state and federal agencies across the Upper Midwest region. Through this network, Extension researchers and educators share programs and coordinate for an array of water resource issues, including groundwater quantity and quality.

One of the programs emerging from ERC regional collaboration is a partnership providing multi-state professional development to conservation professionals (<http://conservation-training.wisc.edu/>). Wisconsin programs have included issues of conservation lands management such as manure management and fractured bedrock geology, including:

- Training public- and private-sector professionals to help farmers more effectively manage manure and commercial nitrogen fertilizers that can negatively impact groundwater
- Training for manure applicators on manure application in karst areas
- Providing conservation planning training and farmer training that includes karst issues
- Projects that help water resource managers understand farmer awareness of, and capacity to adopt, conservation practices that are most likely to fit into farm management systems
- The [*Conservation Reserve Program Readiness Initiative*](#), a national program to train public- and private-sector professionals to assist with implementation of the Conservation Reserve Program, which protects water resources while compensating farmers for taking marginal land out of production

ERC Water Outreach and Education

The [*Water Action Volunteers*](#) Stream Monitoring Program educates both children and adults about stream ecology and stream health. Volunteers continue to monitor over 500 stream sites statewide for a variety of parameters, including stream flow, which is directly affected by groundwater. Volunteer-collected data is helping to characterize water quality and quantity across the state and to identify streams where impairments may exist.

In recent years, a curriculum targeted to middle- and high-school students called *Exploring Streams* was completed. Over 70 Wisconsin teachers have been trained to use it in their classrooms, more than doubling the number of teachers in the state educating students about connections between land use and water quality and quantity.

The [*Wisconsin Master Naturalist*](#) program was piloted in 2012 and fully launched in spring 2013. The program follows a train-the-trainer approach. The course curriculum covers a variety of natural resources issues specific to Wisconsin, including groundwater quality and use. Certified volunteers are expected to provide 40 hours of natural resource-related service annually to Wisconsin host organizations, such as nature centers, state parks, or museums. Areas of service include: education/interpretation, stewardship, and citizen science. This program continues to grow in cooperation with partners across Wisconsin.

Other projects include the National Extension Water Outreach Education project to develop and promote best education practices for water education and to improve access to education resources and strategies. Involvement with the national youth water initiatives, [*Give Water a Hand*](#), Water Equals, and [*Educating Young People about Water*](#), continues, and those programs formed the basis for a new [*Thinkwater*](#) initiative through the UWEX Program Development and Evaluation unit. Find links to these programs on the ERC website at <http://www.uwex.edu/erc>.

UWEX's Regional Natural Resources Program

The University of Wisconsin System cooperates on community-focused educational programs with other state agencies involved with water resources and natural resource issues. Since 1998, UWEX has worked in partnership to support state, county, and local efforts to protect and improve surface and ground water quality and quantity across the state. Locally situated natural resource educators develop and conduct programs that reach local and statewide audiences, accessing state-level support for educational material development and program evaluation. The educational programs address a broad range of groundwater-related topics, including drinking water, threats to groundwater quality, impacts of land-use changes and land management decisions on groundwater quantity, information about localized groundwater problems such as karst geology, water conservation and efficiency, along with a variety of other issues associated with nutrients in surface water and groundwater.

More information on the Regional Natural Resources Program can be found <http://naturalresources.uwex.edu>.

**For more information on UW ERC programs related to groundwater:
Contact Ken Genskow, UW Environmental Resources Center
445 Henry Mall, Room 202
Madison, WI 53706
Phone (608) 262-0020, fax (608) 262-2031, email kgenskow@wisc.edu**

UW Nutrient and Pest Management (NPM) program

Mission Statement:

Wisconsin's Nutrient and Pest Management (NPM) Program works with a wide range of partners to promote agricultural practices for protecting water quality while maintaining or improving farm profitability. The University of Wisconsin NPM Program serves Wisconsin farmers and the agricultural professionals who assist them in making management decisions. The program links farmers and researchers to exchange knowledge on the profitability, practicality, and environmental impact of crop production practices and cropping systems.

Nutrient Management:

The NPM Program is part of a team that develops, distributes, evaluates, and implements nutrient management education programs. Partners include: University of Wisconsin-Madison College of Agriculture and Life Sciences (UW-CALS) faculty/staff, county-based UW-Extension, land conservation departments, Wisconsin technical colleges, the Wisconsin Department of Agriculture, Trade and Consumer Protection, U.S. Department of Agriculture-Natural Resources Conservation Service, along with private-sector agri-businesses and Wisconsin farm producers. Activities include:

- *Nutrient Management Farmer Education Curriculum* development and implementation. Cumulative accomplishments numbers from 2000 to 2014 show that as a result of local delivery of the curriculum, over 5,360 producers farming approximately 1,554,400 acres in 55 counties have received in-depth education on nutrient management planning.
- *SNAP-Plus nutrient management planning software* assistance and refinement in conjunction with the Snap-Plus team (UW-Soil Science). NPM staff assist in developing educational tutorials, updating the online help system and refining output reports to meet the needs of end users.
- Educational support to numerous Wisconsin watershed projects. Activities include coordination and delivery of individual nutrient management plans, phosphorus index model calibration and ground-truthing, manure spreader calibrations, and Total Maximum Daily Load (TMDL) benchmark development.
- On-farm demonstrations, field plot research, and subsequent educational programs on various topics (corn N rates, cover crops, conservation tillage, corn hybrid selection, etc.) at various locations across Wisconsin.

Pest Management:

NPM in conjunction with numerous partners, including UW-CALS faculty/staff, county-based UW-Extension, UW Integrated Pest Management (IPM) Program, Wisconsin Agri-Business Association, and others, delivers timely educational programming on topics associated with pest management. Activities include:

- The *Continuing Custom Applicator Program* which develops and delivers an annual educational program for increasing the professionalism of custom pesticide applicators by broadening their knowledge of the products they use, available new technologies, and customer service.
- *Cut-Bail-Scout* in-field workshops that are practical, hands-on, in-the-field, educational activities where farmers learn about potato leafhopper identification, field scouting techniques, treatment thresholds, and associated management techniques in alfalfa.

- *Corn foliar fungicide on-farm trials* as part of a broader UW network with the charge of evaluating the economics of foliar fungicide use on corn grain or silage.

Food Systems:

- *Healthy Grown Potato / Healthy Farms:* The Healthy Grown Potato program has been a national model of sustainable production systems, winning awards such as:
 - USDA Secretary's Award for Maintaining & Enhancing the Nation's Natural Resources (2003)
 - International IPM Achievement Award (2006)
 - Potato Association of America's Outstanding Extension Project Award (2011)

The program has recently been expanded to Healthy Farms as part of an effort led by UW-CALS faculty to develop a national framework for assessing sustainability and communicating achievements throughout the supply chain. Additional commodities developing sustainability systems include processed vegetables (snap beans, sweet corn, peas, and carrots), commodity crops (soybean), plus high-value crops (potato, cranberries, and strawberries).

- *Cover Crops Research, Education, and Outreach* activities include development and instruction of cover crop professional development training webinars for conservation staff professionals. Also fielding inquiries and providing advice on cover crop selection and management. This includes recommendations of cover crop species, planting dates, and seeding rates to match the planting window and supplemental forage and soil conservation needs.
- *Frac Sand Mining Site Reclamation:* A frac sand mining reclamation site restoration project was initiated in 2014. This project, located in Chippewa County, is in cooperation with the county land conservation department, UW-River Falls, and a mining company. The intent is to investigate the remediation of mining sites to agricultural land use.

Outreach and Communication:

- *Mobile Applications:* The NPM Program is creating mobile applications (apps) for hand-held devices. Five apps are currently available: nitrogen (N) price calculator, Corn N rate calculator, Integrated Pest Management toolkit, Corn Crop Calculators, and Manure and Legume Nutrient Credit calculator. Collectively, these apps have been downloaded by over 10,000 users from every continent except Antarctica.
- *YouTube Videos:* Dozens of YouTube educational videos featuring UW-CALS specialists have been prepared and released by the NPM and IPM programs over the past four years. A complete listing can be found at <http://www.youtube.com/uwipm>. A conservative estimate of the number of views is greater than 80,000.
- *Wisconsin Crop Manager Newsletter and IPCM Website:* The NPM and IPM Program website delivers the popular *Wisconsin Crop Manager* newsletter featuring contributions from faculty and staff across UW-CALS departments. *Wisconsin Crop Manager* is produced weekly during the growing season with semi-monthly and monthly releases during the winter months. This website averages over 400 users per day with 2,500 regular, repeat viewers.
- *NPM Publications:* The NPM Program has a long history of publishing timely, pertinent, high-quality publications on the topics of improved agricultural management practices. Formats have ranged from simple pocket-sized cards to extensive manuals and workbooks. A listing of NPM's print publications can be found at: <http://ipcm.wisc.edu/downloads/>

For more information on the NPM program:

Visit the website (<http://ipcm.wisc.edu>)

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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. The mission of the WSLH 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.

The chemical and microbial groundwater contaminants routinely tested include all contaminants regulated by the federal Safe Drinking Water Act, as well as many emerging contaminants that appear on the USEPA Contaminant Candidate List. Examples include: fecal indicators (total coliform, *E. coli*, coliphage, *Bacteroides* spp., *Rhodococcus coprophilus*, Sorbitol-Fermenting Bifidobacteria), *E. coli* O157:H7, toxigenic *E. coli*, *Salmonella*, waterborne viruses (Norovirus), human-adenovirus, parasites (*Cryptosporidium*, *Giardia*, and microsporidia), radioactivity, inorganic compounds (mercury, nitrate, arsenic), and organic compounds (atrazine, PCBs, PBDEs). The Water Microbiology section currently has molecular capabilities to analyze for human adenovirus and distinguish between bovine and human *Bacteroides* spp. as part of the laboratory's toolbox approach to microbial source tracking in groundwater.

In addition to routine testing of fecal indicators and emerging contaminants, the WSLH now employs a "toolbox" of microbial and chemical source-tracking assays. Microbial and chemical source tracking is used to determine sources of fecal contamination in water, whether from human or animal sources, using multiple microbial and chemical agents. The data is then used for making management decisions regarding control of fecal pollution of groundwater (see Wisconsin Department of Natural Resources (DNR) Activities).

Another important focus of the WSLH is emergency response to incidents involving groundwater. For example, WSLH works with Department of Health Services and DNR to investigate outbreaks of illnesses of unknown (possibly food or water) origin. Staff provides background information on the outbreaks for local public health officials, local media, and the general public. WSLH also responds to spills and incidents and supports state agencies in remediation and emergency cleanup activities. Most recently, WSLH has focused its efforts on enhancing and expanding terrorism response programs.

WSLH also provides educational and outreach activities related to groundwater and drinking water including, (1) instructional consultations for well owners and well drillers, (2) on-site training of municipal water supply operators, and (3) tours for a variety of international, educational, regulatory, and governmental groups. Staff members have developed an interactive study guide dealing with safety, sampling, and chemistry for drinking water operators as well as publications related to drinking water including a well water activity sheet, "Test your well water annually" brochure, and other well water testing promotional materials. Staff members present papers at a variety of conferences and symposia and publish research findings in professional journals.

Summary of Groundwater-Related Work at WSLH

Organic Chemistry Section

- Interpretation of GC-MS analysis of sterols as a chemical source tracking indicator. Sterols are the excreted metabolites of hormones (i.e. - plant and animal) that are ingested by animals or metabolized from endogenous sources (i.e. - human synthesis and metabolism of cholesterol). Depending upon the sterol detected, and in what quantity, determinations may be inferred as to the type of source responsible. For example, a high level of coprostanol, relative to background, indicates anthropogenic contamination of a surface water sample. Detection of cholesterol along

with plant sterols, such as beta-sitosterol and stigmasterol, would be indicative of fecal contamination by animals utilizing a mixed diet. Detection of the plant sterols alone would possibly occur with herbivore fecal contamination. Sterol source tracking data should correlate to orthogonal methodologies, such as the microbial source tracking protocols, in making a final determination.

- Analysis of pharmaceuticals and personal care products and antibiotics as tools to indicate pollution from humans and animals. This analysis in conjunction with the Microbial Source Tracking “Toolbox” is used to support the 2005 Wisconsin Act 123 Well Compensation Act Amendment (Compensation for Bacterial Contamination of Wells).

Chemical Terrorism and Preparedness Section

- The WSLH serves as the only public health emergency preparedness-supported chemical response laboratory in Wisconsin. The lab has extensive capabilities for testing human exposures to priority chemical threat agents provides sampling materials and guidance for first responders including hazardous material, drinking water, and natural resource entities, and performs any needed testing of environmental samples related to chemical incidents. One facet of this support has been the development of a drinking-water collection kit, tailored to allow appropriate collection for assessing a wide range of chemical and microbiological contaminants in drinking water. These kits have been provided to all drinking water utilities serving over 3,000, as well as to public health and other appropriate agencies.

Water Microbiology Section

- “Source Assessment Requirement under the Revised Total Coliform Rule” WSLH has a grant from the US EPA and GCC to develop and implement a scientifically-based well assessment for wells testing positive for coliforms. This project is to develop and test a suite of microbial organisms that can determine the source of contamination by collecting a large volume sample using a hollow fiber ultra-filtration system.
- WSLH is researching changes to the fecal source tracking toolbox by implementing species-specific PCR assays for human, bovine, swine, and poultry *Bifidobacteria*; improving the PCR primer sets for human and bovine *Bacteroides* spp.; and determining the feasibility of using pepper mild mottle virus to determine human contamination in groundwater. The research includes collecting fecal samples from animals throughout the state to determine sensitivity and cross reactivity for microbial sources of contamination.
- As a part of a larger laboratory-wide preparedness program, WSLH is prepared to offer appropriate microbial water quality testing when disaster strikes. WSLH is a member of the Environmental Response Laboratory Network and the Water Laboratory Alliance for both chemical and biological response. This involves participation in nationwide preparedness drills coordinated by the Centers for Disease Control and Prevention in conjunction with the U.S. Environmental Protection Agency. Coming up later in the year, WSLH will be participating in a disaster exercise that has been designed on the scale of the Katrina disaster.
- The WSLH Flow Cytometry unit coordinates and distributes samples for the only *Cryptosporidium* Proficiency Testing Program (PT) available in the United States. This WSLH Program supports environmental laboratories testing water samples for the presence of this parasitic protozoan under the Long Term 2 Enhanced Surface Water Treatment Rule. The Program has been designed to provide water testing laboratories and accreditation agencies with a means of assessing a laboratory's performance of U.S. EPA Method 1622/1623. The Program is accredited under ISO 17043 "General Requirements for Proficiency Testing" by ACLASS and distributes samples twice annually. The Program operates with support from the WSLH Water Microbiology department which evaluates the robustness of the parasites suspensions prior to and following distribution to participant laboratories.

- The Water Microbiology section of the WSLH Environmental Health Division is currently performing work to evaluate the organisms used for the national PT. This work involves the prescreen assessment of the organisms used for proficiency testing as well as the stability of the organisms on the last day before expiration of *Cryptosporidium* spike used in the biannual PT events.

Inorganic Chemistry Section

- Detectable concentrations of hexavalent chromium (Cr(VI)) have been measured in drinking water sourced from Wisconsin groundwater. A current project seeks to determine if there are potential human health concerns within certain aquifers of Wisconsin. The hypothesis that mineralized edges of three major geological basins of Wisconsin provide the conditions favorable to the formation of Cr(VI) is being tested with the goal of characterizing the major aquifers of Wisconsin as to their natural background concentrations and release rates of total Cr and Cr(VI).
- A variety of nutrients are routinely measured in drinking water, surface water, and groundwater. Those with health concerns in drinking water, such as nitrates are submitted by the public and well drillers and results are sent to the clients and the DNR for their database. The DHS has worked with WSLH to provide drinking water kits available to newborn mothers at the county level to monitor for nitrates in well water.
- Most types of metals are also measured. Those of health concern, such as arsenic have become important in monitoring since they have been associated with specific geological formations and conditions in northeastern Wisconsin. For further study, the lab also has separated arsenic into its oxidation states and measured their relative concentrations.
- Ancillary inorganic tests are routinely performed such as chloride, sulfate, pH, alkalinity and conductivity that are important in controlling the chemical conditions for groundwater systems.
- As with other sections of the WSLH, the inorganic section responds to both spills that would affect both surface water and groundwater. The lab has worked extensively with both DNR and DHS to identify contaminants in well water that may have had surficial origins. The WSLH recently has added multi-collector ICPMS instrumentation that can be used to measure isotopic fingerprints of metals to source-track their origin.
- The inorganic section has a dedicated trace-level clean lab that routinely measures metals or elements in water at the parts per trillion (ppt) ranges for unique applied low-level research questions and monitoring.
- The WSLH also works with and receives samples from the U.S. Geological Survey, researchers at UW campuses, the Wisconsin Geological and Natural History Survey on specialized groundwater projects. The lab also routinely measures samples from drinking water utilities that rely on groundwater.

Flow Cytometry Section

- Many *Cryptosporidium* species identified using current methods are not human pathogens and their presence in drinking water may cause undue alarm. The WSLH worked with Texas A&M University to develop methods which distinguish human pathogenic species from those that are non-pathogenic. This was a multi-national study with laboratories in seven different countries participating in the method validation portion of the project.
- The Flow Cytometry Unit at the WSLH continues to provide support for U.S. Environmental Protection Agency Office of Water. One such activity includes the provision of precisely enumerated *Cryptosporidium* and *Giardia* standards for use in method improvement studies.

For more information on the WSLH:

Visit the website (<http://www.slh.wisc.edu/>)

Contact David Webb, Deputy Director, Wisconsin State Laboratory of Hygiene

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USDA Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) is a federal agency within the US Department of Agriculture. The NRCS works with private landowners to promote conservation of natural resources.

The agency protects groundwater by providing technical assistance to landowners for conservation practices and many federal conservation programs which provide financial assistance to landowners. Summaries and highlights of Wisconsin NRCS conservation accomplishments, by program, are available on the Wisconsin NRCS website at www.wi.nrcs.usda.gov

National Water Quality Initiative

The USDA's [National Water Quality Initiative](http://www.nrcs.usda.gov/wps/portal/nrcs/detail/wi/home/?cid=STELPRDB1117406) is committed to improving impaired waterways throughout the nation. Three watersheds have been selected in Wisconsin. USDA's Natural Resources Conservation Service (NRCS) will manage the initiative by making funds available to farmers and forest landowners in the selected watersheds to begin needed conservation practices to reduce sediment and nutrients entering the waterway. <http://www.nrcs.usda.gov/wps/portal/nrcs/detail/wi/home/?cid=STELPRDB1117406>

Great Lakes Restoration Initiative (GLRI)

In 2012 and 2013, Wisconsin NRCS concentrated its effort in the Lower Fox River watershed. Two watersheds that lie within this basin were given additional funding; the Upper Duck Creek in Outagamie County and the Upper East River in Brown, Manitowoc and Calumet Counties. This focus resulted from a combination of resource concerns, potential for improvement and landowner participation. Working with our local and other federal partners, the overall strategy of GLRI is to achieve maximum conservation practices in the focus area, so that water quality improves downstream. GLRI Highlights for FY 2013 include:

- General signup in the Lower Fox, Manitowoc/Sheboygan and Milwaukee River Watersheds
- Financial Assistance = \$1,097,295 in 14 contracts covering 3,009 acres.
- Special Phosphorus Reduction Project conducted in five sub-watersheds in the Lower Fox River
- Watershed Financial Assistance = \$3,120,674 in 48 contracts covering 19,959 acres.

All GLRI EQIP applications submitted in Lower Fox Phosphorus Reduction Priority Watersheds received through July 1, 2013 will be evaluated for funding consideration.

<http://www.wi.nrcs.usda.gov/programs/eqip/GLRI/FY13PhosphorusWatersheds.pdf>

To find out more information about NRCS, go to the home page at <http://www.wi.nrcs.usda.gov>, contact Renae Anderson at 608-662-4422 ext. 227 or renae.anderson@wi.usda.gov.

U.S. Geological Survey: Wisconsin Water Science Center

The mission of the U.S. Geological Survey - Water Mission Area is to provide hydrologic information and understanding needed for the optimal utilization and management of the Nation's water resources for the overall benefit of the people of the United States. The Wisconsin Water Science Center accomplishes this mission in large part through cooperation with other Federal, State, and local agencies, by:

- Systematic data collection for long-term determination and evaluation of the quantity, quality, and use of Wisconsin's water resources.
- Conducting analytical and interpretive water-resource appraisals describing the occurrence, availability, and physical, chemical, and biological characteristics of surface water and groundwater.
- Developing and operating an environmental microbiology laboratory in cooperation with USDA-Agricultural Research Service to support joint research interests on pathogen occurrence and transport in groundwater
- Conducting supportive basic and problem-oriented research in hydraulics, hydrology, and related scientific fields to improve investigation and measurement techniques, and to understand hydrologic systems in order to quantitatively predict their response to stress.
- Disseminating data and the results of investigations and research through reports, maps, Internet distribution and other computer information services.
- Coordinating the activities of Federal agencies in the acquisition of water data for streams, lakes, reservoirs, estuaries, and groundwater.
- Providing scientific and technical assistance to other Federal, State, and local agencies, to licensees of the Federal Energy Regulatory Commission, and to international agencies on behalf of the U.S. Department of State.

The Wisconsin Water Science Center is currently conducting groundwater-related cooperative projects with the Wisconsin Department of Natural Resources (WDNR), UW Systems, UW-Extension through the Wisconsin Geological and Natural History Survey (WGNHS), Southeast Wisconsin Regional Planning Commission (SEWRPC), the Mole Lake, Forest County Potawatomi, Red Cliff, Bad River, and Lac Du Flambeau Tribes of Wisconsin, the US Forest Service, and numerous county and city governments. The federal funds that support these projects come from the Cooperative Water Program, an ongoing partnership between the USGS and non-Federal agencies (<http://water.usgs.gov/coop/>). In addition, the Wisconsin Water Science Center conducts projects that are funded entirely by USGS Federal programs. Recent and current projects that have a significant groundwater component are listed below.

Projects funded cooperatively with state and local agencies:

1. Operation and maintenance of the Wisconsin Observation Well Network; data collection, processing, archiving, and presentation (with WGNHS).
2. Development of the Water Use in Wisconsin summary report (produced at a 5-year interval); data collection and estimation, development of water-use coefficients and default values; evaluation compiled by aquifer, geographic, and political criteria (with WDNR).
3. Evaluating land use and climate change effects on a southern Wisconsin trout stream - results of the Black Earth Creek modeling study (with WDNR and local communities and augmented by USGS Federal funds).
4. Characterization of groundwater resources in US Forests in Wisconsin (with USFS and WGNHS).
5. Simulation of the effects of water diversion from Shell Lake, Washburn County, on the shallow groundwater – lake system (with the City of Shell Lake and the WDNR).

6. Groundwater flow and groundwater/surface-water interactions in Dane County (with WGNHS, Dane County, utilities, and other county municipalities).

Wisconsin projects funded entirely by USGS:

1. Availability and use of fresh water in the United States: Glacial Aquifer System – Upper Midwest.
2. Hydrologic and biogeochemical budgets in temperate lakes and their watersheds, northern Wisconsin Long Term Ecological Research site, <http://wi.water.usgs.gov/webb/>.
3. Western Lake Michigan Drainages National Water-Quality Assessment <http://wi.water.usgs.gov/wmic/index.html>.
4. Great Lakes Restoration Initiative work on forecasting effects of future climate and land use change.
5. Glacial Aquifer System Groundwater Availability Study, <http://mi.water.usgs.gov/projects/WaterSmart/>

USGS/ARS Laboratory for Infectious Disease and the Environment. The USGS Wisconsin Water Science Center has partnered with the US Department of Agriculture-Agricultural Research Service to fund and operate this laboratory in Marshfield, WI. This lab became operational in 2012 and has significant capabilities in the area of identification and quantification of viruses and human bacterial pathogens. The capabilities of this lab have already been instrumental in innovative studies of water quality of municipal water supplies in LaCrosse, Madison, and others cities in Wisconsin (for example, Borchardt et al., 2004; Hunt et al. 2010).
<http://wgnhs.org/wofrs/WOFR2010-04a.pdf>
http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=257971
<http://wisconsingeologicalsurvey.org/pdfs/espdf/ES053.pdf>

The first listed Priority Recommendations of the 2013 GCC Report to the Legislature is the evaluation of “the occurrence of viruses and other pathogens in groundwater and groundwater-sourced water supplies, and develop appropriate response tools”. Developing a full understanding of the water quality of domestic and municipal water supplies in the state will benefit from the capabilities and expertise made available through the Laboratory for Infectious Disease and the Environment.

Compilation of Wisconsin Water-Use Data. Every 5 years, the USGS Wisconsin Water Science Center is responsible for presenting data collected and/or estimated for withdrawals and water diversions to the USGS National Water-Use Information Program. The 2010 water-use dataset is still in development. Accompanying this dataset, a report, detailing water use in Wisconsin, is published that serves many purposes such as quantifying how much, where, and for what purpose water is used, tracking and documenting water-use trends and changes, and facilitating cooperation with other agencies to support hydrologic projects. Presently, the USGS Wisconsin Water Use 2005 report (Buchwald, 2009) is available and can be accessed through the USGS Publication Warehouse at <http://pubs.er.usgs.gov/publication/ofr20091076>.

Over the past year, there were five USGS investigations that incorporated a Wisconsin water-use component (listed at <http://wi.water.usgs.gov/water-use/index.html>). The majority of these investigations integrate water-use data into hydrologic models that evaluate the impact of water use on water resources, including calculation of water budgets, groundwater-flow paths, and baseflow contribution to surface-water features. Water-use data and the periodic report are becoming increasingly critical in understanding water use, supporting Groundwater Management Areas around the state, and supporting implementation of the Great Lakes Compact.

Starting this year, the USGS provides its summarized water-use data, used in the compilation and stored in Aggregate Water-Use Database System (AWUDS), through NWIS Web at <http://waterdata.usgs.gov/nwis>. Persons will have the option to retrieve data for water use by compilation year, area (county or state), and category (e.g., public supply, industrial). Also in 2013, the USGS is developing a Data Exchange with DNR Bureau of Drinking Water and Groundwater to facilitate its cooperative program objectives. To learn more about specific project objectives, visit <http://wi.water.usgs.gov/ground-water/9kh51/index.html>.

The Water-Use Information Program is evolving from being a data-collection and database management program to a water-use science program, emphasizing applied research and development of techniques for statistical estimation of water use, as well as analysis of water using behaviors (National Research Council, 2002). The USGS Wisconsin Water Science Center will continue to develop new and strengthen existing partnerships to broaden the understanding of water use in Wisconsin.

Additional information about these studies and other USGS water-use products, along with summaries of data and information on Wisconsin water use can be found at the following web site: <http://wi.water.usgs.gov/data/wateruse.html>.

Groundwater assistance to Wisconsin Tribes: Several bands of the Lake Superior Chippewa Tribes have been planning expansions to their drinking-water infrastructure and, as part of that work, have needed simulations of the shallow groundwater system to understand the spatial pattern of water pumped by the proposed wells. Results for the first study for Mole Lake were published in Fienen and others (2011). Similar results for Forest County Potawatomi are forthcoming. The Bad River and Red Cliff Tribes also obtained funding from the Bureau of Indian Affairs to fund USGS to provide modeling and analysis of groundwater research on their respective reservations. This will include monitoring network design, field measurements, and state-of-the-art modeling.

Water Resources Impacts of Frac-Sand Mining: New advances in deep horizontal drilling and hydraulic fracturing (“fracking”) technologies have unlocked massive natural gas reserves in shale formations in several areas around the United States. While little potential for such gas extraction is present in Wisconsin, several ancient sand formations provide ideal material for “frac-sand” which is a critical element for fracking. The sand, uniform in size and composition, is pumped into fractures that are created in the fracking process to keep them open, allowing gas to flow. The sand resources in Wisconsin are a major commodity now and sand mining has increased dramatically in the past two years. USGS, in cooperation with WGNHS and Chippewa County is undertaking a regional study in Chippewa County to characterize water resources impacts by frac sand mines and agriculture in the area. The 5-year project is currently in the last part of the planning stage and will launch in early 2013.

Background Water Resources Conditions in the Penokee/Gogebic Iron Range: Proposed taconite mining in the Bad River Watershed in northern Wisconsin has initiated increased interest in potential water resources impacts of the major land-use change. USGS Midwest Area Mining Initiative funds were provided to perform background screening level modeling of groundwater in the area around the ore body. This screening model will then be available for assisting in designing a monitoring network focused on particular impacts of concern to stakeholders. The Bad River Tribe also obtained funds through the Bureau of Indian Affairs which will expand the scope of this effort to include the Reservation in the downstream area of the Bad River watershed.

The Glacial Aquifer System Groundwater Availability Study: This study began in 2012 and will be completed in 2016. The study will assess groundwater availability for the expansive and diverse glacial aquifer system of the United States. The glacial aquifer system is present in parts of 25 states and is subject to a range of climatic conditions from humid to semi-arid. Groundwater availability in the system may be constrained by climatic conditions (limited recharge), poor water quality from natural or man-made constituents, hydrogeology (limited storage or low hydraulic conductivity), concerns of conflicts with current groundwater users, or the desire to maintain or restore environmental streamflows. The glacial sand and gravel principal aquifer is contained within the glacial aquifer system. This principal aquifer, as defined by USGS ([Miller, 1999](#)), is present in parts of 22 states, glacial deposits in Idaho, Washington, and Alaska are not included in the definition given by Miller (1999). Withdrawals from the principal aquifer in 2000 were 5 percent of the total withdrawals from all aquifers ([Maupin and Barber, 2005](#)). The sand and gravel principal aquifer is the largest source for public supply and self-supplied industrial for any principal aquifer; and it also is an important source for irrigation supply.

The glacial aquifer system groundwater availability study is one of the USGS efforts in response to the Department of Interior WaterSMART initiative. This study is designed to provide information and analysis to stakeholders and decision makers for characterizing groundwater availability in regions within the glacial aquifer system. This study complements other regional aquifer studies through the Groundwater Resources Program designed to develop a national assessment of groundwater availability in USGS Principal Aquifers as part of a national Water Census.

The study seeks to quantify:

- the status of groundwater resources in the glacial aquifer system,
- how these resources have changed over time, and
- likely system response to future changes in anthropogenic and environmental conditions.

Evaluating land use and climate change effects on a southern Wisconsin trout stream: Results of the Black Earth Creek modeling study: A well-known trout stream and Outstanding and Exceptional Resource Water – the Black Earth Creek (BEC) watershed in northwest Dane County – is undergoing land-use conversions from agricultural to residential and commercial. Currently the long-term impacts of urbanization on the base flow and stormflow (flood peaks) is not well characterized. Urbanization may increase both stormflow (Steuer and Hunt, 2001) and non-point source loads of nutrients, pesticides, and sediments. Because increased surface flows divert water that normally recharges to the groundwater system; urbanization can result in less groundwater being discharged as base flow to streams. By understanding the interactions between surface water and groundwater systems, the effectiveness of water management alternatives used to mitigate the effects of urbanization can be evaluated. A coupled groundwater/surface-water computer model of the basin has been constructed using the USGS code GSFLOW (Markstrom and others, 2008). This approach includes all elements of the hydrologic cycle including rainfall, snowmelt, evapotranspiration, interflow, streamflow, baseflow, and groundwater flow resulting in a quantitative characterization of the entire hydrologic system.

Expansions to the Groundwater Monitoring Network: In compliance with requirements of the Great Lakes Compact monitoring mandates, the USGS, WGNHS, and WDNR are cooperatively expanding existing groundwater monitoring resources. Of particular interest are areas of substantial past and present groundwater withdrawals in southeastern Wisconsin and the Green Bay area. These additions are being made within the context of the state-wide plan for network

improvements. And these additions represent excellent progress toward more informed management of groundwater resources, particularly where pumping stresses are important.

Dane County Groundwater-Flow Model: In cooperation with the WGNHS, the Dane County Groundwater-Flow model is being comprehensively revised. This model, originally completed in 1999 and published in 2000 (Krohelski and others, 2000) has been used for planning by county and local governments throughout the county. While the 1999 model was developed using the state-of-the-art modeling and calibration tools at the time, techniques, and software continue to evolve, and additional data have been collected. As a result, updating the Dane County model using current capabilities will enhance the value of the model for planning. Improvements include better representation of surface-water features and their interactions with the groundwater system, a finer grid resolution, more representative treatment of recharge, new findings related to the stratigraphy of the county simulation of transient conditions (both historical and predictive), and improved calibration and uncertainty calculation techniques.

Groundwater and Surface Water Interactions in the Upper Fox River Valley of southeastern Wisconsin (Feinstein and others, 2012): The Fox River Valley, including Waukesha County, is experiencing rapid urbanization and consequently increasing demands on deep groundwater pumping for domestic supply needs. These demands are stressing the availability of groundwater and in some cases water-quality considerations (such as radium in Waukesha County) are making it difficult to meet the increased needs through traditional sources. One alternative is to increase pumping from locations at which the shallow aquifer is more closely connected to the surface-water system. To better understand both potential surface-water impacts due to increased shallow pumping and to characterize exchange between the shallow groundwater and surface water the USGS has constructed and applied a model using the newly developed MODFLOW-NWT code (Niswonger and others, 2011) in simulating a number of scenarios.

Great Lakes Restoration Initiative: The USEPA Great Lakes Restoration Initiative (GLRI) has a substantial footprint in Wisconsin. This large, multi-year initiative is aimed at improving water and ecological conditions throughout the Great Lakes Basin (<http://www.epa.gov/glnpo/glri/>). Most of the projects are not directly connected to groundwater. However, the surface-water modeling using the Precipitation Runoff Modeling System (PRMS) throughout the Basin provides important information on groundwater/surface-water interactions and recharge. PRMS modeling combined with proposed background work at several sites in the Lake Superior basin will be vital for responsible management and evaluation of proposed mining activities.

Development and use of the USGS models to evaluate climate change effects at a Northern Wisconsin Long Term Ecological Research site: Modeling has focused on the local isthmus scale (Fienen and others, 2009) as well as larger watershed-scale (Hunt and others, 2008). Initial simulations of climate-change effects on groundwater systems were performed using a simplified representation of the system in a surface water model (Walker et al., 2012) as part of a nationwide synthesis of potential effects on watershed hydrology (Markstrom et al., 2012). The recently developed USGS groundwater/surface-water code, GSFLOW (Markstrom and others, 2008), combines two widely used models: PRMS and MODFLOW. Using this approach, the effect of climate-change driven rainfall and temperature changes on stream flow and groundwater recharge can be predicted.

Two relatively simple climate scenarios were examined using a GSFLOW model of the USGS Trout Lake Water, Energy and Biogeochemical Budgets (WEBB) study site in northern Wisconsin, USA (Hunt and others, 2008; Walker and others, 2009). This work was followed up a

more encompassing set of analyses using 3 IPCC emission scenarios from 4 GCMs (Markstrom and others, 2012; Hunt and others, 2012; Walker and others, 2012). Even though the simulations could be improved by inclusion of more sophisticated processes and scenarios, these results demonstrate a utility for hydrologic modeling for today's resource management actions.

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**Report of the Governor's Representative
Steve Diercks, Coloma, WI**

Several recommendations of the GCC involve developing partnerships to achieve sustainable groundwater quantity and quality, to increase monitoring and applied research and support pro-active groundwater planning. GCC members recognize the importance of groundwater to the health of our communities, families and economy. Wisconsin's Central Sands region has become one of the most productive irrigated vegetable areas in the United States with top five rankings for potatoes, sweet corn, green beans, peas, carrots and several other specialty vegetable crops. Annual production is valued at over \$6.4 billion and the industry generates over 35,000 jobs in the area. At the same time, concerns grew over the potential impact of irrigated agriculture, climate, urbanization, and other factors on the groundwater aquifer and surface waters of the Central Sands. In response, the Wisconsin Potato and Vegetable Grower Association (WPVGA) Groundwater Task Force was formed to bring together resources and expertise to foster the sustainable use of groundwater resources. It is an example of collaboration involving GCC member agencies and the agriculture industry.

The group's diverse membership includes: representatives of 14 potato and vegetable farms from all parts of the Central Sands; 3 major potato and vegetable processors (McCain Foods, Del Monte Foods and Seneca Foods); rural communities (Village of Plover); University of Wisconsin Research and Extension Specialists from the Departments of Soils, Horticulture, Entomology, Plant Pathology, Biological Systems Engineering, the Nelson Institute, the Wisconsin Institute for Sustainable Agriculture; and support expertise from WPVGA, Wisconsin Department of Natural Resources, Wisconsin Geological and Natural History Survey, Wisconsin Public Service, USDA-Natural Resources Conservation Service, irrigation and drainage companies and other groups that are called on as needed.

Groundwater monitoring and applied research are key Task Force activities that consolidate and build on the extensive existing knowledge-base related to the hydrogeology of the Central Sands and the potential impacts of water use, drainage, climate and other factors on the groundwater aquifer and associated surface water bodies. They include:

- A network of privately owned irrigation wells in the Central Sands to monitor groundwater fluctuations. The network currently consists of over 500 wells across 4 counties sampled 1-3 times/year. The database is maintained by the WPVGA and may be accessed subject to WPVGA guidelines.
- Co-funded 3 groups of 8 monitoring wells to continuously track fluctuations in groundwater at 6 hour intervals in transects across 3 areas designated as high risk for surface water impacts (Little Plover River, Long Lake, Pleasant Lake) and an additional 5 new monitoring wells in 2015 in the Little Plover watershed to aid in ongoing modeling. Groundwater elevations are posted at (http://wisa.cals.wisc.edu/central_sands_water/csw-monitoring-wells) every 3 weeks.
- Funded a WGNHS study to examine the geophysics and stratigraphy of the Little Plover River Basin (2014-2015) and enhance the DNR-funded modeling project in the area.
- Co-funded WGNHS model of potential impacts of drainage system modifications on water retention and groundwater recharge and study of potential inter-relationships between cropping landscapes, watersheds and groundwater fluctuations in the Central Sands.

Work leading to sustainable groundwater quantity through evaluating and implementing strategies to increase the efficiency of irrigation includes:

- Funded a new, web-based irrigation scheduling program (WISP-2012) by UW Department of Biological Systems Engineering (ADD link to Publication) and collaborated in statewide training and on farm visits to increase use of WISP-2012 throughout the industry. The program is available to commercial software developers for incorporation into farm management software.
- Collaborated with UWS and funded evaluation of soil moisture sensors, drip irrigation methods to conserve water and manage nutrients and pesticides, deferred and deficit irrigation (withholding water at early growing stages to increase root depth and throughout the growing season). Among the useful results, drip irrigation demonstrated use of 15% less water.
- Conducted an industry-wide assessment of irrigation practices currently used by growers (2014). Assessment completed by 90% of growers representing 185,375 acres. Data will serve as a baseline against which growers can measure future improvement and is currently being used to identify key practices which can be promoted to increase irrigation efficiency as a component of a new WDATCP grant. WPVGA is collaborating with DNR on a new initiative to recognize and reward irrigation expertise.

To support pro-active regional groundwater planning, the task force is developing digital maps of the distribution of crops, natural plant communities, woodland and urban areas and investigating evapotranspiration from crops, natural landscapes and bare soil in relation to climate, irrigation, and fluctuations in groundwater.

As the Governor's Representative, I am pleased to report these examples of support for achievement of Wisconsin's important groundwater management recommendations to the people of Wisconsin, and seek broad input from all concerned parties to determine potential solutions to groundwater issues.

Evaluating pumping impacts on lakes, streams, and wetlands

Groundwater pumping is developing rapidly in many parts of the state, often with poorly-known impacts on lakes, streams, and wetlands. One area of the state where pumping impacts have long been predicted and are reasonably understood is the central sands. About 20% of the state's groundwater pumping occurs in the region (Portage, Waushara, and Adams are the first, third and fourth largest pumping counties).

Three recent studies on the linkages of pumping and surface water stresses have been completed in the central sands, one study is in progress, and a fifth will be initiated in July 2013. These are in addition to historical studies by the USGS in the 1960s. A Little Plover River study (Clancy et al. 2009) quantified pumping impacts on this flow-stressed stream, concluding that pumping on average takes 45% of the streams average flow. A broader study on the greater central sands area (Kraft et al. 2010, Kraft et al. 2012) concluded that numerous lakes have their water levels depressed by three feet and more due to pumping, and that most central sands headwaters streams are pumping impacted. The broader study has been supplemented through 2011 by Kraft et al. 2012 and an ongoing study slated for completion in 2014. In July 2013 a detailed modeling project is anticipated to be in the Little Plover region with the goal of understanding how to manage groundwater pumping within a constraint of healthy stream discharges.

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Arsenic Research

Naturally-occurring arsenic was discovered in Wisconsin's groundwater in 1989 during a routine investigation conducted by the DNR. Approximately 4% of the private wells located in Winnebago and Outagamie Counties had arsenic levels that exceeded the federal drinking water standard at that time (50 µg/L). Over the years the department has continued to work with drillers to improve well drilling and construction techniques to minimize arsenic levels in potable wells.

Arsenic is released from aquifer materials by several mechanisms. The primary mechanism in NE Wisconsin is oxidation of sulfide minerals when groundwater is drawn down and the rock is exposed to air, or air is introduced to the rock formations during well drilling. Other metals (such as nickel, cobalt, cadmium, chromium, lead and iron) associated with the sulfide minerals can also be released to groundwater and may increase health risks. The primary mechanism in SE Wisconsin, and in some glaciated areas of Northern Wisconsin, is the release of arsenic bound to iron oxide minerals in the aquifer sediments. In these settings, lack of oxygen in the groundwater system makes the iron oxides soluble which also frees the arsenic.

Between 2002 and 2004 the DNR required more stringent specifications within four small areas where arsenic contamination problems were severe. To avoid creating a 'hodge-podge' of small special well casing depth areas (SWCDAs) scattered over a two-county region, DNR expanded the SWCDAs to include all of Winnebago County and Outagamie County. Information on the specifics of the SWCDAs requirements can be found at:

<http://dnr.wi.gov/topic/Groundwater/arsenic/casingRequirements.html>.

Understanding the occurrence of arsenic in Wisconsin's groundwater has been a good example of interagency cooperation. Initial work with DHS and local health departments and town boards effectively defined the problem and raised awareness. Research supported by the joint solicitation helped define the extent and mechanisms of release. DNR and Commerce (now DSPS) worked jointly with water treatment companies on developing treatment systems for arsenic removal. Well drillers assisted in identifying drilling methods that reduce arsenic.

Sixteen studies through the joint solicitation have explored arsenic related topics from detection to geologic controls to well construction and treatment (See <http://dnr.wi.gov/topic/Groundwater/arsenic/>). Recently completed research focused on release mechanisms, triggers and reaction kinetics that affect well construction, disinfection, and rehabilitation. A second focus of recent work is identifying other areas of the state with impacted groundwater.

A DHS Health Consultation study on arsenic in private wells in the Wind Lake, Racine County area showed arsenic is present in both the deep glacial and Silurian bedrock aquifers (<http://www.atsdr.cdc.gov/HAC/pha/WindLakePrivateWells/WindLakeHC04-28-2009.pdf>). Of 25 wells tested, 12 contained arsenic levels above the Enforcement Standard (ES) of 10 µg/L. Free test kits were made available to any interested resident in the area and resulted in 92 samples from 70 different private wells. The results showed 22 of 70 (31%) wells with arsenic levels at or above the ES. Test results ranged from 10 to 27 µg/L. In addition to arsenic, water from 10 wells had lead at levels above the ES of 15 µg/L.

The DNR, DHS, DSPS and others continue to work on arsenic problems around the state. Arsenic has been found at levels above the ES in every county. DHS has conducted two separate

studies on the health effects of arsenic on Wisconsin citizens. DHS researchers have observed higher rates of skin cancer, heart disease and depression among consumers of water that contains traces of arsenic (Knobeloch et al, 2002; Zierold et al, 2004).

A 2007 study funded through the joint solicitation examined the relationship between arsenic contamination and common well disinfection practices such as shock chlorination. Results indicate a complex cycling of iron and arsenic in well bores and aquifers. Microbiological activity in the aquifer and the amount of pumping from a well affect arsenic release related to shock chlorination (Gotkowitz et al, 2008; West et al. 2012). Results suggest that managing the quality of water in domestic wells in arsenic-impacted areas of Wisconsin may be beyond the ability of individual homeowners.

Effective well construction requirements implemented in SWCDAs in Winnebago and Outagamie Counties are being applied in other areas of the state. In addition, extending public water supplies or promoting use of household treatment systems are alternatives for providing a reliable source of potable water.

Ongoing efforts to address arsenic in groundwater include:

- Ongoing testing of private wells for arsenic through the fee-exempt testing offered to low-income families by local health departments.
- Refinement of the geology in the Outagamie and Winnebago county area and updating casing requirements,
- DHS and DNR sampling of transient non-community wells.
- DSPS and DNR evaluating and pilot testing arsenic treatment systems for public and private systems that do not have an alternative aquifer option. One point-of-use treatment system was recently approved.
- DNR efforts to improve well construction for school and community wells
- DHS, DNR and the WGNHS are working together to gather information from drillers and pump installers on areas with high iron and corrosive water, which may be indications of an arsenic problem. Sampling of these areas is being lead by DHS.
- DHS and DNR targeting of wells for sampling in the southern and SW portions of the state.
- Requiring arsenic sampling for all new and reconstructed wells in Florence County.
- Educational outreach to the well drillers continues.

More information related to arsenic can be found on the DNR Arsenic Web Page:
<http://dnr.wi.gov/topic/Groundwater/arsenic/index.html>

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The Atrazine Rule

The development of the Atrazine Rule (ATCP 30, Wis. Adm. Code) illustrates how the benefits of state-funded research and monitoring can build on one another. In the mid-1980s the corn herbicide atrazine was first detected in monitoring wells and private drinking water wells in Wisconsin. The first systematic well sampling program to characterize atrazine contamination on a statewide basis was the 1988 DATCP Grade A Dairy Farm Well Water Quality Survey (LeMasters, 1989). This state-funded well survey estimated that atrazine was present in 12% of the Grade A Dairy Farm Wells in the State.

This study left unanswered many questions regarding the sources, groundwater susceptibility, and the presence of pesticides other than atrazine. Without better information on these and other questions, it was challenging for DATCP, the agency charged with groundwater protection related to agricultural chemicals, to develop a plan of action. It was obvious that a concerted information gathering program was needed. Over the next several years, before and during the development of the DATCP atrazine rule, the Wisconsin Groundwater and Pesticide Research Program played an essential role in providing the needed information. Research and monitoring were conducted on several topics that played a direct role in the evolution of the atrazine rule.

The state research and monitoring program funded several key projects to better understand the sources of atrazine contamination. When atrazine was first found in groundwater, an argument had been made that this was the result of point sources such as spills and mishandling. One of the most important findings that allowed DATCP to begin developing the atrazine rule was that normal agricultural applications of atrazine could lead to groundwater contamination. The DATCP groundwater monitoring project for pesticides (Postle, 1986-96) used monitoring wells located next to agricultural fields to study groundwater contamination by atrazine and other pesticides. This study showed that atrazine from field use on sandy soils could cause contamination, often above the 3 µg/L ES. The UW Water Resources Center conducted a detailed hydrogeologic study (Chesters, 1990-91) at a farm in Dane County and showed conclusively that atrazine contamination could result from both field applications and mixing/loading practices. With the knowledge that nonpoint contamination of groundwater by atrazine was indeed occurring, DATCP could develop ways to reduce this contamination.

State-funded research was essential in showing that atrazine contamination did not follow simplistic notions of groundwater contamination susceptibility. One of the most important findings was that the Central Sands and the Lower Wisconsin River Valley (LWRV), two areas that appear similar in soils and agricultural practices, had significantly different susceptibility to contamination. These differences were pointed out in several research projects conducted by the UW Soil Science Department (Daniel, 1991; Lowery, 1991; McSweeney, 1991; Lowery, 1992-3). This information had a direct influence on the atrazine rule in that there is now a use prohibition in the LWRV and managed use in the Central Sands.

Another key finding related to the susceptibility of groundwater to atrazine contamination was that many of the areas with high frequency of detections had medium textured (loamy) soils. It had previously been thought that these areas were less susceptible to leaching and groundwater contamination than areas with sandy soils. State-funded research and monitoring efforts, however, showed that the intensity of atrazine use, in addition to soil and geologic conditions, played an important role in the contamination. This finding helped to explain why many areas in south central Wisconsin, with medium textured soil and high corn production, had many wells contaminated with atrazine. This knowledge allowed DATCP to adopt management strategies for reducing atrazine contamination in these areas.

When atrazine was first discovered in Wisconsin's groundwater in the mid-1980s, DATCP was interested in managing its use based on predictive modeling of contamination processes. Modeling activities funded

by the state research program, however, indicated that the behavior of atrazine and other contaminants in the environment was complex and could not be reliably predicted by modeling. In response to this finding, DATCP adopted a more empirical approach to identifying management areas. Actual well results were plotted on maps and, together with an analysis of soils and geology, management areas were delineated.

When monitoring and rule making efforts for atrazine first started, parent atrazine was the only compound that was considered. As more research was conducted, however, it was discovered that three metabolites (breakdown products) of atrazine were present in groundwater and were of health concern (Chesters, 1990-91; LeMasters, 1990; Cowell, 1990; Cates, 1991). State-funded sampling programs showed that due to the presence of atrazine metabolites, the groundwater problems were more serious than previously considered. This knowledge allowed DNR to strengthen the groundwater standard for atrazine in 1992 and allowed DATCP to strengthen the atrazine rule in 1993 and extend required use reductions to the entire state.

It is interesting to try to envision how DATCP's atrazine rule would look if it did not have the benefit of the intensive research and monitoring efforts. It is safe to say that it would not have been developed on as good an understanding of the behavior of atrazine in the environment or the geographic patterns of contamination. It is possible that without the intensive monitoring efforts, the full extent of the problem would not have been discovered and atrazine use would not have been reduced. On the other hand, it is possible that with inadequate knowledge a "broad brush" approach would have been taken. This could have resulted in unfair regulations that were not tailored to the different geographic areas of the state.

Two important aspects of environmental regulation that promote its acceptance are that it is based on science and that it is fair. Good research is necessary to achieve these two characteristics. The Atrazine Rule has experienced a relatively high degree of acceptance due to the effort that was put into its development.

Comprehensive Planning

The State of Wisconsin requires Wisconsin cities, villages, towns and counties that adopt or amend zoning, land division or official mapping ordinances to do so consistent with a comprehensive plan beginning January 1, 2010. As of January 2012, the Wisconsin Department of Administration estimated that 60 county comprehensive plans, 1402 municipal plans, 4 tribal plans and 5 regional plan commission plans were submitted. A map of counties and municipalities with a final, adopted plan is available at <http://www.doa.state.wi.us/docview.asp?docid=5961>. Of those communities that have not adopted a plan, many do not exercise land use regulations that require consistency with a plan (Herreid, 2011).

Communities that rely on groundwater as their sole source of water need to assess the magnitude and limits of their water source as part of their comprehensive plan, but most have little expertise in quantifying and protecting their water supply. A project funded by the UWS partnered with such a community (Richfield, WI) to determine what kinds of groundwater supply information are most relevant and usable for planning from a community's perspective (Cherkauer, 2005). This study determined that a good basic understanding of the geology, sources, sinks and water balance of its aquifer system are needed so that residents and community leaders know where their water comes from. Interaction with users at all levels is also crucial to developing the awareness needed to create long-term plans and supporting laws to ensure a sustainable water supply under foreseeable future conditions. The next step is to share this model with other communities to help them plan how best to actively manage and protect the recharge areas that supply their water.

A related UWS-funded project evaluated whether Wisconsin communities are addressing groundwater in their comprehensive plans, and what tools would make them more likely to do so (Markham, 2005(A)). This project provided multiple presentations to local and state groups involved in groundwater planning; a webpage of study results; articles in a Center for Land Use Education newsletter distributed to more than 160 community planners and educators; a presentation to about 100 people at the 2005 conference of the American Water Resources Association-Wisconsin Section; and publication of an article in a national journal (Markham, 2005(B)).

A DNR- and USGS-funded project provided support for centralizing access to groundwater information for use in comprehensive planning (Markham, 2008). The project utilized an interagency team of federal, state and local agencies to assist numerous Wisconsin communities with comprehensive planning by providing groundwater information and data in an accessible and user-friendly manner. Specifically, the interagency team provided personalized assistance for three pilot counties in the form of a 20-30 page report and a locally-tailored presentation for citizen plan commission members. The same interagency team prepared a centralized website that provides a suggested process for integrating groundwater information into comprehensive plans. The website also includes web pages for each of Wisconsin's 72 counties that include local data about groundwater susceptibility, sources of drinking water, groundwater quality, potential sources of contaminants, groundwater quantity, and money spent on cleanup and ground-water protection strategies. The website is available at <http://wi.water.usgs.gov/gwcomp/index.html>. From July 2012 through May 2013 the website had an average of 1,678 unique visitors per month who accessed an average of 3,605 pages per month during this timeframe. February 2013 was excluded from this analysis due a suspected error in the statistics. The comprehensive planning law states that comprehensive plans must be updated at least every 10 years. As communities update their plans, the most recent data on the website is from 2002-2006 for water quality and 2005 for water quantity.

Long term hosting and maintenance of the site is undetermined.

Funding for development of this web site came from the DNR through the GCC-coordinated Joint Solicitation for Groundwater Research & Monitoring. Additional funds were provided by the USGS Cooperative Water Program.

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Detection and Monitoring of Microbiological Contaminants

Protecting groundwater from microbial contamination is a top public health priority. The United States and Canada experience significant levels of gastrointestinal disease from drinking water, more than 70 percent of which is associated with contaminated well water. The GCC has solicited research projects during the last several years that attempt to improve understanding of microbiological aspects of groundwater contamination.

Bacteria

Several projects have focused on developing new techniques for detecting, quantifying, and monitoring microorganisms in groundwater and soils. Researchers at the UW-Madison Soil Science Department developed a rapid molecular method using the polymerase chain reaction (PCR) to assay soils for the presence of specific sewage-borne pathogens (Hickey 1998). PCR-based methods eliminate the need to culture organisms for detection, and remedy shortcomings of traditional techniques by allowing rapid, sensitive, and specific identification of the pathogens of concern rather than indicator organisms. The PCR protocol Hickey developed was designed to detect DNA originating from *E. coli*, which is one of the major species of bacteria associated with human waste. This method is capable of distinguishing *E. coli* DNA from that of its closest relative, *Shigella* and detecting the DNA equivalent to about 20 cells.

Because they have the capacity to co-metabolize a wide variety of organic chemicals, including halogenated compounds, methanotrophic bacteria have significant potential for bioremediation. The UW-Milwaukee Department of Biological Sciences has developed methods for quantification of methanotrophs in groundwater (Collins 1998, 2000). These methods, that include competitive PCR and direct PCR, provide approaches to monitoring bioremediation and natural attenuation. In addition, this work has provided the basis of another study that applied direct PCR to the detection of pathogens in groundwater (Collins 2002).

A study by the Wisconsin State Laboratory of Hygiene (WSLH) investigated storage and handling requirements for water samples submitted for coliform and *E. coli* analysis (Degnan and others, 2003). Currently the USEPA has no guidelines for sample holding times and shipping temperatures for drinking water samples submitted for *E. coli* testing. The study provided evidence to expand the allowable storage time of water samples submitted for *E. coli* analysis beyond the current eight hour limit as well as supporting a single preservation protocol for both surface waters and drinking water samples. A change to a maximum holding time of chilled samples for up to 30 hours could easily be supported by the data presented in this study. The data also called into question the current practice of allowing up to 48 hours for submitting drinking water samples with no attempt to cool them. A reduction in the time period to 30 hours, or a requirement to ship the samples at less than 10 degrees C, could be supported by the data.

Another WSLH study developed a culture method for detecting *Helicobacter pylori* from a heterogeneous microbial population in water, and then use this method to establish a data base for its occurrence in Wisconsin groundwater (Degnan and others 2003). Prior to this study, there were no reliable methods for detecting viable *H. pylori* in environmental samples (water, manure, vegetables, etc.). *H. pylori* is recognized by the World Health Organization to be the primary cause of peptic ulcers, chronic gastritis and stomach cancer. About 50% of the U.S. population is thought to be symptomatic or asymptomatic carriers, even though the source of human infection is not well understood. The efforts of this study resulted in the development of a high quality plating media for selecting viable *H. pylori* from mixed microbial populations. Samples from over 400 private wells were *H. pylori*-absent, including wells used by infected residents. These results suggest that the route of *H. pylori* to humans in Wisconsin probably does not involve private well water.

WSLH researchers in the Water Microbiology Unit recently completed testing of a hollow fiber ultrafiltration method for concentrating low levels of microorganisms from large volumes (up to 100 L) of drinking water. Acceptable levels of organism recoveries were demonstrated for bacteria (*E. coli* and enterococci), viruses (MS2 coliphage) and parasites (*Cryptosporidium* and *Giardia*). Quantitative recoveries were recorded for concentrations as low as 0.3 organisms per 100 ml. Establishing testing with lower detection limits for pathogens and indicators adds an additional margin of safety in the protection of public health from waterborne diseases.

A study conducted at the WSLH (Long, 2009), and funded by the DNR, developed a Real-Time PCR assay for the molecular detection of *Rhodococcus coprophilus*. Detection of *Rhodococcus coprophilus* is an indicator of fecal pollution from grazing animals. This data is useful as part of the WSLH's "toolbox" of microbial source tracking methods to determine the source of fecal contamination of groundwater. Other assays performed as part of the microbial source tracking (MST) toolbox are; genotyping of male-specific coliphages, detection of sorbitol-fermenting *Bifidobacteria* and detection of *Bacteroides* using different primer and probe sets to distinguish between human and animal sources of fecal pollution. In the last 2 years there have been 49 groundwater samples collected for analysis. One sample was from a drain tile and the others were from 40 different private wells (with 8 wells sampled twice). Results indicate 28 of the 49 samples were positive for contamination from grazing animals, 3 samples tested positive for bacteria associated with human waste, 10 samples tested positive for recent but inconclusive fecal contamination, and 9 samples tested clean. The use of these analyses has proven valuable to DNR in granting Well Compensation awards for replacement wells for wells contaminated with livestock waste (manure)

A powerful microbial source tracking tool was developed by Sibley et.al that enables scientists to detect bovine adenovirus. This assay determines environmental fecal contamination from those animals. These viruses were detected from both stool and urine (Pedersen, 2008).

A UW Water Resources Institute project examined the strengths and weaknesses of 10 enzyme-based tests approved by the U.S. EPA for detecting total coliform and *E. coli* in drinking water (Olstadt and others, 2007). The results suggest these tests differ significantly in their ability to detect/enumerate total coliforms and *E. coli* and to suppress false positive results from *Aeromonas ssp.*, a non-coliform organism. The most significant of these findings was the inability of some test method/sample matrix combinations to even detect *E. coli* in high concentrations.

The release of antibiotics into our water resources is driving efforts to characterize the occurrence, fate, and transport of resistant bacteria in the environment. In a recent WRI-sponsored project, onsite-wastewater treatment systems were evaluated as a potential source of genes that encode antibiotic resistance in bacteria (McMahon, 2006). The concentrations of resistance genes in the septic tanks were several orders of magnitude higher than those observed in treated municipal wastewater effluent. The investigators hypothesize that past agricultural activity may have contributed to the presence of resistance genes in subsurface bacteria, but long term sampling with higher spatial resolution is required to adequately confirm the hypothesis.

Current methods for the detection of the presence of toxigenic *E. coli* in a water sample require several days to complete (USEPA, 2010). In the case of an emergency outbreak, the source of infection remaining unproven for this amount of time may result in continued exposure, increased incidence of infection and possibly deaths to vulnerable populations. Research is currently underway at the WSLH for development and optimization of a quantitative polymerase chain reaction method to detect generic *E. coli* and toxigenic *E. coli* for recreational water as well as drinking water. This method will be challenged by experimentation with effects of PCR inhibitors commonly found in drinking and surface water, effects

of competing organisms and performance on a wide range of groundwater samples with a variety of water chemistries. This development will increase the already broad array of testing offered by the WSLH and assist with expediency in a potential outbreak situation involving toxigenic *E. coli*.

The WSLH had taken part in a USEPA/CSC study involving the validation of a culture method for *Vibrio cholera* as a tool in an emergency response situation. The method consists of a mock hurricane “occurrence” resulting in multiple deaths and illnesses. The Water Microbiology unit was tasked with analyzing water for *Vibrio cholerae* from targeted sites from hurricane affected areas. The lab was able to use the *V. cholerae* culture method to detect *V. cholerae* from the spiked samples and effectively report our data to the EPA/CSC.

The WSLH is currently taking part in a validation study overseen by USEPA/CSC evaluating a method to characterize “Human Fecal Pollution in Water by TaqMan Quantitative Polymerase Chain Reaction (qPCR).” The validation entails evaluation of multiple primer/probe sets for human-associated *Bacteroides* in a multiplex reaction incorporating an internal amplification control. The purpose of this study is to standardize a method for laboratories to detect the presence of human-associated *Bacteroides* in an effort to source track human fecal contamination of groundwater and surface/recreational water.

Viruses

The Marshfield Clinic Research Foundation has investigated the association of pathogenic viruses and bacteria in private wells with incidences of infectious diarrhea and indicators of well water contamination (Borchardt 1998, 2000). In general, infectious diarrhea was not associated with drinking from private wells, nor was it associated with drinking from wells positive for total coliform. However, wells positive for enterococci were associated with children having diarrhea of unknown etiology, which was likely caused by Norwalk-like viruses. Final results indicate that the incidence of virus contamination in private wells may affect 4-12% of private wells. Of concern to drinking water regulators is the seasonal variability of the virus occurrences and lack of correspondence between viral presence and common microbial indicators.

In another study with the US Geological Survey, Marshfield researchers found that 50% of water samples collected from four La Crosse municipal wells were positive for enteric viruses, including enteroviruses, rotavirus, hepatitis A virus, and Norwalk-like virus (Hunt, 2003; Borchardt, 2004). As with the private well study, there was no correspondence to common indicators of sanitary quality. More surprising, there was no relationship between presence of surface water in the well water samples as determined by isotope analysis and virus occurrence. Recent work between Marshfield Clinic and USGS targeted the source and transport of viruses to drinking water wells. This work was funded by the WDNR and USGS, and involved field investigation using physical measurements, wastewater tracers, and virus analyses. Water sampling screening in 14 Wisconsin communities again documented virus occurrence in wells without surface water sources, and a second sanitary sewer source was supported by wastewater tracer presence. Using more intensive characterization at one municipal well in three Wisconsin communities, the relation between high wastewater tracer and virus occurrence was documented, and also demonstrated sufficiently short travel times such that viruses would be expected to remain infectious even in a 400 foot deep municipal well. Given the wide extent and age of infrastructure, these findings suggest that viruses may be more common than previously expected in Wisconsin drinking water. Recent work by Marshfield Clinic has begun to evaluate whether the viruses are inactivated through disinfection processes, or result in illness in the community. This type of research into the link between virus occurrence and human health will provide the overall context to this extensive Wisconsin research topic.

Very recently viruses have also been found in deep bedrock wells that are thought to be protected by low permeability confining units. Studies funded by AWWARF and DNR examined virus occurrence in

three deep (>400 feet) confined bedrock wells serving Madison. The surprising result was that infectious viruses were repeatedly present in two of three wells sampled. Examination of potential virus sources and pathways was inconclusive, but sampling results suggest that the deep groundwater is more vulnerable to virus contamination than previously thought (Borchardt, 2007). A follow-up study (Bradbury and others, 2010) funded through the Wisconsin Joint Solicitation found viruses in each of seven deep wells sampled over a period of two years, with many samples positive for infectivity. Correlation between viral serotypes found in sewage, lakes, and groundwater suggests very rapid transport, on the order of weeks, from the source(s) to wells. If such rapid transport exists, then deeply-cased municipal wells may be much more vulnerable to shallow contamination than previously assumed (see <http://wisconsingeologicalsurvey.org/wofrs/WOFR2010-04a.pdf>). One outcome of the initial study was the use of increased disinfection by the Madison Water Utility in order to assure public health.

A combined microbial and chemical target toolbox is being tested, validated and applied at WSLH to conduct microbial source tracking. The toolbox uses microbial and chemical tracers that are specific or unique to waste sources to determine sources of contamination and allows for a weight-of-evidence approach for identifying sources of contamination. Current methodology discriminates between human sewage-related sources and animal fecal contamination and can identify grazing animal contamination. This suite of tests has been applied to contamination events in Dodge and Door Counties, among others. In one instance, an improperly installed septic system was the culprit. In another instance, farm field manure runoff during heavy rains was identified. By identifying the source of microbial contamination, remediation or correctional actions can be targeted and the spending limited funds on "false sources" can be avoided. Research to improve on the methods in this toolbox is being funded by the DNR and UWS.

After several years of development and validation, researchers at the Marshfield Clinic Research Foundation now possess the capacity for high-throughput testing of waterborne viruses. Virus tests include six common human enteric virus groups and six common bovine viruses. The number of tests that used to take three months to complete can now be accomplished in an afternoon. Recently, these researchers completed a study involving more than 20,000 virus analyses of the groundwater supplying drinking water in 14 Wisconsin communities. This level of laboratory capacity relies on three major advances: 1) Inexpensive and effective concentration of waterborne viruses using glass wool filtration, a method developed and fully validated at Marshfield Clinic (Lambertini, 2008); 2) Virus detection by real-time quantitative polymerase chain reaction (qPCR) using recently developed high-throughput platforms and highly specific fluorescent probes; and 3) Development at Marshfield Clinic of a unique Laboratory Information Management System (LIMS) for quality assurance, quality control, and data management of analyses for waterborne pathogens. Contingent on several more advances, the researchers believe it will be possible to screen a water sample for all common waterborne pathogens using an approach that is inexpensive, efficient, and reliable.

The sole use of bacterial fecal markers is not adequately protective of human health or indicative of the presence of other microorganisms, including viruses. Therefore, the fecal source tracking toolbox available to WSLH has been expanded to with the conception and optimization of novel species-specific PCR assays for distinguishing human from bovine adenoviruses in groundwater samples (Pedersen, 2008, 2010 and 2011). These viruses are widespread in human and bovine populations, and have already proven useful for indicating the presence and source of wastes in groundwater. Because the environmental fate and transport behaviors and prevalence of enteric viruses can differ, we are currently evaluating additional species-specific virus targets, polyomaviruses and Torque Teno Viruses. The additional of these viral targets will provide the WSLH with unique source tracking capacity and with a robust set of makers for describing the presence of fecal contamination. The interrogation of samples for multiple viral and bacterial targets is especially important for situations where contamination is suspected in private wells.

Protozoans

The WSLH Flow Cytometry unit completing the final phase of a multi-year project to develop and round-robin validate methods for genotyping *Cryptosporidium* from microscope slides. This method will aid water utilities, states, and EPA regions by providing information regarding the human health risk when water tests positive for the presence of *Cryptosporidium*. The method currently mandated by the U.S. EPA (method 1622/1623) does not speciate human infectious from non-human infectious species. This “add-on” method can be used to provide supplemental information which will aid water treatment and source water protection decision-making processes.

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Groundwater Drawdowns

Large-scale withdrawals of groundwater are adversely affecting the environment, economy and public health in large areas of Wisconsin. These drawdowns can cause the water level in wells, lakes, streams and wetlands to drop or cause them to dry up entirely. Drawdowns can also cause the levels of arsenic, radium, and salinity in drinking water to increase.

State-supported research is using groundwater information and groundwater flow models developed at a regional scale and adapting it for use at the local level. In Washington County, researchers worked with the city of Richfield to develop a protocol for quantifying its groundwater budget (Cherkauer and LaCosse, 2001). That information will be coupled with projected changes in land use and pumping demand to define the effects of several development scenarios on the community's water supply. This protocol is currently being applied to the entire 7-county SEWRPC region of Southeast Wisconsin.

Regional studies have identified central Waukesha County as an area where continued deep groundwater pumping might be causing the deep aquifers to become unconfined as water levels fall (Eaton, 2004). A 2004 project installed one deep piezometer near Pewaukee for use as a monitoring point to document water-level declines.

The Maquoketa shale forms an important aquitard, or low permeability geologic layer, in eastern Wisconsin. Restriction of recharge to the deep sandstone aquifer by the Maquoketa is the major reason that drawdowns in the deep sandstone aquifer in Southeast Wisconsin are so severe. Hart and others (2007) investigated groundwater flow across the Maquoketa and in particular studied how cross-connecting wells and fractures control flow across the shale. Cross connecting wells are generally older wells that are open to aquifers both above and below the shale. These wells form conduits from one aquifer to another and can cause drawdown in the upper aquifer while also causing water-quality degradation in the lower aquifer. The investigators searched state records and discovered that approximately 170 such wells exist in Southeast Wisconsin. They also investigated faults and fractures through the Maquoketa and discovered that such features, although sparse, also can have a major impact on the overall rate of flow across the shale. The implication is that naturally occurring low-permeability formations, such as the Maquoketa, may transmit more water than originally thought due to the presence of cross-connecting wells and fractures.

Another project investigated the sources of high salinity and radium in the deep sandstone aquifer that supplies water to residents of eastern Wisconsin (Grundl and Bradbury, 2000). This project examined the chemistry of the groundwater and the rock formations of this complex aquifer to determine the causes behind rising salinity and radium levels to help city planners and water utility directors better understand the relationship between well operations and water quality in this region, and evaluate effects of urban growth on water supplies. Results showed that radium in excess of the EPA drinking water limit occurred in a band located just inside the western edge of the Maquoketa Shale. As groundwater in the deep sandstone aquifer transitions from unconfined conditions to confined conditions beneath the Maquoketa Shale, geochemical interactions with aquifer minerals, primarily sulfate minerals, cause radium levels to rise. A more complete understanding of geochemical processes occurring in the deep sandstone aquifer is hindered by the paucity of data points, in particular the complete lack of vertically discrete data.

In late 2007, several suburban communities in the Lower Fox Valley reduced consumption of groundwater by switching to surface water supplied by pipeline from Lake Michigan. As a result, water levels in the deep sandstone aquifer near Green Bay in Central Brown County have begun

to recover. In mid-2007 the WGNHS began an effort to monitor the water level recovery in the deep sandstone aquifer near Green Bay with the objective of documenting the recovery and improving our understanding of the deep hydrogeologic system in this region of the state (Luczaj and Hart, 2009). Since 2007, as part of a regional study, water levels have been monitored and collected into a database. As of spring 2009, water levels had risen by 100 feet in much of the region and, in some wells, by more than 150 feet. In 2011, the rate of recovery has significantly slowed. The water levels are still rising but more slowly and are expected to level off in the next several years but its not clear exactly how soon or at what level (Luczaj, 2011, and Maas, 2010). Another result of the decrease in pumping and increasing water levels is that some wells in the northwestern part of the GMA near Howard and Suamico have begun flowing. The highest level since recording began in 1952 was recorded in a USGS monitoring well in April 2012. This well is located on the southern shore of Green Bay in the deep sandstone aquifer. In addition to water levels, the pumping rates of current groundwater users in the region have also been collected. The study also identified a smaller cone of depression near Little Chute, Kaukauna, and Kimberly where water use has remained steady. The water levels there were not affected by the decreased pumping to the north and have remained relatively steady since 2005.

These projects illustrate the importance of monitoring the resource. We now know that if the pumping around Little Chute, Kaukauna, and Kimberly does not impact the Central Brown County cone of depression. We also know that a further decrease in pumping will cause more wells to flow along the western edge of the Central Brown County cone of depression and that if pumping stays below 4-7 mgd that the St Peter sandstone will likely remain saturated and will pose less risk for release of arsenic.

Other State-supported research has investigated the viability of aquifer storage and recovery (ASR) for Wisconsin, where excess water is stored in aquifers when demand is low and withdrawn for use when demand increases (Anderson, 2004). Computer models of groundwater flow and transport in ASR systems have been developed for two representative groundwater systems in Wisconsin. A better understanding of pumping rates, storage times and other factors that affect recovery efficiency of ASR systems has helped guide decision-making about using these systems in Wisconsin.

For more information on regional drawdowns see:

<http://dnr.wisconsin.gov/topic/Groundwater/GCC/groundwaterQuantity.html>

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Groundwater Monitoring At Solid Waste Disposal Sites

The DNR's Waste and Materials Management (WMM) program received project funding ten times from 1985 to 2003 through the joint solicitation process. These projects have benefited the program in many ways, primarily impacting regulations and monitoring practices.

The first two studies (Friedman, 1985-87; Battista, 1988-89) revealed for the first time that groundwater around many Wisconsin landfills was contaminated by VOCs. The studies also showed that VOC contamination of groundwater was more common at unlined municipal solid waste landfills than at other types of landfills. A follow-up VOC study (Connelly 1993-94) showed that VOC levels have decreased at most of the unlined landfills, though at many of the sites VOC levels do not show continued decline. There was no VOC contamination definitely attributable to leachate migration at any of the older, engineered landfills confirming that these sites are performing as WMM program staff had hoped. The results of the three VOC studies were used to establish requirements for VOC sampling at new and existing landfills. These studies also indicated that inorganic compounds could be useful in predicting VOC contamination at landfills. Therefore, until EPA rules began requiring VOC monitoring in 1996, the WMM program allowed sites to sample for inorganic parameters as part of routine monitoring and not sample VOCs unless inorganics were elevated. The VOC studies provided valuable data that were used to convince EPA to reduce the number of VOCs required for monitoring at municipal solid waste landfills in Wisconsin. This reduction in monitoring (the use of inorganics and the reduced number of VOCs when they are required) allowed landfill owners considerable cost savings while maintaining equivalent environmental protection. Additionally, the VOC data were used to require responsible parties to define the degree and extent of contamination and remediate groundwater contamination at their landfills.

Research on methods of assessing groundwater quality data and data quality control completed in the third VOC study has been helpful to WMM program staff and consultants in interpreting groundwater quality data from landfills and other facilities. This study also showed the need to require laboratories to report data between the limit of detection and the limit of quantification.

An assessment of Wisconsin's Groundwater Monitoring Plan program (Pugh, 1992) for active non-approved landfills provided the documentation of a set procedure for selecting monitoring sites. This information was useful in meetings held to convince municipalities that they had not been singled out for further evaluation of groundwater contamination and to demonstrate that the process used for selecting landfills for monitoring was objective.

Three studies from 1991 to 1994 on the potential groundwater impacts at deer pits, yard waste sites, and construction and demolition landfills (Pugh, 1992-3; Pugh, 1994) were conducted because little or no data existed on the potential impact to groundwater from these sites. Research provided the information necessary to revise rules and establish policy regarding monitoring and siting of construction and demolition (C/D) landfills, deer pits, and yard waste sites in Wisconsin. The groundwater study of deer pits showed that impacts were minimal and helped the WMM program decide not to require liners and loosen some construction and reporting requirements. Similarly, the yard waste site study showed only minor groundwater impacts, which led the WMM program to encourage active management of these sites rather than stiffen regulations. The study of construction and demolition landfills showed some groundwater impacts at large sites but little or no impacts at smaller sites. These findings led to revisions of DNR regulations in 1996 allowing lined intermediate size C/D landfills, which can provide the economic benefits of a large site without the potential negative impacts of very large sites. Based on the research, the

regulations were written to require groundwater monitoring of inorganic parameters at small size C/D landfills but only require VOC sampling when establishing background. Since these studies have been conducted, many states and the EPA have contacted the WMM program about the information collected.

Another study undertaken by the WMM program (Connelly, 1994) was a comparison of groundwater sampling methods for collecting metals samples at monitoring wells. The study was in response to EPA's October 1991 ban on field filtering of groundwater samples that became effective in October 1994. The WMM program opposed this ban because many Wisconsin monitoring wells produce very turbid water which can lead to false positive results for metals if samples are not filtered. Additionally, the new EPA-recommended procedure, low-flow pumping, requires a significant amount of additional equipment. The study showed that the low-flow pumping method was appropriate in many circumstances but could not be used to sample slowly recovering wells. The results showed that turbidity was the best indicator that a well has been sufficiently purged. The results of the investigation were used to revise groundwater sampling procedures required by the WMM program. Additionally, the study helped establish Wisconsin as one of two leading states playing a major role in advising EPA on revisions to their groundwater sampling requirements at municipal solid waste landfills.

A follow-up study by the WMM program (Svavarsson, 1995) compared low flow pumping and bailing for VOC groundwater sampling at landfills. The study indicated that, in contrast to what some were claiming, there was very little difference in the results when using the two different methods. These findings were incorporated into the new groundwater sampling code and allowed the use of either method for sampling VOCs. This reduced the cost that landfill owners would otherwise have had to bear to purchase and operate low-flow pumping equipment.

A joint project between WMM and UW Stevens Point evaluated the effectiveness of chemical oxygen demand (COD) as an indicator parameter at landfills (Connelly and Stephens, 2000). One reason for evaluating COD is that mercury waste is generated when COD is analyzed in the laboratory. The DNR's overall goal was to reduce the amount of mercury that gets into the environment. Eliminating COD sampling at the 400+ landfills that currently sample for it would help the agency meet that goal. Findings from the first year of the study indicated that there is potential to eliminate COD monitoring at some types of landfills. The second year of the study evaluated possible alternatives to sampling for COD. Dissolved organic carbon (DOC) appears to be an acceptable alternative in certain circumstances. WMM staff incorporated the recommendations of this study into code changes that went into effect in February 2006.

Between July 2000 and July 2001 the Bureau studied 31 landfills accepting municipal solid waste, to try to determine whether VOC contamination in groundwater at these landfills is increasing, decreasing or remaining stable (Connelly 2001). Investigators chose sites with 10 years of data and summarized the trends over this period of time. One purpose of this study was to determine whether natural attenuation is occurring in groundwater near leaking landfills. The study showed that natural attenuation processes were occurring at most of the landfills as evidenced by the large number of stable or decreasing concentration trends. However, the concentrations took longer to stabilize and stabilized at higher levels than at other types of VOC contamination sites described in the literature.

WMM received funding for the period October 2002 to October 2003 to study groundwater quality at solid waste landfills to determine whether they are a source of pesticide contamination. Eleven sites were sampled in the spring and summer of 2003 and the findings summarized in a 2005 GEMS Newsletter article. Groundwater samples were analyzed for 14 common Wisconsin

pesticides using immunoassays and additional GC/MS methods. Preliminary findings indicated that leaking landfills may be contributing alachlor, aldicarb, atrazine and 2,4-D to groundwater. The study researchers believed a follow-up study was needed to provide more evidence to help make concrete recommendations about which pesticides to sample for. However, staff and funding have not become available to do the follow-up study.

Methylmercury Formed in Groundwater

Methylmercury (MeHg) is one of the most toxic and persistent substances in the environment. Research has focused on how MeHg forms from inorganic mercury deposited from atmospheric sources such as coal combustion. A UW study conducted at the Allequash Creek watershed in northern Wisconsin determined that anoxic zones in shallow groundwater are an important site of MeHg formation (Stoor, et al., 2002).

Further study showed that MeHg concentrations in these hyporheic (shallow zone) pore waters co-vary with the mercury methylation rate at depth (Meyer, et al., 2005). This suggests that the measured MeHg concentrations are likely produced in situ, and are not from legacy sources. Methylation rates in the hyporheic zone of the peat bog are generally higher than those of the headwater springs – which is consistent with previous observations of increased wetland export of MeHg (Armstrong, et al., 2006).

Additional work also showed that methylation rates were not controlled by the total mercury concentration in pore waters (Creswell, et al., 2008). Instead, high concentrations of strong mercury-binding ligands have been observed and are believed to influence methylation rates by one of several possible mechanisms (Creswell, et al., 2010). Current research examines the leading mechanism by determining the role of neutral sulfide complexes on methylation in Allequash groundwater (Shafer 2011).

This information advances our understanding of mercury transport and methylation in groundwater, and will help us interpret the watershed response to changing conditions in the hyporheic zone. For example, due to the lack of correlation between total mercury and the methylation rate in pore water, the mitigation of atmospheric mercury inputs to the watershed, may not immediately affect MeHg export. In addition, any variation in groundwater levels, whether due to climate change or conjunctive use of groundwater and surface waters, will likely influence MeHg production in both natural and engineered wetlands.

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Pharmaceuticals, Personal Care Products and Endocrine Disrupting Compounds in Groundwater

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

Pharmaceuticals such as antibiotics, birth control pills and various prescription medicines may be present in wastewater effluents. PCPs, including shampoos, detergents and "over the counter" non-prescription medications, are found in both treated wastewater discharges and the municipal solid waste stream. EDCs adversely affect the behavior of natural hormones in humans and other animals. They include both anthropogenic chemicals, such as pesticides and plasticizers, and naturally occurring compounds like steroids and plant produced estrogens. EDCs are found in domestic and industrial wastewaters and in agricultural run-off. Some pharmaceutical and PCP compounds act as endocrine disruptors. 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.

Discharges of treated wastewater through land (soil) treatment systems, leachate leaking from solid waste landfills, sludge biosolids landspreading activities and infiltration of polluted surface waters can potentially contaminate groundwater aquifers. 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.

A DNR and DATCP-funded study (Karthikeyan and Bleam, 2003), investigated the presence of antibiotics in treated wastewater effluents, and their potential fate in the subsurface. A variety of antibiotics were detected in wastewaters analyzed for the study. Two antibiotics, tetracycline and sulfamethoxazole, were found in all of the treated wastewater effluents tested for the project. Very small concentrations of these two antibiotics were also detected in groundwater monitoring wells located directly adjacent to one of the study land treatment system seepage discharge sites.

A UW-funded study (Pedersen and Karthikeyan, 2005) investigated the soil adsorption properties of common antibiotics. This study found that under certain soil conditions some antibiotics, such as the sulfonamide antibiotics, have the potential to be mobile in the subsurface. A number of additional studies, focused on specific antibiotic compounds, have evaluated the factors that affect antibiotic mobility and fate in the subsurface environment (Gao and Pedersen, 2005) (Gao and Pedersen, 2010) (Gu and Karthikian, 2005a) (Gu and Karthikian, 2005b) (Gu and others, 2007) (Gu and Karthikian, 2008) (Sibley, 2008) (Pedersen and others, 2009).

A study of the use of a screening assay to evaluate the occurrence of estrogenic endocrine disrupting chemicals in groundwater was conducted by the Wisconsin State Lab of Hygiene (Sonzogni and others, 2006). This study included testing of both high capacity water supply wells located in close proximity to surface waters into which treated wastewater effluent was being discharged, and water supply wells located in areas of home on-site wastewater-treatment-system discharge into groundwater. A breast

cancer cell line assay (E-screen assay) was used to test study samples for the presence of estrogenic endocrine disrupting compounds. Estrogenic EDCs were detected in surface waters tested but multiple groundwater samples from high-capacity water-supply wells located near those surface waters showed no estrogenic endocrine disruptor activity. Samples for estrogenic EDC analysis were collected from home on-site wastewater treatment systems and from groundwater monitoring wells located adjacent to two of the systems. Estrogenic activity was detected in wastewater treatment system effluent but was not detected in groundwater monitoring well samples.

A DNR project conducted in Dane County (Bradbury and Bahr, 2005) assessed groundwater impacts from on-site wastewater-treatment-system discharge. This project included an assessment of pharmaceuticals, PCPs and estrogenic EDCs in treatment system effluent, soil porewater and groundwater. Four compounds, acetaminophen (Tylenol), paraxanthine (caffeine metabolite) and the hormones estrone and β -estradiol, were detected in wastewater treatment system effluent samples. No pharmaceuticals, PCPs or estrogenic EDCs were detected in the groundwater or soil pore water samples collected for the study.

A UW study (Bauer-Dantoin, 2009) monitored the extent to which groundwater in northeastern Wisconsin is contaminated with endocrine disrupting chemicals (EDCs). The Silurian aquifer of northeastern Wisconsin may be particularly susceptible to nonpoint source contamination due to the existence of shallow soils, dolomite bedrock, and karst features, which combine to facilitate the transport of surface runoff to groundwater. Land application of manure containing synthetic and endogenous hormones may be a significant source of nonpoint source pollutants, including EDCs, to groundwater in the heavily farmed regions of northeast Wisconsin. This study used the MCF-7 breast cancer cell proliferation assay (E-screen) to determine if groundwater samples collected from four northeast Wisconsin counties, including Brown, Calumet, Fond du Lac, and Kewaunee, exhibited estrogenic behavior. Groundwater samples were collected four times between the summer of 2008 and the spring of 2009, and were analyzed for estrogenicity, 17β -estradiol concentrations, nitrate, conductivity, total coliform, enterococci, and *E. coli*. The wells chosen for this study were located in agricultural areas of northeast Wisconsin, were cased into the Silurian aquifer, and were chosen in light of past contamination with bacteria and/or nitrate. Estrogenic activity was detected in a portion of the groundwater samples during all four sampling periods, despite apparent toxicity and/or anti-estrogenic effects observed in the E-screen. The estradiol equivalents found in the study are below the range known to cause endocrine disruption in wildlife and are within the range of levels found in other studies that utilized the E-screen to analyze water samples. Unsafe levels of bacteria and nitrate occurred during all four sampling periods. Average bacterial contamination increased following snowmelt events in February and March 2009. Coliform, enterococci, and *E. coli* were positively correlated throughout the study, with the strongest correlations occurring in the March 2009 sampling period. Correlations were not found between nitrate and bacteria, or nitrate and estrogenicity. One weak, positive correlation was found between *E. coli* and estrogenicity in the March 2009 sampling period.

A DNR project conducted by the Wisconsin State Laboratory of Hygiene explored the potential of hormones from livestock operations to contaminate groundwater. Water samples were collected during precipitation or snowmelt from agricultural fields and subsurface tiles and evaluated for hormones and hormone activity. Some samples did contain hormones (including estrogens, androgens and progesterone) in ng/L concentrations, and concentrations were usually lower in tile water samples than on the surface water samples. Additionally, groundwater samples were collected from monitoring wells at UW-Platteville Pioneer Farms. None of the groundwater samples had detectable levels of hormones or hormone activity, indicating that sorption by soil and degradation of hormones can occur and will protect groundwater at some sites.

The DNR 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 DNR develop effective monitoring strategies. Studies evaluating new sampling techniques and analytical test methods have helped assure that the DNR is utilizing the best available tools to assess the occurrence of these substances in the environment.

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Prevention and Remediation of Groundwater Contamination

The State of Wisconsin (through the UWS Water Resources Institute) has supported many research projects emphasizing new technologies for prevention or remediation of groundwater contamination. Final reports and studies in progress provide information or products that will be important for future efforts aimed at controlling or attenuating groundwater contamination in Wisconsin. The findings cover a wide range of technologies (see list of projects at:

<http://dnr.wi.gov/topic/groundwater/documents/GCC/MonitoringResearch/AllProjects.pdf>):

- New and enhanced physicochemical or biological methods to renovate waters contaminated by pesticides and volatile organic carbon compounds (Hickey, 2006-08), (Park and Benson, 2007), (DeVita and Dawson, 2005-06), (Li, 2004-05), (DeVita and Dawson, 2003-04), (Evangelista and Pelayo, 2003), (Collins, 1997-2002), (Li, 2000), (Benson and Eykholt, 2000), (Benson, 1997-2000), (Hoopes, 1997-99), (Park, 1997-98), (Bahr, 1996-98), (Hickey, 1994-96), (Anderson, 1994-95), (Chesters and Harkin, 1991), (Harris and Hickey, 1991-92);
- Enhancements in the ability to control, monitor, and predict the movement of landfill and mine waste contaminants to groundwater (Edil and Benson 2006-07), (Edil, Benson and Connelly, 2004-05), (Edil and Benson, 2000), (Edil 1997), (Benson, 1995-96), (Edil and Park, 1992-93);
- New technologies for the treatment and removal of Arsenic and heavy metals from groundwater. (Li 2009-11), (Metz and Benson, 2007), (Li et. al. 2007), (Shafer et. al. 2005-07), (Benson and Blowes, 2005-06), (Metz, 2006), (Metz & Benson, 2004-06), (Anderson, 2003), (Park, 2002-03), (McGinley, 2002-03);
- Improvements in the predictability of pump-and-treat or excavate-and-treat remediation applications to contaminated aquifers (Evans & Li, 2002-03), (Bahr, 1994-95);
- Innovative agricultural practices designed to reduce groundwater contamination by pesticides and nitrate (Larson, 2011-13), (Thompson 2010-12), (Stelzer and Joachim, 2010), (Miller, 2009), (Bahr and Roden, 2009), (Kraft and Mechenich, 2007), (Kraft and Browne, 2006-07), (DeVita and Dawson, 2001-04), (Norman, 2000-03), (Bundy, 1993-94, 1997-98), (Shinners, 1995-96), (Newenhouse, 1995), (Harrison, 1992-93), (Bahr, 1991-92);
- Development of new technologies for evaluating the integrity of water supply well and exploration borehole seals (Edil, 1998-99), (Edil and Benson, 1997-98), (Edil, 1996);
- Multi-parameter sensors for monitoring groundwater quality and quantity (Bahr and Hart, 2009-10), (Loheide 2007-09), (Krabbenhof et. al, 2007), (Geissinger, 2006-08), (Anderson & Glanchandani, 2002-03); and
- Assessment of emerging biological pathogens and pharmaceutical compounds (Li and McWilliams 2010-12), (Xu 2010-12), (Li & Yang, 2007-09), (McMahon 2005-07), (Sonzogni et al., 2004-06).

Rain Garden Design & Evaluation

“Design Guidelines for Stormwater Bioretention Facilities” (Atchison and others) published by WRI and the UW-Madison Department of Civil and Environmental Engineering, provides design guidelines and a numerical model (RECARGA) that can be used for creating bioretention facilities for small-scale stormwater management. The system promotes infiltration of stormwater in order to reduce its volume, improve its quality and increase groundwater recharge. A basic bioretention facility is commonly referred to as a rain garden. It is a landscaped garden in a shallow depression that receives stormwater from nearby impervious surfaces. The model, which was based on WRI supported research (Potter, 2002), is now recommended by the Wisconsin Department of Resources (DNR) for use in meeting its new stormwater infiltration regulations. The manual is available free of charge on the DNR website (<http://dnr.wi.gov/topic/Stormwater/raingarden/>). The manual continues to be extremely popular at the UW Aquatic Sciences Center Publications Store. The entire run of 502 printed copies was distributed between FY07 and FY10. The document continues to be popular with 959 electronic downloads in FY13 bringing the total number of electronic downloads to 26,400 since FY07.

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Groundwater Movement in Shallow Carbonate Rocks

Shallow carbonate bedrock (dolomite and limestone) underlies much of Northeastern Northwestern, and Southwestern Wisconsin (Figure 1).

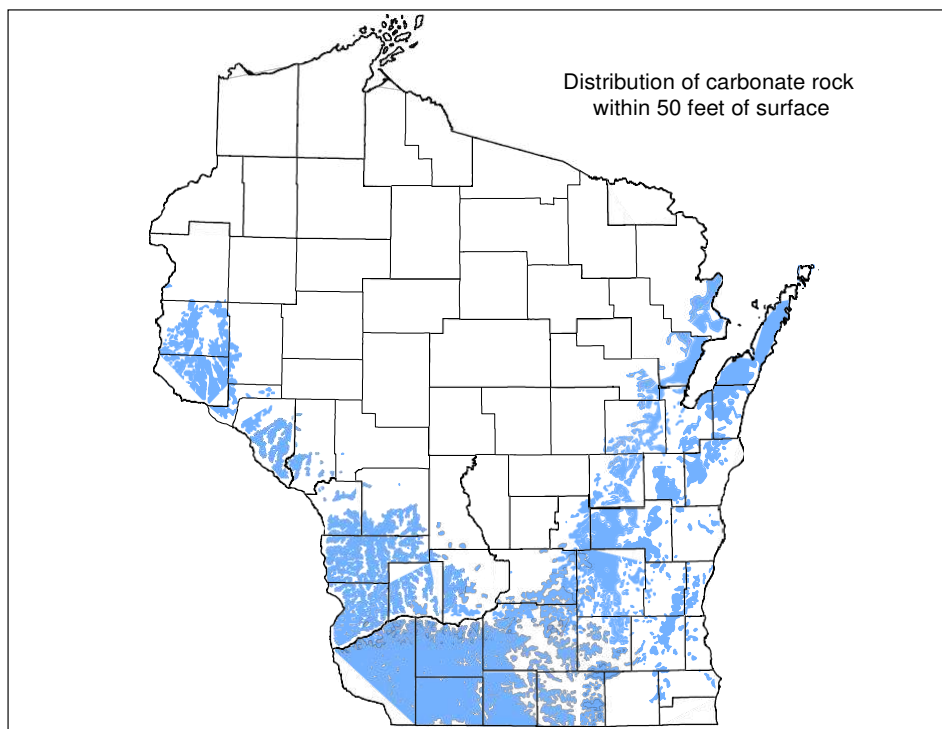


Figure 1: Location of shallow carbonate bedrock in Wisconsin

The WGNHS has conducted a series of projects to examine the hydrogeology of fractured carbonate rock in Wisconsin. In 2011, the WGNHS and UW-Oshkosh Geology Department received a Wisconsin Coastal Management Grant to develop a groundwater monitoring network around the Mink River Estuary in Door County. This pristine estuary is fed by springs originating in the fractured dolomite. The instrumentation phase of this project was completed in 2012. A second WCM grant is funding construction of a numerical groundwater flow model for the estuary, is scheduled for completion in June, 2013.

Over the past few years, the WGNHS has developed a program of research and public education on groundwater movement in fractured rocks and has provided assistance to various agencies facing carbonate-rock problems. During FY 2013, the WGNHS will continue such activities. WGNHS staff members are also involved in presenting professional short courses on fractured-rock hydrogeology.

Karst features, including a variety of sinkholes, cavities, and solution openings, commonly occur in carbonate rock (limestone and dolomite). Environmental problems associated with karst features include rapid groundwater contamination, unpredictable groundwater flow, difficulty in groundwater monitoring, and unexpected failure or collapse of surface structures such as roads and foundations. In recent years, there has been increased concern about the hazards and effects of karst features in many parts of Wisconsin but little published information has been available.

The WGNHS is serving as a clearinghouse for karst information and has begun assembling a karst database for the state. WGNHS scientists have conducted geophysical surveys near some of these features in order to characterize their depth and extent. The results of those studies have been used by municipalities for planning purposes and selecting options for sinkhole remediation. The WGNHS will continue to refine these geophysical techniques so that karst can be more effectively characterized across Wisconsin.

During FY 2014, the WGNHS will continue to provide data and consultation on karst issues as requested by various units of government and the public.

Nitrate

Nitrate is Wisconsin's most widespread groundwater contaminant (data from DNR, DATCP and UW-Extension's Central Wisconsin Groundwater Center) and is increasing in extent and severity (Kraft et al. 2008, Kraft 2003, Kraft 2004, Saad 2008). Nitrate (NO_3) is a water-soluble molecule that forms when ammonia or other nitrogen rich sources combine with oxygenated water. Nitrate levels (as nitrate-N) in groundwater are below 2 milligram per liter (mg/L) where pollution sources are absent. Higher levels indicate a source of contamination such as agricultural or turf fertilizers, animal waste, septic systems, and wastewater. At least 90% of nitrate inputs into our groundwater originate from manure spreading, agricultural fertilizers, and legume cropping systems (Shaw, 1994).

Human health concerns, both acute and chronic, are 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. This condition deprives the infant of oxygen and in extreme cases can cause death. DHS has investigated several cases of suspected blue-baby syndrome and associated at least three with nitrate contaminated drinking water. Some studies raise concern regarding the effect of nitrate on the developing fetus in early stages of pregnancy, thyroid function, diabetes and cancer. While more research is needed in this area, 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.

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).

Nitrate exposure has also been linked to birth defects. A recent report (Brender et al., 2013), is one of several epidemiological studies over the past decade examining statistical links between nitrate exposure and neural tube birth defects. Some, but not all, of these studies have concluded there is a statistical correlation between maternal ingestion of nitrates in drinking water and birth defects. At this time, there is no clear animal model demonstrating this effect. Further work would be needed to conclusively demonstrate that exposure to nitrates and nitrites during pregnancy increase the risk of birth defects. Nonetheless, these studies collectively indicate an ongoing need for caution in addressing consumption of nitrates, and support the continuation of private well testing programs for pregnant females. Given the need for more knowledge in this area, and the pervasiveness of nitrate contamination in groundwater, we expect that this will continue to be a subject of investigation. DHS will continue to monitor and review the literature on this topic.

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 $\text{NO}_3\text{-N}$. 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. Stream nitrate concentrations and nitrogen exports are expected to increase on average as older water within the aquifer is replaced by modern water that is reflective of current land-use (Masarik, et.al, 2007).

Due to human health concerns, community water supplies that exceed the 10 mg/L ES are required to treat drinking water to the federal drinking water standard of 10 mg/L. Common solutions include drilling of 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.

In 2012 DNR began working with other stakeholders on the “Wisconsin Safer Drinking Water Nitrate Initiative. The initiative is targeted at reducing nitrate levels in groundwater by making the most efficient use of nitrogen in agricultural production. Activities in project areas include measuring all current nitrogen inputs and baseline groundwater nitrate levels, calculate agricultural input and production costs, determine and implement best nitrogen management practices that optimize groundwater conditions and agricultural production efficiency, and measure whether predicted results are achieved. Project areas have been selected in Rock and Sauk Counties within subwatersheds with large numbers of public drinking water systems approaching unsafe levels of nitrate contamination. DNR is currently working with stakeholders to determine an optimal nitrogen management system. In the next phase of the project the nitrogen management system will be applied in one of the project areas. Monitoring of nitrogen inputs, groundwater nitrate levels, production costs will continue and costs of nitrogen management will be compared to water treatment costs.

About one third of Wisconsin’s families obtain their 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 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.

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. Exceedence rates are greater in agricultural districts, with rates in highly cultivated areas in south-central Wisconsin estimated at 21% of wells. As seen in Figure 1, 20-30% of the privately owned wells in Calumet, Columbia, Dane, La Crosse and Trempealeau counties exceed the 10 mg/L nitrate standard. A nationwide USGS study compared nitrate concentrations in 495 wells between 1992 and 2004 and showed that the proportion of wells with concentrations of greater than 10 mg/L increased from 16 to 21 percent (Dubrovsky et al. 2010).

Owners of nitrate-contaminated private wells do not qualify for 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 by DHS examined this issue (Schubert et al., 1999). 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.

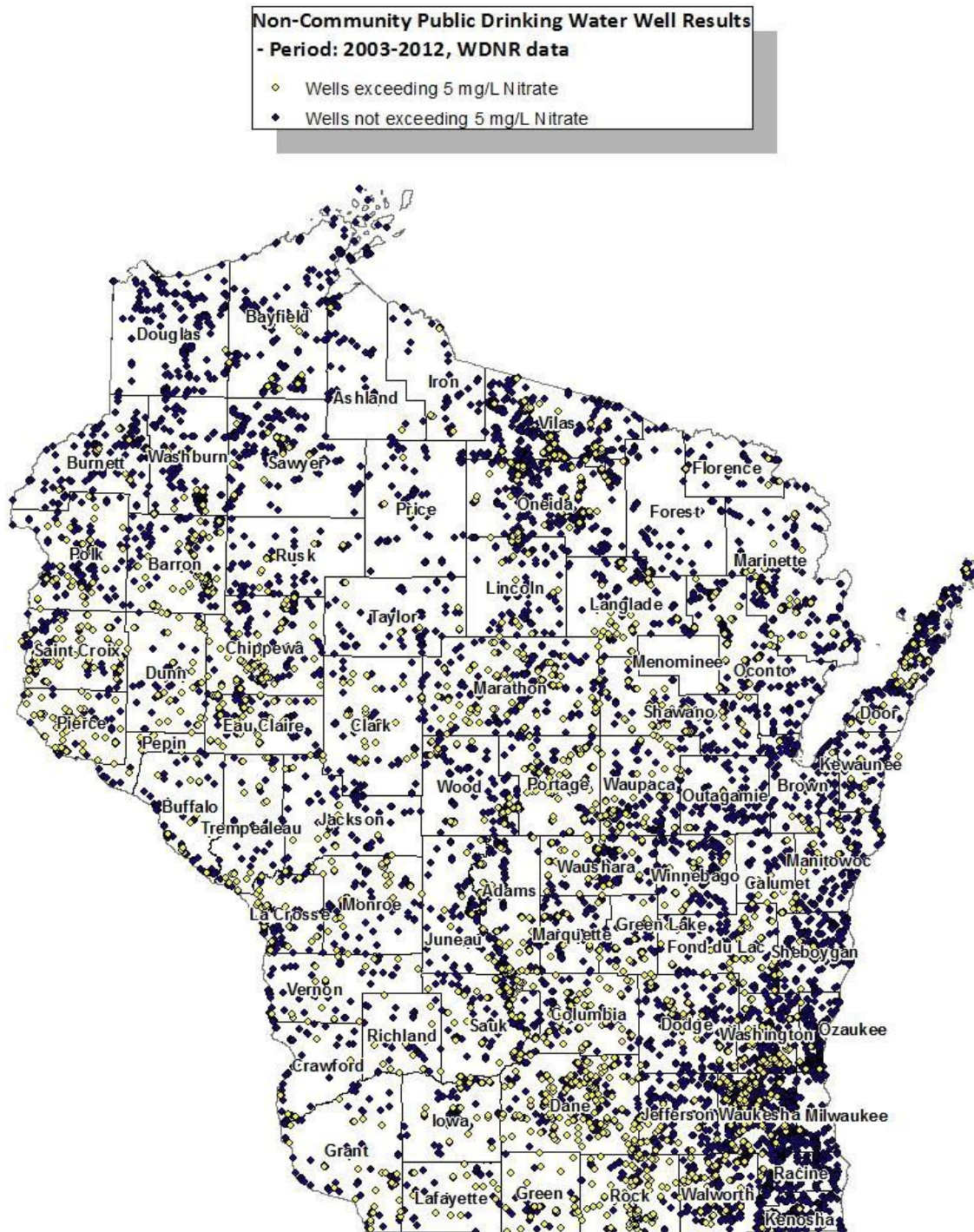


Figure 1: Non-community public wells with raw water samples exceeding 5 mg/L Data source: DNR Drinking Water System, 2013.

Various studies indicate nitrate in drinking water systems is increasing and that current management activities to limit nitrate pollution have questionable effectiveness (Mechenich and Kraft 1997, Kraft 2003, Saad 2008). For instance, nitrate concentrations in Central Wisconsin groundwater will continue to increase even using University recommendations for fertilizer application. Nitrate concentrations will increase as nitrate pollution penetrates deeper into thick aquifers (Kraft et al. 2008).

According to Tesoriero (2013) long travel times of groundwater discharge is the reason nitrate trends in streams and rivers do not match expectations based on reduced regional use of nitrogen-based fertilizer. In this same study, the USGS hydrologic researchers found that the movement of nitrate through groundwater to streams can take decades to occur, which means that changes in the use of nitrogen-based fertilizer may take decades to be fully observed in streams: “This is an important finding because long travel times will delay direct observation of the full effect of nutrient management strategies on stream quality.” 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 high concentrations moves downward 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. Similar time delays also are expected for streams that receive considerable groundwater discharge.”

Several studies funded through the joint solicitation and done at the UW Arlington Agricultural Research Station have looked at nitrogen inputs on fields in continuous corn (Brye, 2001; Masarik, 2003; and Norman, 2003). Important findings include:

- Nitrate concentrations are highly variable throughout the year, and from year to year. Highest concentrations are measured in wet years, particularly when wet years follow dry years. Highest concentration measured in leachate (for two week period) on optimally fertilized fields – around 45 mg/L. Highest annual flow-weighted mean concentration – 24 mg/L. During the dry years the nitrate concentrations were actually quite low.
- Over the long-term (7 years), flow-weighted mean nitrate leaching values on continuous corn rotations fertilized at economic optimum rates were around 10 mg/L. Nearly 20% of nitrogen fertilizer applied at economic optimum rates is lost to leaching over the long-term. These studies show that even in the best managed agricultural systems, groundwater concentrations at or above the health standard for nitrate-nitrogen are likely.
- When manure was applied to a field in addition to the optimal rate of nitrogen fertilizer, the flow-weighted mean concentration was two to three times greater than the flow-weighted mean concentration from fields that just received the optimum amount of fertilizer. This finding suggests that when applications of nutrients exceed the crop need, the nitrate losses to groundwater increase significantly.

It is important to recognize that not all farms can be required to have a nutrient management plan (NMP). As of 2008, all farms can be required to implement nutrient management with a \$28/ac cost share offer 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 2012 about 22% of the state’s land was covered by a NMP. It is difficult to assess the impact and effectiveness of nutrient management planning on groundwater nitrate levels without full

coverage and implementation of NM is achieved across the state. Figure 2 shows each county's percentage of cropland covered by a NMP. A comparison of Figure 1 and Figure 2 shows where the greatest needs are for NMPs.

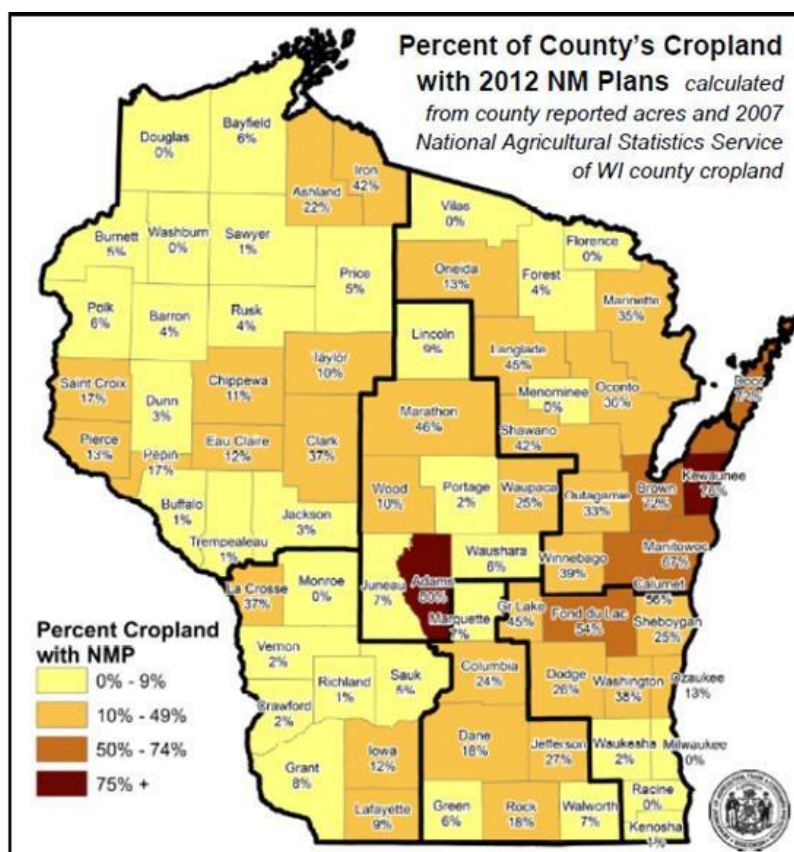


Figure 2. The percent of cropland with nutrient management plans in 2012 as reported to DATCP.

For more information on DATCP's efforts to reduce nitrate levels in groundwater, as well as efforts to reduce nonpoint source pollution in general, please refer to DATCP's Activities in this report:

<http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/DATCPactivities.pdf>

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Arsenic

Naturally-occurring arsenic was discovered in Wisconsin's groundwater in 1989 during a routine investigation conducted by the DNR. Investigations done in the early 1990s found that approximately 4% of the private wells located in Winnebago and Outagamie Counties had arsenic levels that exceeded 50 µg/L which was the federal drinking water standard at that time. The most seriously contaminated water supply had an arsenic level of 15,000 µg/L. The DNR issued an advisory for the area recommending drilling and casing 80 feet beyond the top of the St Peter sandstone which is the primary source of the arsenic. Increasing the casing length was successful in bringing arsenic concentrations below 50 µg/L in about 85% of the wells studied. Over the years the department has continued to work with drillers to improve well drilling and construction techniques to minimize arsenic levels in potable wells.

Arsenic is released from aquifer materials by several mechanisms. The primary mechanism in NE Wisconsin is oxidation of sulfide minerals when groundwater is drawn down and the rock is exposed to air, or air is introduced to the rock formations during well drilling. Other metals (such as nickel, cobalt, cadmium, chromium, lead and iron) associated with the sulfide minerals can also be released to groundwater and may increase health risks. In areas of SE Wisconsin and in some glaciated areas of Northern Wisconsin, arsenic is bound to iron oxide minerals in the aquifer sediments. In these settings, groundwater at depth is susceptible to elevated arsenic due to a lack of oxygen in the groundwater system.

Prior to implementation of a new, lower federal standard for arsenic in 2006, the department coordinated with DHS and local health departments to sample private wells in several towns in Outagamie and Winnebago Counties. Nearly 4,000 wells were sampled between 2000 and 2002. Test results indicated that approximately 20% of the wells had concentrations over the proposed standard of 10 µg/L (same as the earlier sampling). In some areas, over 40% of the wells exceeded 10 µg/L. A high density development in the Town of Algoma became the first special well casing depth area (SWCDA) in 2002. Three other smaller areas followed soon after.

Between 2002 and 2004 the DNR required more stringent specifications within four small areas where arsenic contamination problems were severe. To avoid creating a 'hodge-podge' of small SWCDAs scattered over a two-county region, DNR decided to seek a more comprehensive regional approach. Based on the success of the SWCDA and the large number of wells involved, the DNR expanded the SWCDAs to include all of Winnebago County and Outagamie County. Information on the specifics of the SWCDAs requirements can be found at: <http://dnr.wi.gov/topic/Groundwater/arsenic/casingRequirements.html>.

Understanding the occurrence of arsenic in Wisconsin's groundwater has been a good example of interagency cooperation. Initial work with DHS and local health departments and town boards effectively defined the problem and raised awareness. Research supported by the joint solicitation helped define the extent and mechanisms of release. DNR and Commerce worked jointly with water treatment companies on developing treatment systems for arsenic removal. Well drillers assisted in identifying drilling methods that reduce arsenic.

Sixteen studies through the joint solicitation have explored arsenic related topics from detection to geologic controls to well construction and treatment (See <http://dnr.wi.gov/topic/groundwater/documents/GCC/Benefits/ArsenicResearch.PDF>). Recently completed research focused on release mechanisms, triggers and reaction kinetics that affect well

construction, disinfection, and rehabilitation. A second focus of recent work is identifying other areas of the state with impacted groundwater.

A DHS Health Consultation study on arsenic in private wells in the Wind Lake, Racine County area showed arsenic is present in both the deep glacial and Silurian bedrock aquifers (<http://www.atsdr.cdc.gov/HAC/pha/WindLakePrivateWells/WindLakeHC04-28-2009.pdf>) Of 25 wells tested, 12 contained arsenic levels above the ES of 10 µg/L. Free test kits were made available to any interested resident in the area and resulted in 92 samples from 70 different private wells. The results showed 22 of 70 (31%) wells with arsenic levels at or above the ES. Test results ranged from 10 to 27 µg/L. In addition to arsenic, water from 10 wells had lead at levels above the ES of 15 µg/L.

The DNR, DHS, Commerce and others continue to work on arsenic problems around the state. Arsenic has been found at levels above the ES in every county. DHS has conducted two separate studies on the health effects of arsenic on Wisconsin citizens. DHS researchers have observed higher rates of skin cancer, heart disease and depression among consumers of water that contains traces of arsenic (Knobeloch et al, 2002; Zierold et al, 2004).

A 2007 study funded by the joint solicitation examined the relationship between arsenic contamination and common well disinfection practices such as shock chlorination. Results indicate the complex cycling of iron and arsenic in well bores and aquifers. Microbiological activity in the aquifer and the amount of pumping from a well affect arsenic release related to shock chlorination (Gotkowitz et al, 2008; West et al. 2012). This work suggests that managing the quality of water in domestic wells in arsenic-impacted areas of Wisconsin may be beyond the ability of homeowners. Effective well construction requirements implemented in SWCDAs in Winnebago and Outagamie Counties are being applied in other areas of the state. In addition, extending public water supplies or promoting use of household treatment systems are alternatives for providing a reliable source of potable water.

In summer of 2012, at the height of the drought, the DNR received many complaints about changes in water quality from private well owners in NE Wisconsin. Suspecting that the drought conditions contributed to greater arsenic levels in private wells the DNR recommended sampling for arsenic and discovered high arsenic levels in many wells in areas in Shawano and Oconto County. These areas are in a geologic region containing the St. Peter Formation consisting of sandstone with some shale and conglomerate, the Prairie du Chien Group consisting of dolomite with some sandstone and shale, and the Cambrian series consisting of sandstone with some dolomite and shale. Arsenic has been found in all the formations but is more concentrated in the St Peter and Prairie du Chien Group. The sampling results led the DNR, Oconto County Health Department, and Shawano County Health Department to issue a press release. The result was an informed public taking the initiative to sample their drinking water wells. The three departments have been working with well owners to obtain safer water.

Ongoing efforts to address arsenic in groundwater include:

- Ongoing testing of private wells for arsenic through the fee-exempt testing offered to low-income families by local health departments.
- Refinement of the geology in the Outagamie and Winnebago county area and updating casing requirements,
- DHS and DNR sampling of transient non-community wells

- Commerce and DNR evaluating and pilot testing arsenic treatment systems for public and private systems that do not have an alternative aquifer option. One point-of-use treatment system was recently approved.
- DNR and local governments are working with several Blue Cross/Blue Shield grants for a healthier Wisconsin to explore impediments to private wells sampling and promote well sampling programs
- DNR efforts to improve well construction for school and community wells
- DHS, DNR and the WGNHS are working together to gather information from drillers and pump installers on areas with high iron and corrosive water, which may be indications of an arsenic problem. Sampling of these areas is being lead by DHS.
- DHS and DNR targeting of wells for sampling in the southern and SW portions of the state.
- Requiring arsenic sampling for all new and reconstructed wells in Florence County.
- Educational outreach to the well drillers continues.

More information related to arsenic can be found on the DNR Arsenic Web Page:

<http://dnr.wi.gov/topic/Groundwater/arsenic/index.html>

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Pesticides

Pesticide contamination in groundwater results from field applications, pesticide spills, misuse, or improper storage and disposal. Serious concerns about pesticide contamination in Wisconsin were first raised in 1980 when aldicarb, a pesticide used on potatoes, was detected in groundwater near Stevens Point. The DNR, DATCP, and other agencies responded to these concerns by implementing monitoring programs and conducting groundwater surveys. In 1983 the DNR and DATCP expanded their sampling programs to include analysis of pesticides commonly used in Wisconsin. These programs now include sampling for pesticide metabolites which are chemical compounds that form when pesticides break down in the soil and groundwater. The most commonly detected pesticides compounds in Wisconsin groundwater are metabolites of alachlor (Lasso), metolachlor (Dual) and atrazine and its metabolites (DATCP, 2008).

Health Effects

The health effects of pesticide exposure vary by pesticide.

Atrazine

Atrazine is an herbicide widely used in Wisconsin, particularly on corn.. The presence of residues of atrazine and atrazine metabolites in residential well is an important non-occupational route of exposure. Effects of atrazine observed in animals include liver, kidney, and heart damage, and reproductive effects have been noted among people exposed occupationally (ATSDR 2003). A number of epidemiological studies suggest developmental and reproductive hormone effects in people (e.g. Craigin et al. 2011; Agopian et al., 2013; Agopian et al., 2012). Developmental feminization effects have been reported in aquatic vertebrates exposed to atrazine (Hayes et. al. 2002, 2003, 2006 and 2011))

The International Agency for Research on Cancer (IARC) has determined that atrazine is “not classifiable as to its carcinogenicity to humans based on inadequate evidence in humans and sufficient evidence in experimental animals” (ATSDR 2003). As of 2011 the epidemiologic evidence linking atrazine to cancers is not compelling, but a few studies have raised sufficient doubt that the EPA will consider cancer effects in its 2013 registration review of atrazine (see http://www.epa.gov/pesticides/reregistration/atrazine/atrazine_update.htm)

Alachlor

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 (<http://www.epa.gov/safewater/pdfs/factsheets/soc/alachlor.pdf>).

Organophosphates

Organophosphates are used as insecticides. The Center for Disease Control reports that organophosphates can contaminate groundwater. (CDC, no date) Recent research has found correlations between higher organophosphate levels and learning difficulties in children. Specifically, research has found:

- Children with higher levels of organophosphates in their urine were more likely to be diagnosed with ADHD. (Bouchard, 2010; Marks, 2010)
- Children whose mothers had higher levels of organophosphates in their urine when pregnant had lower IQ scores at ages 2-3 and ages 6-9. (Bouchard, 2011; Engel, 2011; Rauh, 2011)

Reports from the National Agricultural Statistics Service show use of organophosphates on soybeans in Wisconsin have increased from 19,000 pounds per year in 2005 to 134,000 pounds

per year in 2012. (Wisconsin Agricultural Statistics Service (WASS), 2006; National Agricultural Statistics Survey (NASS), 2012) From 2005-2010 organophosphate use on potatoes in Wisconsin decreased from 7,000 pounds to zero. (WASS, 2006; NASS 2010)

In Wisconsin about 30 pesticides currently have health-based drinking water limits and groundwater standards in ch. NR 140, Wis. Adm. Code. The pesticides with standards are a fraction of the 90 different pesticides Wisconsin farmers reported using on major crops in 2005. (WASS, 2006) 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.

Pesticide Mixtures

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 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 (Porter, 1999). 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 (Hayes, 2006).

Pesticides Found in Wisconsin Groundwater

Atrazine

Atrazine, an 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 (Figure 1). 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 levels over the enforcement standard in about 8 percent of the wells. The enforcement standard for atrazine includes parent atrazine and three of its breakdown products (metabolites).

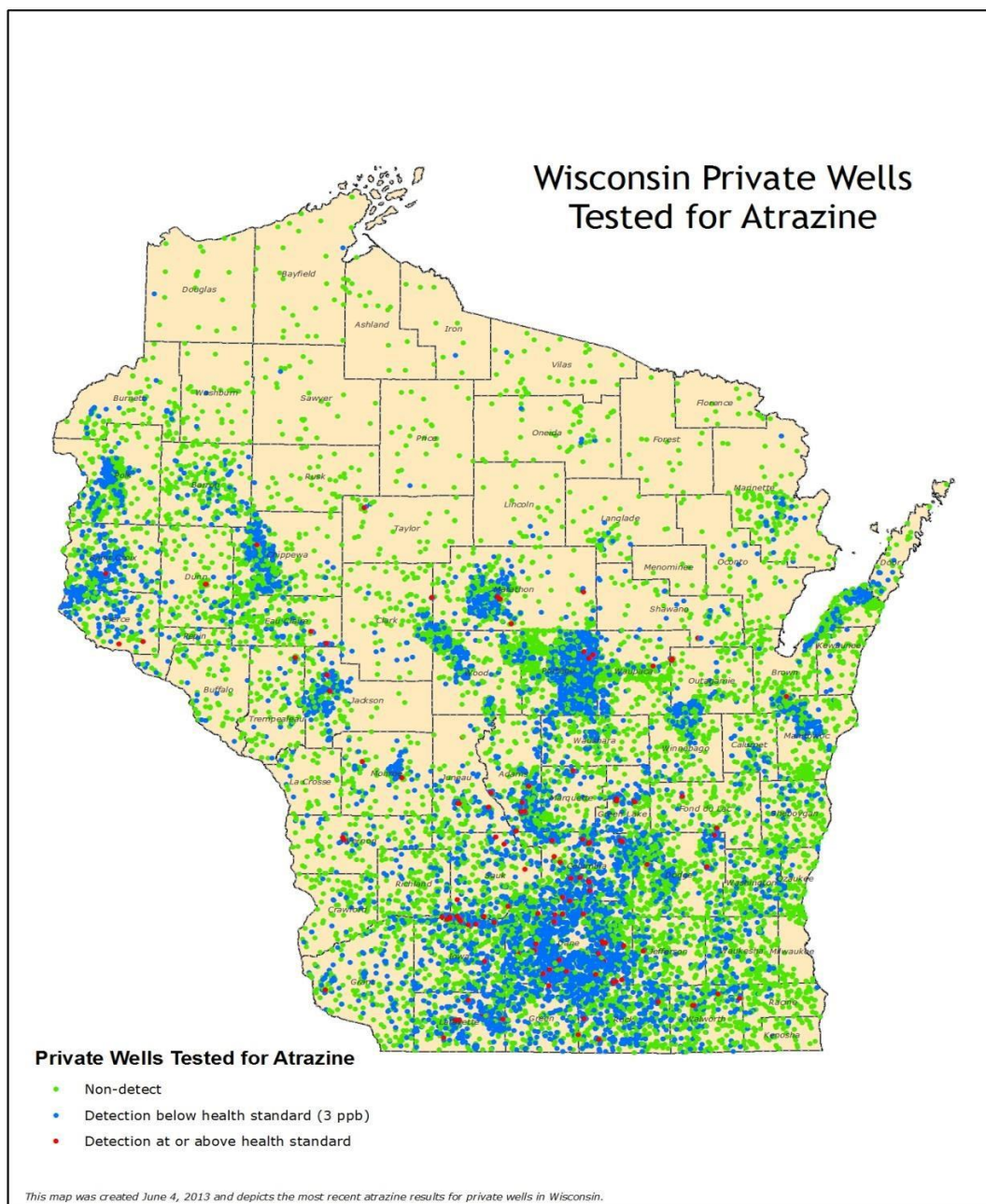


Figure 1: Private wells tested for atrazine in Wisconsin as of June 2013 (source: DATCP)

Some 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 this 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 soy beans and corn, but fortunately glyphosate is not a groundwater threat because it is tightly bound to the soil)
- Atrazine was commonly used at much higher rates and applied more often before DATCP's

Atrazine rule (ch. ATPC 30, Wis. Adm. Code) began in 1991

- Atrazine leaches through the soil into groundwater more readily than many other herbicides

Grade A Dairy Farm Well Water Quality Survey

The first systematic well sampling program to characterize atrazine contamination on a statewide basis was the 1988 DATCP Grade A Dairy Farm Well Water Quality Survey. This state-funded well survey estimated that atrazine was present in 12 percent of the Grade A Dairy Farm Wells in the State. Since that initial study, DATCP has collected data from many private and monitoring wells in the state as part of statewide surveys and focused monitoring projects (summarized below).

Weed Management Survey in Atrazine Prohibition Areas

In 2011 DATCP completed a report entitled Final Report on the 2010 Survey of Weed Management Practices in Wisconsin's Atrazine Prohibition Areas. The main purpose of this 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 PA 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>.

Chloroacetanilide herbicide metabolites

In a study completed in 2000, 27 monitoring wells, 22 private drinking water wells, and 23 municipal wells in Wisconsin were sampled for alachlor, metolachlor, acetochlor, and their ethane sulfonic acid (ESA) and oxanillic acid (OA) metabolites. Wells were selected based on previous detections of pesticides or proximity to agricultural fields. Alachlor, metolachlor, and acetochlor are chloroacetanilide herbicides that are commonly used on corn and other crops in Wisconsin. With the exception of alachlor ESA, no historical data exists for these metabolites in Wisconsin groundwater because laboratory methods were not previously available. Over 80 percent of the monitoring wells and drinking water wells included in the survey contained the ESA and OA metabolites of alachlor and metolachlor. The metabolites of acetochlor showed a lower frequency of detection. Metabolite concentrations ranged from near the level of detection

to 42 µg/L. Monitoring wells and private drinking water wells showed higher detection frequencies and concentrations than the deeper municipal wells, but the municipal wells did show significant impacts. Fifty-two percent of the municipal wells had at least one detection. No municipal well had pesticide levels that exceeded an enforcement standard.

The following are other DATCP pesticide-related studies conducted recently or as part of ongoing research.

Exceedence Survey

In 1995, DATCP completed a re-sampling of 122 Wisconsin wells that previously exceeded a pesticide enforcement standard. Most of the wells in the survey had exceeded standards for atrazine. Most were also within an atrazine prohibition area. Of wells exceeding standards for atrazine, 84 percent had declined in concentration and 16 percent had increased. About 50 percent of well owners continued to use their contaminated well and about 25 percent had installed new wells at an average cost of \$6,300. This well survey has been repeated annually through 2012, with samples collected from 150 different wells at least once during this time period. As of 2012, atrazine levels had gone down in over 80 percent of the wells. Six wells remain above the enforcement standard. A full report on this program can be found at <http://datcp.wi.gov/uploads/Environment/pdf/FifteenYearsoftheDATCPExceedenceSurvey.pdf>.

Pesticide and Groundwater Impacts Study

In 1985, DATCP and DNR began a study to evaluate the potential impact of agriculture on groundwater quality. The study focused on areas of the state with high groundwater contamination potential. In 2012, this study entered its 26th year. In 2012 samples from monitoring wells near 22 agricultural fields were sampled. A total of 14 compounds were detected in groundwater, but only nitrate-N was found at a level above an existing water quality standard. Other compounds detected include alachlor ESA, acetochlor ESA, metribuzin, thiamethoxam, and metolachlor and its ESA and OA metabolites.

Monitoring Reuse of Atrazine in Prohibition Areas

In FY 98 through FY 05, DATCP monitored the limited reuse of the herbicide atrazine in selected areas where atrazine use has been prohibited. DATCP gathered the data to see if renewed atrazine use at current restricted use rates will cause groundwater contamination. DATCP monitored groundwater quarterly at 17 fields, 10-40 acres in size, for 5 to 7 years. The data showed that all of the sites that followed study protocols exceeded the ES for atrazine at some point during the study. The nitrate enforcement standard was exceeded at 100 percent of these sites over the same sampling period. A technical advisory committee reviewed the study results and recommended that the atrazine prohibition areas remain in place and the DATCP Board concurred.

2007 Survey of Agricultural Chemicals in Wisconsin Groundwater

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 2 below. The two most commonly-detected pesticide compounds were the herbicide metabolites metolachlor ESA and alachlor ESA which each had a proportion estimate of 21.6 percent. The final report for this project can be found at <http://datcp.wi.gov/uploads/Environment/pdf/ARMPub180.pdf>. DATCP does not have a plan to update this six-year old study, which has been conducted four times since 1994.

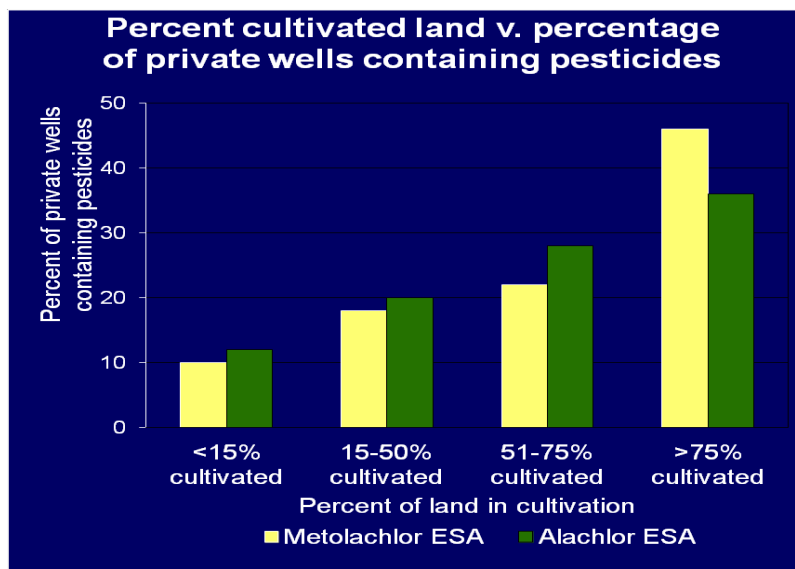


Figure 2: Percent of private wells containing pesticides at various levels of land cultivations
(Source UW-SP with 2007 DATCP data)

Organic Farming

Wisconsin has seen 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%. Similarly, from 2002 to 2011, organic acreage in Wisconsin has increased from 81,026 acres to 195,603 acres, a 241% increase. Though the percentage of farms and farm acreage in Wisconsin that are organic remains below 2% of the total, organic markets continue to expand due to increased consumer interest in organic food, and reports of increased profits by organic producers (DATCP, 2011). Another benefit of organic farming is the significantly decreased potential for pesticides in groundwater (drinking water in rural areas) where organic practices are followed.

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Naturally-Occurring Radionuclides

Naturally-occurring radionuclides, including uranium, radium, and radon are becoming an increasing concern for groundwater quality, particularly in the Cambro-Ordovician aquifer system in eastern Wisconsin. The water produced from this aquifer often contains combined radium activities in excess of 5 pCi/L (picocuries/liter) and in some cases in excess of 30 pCi/L. For municipal supplies, this aquifer is the main source of water that contains radionuclides in excess of DNR standards. Historically, about 80 public water systems have exceeded a radionuclide drinking water standard. Over 50 public water systems exceeded both the drinking water standards of 15 pCi/L for gross alpha activity, and 5 pCi/L for combined radium, (see map below). The DNR is enforcing the radionuclide standard adopted into NR 809. The DNR has been working with these systems since 2003 to ensure that they develop a compliance strategy and take corrective actions. The vast majority of these systems are now serving water that meets the radium and gross alpha standards.

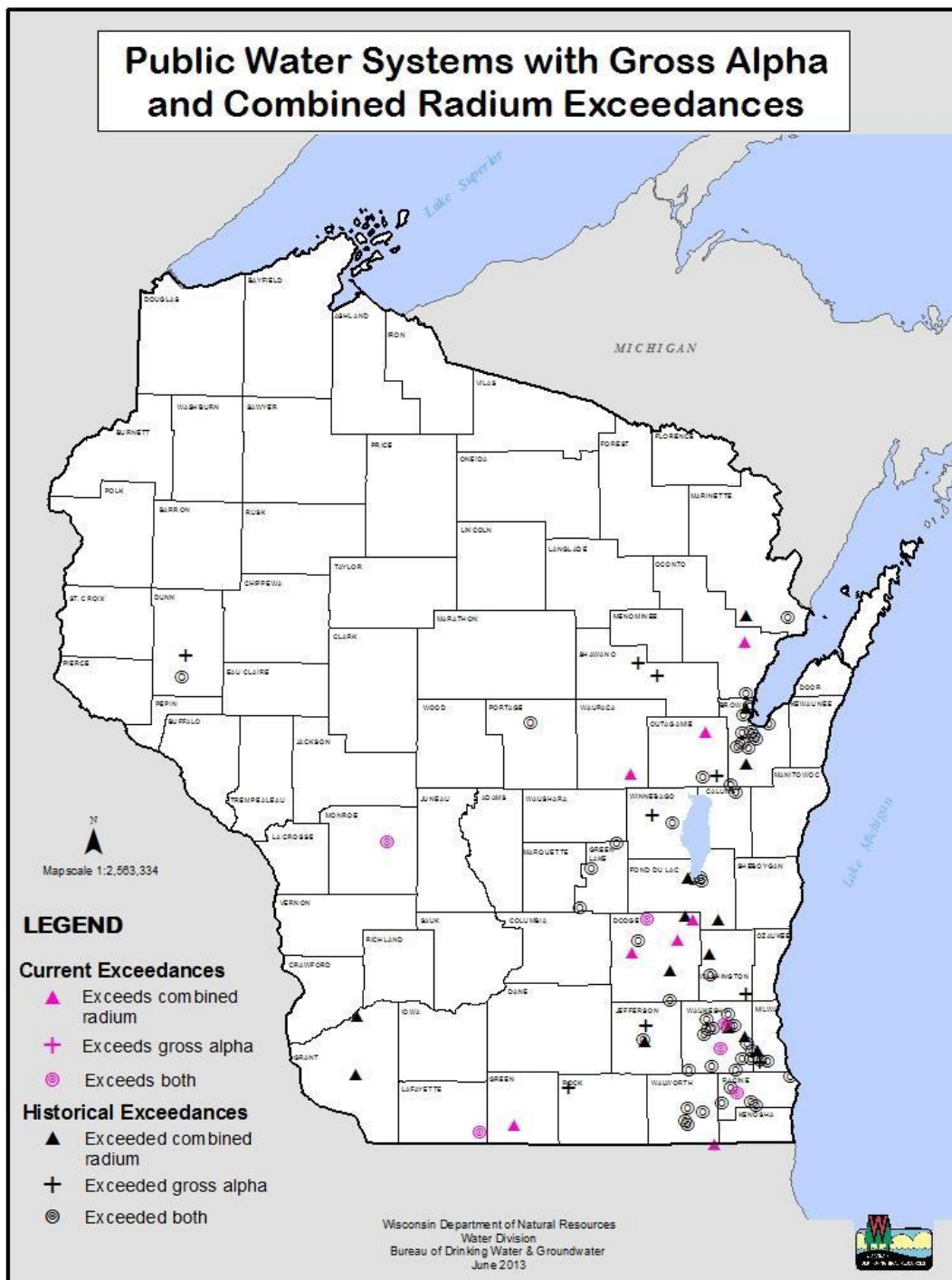
Drinking water monitoring completed since 2009 has shown a few more systems that have exceeded a radionuclide standard. Currently, there are less than 10 systems that are serving water that exceeds a radium or gross alpha standard. The DNR has formal agreements with these systems to gain compliance with the drinking water standards for radionuclides.

Previous studies have shown that radium concentrations in excess of 5 pCi/L cannot be explained solely by the presence of parent isotopes in the aquifer solids but rather is controlled by co-precipitation of daughter isotopes into the sulfate minerals barite and celestite (Grundl, et al. 2006). These minerals occur naturally in the aquifer. High radium activity occurs in the Cambro-Ordovician aquifer in a band coincident with the westward edge of the Maquoketa shale (Grundl and Cape 2006). This band extends across the entire eastern portion of the state from Brown County in the north to Racine County in the south. Radium activities have remained relatively constant from the middle 1970s to the present. High gross alpha activity also occurs in a band roughly coincident within the Maquoketa shale that extends along the entire eastern portion of the state.

Although sulfate minerals control the observed radium concentrations, determining which process(es) control the original release of radioactivity from aquifer solids into the groundwater will require a more thorough understanding of the system

In 2000 and 2001, DNR staff collected samples from about 100 community and non-transient non-community public water wells. The WSLH analyzed each sample for several alpha-emitting radioisotopes (total Uranium (U-238, U-234, U-235), total Thorium (Th-228, Th-230, Th-232), Radium 226, and Polonium 210) in an attempt to identify and quantify the relative contribution of each chemical to the total gross alpha activity in the samples (Arndt and West, 2004).

Results indicate that radium and its progeny (uranium is a major contributor in only 2 or 3 systems. is the major contributor to high gross alpha activities. Small quantities of polonium and thorium have also been detected but they do not appear to be major contributors to the total gross alpha activity in public water system wells. Another important finding was that total gross alpha measurements are an overestimate of the activities of all of the alpha emitters. The WSLH has developed models to account for the discrepancy between the total gross alpha activity and measurements of individual radionuclides.



Public water systems that exceed radionuclide standards as of June 2013 or have exceeded radionuclide standards in the past. Source: DNR

The same study showed that the gross alpha activity depends appreciably on the radionuclide used as the calibration standard, the time between sample collection and sample preparation, the time between sample preparation and sample analysis, and whether a radiochemical or a

gravimetric method is used to determine the total uranium activity. This is important since according to EPA regulations an adjusted gross alpha activity exceeding 15 pCi/L is considered to be a gross alpha violation. Using the model, it is shown that for some water samples the value obtained for the adjusted gross alpha activity can range from being well within compliance to being well out of compliance. Thus the use of the model developed in this work should be of assistance in helping a water utility with a gross alpha violation determine the reason for the violation, and, therefore, how to correct it (http://www.slh.wisc.edu/ehd/radiochem/dnr_reports/dnrfinal.pdf).

A second study "Factors Affecting the Determination of Radon in Groundwater" (http://www.slh.wisc.edu/ehd/radiochem/dnr_reports/factors.pdf) will help determine the impact of expected new EPA standards for radon in drinking water. Staff from the DNR will sample about 340 non-community, non-transient and other-than-municipal water systems per year. To date, approximately 250 samples have been collected from non-transient, non-community wells. Preliminary results tend to support findings from earlier community water system monitoring which indicated that approximately 50% of the public water systems monitored in Wisconsin exceed the proposed radon standard of 300 pCi/L. As of July 2012, EPA has not finalized the drinking water standard for radon. The standard will likely be set at 3,000 pCi/L.

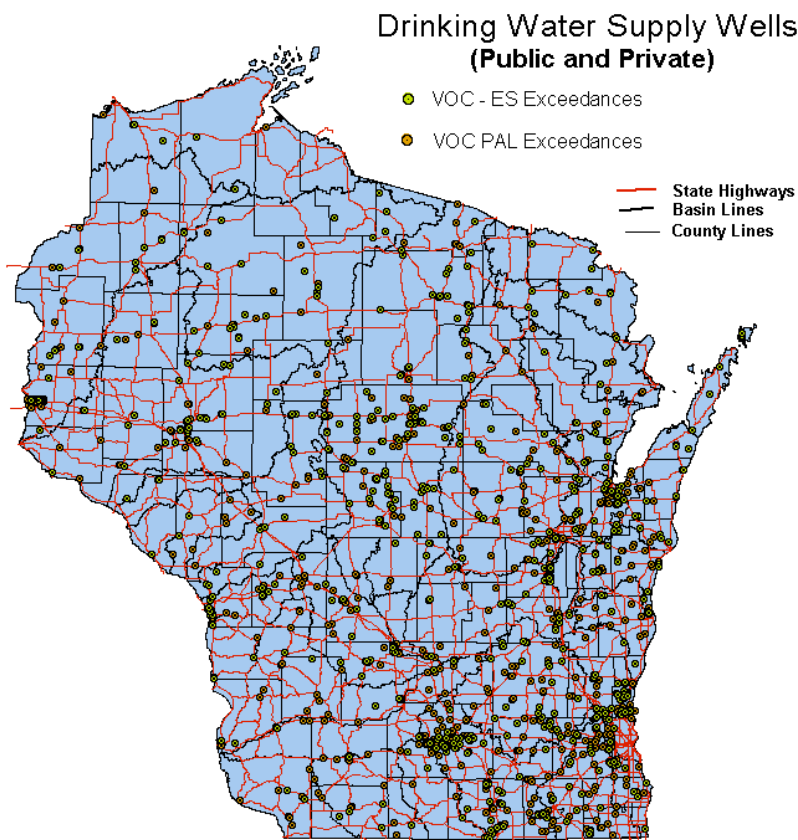
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Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are a group of common industrial and household chemicals that evaporate, or volatilize, when exposed to air. Examples of VOCs include gasoline and industrial solvents, paints, paint thinners, drain cleaners, air fresheners, and household products (such as spot and stain removers). Short-term exposure to high concentrations of many VOCs can cause nausea, dizziness, tremors or other health problems. Long term exposure to some VOCs may cause cancer. Sources of VOCs in Wisconsin's groundwater include landfills, underground storage tanks (USTs), and hazardous substance spills.

Thousands of wells have been sampled for VOC analysis. Fifty-nine different VOCs have been found in Wisconsin groundwater, though only 34 of those have health based standards. Trichloroethylene is the VOC found most often in Wisconsin's groundwater. The figure below 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 DNR's Groundwater Retrieval Network (GRN) database.



Volatile Organic Compounds (VOCs) past enforcement standard (ES) and preventive action limit (PAL) exceedances for public and private drinking water supply wells.

Source DNR

Wisconsin has 66 active as well as 600 closed, licensed solid waste landfills which are required to monitor groundwater. In addition, the DNR 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 DNR also tracks approximately 33,000 spills, some of which were also sources of VOCs.

Landfills

Two studies conducted over four years revealed that VOCs were significant contributors to groundwater contamination at unlined Wisconsin landfills (DNR 1988, 1989). Out of a total of 45 unlined municipal and industrial landfills tested, 27 (60%) 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%). 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 DNR 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, though at many sites VOC levels did not show continued improvement. Also, the level of contamination, while below 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.

Increasing numbers of residential developments are located close to old, closed landfills. In 1998 and 1999 the Department of Health Services (DHS) sampled private wells down-gradient of 17 small, closed landfills in Ozaukee County. Eight of the private wells had VOC results above maximum contaminant levels. The results of this sampling showed that there might have been more closed landfills with problems than had been previously identified.

The DNR Bureaus of Waste & Materials Management, Remediation & Redevelopment, and Drinking Water & Groundwater in cooperation with the DHS, responded to this issue in early 1999 by evaluating 16 old, closed landfills – at least three from each of the five DNR regions across the state. Private wells around each of the landfills were sampled in 1999 and significant levels of contamination found. Of the 113 wells that were tested, 31 had detects of VOCs. Fourteen of the homes had levels exceeding drinking water standards and were given health advisories to not drink their water. The DNR evaluated all of the landfills where the private wells had detects to determine whether more sampling or further action was required and took follow-up measures at all of the landfills where levels exceeded drinking water standards.

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 DNR'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 DNR. Approximately 550 were spills, 310 were Environmental Repair Program sites or LUSTs, and 13 were agrichemical discharges reported to DNR.

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.

Summaries of hazardous substance release and cleanup information may be found at <http://dnr.wi.gov/topic/Brownfields/RRProgram.html>.

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Microbial Agents

The United States produces some of the cleanest drinking water in the world and yet there are still reports of waterborne disease outbreaks. These outbreaks are produced by microbial agents or pathogens including bacteria, viruses and parasites. These agents can cause acute and chronic illnesses and result in life-threatening conditions for individuals with weakened immune systems. Of the approximately 20 outbreaks reported nationally per year, more than half are related to groundwater consumption (Lee, and others 2002; Yoder and others 2008). Many waterborne outbreaks are not reported or detected.

In Wisconsin, a statewide assessment showed approximately 23 percent of private well water samples tested positive for total coliform bacteria, an indicator species of other biological agents (Warzecha, and others 1995). Approximately 3 percent of private well water samples tested positive for *E. coli*, an indicator of potential water borne disease that originates in the mammalian intestinal tract.

The DNR recommends that private well owners test their water for total coliform bacteria annually or when there is a change in taste, color, or odor of the water. Public drinking water systems that disinfect their water supplies are required to sample, on a quarterly basis, for bacteria from the raw water (before treatment) in each well. These raw water samples are representative of the source from which the wells draw groundwater. The DNR has recently begun tracking total coliform detects in the raw water samples through its Drinking Water System database. Approximately

Manure spreading can contaminate groundwater with bacteria and/or viruses in karst areas and/or where soils are thin. Contamination is more likely when landspreading of manure occurs prior to, or during runoff events. Runoff events occur when precipitation exceeds soil infiltration rates, or snowpack melts during the spring thaw. 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 to thin soils and locally identified karst features. Currently, however, less than 21 percent of state farmland is covered by a state-approved nutrient management plan. Scores of private wells have had to be replaced due to manure contamination at a cost to the state of over \$500,000

DNR private water staff responds to homeowner complaints regarding private well contamination events, 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 show whether the bacteria are derived from human or animal sources. Recently developed laboratory techniques have made it possible to discern whether bacteria are from human, animal or other sources. These microbial source tracking (MST) tools include tests for *Rhodococcus coprophilus* (indicative of grazing animal manure), *Bifidobacteria* (indicative of human waste) and *Bacteriodes* (indicative of recent fecal contamination by either humans and/or grazing animals). Recently, an analysis was developed by Sibley et al. that can successfully detect bovine adenoviruses to indicate bovine fecal contamination of groundwater thus increasing the size of the molecular “toolbox” for better understanding of the origin of fecal contamination. The DNR has been using these tools since 2007 to determine the source of fecal contamination in private wells. Since 2007, in response to private well water quality complaints over 60 groundwater samples have been analyzed. Results indicate that the majority of well water samples were contaminated with grazing animal waste. Less than ten percent of samples collected indicate microbial contamination from human sources. Even more rare were wells contaminated with

both grazing animal and human fecal bacteria. Approximately twenty percent of the well samples had no indication of microbial contamination. DNR's Drinking Water & Groundwater and Runoff Management programs are working with the DATCP nutrient management program to find ways of controlling this significant threat to health.

Some parts of the state are particularly vulnerable to microbial contamination. Microbiological contamination often occurs in areas where the depth to groundwater or depth of soil cover is shallow or in areas of fractured bedrock. In these areas, there is little natural attenuation potential. Door County is one such location where bedrock is fractured and wells are often shallow. Many other parts of Wisconsin contain areas of shallow, fractured bedrock or minor karst features making them very vulnerable to microbial contamination from the land surface.

In a recent survey of 25 private wells in Door County, 18 had detections of total coliform in at least one monthly sample over a 1-year period (Braatz, 2004). Forty percent had detections of a fecal indicator (*E. coli* or enterococci). Significant seasonal trends were also apparent, with higher percentages of wells with fecal indicators in the summer months. There were also waterborne illness outbreaks at two Door County restaurants, one in December 2004 and another in May 2007 (Borchardt, M. A., 2010). The cause of the May 2007 outbreak was a genogroup 1 norovirus, quantified in the restaurant's well water at more than 50 viruses per liter, well above the infectious dose necessary for a widespread outbreak. More than 250 people became ill and 6 people were hospitalized. The nucleic acid sequences of the viruses from the well and stool specimens from ill patrons were identical, providing definitive evidence for the waterborne transmission route. Moreover, a state-of-the-art dye tracer study conducted by the University of Minnesota demonstrated unequivocally a rapid transport route from the restaurant's new septic system to its well. Transport was from both: 1) untreated effluent discovered leaking from a broken pipe fitting near a septic tank; and 2) discharge from the septic drainfield. Groundwater and public health experts believe another outbreak in Door County may be imminent due to the widespread shallow soils and karst bedrock found in the county, which makes it difficult to find an appropriate place for locating septic systems.

There is overwhelming evidence in the state of Wisconsin and nationwide that karst areas have highly vulnerable groundwater requiring special consideration and protection. These findings lead to the conclusion that current requirements for septic systems and associated leach fields are inadequate to protect public health and the environment in areas of Wisconsin where water wells are completed in shallow carbonate aquifers. Wisconsin's requirements for construction of private water wells in these settings, should be revised to require practices that will most likely provide safe, potable groundwater in these settings.

Researchers at the Marshfield Clinic Research Foundation have investigated the association between pathogenic viruses and bacteria in private wells with incidences of infectious diarrhea as indicators of well water contamination (Borchardt, and others 2003b). In general, infectious diarrhea did not correlate with drinking from private wells or drinking from wells that had positive analytical results for total coliform. However, wells which tested positive for enterococci were associated with children having diarrhea of unknown etiology likely caused by noroviruses. A subsequent study of 50 private wells throughout the state indicates that 8 percent of private wells may be subject to virus contamination (Borchardt and others 2003a). Wells positive for viruses did not show seasonal trends nor were they associated with commonly used indicators of microbial contamination such as total coliform or fecal enterococci. These studies suggest that increased monitoring and detection methods for viruses are needed to assess the risk of drinking water with potential microbial contamination.

In another study in collaboration with the US Geological Survey, Marshfield researchers found that 50 percent of water samples collected from four La Crosse municipal wells were positive for enteric viruses, including enteroviruses, rotavirus, hepatitis A virus, and norovirus (Borchardt and others 2004). As with the above described private well study, there was no correlation to common indicators of sanitary quality, nor was there a consistent seasonal trend. More surprising, viruses were common even in those wells without any Mississippi River water infiltration (Borchardt and others 2004, Hunt and others 2005), suggesting fecal sources other than those associated with surface waters were contaminating the wells. The most likely source is leaking sanitary sewers. The study did not address whether the viruses are inactivated through disinfection processes, or result in illness in the community.

Leaking sanitary sewers were shown to be a source of infectious viruses to drinking water wells in subsequent work funded by WDNR and the USGS (Hunt and others, in review). Marshfield Clinic and USGS researchers performed a synoptic sampling of over 30 unconfined municipal wells in 14 Wisconsin communities. Groundwater collected was evaluated for surface water contributions and presence of waste-water tracers and human enteric viruses. From this survey 8 wells had surface water contributions, 4 had unambiguous waste-water tracers, and 5 were positive for viruses. These analyses were used to identify 3 well sites used for intensive instrumentation of the shallow groundwater system between the wellhead and suspected sanitary sewer sources. Viruses and waste-water tracers were found in the groundwater at all three instrumented sites. The work showed that concurrent sampling at any one time may not show simultaneous virus and trace presence due to differences in analytical precision and seasonality of the sources in the waste stream. However, given sufficient sampling over time, a good relation between unambiguous waste-water tracers and virus occurrence was identified such that locations that were characterized by recurring unambiguous tracer occurrence also were found to have enteric viruses present. Moreover, nearby groundwater velocities and presence of infectious viruses at the wellhead demonstrate that high-capacity pumping can induce travel times that are sufficiently short such that viruses are not inactivated during their time in the subsurface. 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 that 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 addition to traditional high yield-slower transport plume contaminants currently included in wellhead protection. Such evaluations are thought to be important in communities such as the 14 included in the study, as they were chosen because they did not routinely employ chlorination or other disinfection procedures at the time of the study.

Microbial contamination of groundwater is not restricted to aquifers typically regarded as vulnerable or shallow aquifers. In a novel study, researchers at the Marshfield Clinic, Wisconsin Geological and Natural History Survey, and the University of Waterloo, discovered human viruses in the confined aquifer supply Madison's drinking water (Borchardt et al 2007). 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 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 (Bradbury et al., 2013). 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. However, as described below, there is no

federal or state requirement for such systems to disinfect their drinking water. Approximately sixty communities in the state do not disinfect the groundwater supplied for drinking water.

Public and private water samples are not regularly analyzed 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 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. Recently, water samples from private residences in Door County found low levels of some viruses but water samples did not contain coliform (Wisconsin DNR). 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 point in 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.

Data from the U.S. EPA shows that the highest percentage of microbial unsafe water is found in small water systems, like transient non-community (TN) systems such as restaurants and convenience stores (Peterson, 2001). There are approximately 9,500 active TN systems in Wisconsin. The mobility of people consuming water at small water systems and general lack of knowledge of illness symptoms hinder waterborne illness outbreak identification.

Nationally, the Center for Disease Control tracks and identifies failures in water systems that lead to illness outbreaks. Because of the increasing evidence for widespread occurrence of microbial contaminants, additional monitoring requirements for vulnerable public water systems are on the horizon.

The U.S. EPA promulgated the Groundwater Rule (GR), on November 8, 2006 which modified Safe Drinking Water Act requirements to increase monitoring for fecal contamination in groundwater and reduce the occurrence of illness from drinking water borne microbial pathogens. Components of the GR include:

1. Sanitary surveys of public systems to identify deficiencies in system construction and operation.
2. Improvement on Safe Drinking Water Act requirements which have focused on sampling for microbial indicators in the distribution system. The GR requires source water monitoring when total coliform is detected in the distribution system.
3. A requirement of corrective action for non-complying features found in the water system and eliminating fecal contamination with treatment or providing an alternative permanent source of water.
4. Monitoring requirements to ensure that treatment equipment is maintained.

Implementation of the deficiency and monitoring requirements of GR began on December 1, 2009. DNR conducts inspections and requires correction of non-complying features. Therefore, the major changes resulting from the GR are additional monitoring of source water and installation of approved treatment devices or a new water source for the wells found to contain fecal contamination. However, the GR does not require testing for all pathogens. Recent research provides adequate evidence to suggest that requiring disinfection of groundwater-sourced public water supply systems would improve protection of public health.

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Surface Water Impacts

Groundwater pumping is substantially impacting streamflows and water levels in lakes and wetlands in parts of Wisconsin. This issue differs from the large regional drawdown issues in the northeast and southeast, where water level declines are mainly in the confined or semi-confined systems not well connected to surface waters.

Central Sands

The problem has been well documented in the central sands region of the state (parts of Portage, Waushara, Waupaca, Adams, and Marquette Counties), where 20% of the state's groundwater is pumped from several thousand high capacity wells, predominantly for irrigation. Dozens of lakes and potentially hundreds of stream miles may be affected. Some lakes have completely dried, most notably Long Lake near Plainfield. Others have suffered varying degrees of ecological impacts. Recreation has been impaired, for instance, in Portage County where the county swimming beach at Wolf Lake has been closed for about 8 years. The Little Plover River, a Class I trout stream and Exceptional Resource Water in Portage County, has dried in parts during various years since 2005.

Statistical approaches and groundwater flow modeling indicate that area streams and lakes would have had continuous and healthy flows and water levels in the absence of groundwater pumping in the area.

Several of the GCC agencies are participating in a Wisconsin Institute on Sustainable Agriculture (WISA) consortium (<http://wisa.cals.wisc.edu/current-projects>) to help understand the potential impacts of irrigation pumping on lake levels in Wisconsin's Central sands region.

Dane County

Although groundwater and surface water resources are plentiful in Dane County, there several well documented cases of impacts to surface water due to groundwater withdrawals. Just as regional drawdowns have developed across Dane County in response to high-capacity pumping of groundwater for municipal and industrial supply (<http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuantity/RegionalDrawdowns.pdf>), several smaller streams and spring systems have also been impacted over the past several decades resulting in reduced flow rates.

Some of the most significant impacts have been to Starkweather Creek on the east side of Madison as well as springs along the south shore of Lake Mendota, north shore of Lake Wingra and around lake Monona. Baseflow in Starkweather Creek has decreased as stormwater is diverted from impervious areas to drainage ditches and high-capacity pumping lowers water levels. At Springhaven Pagoda, which was built in the late 1800's to house a spring near the shore of Lake Monona, the spring has stopped flowing entirely. At Merrill Springs, near Spring Harbor along the south shore of Lake Mendota, a spring pool that was built in the mid-1930s has decreased its flow by upwards of 90% (<http://www.springharboronline.com/where-are-the-springs-in-spring-harbor.html>). The reduction in these surface water flows is considered to be due to decreases in recharge from urbanization and, even more importantly, the result of regional drawdowns from pumping high-capacity wells.

The Dane County groundwater flow model, which is calibrated based on observed water levels in wells and lakes, as well as flow rates in streams and springs, has provided further evidence of impacts to surface water along the Yahara River corridor. Model simulations over the past

decades have consistently shown a reversal in groundwater flow along the southern two-thirds of Lake Mendota and all of Lake Monona. The result is that lakes that historically gained groundwater now lose water to the groundwater system. This reversal, which is due primarily to the concentration of high-capacity wells in the greater Madison area, has effectively drawn groundwater levels down in wells and impacted flows in sensitive stream and spring systems which are replenished by shallow groundwater supplies.

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Regional Drawdowns

The effects of groundwater withdrawals on a regional scale are seen in the Lower Fox River Valley, southeastern Wisconsin, and Dane County. The Lower Fox River Valley and southeastern Wisconsin were designated Groundwater Management Areas based on water level drawdowns of more than 150 feet observed in those two regions. Drawdowns in parts of Dane County have been around 50 feet. Large groundwater drawdowns indicate changes in the flow systems. Around 1900, flowing wells were present in both the Lower Fox River Valley and southeastern Wisconsin. Pumping has caused drawdowns in those aquifers so that today the water levels are often hundreds of feet below the ground surface. Excessive drawdowns can cause reduced yields to wells, lower water quality, and divert water from surface waters.

Lower Fox River Valley

Water levels in the Lower Fox River Valley have varied widely over time. Water levels in the deep aquifer of the Lower Fox River Valley were above the land surface before significant pumping from that aquifer in 1900. By 1957, increased pumping in the deep sandstone aquifer lowered water levels by hundreds of feet. In response the City of Green Bay switched from groundwater supply to surface water supply and the water levels increased more than 200 feet in the aquifer. By 2005, increased pumping from the communities surrounding Green Bay caused water levels to have decreased to the low levels seen in 1957. In response to that drawdown, six suburban communities in the Lower Fox Valley reduced consumption of groundwater by about 8.2 million gallons per day by switching to surface water supplied by pipeline from Lake Michigan in 2007. As a result, water levels in the deep sandstone aquifer in and around Green Bay have risen. These changes at one well can be seen in Figure 1.

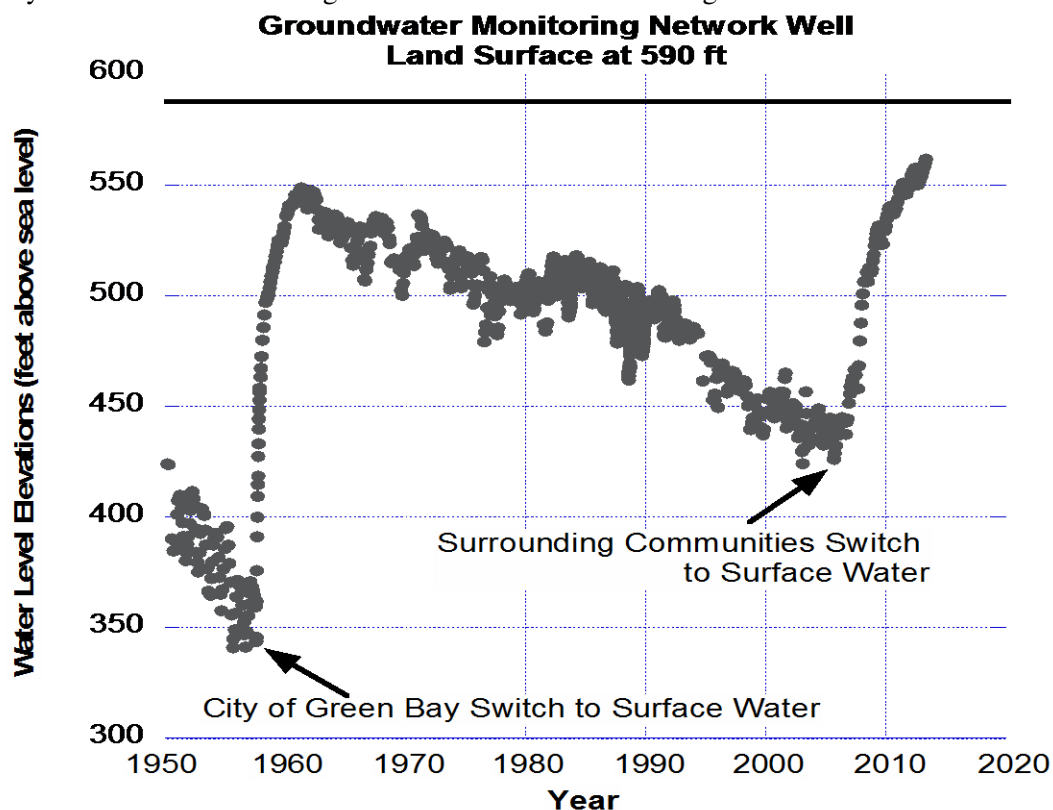


Figure 1: Changes in groundwater levels in a groundwater level monitoring well in Green Bay, Wisconsin (WGNHS)

The water levels continue to rise and some homeowners and the town of Howard have reported flowing wells. If water use continues to decrease, the number of flowing wells will increase over time as the water levels rise above the land surface. Contours of water levels before and after the reduction of pumping in 2007 are shown in Figure 2.

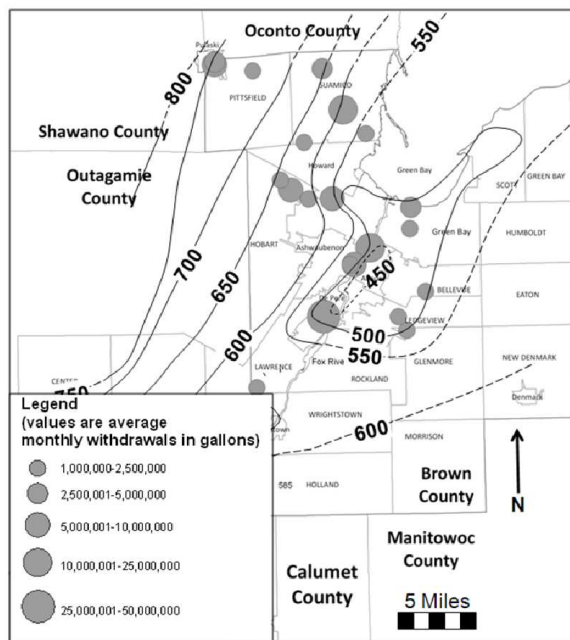
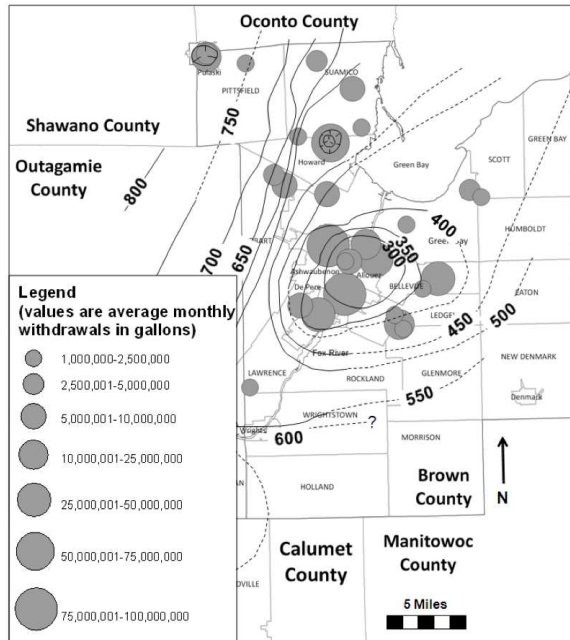


Figure 2: Water table elevations in Brown County (WGNHS).

We know from previous drawdown and pumping records that when the pumping rate reaches around 6 million gallons per day that the deep aquifer has the potential to become dewatered, raising concerns about changes in the aquifer chemistry that might increase arsenic or radium concentrations. This provides good rationale for monitoring high-capacity pumping in this aquifer.

Southeastern Wisconsin

Water levels in southeastern Wisconsin have shown the largest decreases in Wisconsin. These decreases have raised concerns about increases of radium to wells above drinking water standards and increased pumping costs. As was the case for the Lower Fox River Valley, water levels in the deep sandstone aquifer were above the land surface before significant pumping in 1900. Pumping increased steadily from 1900 to 2000 and water levels in some wells steadily decreased by more than 500 feet. Figure 3 shows the water table decline until around 2000 to 2005. Research and monitoring from the late 90's and early 2000's demonstrated an average of 7 feet per year decline in deep wells (Feinstein et al., 2004). However, a recently added well in Waukesha County, to the groundwater observation network shows 2013 water levels to be approximately 50 feet higher than the levels observed in a nearby observation well in 1998 (Pfeiffer, 2013). The reduced drawdown is likely due to reduced pumping by communities from groundwater conservation efforts and from seeking alternative sources of water to the deep sandstone. The deep sandstone aquifer sometimes has radium concentrations over the drinking water standard of 5 pCi/l. Treatment of that water can be costly, leading some communities to look at other water sources.

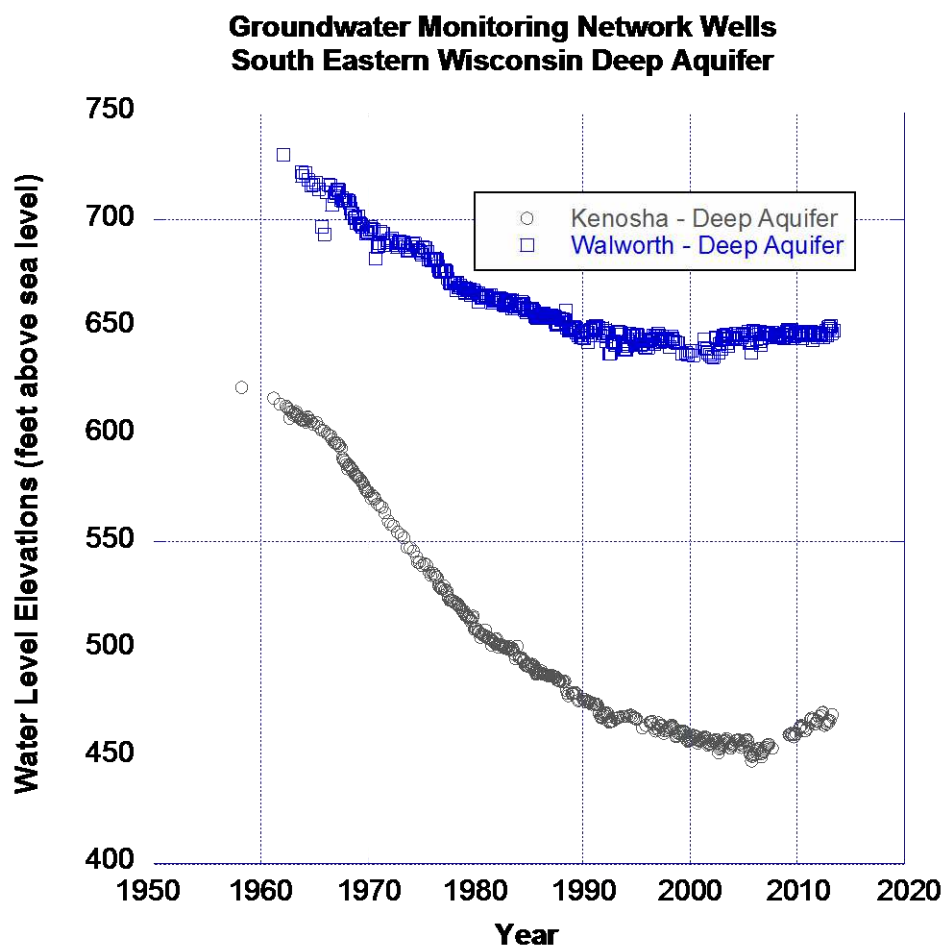


Figure 3: Water levels in a groundwater level monitoring wells in Kenosha and Walworth counties (WGNHS).

Dane County

Dane County presents another example of regional drawdowns which have been well documented through water level measurements and the development of multiple groundwater flow models, at a county-wide scale, over the past several decades. The latest version of the Dane County model, begun in 2010 and slated for publication later this year (2013), has focused on increasing the spatial resolution of the model grid, better simulating surface water groundwater interactions, and introducing transient flow capabilities, all while upgrading the computer codes and calibration methods. Each of these model improvements will provide new insights into the groundwater system within Dane County and a greater understanding of regional scale drawdowns.

The existing Dane County model, developed in the mid-1990s (Krohelski, 2000), was used to simulate drawdowns in both the Mount Simon Sandstone and at the water table. Figures 4 and 5 were generated by comparing predevelopment water levels to those measured in 2000 and document the presence of significant drawdowns in central Dane County, below the Yahara River corridor. In Dane County, municipal water supply is by far the primary groundwater user, representing roughly 80% of the total withdrawal rate of 60 million gallons per day. The next largest withdrawals are made by irrigation (under 10%) and aquaculture (under 5%).

Dane County

**Simulated drawdown (feet) in the Mount Simon Sandstone;
predevelopment to 2000**

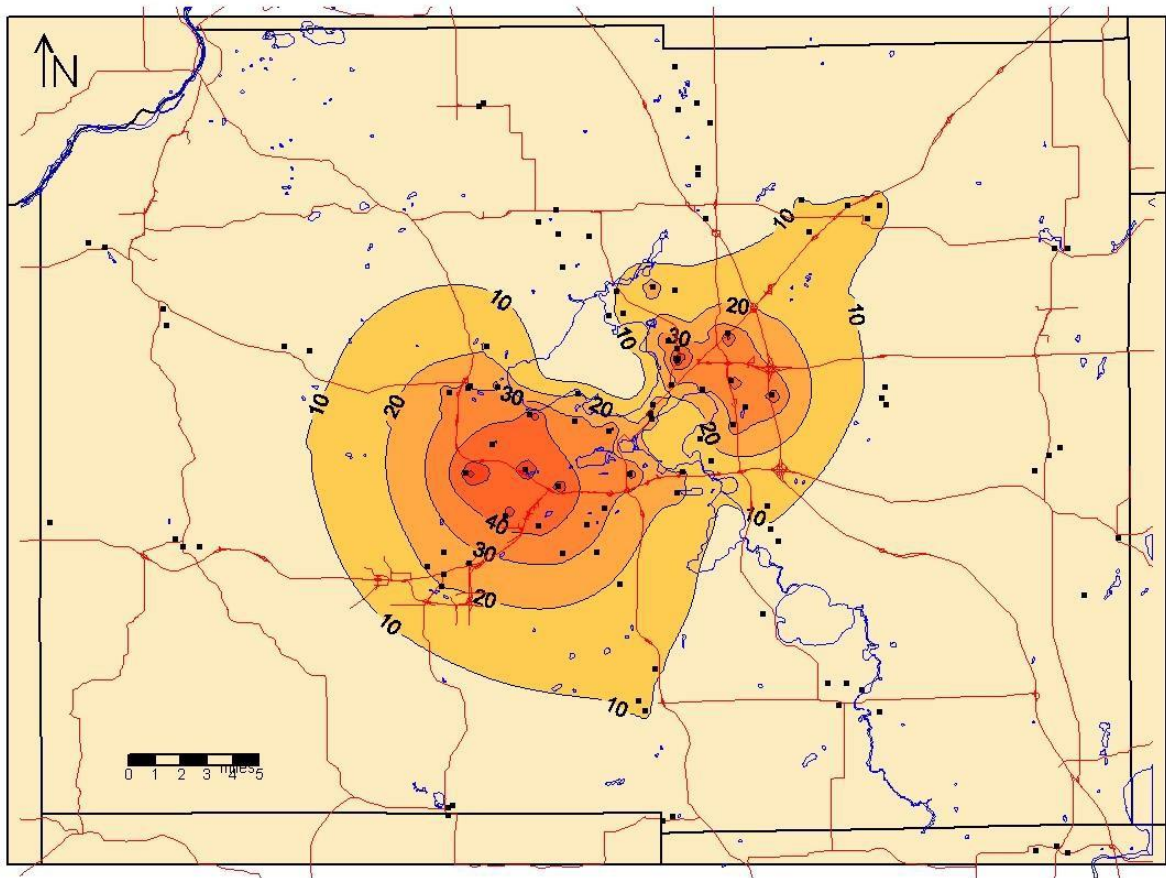


Figure 4 - Simulated drawdown (feet) in the Mount Simon Sandstone; predevelopment to 2000. The Mount Simon Sandstone, located several hundred feet below land surface and up to 800 feet thick, is the lowermost aquifer unit within Dane County. This porous sandstone is a highly productive aquifer which provides the bulk of groundwater supplies to high-capacity municipal and industrial wells across Dane County.

Dane County

**Simulated drawdown (feet) at the water table;
predevelopment to 2000**

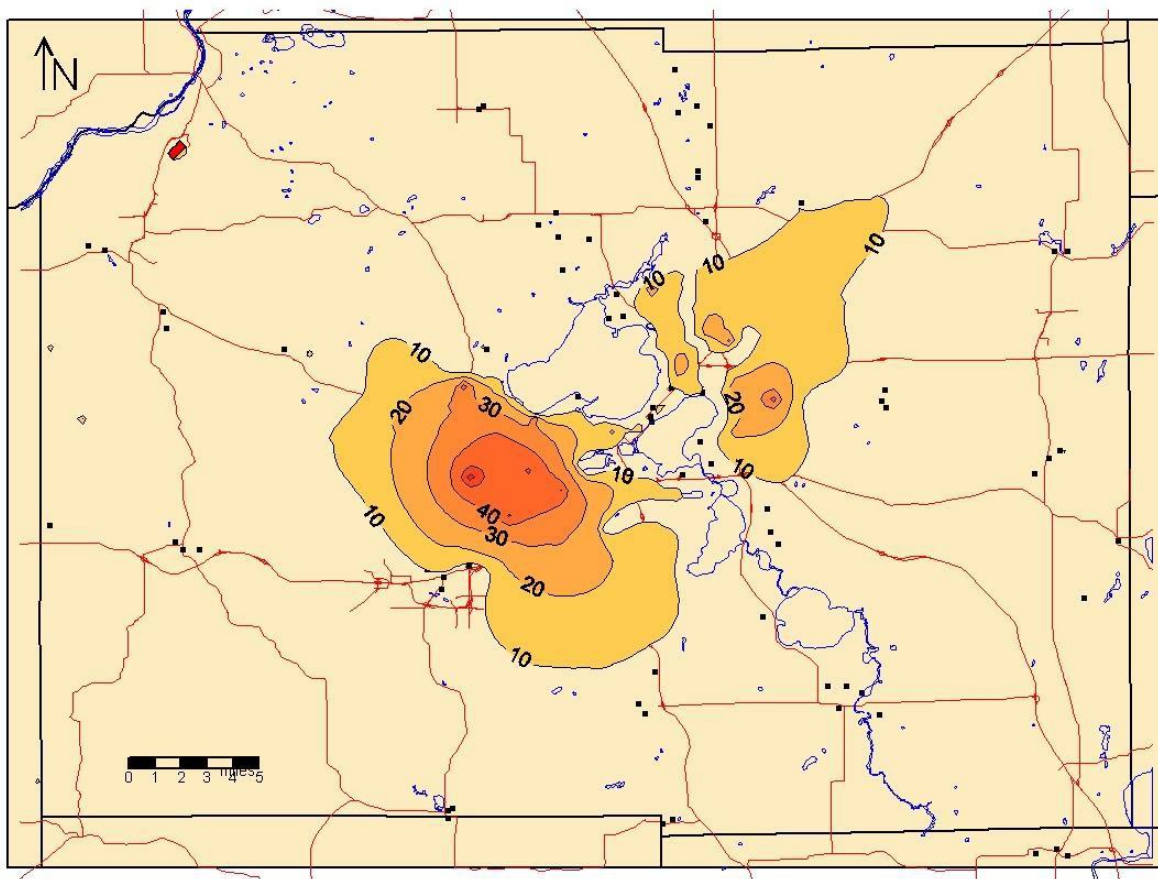


Figure 5 - Simulated drawdown (feet) at the water table; predevelopment to 2000. Drawdowns from the lower Mount Simon aquifer system propagate upwards to the shallow sand and gravel and upper bedrock aquifer systems to create drawdowns at the water table.

Water use data collected for the updated 2013 model, indicate that groundwater withdrawals have declined by up to 15% over the past 10-15 years across Dane County. These reductions are believed to be primarily attributable to recent wet years, during which water demand drops, and local groundwater conservation efforts. Once the updated 2013 model is complete, it will improve our understanding of regional drawdowns across Dane County and provide insights into groundwater systems across South Central Wisconsin.

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Impact of Reduced Quantity on Groundwater Quality

Overuse of groundwater resources can result in water quality problems as well. One example of this problem is seen in Southeastern Wisconsin. As prolonged heavy water withdrawals from wells in the deep sandstone aquifer have drawn water levels down hundreds of feet and in recent years, the concentrations of radionuclides and other elements have increased in many of these wells. Radionuclides are carcinogenic and very costly to remove. As a result, several communities facing a regulatory deadline for reducing the level of a specific radionuclide, radium, in their drinking water must look for alternative sources. Alternatives have included switching from a groundwater source to a surface water source, namely Lake Michigan, extensive treatment of water from deep wells to remove the contaminants, and expanded use of wells in shallow aquifers. Each of these options presents significant obstacles or concerns. Continued use of the deep aquifer with extensive treatment will be quite expensive, will continue the existing drawdown problems and may not be sustainable in the long term. Use of Lake Michigan water outside of the Great Lakes Basin would be precedent-setting and requires an applicant to meet rigorous Great Lakes Compact criteria and the concurrence of other Great Lakes states. Currently, the DNR is reviewing the City of Waukesha's application for a diversion of Lake Michigan water. Expanded use of shallow wells may also be problematic because it may impact streams, wetlands, springs, lakes or other shallow wells. In addition, shallow wells are generally more susceptible than deeper wells to contamination from near-surface sources such as nitrate and pesticides.

A second example of regional drawdown causing groundwater quality problems occurs in the Lower Fox River Valley. Here the lower water levels have led to increased detections of arsenic in private well water in recent years (also described in the Groundwater Quality Section of this report). Investigations in the affected area indicate that most of the arsenic is coming from a highly mineralized zone at the top of the St. Peter Sandstone. Increased groundwater use in the Lower Fox River Valley has lowered water levels in the bedrock aquifer. In some locations, this has exposed the mineralized zone to the atmosphere leading to oxidation and subsequent release of arsenic to the groundwater. In 2006 a new (lower) standard of 10 µg/L for arsenic in drinking water took effect, leading to many wells being in violation of this standard.

Land use and high groundwater conflicts

In contrast to the groundwater issues above that relate to a lack of sufficient groundwater quantity, too much groundwater can also be a problem. A dramatic example was when Southern Wisconsin experienced record amounts of precipitation from August 2007 through July 2008. Severe flooding occurred across this region, resulting in significant property loss, human displacement, and disruption of transportation. While most of the initial flooding occurred as surface water overflow, longer-term groundwater flooding remained for many weeks or months following the rain events. Groundwater flooding occurs when the water table rises above the land surface, and can be long-lasting because water-table decline requires drainage of an entire aquifer. Seepage lakes may also experience flooding of shoreline beaches and developments due to a rise in the water table elevation and the related long-term increase in lake stage.

Several communities recently affected by elevated groundwater levels experienced a return to drier conditions in the first half of 2012. Examples include Clear Lake, in Rock County, where the lake stage increased by about 7 feet in 2009, but returned to previous conditions in May 2012. In Spring Green, 4,378 acres outside of areas currently designated as floodplain by the Federal Emergency Management Agency (FEMA) flooded for over five months in 2008. Modeling and field investigation indicate this flooding was caused by water table rise above ground surface. Mitigation of high groundwater elevations in Spring Green included a \$5.4 million FEMA grant in 2009 to acquire and demolish 28 flood damaged homes.

Although the hydrogeologic setting varies among affected areas, the widespread occurrences of groundwater flooding and the regional nature of intense precipitation events in 2007 and 2008 suggest this is a regional issue. A recently completed study of affected hydrologic systems and climate change, funded by the UW System., suggests that years of extremely high water table conditions may still occur but will remain relatively rare in this century (Joachim et al, 2011). Water resource managers should expect to see some years of high recharge amongst overall less recharge on average. The study concluded that warmer climate conditions will increase evapotranspiration and result in a reduction of groundwater recharge under certain crop types or land cover. Specifically related to the Spring Green region, the study indicated that water table fluctuations up to 3 meters should be expected in planning basement and foundation depths, road construction, or design of on-site wastewater treatment systems.

Reference:

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Wisconsin Groundwater-Level Monitoring Network

The Wisconsin Groundwater-Level Monitoring Network has been operated jointly by the Wisconsin Geological and Natural History Survey (WGNHS) and the U.S. Geological Survey (USGS) since 1946. This network consists of approximately 160 wells in 54 counties providing a consistent, long-term record of fluctuations in water levels in deep and shallow aquifers. In addition to permanent wells, additional limited-term monitoring wells are managed and paid for by other ongoing groundwater studies across the state and greatly increase the cost savings and value of the network. The total number of active monitoring wells (long-term + limited-term) often fluctuates between 120 and 200. As of June 1st, 2013, there were 170 active monitoring wells in 54 counties. Such information is critical to track the impacts of high-capacity well pumping, the response of groundwater levels to droughts, the effects of land-use changes on groundwater systems, and the impacts of climate change. The long-term data provided by the network are also essential for calibration of regional groundwater-flow models.

For available data, see <http://wi.water.usgs.gov/data/groundwater.html>

In 2012 and 2013, the WGNHS, in consultation with DNR and USGS, began a project to perform a number of upgrades to the network by retrofitting existing wells with monitoring equipment, drilling new wells in regionally important hydrogeologic units (e.g., Maquoketa shale, St. Peter Sandstone), and instrumenting two spring complexes in Waukesha County with flow gages. These upgrades to the network were identified as critical steps to improve the monitoring network in the Great Lakes Basin in areas of intense groundwater pumping (southeast and northeast Wisconsin). We anticipate completing additional retrofitting and repair work in 2013 and 2014 to rehabilitate and incorporate several older monitoring wells into the network.

An important part of this project has involved coordinating and fostering cooperation between multiple municipal, county, state, and federal agencies to ensure that network upgrades are performed correctly and that all stakeholders recognize the importance and value of groundwater data collected by the network. Thanks to this spirit of cooperation, upgrades completed thus far have gone further than anticipated. For example, at the two spring gaging stations in Kettle Moraine State Forest (Southern Unit), the USGS installed an interactive display which allows “citizen scientists” (park visitors) to make flow measurements using staff gages and submit the data via text message. These data are then compiled and provide a secondary source of data for comparison to official real-time measurements. Besides field truthing official flow measurements, Park staff have remarked that the interactive displays help engage the public and demonstrate the value of the statewide monitoring network.

To view the PDF of a recent Powerpoint slideshow on the project to upgrade the groundwater-level monitoring network, see <http://wisconsingeologicalsurvey.org/ftp/monitoring-network-presentation.pdf>

Wisconsin Stream Model

DNR researchers have developed a detailed model that predicts streamflows in ungaged streams using identify factors (such as land use, groundwater recharge, and climatic elements). The model also links these variables to the abundance of fish species in Wisconsin's streams. This project will help determine what hydrologic changes are likely to cause significant environmental impacts to Wisconsin streams.

Aquifer Storage and Recovery

Aquifer storage and recovery (ASR) is a water management technique that uses an injection well to temporarily place surface water or treated drinking water directly into an aquifer for storage. The injected water is then recovered from the aquifer, most often by means of the same well, as it is needed. In some settings, ASR may be an effective way to manage the seasonal peaks in water demand that confront many drinking water utilities. Use of ASR can prove to be a lower cost alternative to the other more traditional engineering approaches that would involve constructing more above ground water storage facilities or surface water reservoirs, drilling additional water supply wells, or expanding the output capacity of a utility's water treatment plant.

Water systems using ASR must be carefully evaluated and designed. The water to be injected must often be conditioned (dechlorinated, deoxygenated, pH adjusted, etc.) prior to its placement underground in order to avoid adverse chemical interactions with the mineralogy of the bedrock of the receiving aquifer. Mobilization of metals such as arsenic and manganese has been observed at a number of ASR sites in the United States. In-situ formation of trihalomethanes (chlorinated compounds such as chloroform, bromoform, etc.) has also been reported at ASR sites where drinking water containing a chlorine residual from water disinfection practices has been injected. A number of these elements and compounds have been determined to be carcinogenic.

Administrative rules in Chapter NR 811, Wis. Admin. Code, regulate the use of ASR wells in Wisconsin. The rules were promulgated to ensure that the quality of public drinking water supplies is maintained and to protect the state's groundwater and surface water resources from any harm that may result from ASR activities. Only municipal water systems are allowed to construct ASR wells and only water piped directly from a municipal water distribution system may be injected into an ASR well. Demonstration testing is also required before routine operation of an ASR well or ASR system may be approved by the DNR.

To date, only the municipal water utilities serving Oak Creek and Green Bay have sought approval to construct ASR wells in Wisconsin. The Oak Creek utility completed the required demonstration testing and received conditional approval to operate its ASR well in 2004. However, after several operational ASR cycles, the concentrations of iron and manganese in groundwater at the ASR well site increased to levels that exceeded the respective groundwater quality enforcement standards for those elements. In 2011 the utility discontinued ASR operations and, instead, expanded its surface water treatment capability.

In Green Bay ASR was pilot-tested , but yielded water with significant concentrations of arsenic and other contaminants, mobilized from the rock matrix of the aquifer. The Green Bay utility suspended ASR-related activities after arsenic and other metals were mobilized during the initial stages of the required ASR demonstration test. The Green Bay Water Utility stopped pursuing an ASR well after learning that the Central Brown County Water Authority would construct a pipeline and purchase drinking water from the Manitowoc Water Utility rather than buy additional drinking water from the Green Bay utility.