Wisconsin Groundwater Coordinating Council

Fiscal Year 2016

REPORT TO THE LEGISLATURE

2016 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 - **Jonathan Meiman, 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***

* Member of Standing Joint Solicitation Work Group

Outreach & Partnership

Center for Watershed Science and Education - **Kevin Masarik** (Co-Chair)
Department of Natural Resources – **Mary Ellen Vollbrecht** (Co-Chair)
University of Wisconsin System –**Moira Harrington**
Department of Agriculture, Trade and Consumer Protection –**Steve Martin**
Department of Safety and Professional Services - **Thomas Braun**
Department of Health Services – **Anke Hildebrandt**
Geological and Natural History Survey - **Dave Hart and Carol McCartney**
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**
Wisconsin Water Association - **Nancy Quirk**
Wisconsin Water Well Association – **Cindy Denman**

State of Wisconsin \ GROUNDWATER COORDINATING COUNCIL

GROUNDWATER
Wisconsin's
buried treasure

Scott Walker, Governor

101 South Webster Street
Box 7921
Madison, Wisconsin 53707

August 30, 2016

To: The Citizens of Wisconsin
The Honorable Governor Scott Walker
Senate Chief Clerk
Assembly Chief Clerk
Secretary Mark Gottlieb - Department of Transportation
Secretary Dave Ross - Department of Safety and Professional Services
Secretary Ben Brancel - Department of Agriculture, Trade & Consumer Protection
Secretary Linda Seemeyer - Department of Health Services
Secretary Cathy Stepp - Department of Natural Resources
President Ray Cross - University of Wisconsin System
State Geologist Kenneth Bradbury - Geological and Natural History Survey

The Groundwater Coordinating Council (GCC) is pleased to provide its 2016 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 over 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 FY16 (July 1, 2015 to June 30, 2016). 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

Table of Contents

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 2016 (FY16). 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 16 proposals, nine new projects were selected for funding in FY17, three by UWS and six 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 16th 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 FY16 meetings:

- US Geological Survey monitoring and analysis available on the USGS national data portal
- DOT use of the winter severity index to reduce salt use and allocate funds among county contractors
- Data and analyses available on the DHS Environmental Public Health Tracking portal
- WI Potato and Vegetable Growers Association efforts related to Central Sands groundwater issues
- Research results from UWS on chemical indicators for waste stream identification
- Research results from UWS on barriers to private well testing

More information on these topics and the coordinating efforts of the GCC can be found in the FY16 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 FY16. 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 the previous 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 detectible 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 23 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
- Extent of arsenic in Northeastern Wisconsin
- Evaluation of drawdown in Eastern 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
- Statewide inventory and database of springs

See the “Progress Portfolio” tab in the on-line report for more information on how agency collaboration and 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.

<u>**Emerging Issues**</u>

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

DNR establishes the groundwater quality standards for the state and coordinates their implementation by diverse agencies and programs (ch. 160, Wis. Stats.). DNR works with operators of landfills, land spreading of waste, remediation and redevelopment of contaminated sites, to ensure that standards are met that avoid concentration of pollutants in groundwater. The DNR works with public water systems across the state to protect groundwater quality and quantity to provide safe and reliable drinking water supplies. DNR manages groundwater quantity (ss. 281.11, 12, 34, and 346, Wis. Stats.) DNR staffs the Groundwater Coordinating Council and collaborates with the UW-System on the joint solicitation for groundwater research and with the Wisconsin Geologic and Natural History Survey on an annual groundwater work plan.

DNR water supply specialists test a new water supply sampling method developed by the State Laboratory of Hygiene. The method will help public water systems distinguish whether the source of bacterial contamination is in the groundwater or from within the water system.

FY 2016 Highlights

- Owners of private and non-community public wells more routinely receive current information about arsenic levels in drinking water under new sampling protocol for pump work or a property transfer inspection
- Review and monitoring of municipal sludge, septage and industrial land-applied wastes uses a new GIS system to protect separation distances between waste application and community and school water supply wells.
- The Interagency Pharmaceutical Waste Working Group led by DNR and UW-Extension with diverse partners coordinated efforts, set up drug collection programs and developed informational materials. Keeping pharmaceuticals out of household and industrial waste streams is the main way to reduce the risk that the substances will reach groundwater through landspreading or septic systems.
- With financial support from the DNR, the Wisconsin Geological and Natural History Survey constructed a groundwater flow model for the Little Plover River watershed in Portage County. This model is a scientific tool for understanding the complexities of geology, groundwater recharge and discharge, surface-water flow, well development and use, and water balance. The model simulates the interactions among streamflow, pumping, and climate to provide users "what-if" evaluations of possible decisions involving water use or land-use changes. The Little Plover River Basin was chosen for this pilot study because the river has been the focus of recent management concern and because a great deal of hydrogeologic data already exists for this area.

Details of Ongoing Activities

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 has canvassed agencies for 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 continued to provide training to new staff in runoff management and drinking water programs on 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. 281, 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 DNR changed its procedures in July 2011 in response to a 2011 Wisconsin Supreme Court decision to review each application for a new high capacity well to determine whether the well, along with other high capacity wells on the contiguous property, would result in significant adverse environmental impacts to waters of the state – which includes all streams, lakes, wetlands, public and private wells. Section NR 820.12(19), Wis. Adm. Code defines significant adverse environmental impact as:

> *Alteration of groundwater levels, groundwater discharge, surface water levels, surface water discharge, groundwater temperature, surface water temperature, groundwater chemistry, surface water chemistry, or other factors to the extent such alterations cause significant degradation of environmental quality including biological and ecological aspects of the affected water resource.*

If the DNR determined the proposed well could directly result in significant adverse environmental impacts, the DNR would either deny the well application or request that an applicant modify their proposed construction or operation of the well to prevent such impacts. DNR based the need to modify or deny an application on the projected impacts to the affected water resource, e.g., estimated reductions in stream flow or lake level, and the resultant impacts to water temperature, the fishery and other ecological aspects of the stream or lake. In conducting these assessments, DNR considered site-specific hydrogeology, separation distance between the well(s) and the water resource, the hydrology and characteristics of potentially-affected surface waters, construction details of nearby wells, characteristics of the proposed wells such as construction, pump capacity, and the water use and pumping schedule for the proposed well and any other existing wells on the property. This version of the technical review methodology was in place from July 2011 through May 2016.

In May 2016 the Wisconsin Attorney General issued a formal opinion (OAG-01-16) regarding the DNR's authority to consider environmental impacts when reviewing high capacity well applications. The Attorney General concluded that through the adoption of 2011 Act 21 (§ 227.10(2m)), "[t]he Legislature has defined the parameters in which DNR can act to protect the state's navigable waters and additionally has clarified the ways in which DNR can regulate non-navigable waters." (OAG ¶52). The Attorney General concluded that section 227.10(2m), Stats., prohibits the DNR from conducting an environmental review of a high capacity well unless it is in one of the specific categories identified in Wis. Stat. § 281.34, such as a well in a groundwater protection area; with a water loss of more than 95 percent of the amount of water withdrawn; or that may have a significant environmental impact on a spring (these categories are specified in Wis. Stat. § 281.34(4)); or if it may impair the water supply of a public utility (as described in Wis. Stat. § 281.34(5)). According to the Attorney General, the Department lacks explicit authority to review the environmental impact of wells outside of those specific categories identified in Wis. Stat. § 281.34. High capacity well reviews are conducted in accordance with the Attorney General opinion as of June 2016.

<u>Great Lakes Compact and Implementation of 2007 Act 227</u>

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 – 2016 is 95 percent annually.

Water Withdrawal Registrations by Source Type and Major Basin (2016)

	Great Lakes Basin	Mississippi River Basin	**Total**
Groundwater	3,959	10,890	14,849
Surface Water	392	666	1,058
Total	4,351	11,556	15,907

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. The compilation of more than five years of water use reporting data has allowed DNR to assess trends in water use over time Summary analysis is conducted on reported withdrawals and an annual water withdrawal reporting summary is made publicly available on the *DNR 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.

DNR is developing a statewide set of conservation standards for agricultural irrigation with partners including the University of Wisconsin, environmental non-profit organizations and the Wisconsin Potato and Vegetable Growers. Participation in the Conservation Standards Program will require growers to report specific data such as cropping rotations, acreages and irrigation practices. In addition, growers will be expected to report economic factors so that the savings and efficiencies from water conservation can be calculated. DNR staff also began working with individual golf courses, the University of Wisconsin, USGA and the Wisconsin Golf Course Superintendents Association to benchmark irrigation withdrawals and identify practices that conserve the most water at the greatest cost savings.

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 and additional environmental review. Since December 8, 2011, 207 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.

Industrial Sand Mining

As noted in previous sections, DNR reviews high capacity wells including those associated with industrial sand mining (ISM) operations in accordance with existing Wisconsin statute and administrative code. Each facility is unique, and each may present potential impacts to proximal water resources. In an effort to better understand the impact of water use related to current and proposed ISM facilities, DNR is working with Chippewa County, the WGNHS, and the USGS to model groundwater conditions.

While sand has been mined for industrial use in Wisconsin for over a hundred years. the recent boom in industrial sand mining for use in the energy sector has created regulatory challenges as new programs adjust to a new major industry,. Concerns have been raised over potential for contamination from flocculants used during sand processing. DNR is working with Chippewa County as they evaluate potential risks associated with these chemicals. Exploratory boreholes have been found in proximity to ISM facilities that have not been properly filled and sealed, which can create a conduit for contaminants to reach groundwater. DNR is providing technical assistance on a project evaluating potential groundwater quality impacts associated with ISM facilities. The project is focused on elevated concentrations of metals and pH fluctuations in stormwater ponds and will be led by DNR's runoff management program.

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: 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 industry groups to implement and reinforce the requirements of October 2014 rule revisions to NR 146 and NR 812, Wis. Adm. Code. DNR sends monthly emails to a GovDelivery list of drillers and installers, with news and updates, and refers people to an updated web page with information and resources for the industry. DNR issued new Heat Exchange Driller licenses to 43 individuals who met eligibility requirements and passed an examination. DNR staff reviewed data to determine if additional nitrate and arsenic sampling requirements for pump work are being met, and follow up any noncompliance. Inspectors, property owners and real estate agents continue to have questions about property transfer well inspection requirements. Lender requirements during a real estate transaction often result in a noncomplying well being brought into compliance, or a new well being constructed.

DNR Private Water Supply staff presented code training to drillers and pump installers at ten Continuing Education sessions sponsored by the Wisconsin Water Well Association and Wisconsin Geothermal Association. Based on a 2015 customer survey of license holders, many individuals would like more options for continuing education, including different training providers, and on-line or hands-on training. DNR will implement changes to the continuing education process starting in 2017, to respond to these customer requests.

Private Water Supply staff are often the first-responders to complaints regarding the contamination of private wells. Well contamination by manure has been an increasing problem in recent years. Using field investigation and analytical tools for investigating the source of microbial contamination – known as MST sampling – DG staff are able to determine whether fecal contamination is 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 sampling and well inspection 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 recently updated the popular web page titled "*What's Wrong with My Water*?" to help answer commonly-asked questions about private well water quantity, help well owners diagnose their aesthetic water quality problems, and provide DNR water supply institutional knowledge.

DG continues to develop electronic tools for management of well construction, well abandonment, and other data. An on-line Well Abandonment Report system, which allows licensed individuals to electronically submit required well filling and sealing reports has been in use for a year, and electronic filing of these reports will be required by July 1, 2016. DG is currently developing an electronic system for submitting well construction reports, and continuing to implement last year's LEAN project by developing an electronic license renewal option for licensed drillers and pump installers.

Public water systems

DNR's Public Water Supply (PWS) program oversees the drinking water quality provided by public water systems [ch. NR 809 (Safe Drinking Water), Wis. Adm. Code]. 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 also 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. Additionally, the PWS program 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 maintains 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).

DNR maintains an electronic data system (EMOR) to accept and store monthly operating report data from public drinking water systems. EMOR contains required documentation of a system's operations such as monthly pumpage, chemical useage for treatment, chlorine residual, turbidity, and temperature. EMOR generates data reports to monitor treatment operations and make efficient water quality and quantity management decisions.

Public water systems continue to face rising nitrate levels. At the top risk tier, municipal water systems must take immediate action if a nitrate MCL of 10 mg/L is observed (e.g., take well off-line, blend, treat, etc.). At the lowest risk tier, transient non-community systems, which include taverns, restaurants, churches, and campgrounds, are required to post notices warning customers of the exceedance and to provide bottled water to infants and pregnant women. Rising nitrate concentrations are 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.

The PWS program is working with public water systems to implement the federal revised total coliform rule (RTCR). Wisconsin has adopted a "find-and-fix approach" so that when bacterial contamination potential is detected by the presence of total coliform, DNR and water system operators investigate to find the cause, take action to fix it, and monitor to ensure public health protection. Among many RTCR implementation activities, water supply specialists tested new water supply sampling methods developed by the State Laboratory of Hygiene. The method will help public water systems distinguish whether the source of bacterial contamination is in the groundwater or due to a defect of the water system.

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. DNR promotes and encourages but does not require wellhead protection planning for all wells. With planning assistance from Wisconsin Rural Water Association (WRWA), 11 communities completed WHP plans this year (4 required and 7 voluntarily).

DNR and 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 and using groundwater monitoring, modelling and related tools in Spring Green, Fall Creek and Waupaca to demonstrate a voluntary community-based approach to rising nitrate levels. The village of Luck, WI has updated its WHP plan, participated in groundwater teacher workshops and is evaluating new spill prevention and remediation and redevelopment opportunities with support from DNR and WRWA. Unluckily, several contaminant plumes have the potential to affect the village's two municipal wells.

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 Treasur*e publication, and the *Groundwater Study Guide* packet.

Groundwater Monitoring and Research

Chapter 160 of the Wisconsin Statues 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.

Based on measured stream flow and groundwater levels, the Little Plover River groundwater flow model was developed to help people understand the groundwater system and inform management decisions.

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 contaminant 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.

<u>Cleanup Of Groundwater Contamination</u>

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.

<u>Investigation, Cleanup and Redevelopment of Brownfields</u>

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 geolocational 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. WMM provides access to the environmental monitoring data contained in GEMS by using “GEMS on the web.” In addition to enhancing “GEMS on the web” to allow more flexibility in choosing a specific date range and particular monitoring points, WMM is seeking resources to program a web interface, possibly using the Department’s Data Portal and/or Web Access Management System, so that facilities can upload environmental monitoring data into GEMS.

WMM Program is placing stronger emphasis on having facilities collect water samples for VOC analysis rather than for indicator parameters, in exchange for a reduced sampling frequency. VOCs are a key contaminant used to determine water supply well vulnerability to contamination and set monitoring requirements.

Bags of pharmaceuticals collected by Jefferson County as part of effort to keep pharmaceutical waste out of the groundwater. *Photo credit: Barbara Bickford*

WMM continues to co-lead the Interagency Pharmaceutical Waste Working Group, with UW-Extension and diverse partners. Keeping pharmaceuticals out of household and industrial waste streams is the main way to reduce the risk that the substances will reach groundwater through landspreading or septic systems.

<u>Monitoring Groundwater Quality Around Metallic Mines</u>

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. Groundwater monitoring wells on the property are in the process of being abandoned.

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.

<u>Wastewater Discharges</u>

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

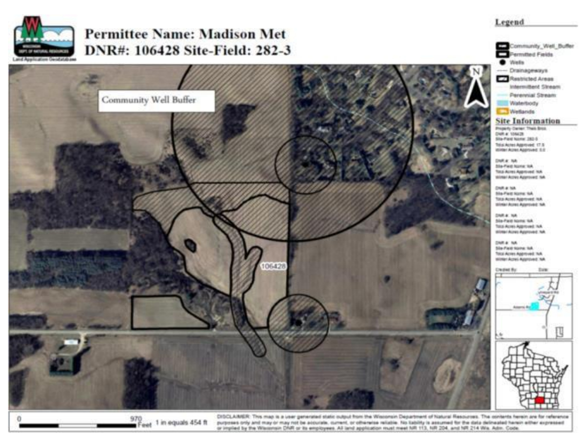
WQ implements the regulations in chapters NR 113, NR 204, and NR 214, Wis. Adm. Code. NR 113 relates to septage management and ch. NR 204 governs the treatment quality, use, and disposition of municipal wastewater treatment plant sludge. ch. NR 113 and ch. NR 204 incorporate federal septage and sludge 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.



Clearer, more easily-produced maps in permits to land-apply wastes now help protect community and school water supply wells.

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.

<u>Agricultural runoff and groundwater quality</u>

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 updates 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 implement 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.

FY 2016 Highlights

- Awarded the first-annual Producer Led Watershed Protection Grants to provide farmer-led groups incentives to address agricultural nonpoint contributions.
- Repeated the statewide statistical sampling survey of pesticides and nitrates in private wells for the first time since 2008, expanded to analyze close to 80 pesticide compounds

Details of Ongoing Activities

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 and related conservation practice implementation. The DNR's NR 151 rule on runoff management is intended to protect both groundwater and surface water and lays out the process by which DATCP identifies the practices and procedures for implementing and enforcing compliance with the agricultural performance standards, including nutrient management. In 2005, DATCP adopted the USDA-NRCS 590 Nutrient Management Standard via administrative rule, ATCP 50, to meet DNR's nutrient management performance standard.

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 or pastures. 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 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 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)
- UW's recommendations for each crop and soil type
- 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

The NRCS 590 Nutrient Management Standard was updated in 2015. This update was made mainly to address winter spreading risks, groundwater protection and improved management of nitrogen. Previously, the 2005 590 Standard focused on reducing the phosphorus losses to surface water systems but now addresses more loss pathways. A few of the new requirements that will further protect groundwater quality:

- Show adequate acreage and a winter spreading plan for all farms with mechanically applied manure or organic by-products.
- Account for N and P2O5 deposited by pastured or gleaning animals.
- Applications are prohibited on:
    - Concentrated flow channels; surface water; saturated soils; areas of active snow melt where water is flowing; land where vegetation is not removed.
    - Direct conduits to groundwater, a potable well, or within 8 feet of irrigation wells.
    - Areas near public water supplies within 1000 feet of a community potable water well; or areas within 100 feet of a non-community potable water well (church, school, and restaurant) unless manure is treated to substantially eliminate pathogens.
    - Areas locally delineated by the Land Conservation Committee or in a conservation plan as areas contributing runoff to direct conduits to groundwater unless manure is substantially buried within 24 hours of application.
- Limits on surface applications in Surface Water Quality Management Areas and over subsurface drainage.
- Additional limits for manure applications on frozen or snow-covered soils:
    - No applications in areas where DNR Well Compensation funds provided replacement water supplies for wells contaminated with livestock manure or where Silurian dolomite is within 60 inches of the soils surface.
    - No applications of manure within 300 feet of direct conduits to groundwater.
- Fertilizer applications on N restricted soils that include high permeability soils (P), or rock soils with less than 20 inches to bedrock (R), or wet soils with less than 12 inches to apparent water table (W):
    - Or if the soil depth is less than 5 feet over bedrock or the area is within 1,000 feet of a community potable water well, no commercial N applications in late summer or fall (exclusions apply).

  - Spring applications of N cannot exceed the crop recommendations of all N sources and on highly permeable soils additional N strategies must be followed to slow the release (i.e., inhibitor, controlled release fertilizers) or minimize the amount spread at once (i.e., split applications).
- Manure sources of nitrogen need to minimize the amounts spread on P, R, and W soils in accordance with the soil types, the amount of dry matter in the manure, the date and the soil temperature in order to decrease losses.

The 2005 590 Standard did include a number of practices to protect groundwater from the impacts of nutrient applications and these provisions still need to be met under the new standard, such as:

- Nutrient and manure application setbacks from karst features and other conduits to groundwater
- 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, 31 percent of agricultural land in Wisconsin is covered by an approved nutrient management plan (Figure 2).

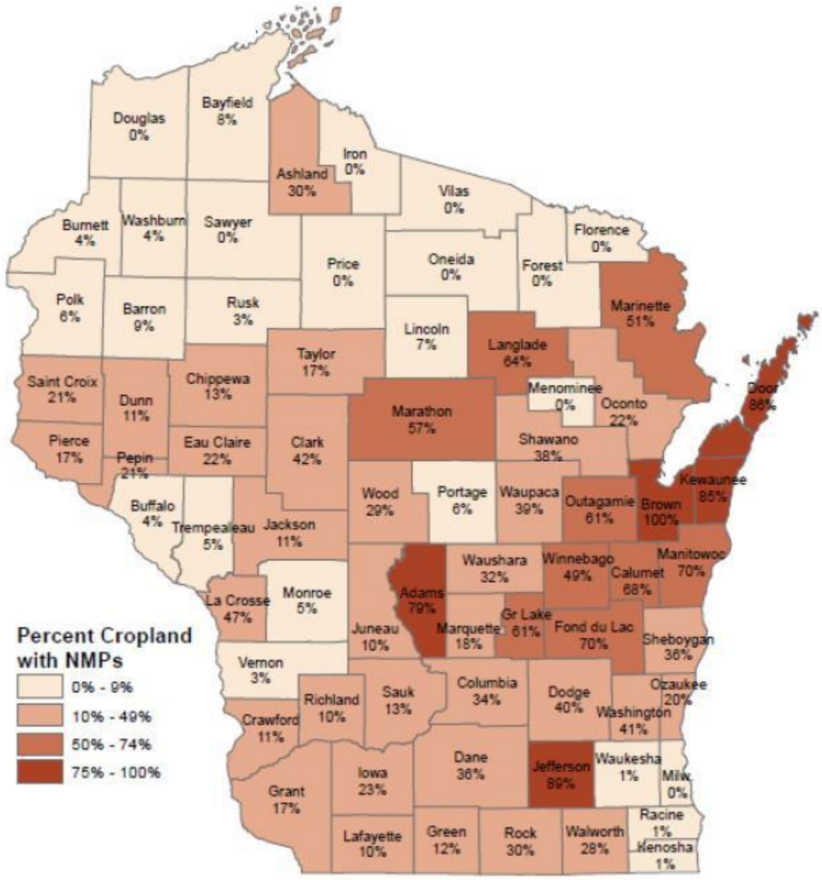


Figure 2. Percent of each county's cropland with a nutrient management plan in 2015 (calculated from county reported acres and 2012 National Agricultural Statistics Service of Wisconsin county cropland).

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, and although not maintained at those levels, cost-share funding has continued to remain in the $2-3 million range each of the subsequent biennium.

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 was provided to counties for landowner cost-sharing, $175,000 to fund grants for farmer training (Nutrient Management Farmer Education grant program), and the remainder of the $523,000 was awarded to supporting partners, including UWEX/CALS, which includes SnapPlus software support in addition to outreach and education support.

DATCP's annual appropriation in the 2015-17 budget of $3,027,200 in GPR funds and $5,711,900 in SEG funds "for support of local land conservation personnel under the soil and water resource management program." DATCP has no underspending from prior years that might be added to the funds appropriated for this allocation. DATCP would need an increase of about $3.0 million in its annual appropriations to reach the statutory goal of funding 3 positions at 100, 70 and 50 percent. DATCP's 2016 final allocation plan under the Soil and Water Resource Management Grant Program is summarized in Table 1 below.

Table 1. Summary of Requests and Allocations for Grant Year 2016.

Funding Category	Total Requests	Unmet Requests	Final Allocations
County Staff/Support	$16,025,340	$7,286,240	$8,739,100
County LWRM Cost-Share	$7,146,000	$3,470,952	$3,675,048
NR 243 Reserve	$200,000	$0	$200,000
LWRM Cost-Share (SEG)	$2,643,900	$990,895	$1,653,005
Project Contracts (SEG)	$592,931	$45,800	$547,131
NMFE Training Grants (SEG)	$101,064	$0	$101,064
Total	**$26,709,235**	**$11,793,887**	**$14,915,348**

The majority of SEG 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.

In 2015, total requests from counties for SEG funds exceeded available funds by $3,534,292, this increased to $5,343,062 in 2016. 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 ATCP 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 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.

The 590 Restriction maps have been available statewide to assist farmers in making sound decisions about how and where to apply nutrients on their cropland. The mapped data used to create the restriction maps are also available for GIS-users to download into their own mapping applications. In 2015, the restriction maps were integrated directly into the SnapPlus program allowing the software to automatically identify and import field information from the maps. This will allow plans to be written and updated faster and more accurately using better information that is updated at least annually and will also provide a better user experience by making data management easier. Early feedback from users was extremely positive and increases in compliance are expected to be seen in the 2016 Quality Assurance Team plan reviews.

Through these combined efforts, the total number of acres covered by over 6,700 nutrient management plans statewide in the 2015 crop year rose to over 2.8 million acres, see Figure 3.

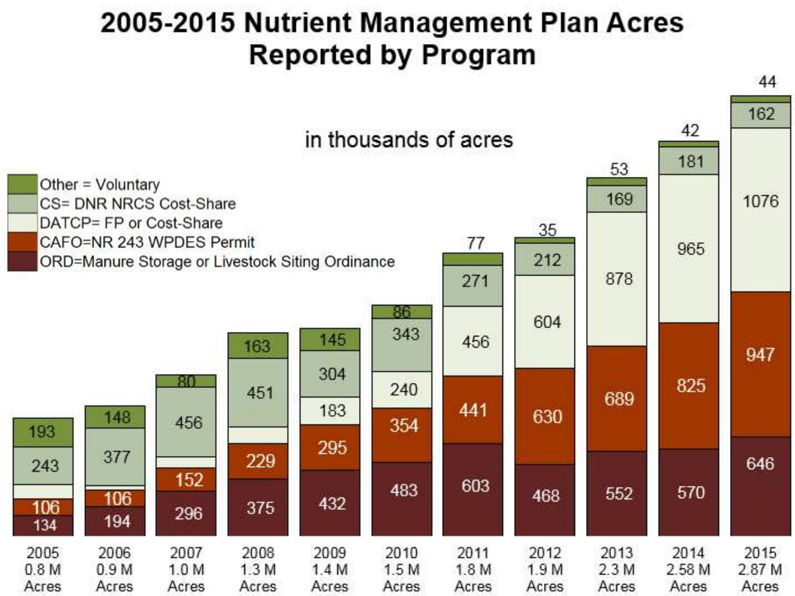


Figure 3. Acreage trends in nutrient management as reported to DATCP. Taken from DATCP's annual nutrient management report: http://datcp.wi.gov/uploads/Farms/pdf/NMUpdate2015.pdf

A New Program to Address Agricultural Nonpoint Contributions

The new Producer Led Watershed Protection Grant program was created to provide farmer-led groups financial incentives of up to $20,000 each from a $250,000 annual allocation (ATCP 52). The first awards were made in 2016 to 14 different groups around the state (see Figure 1). This financial incentive, combined with the requirement of working closely with neighbors and local conservation groups, will allow those most intimately involved with the local soil and water issues to tailor the best possible solutions to their unique, local challenges in a way that statewide requirements cannot.

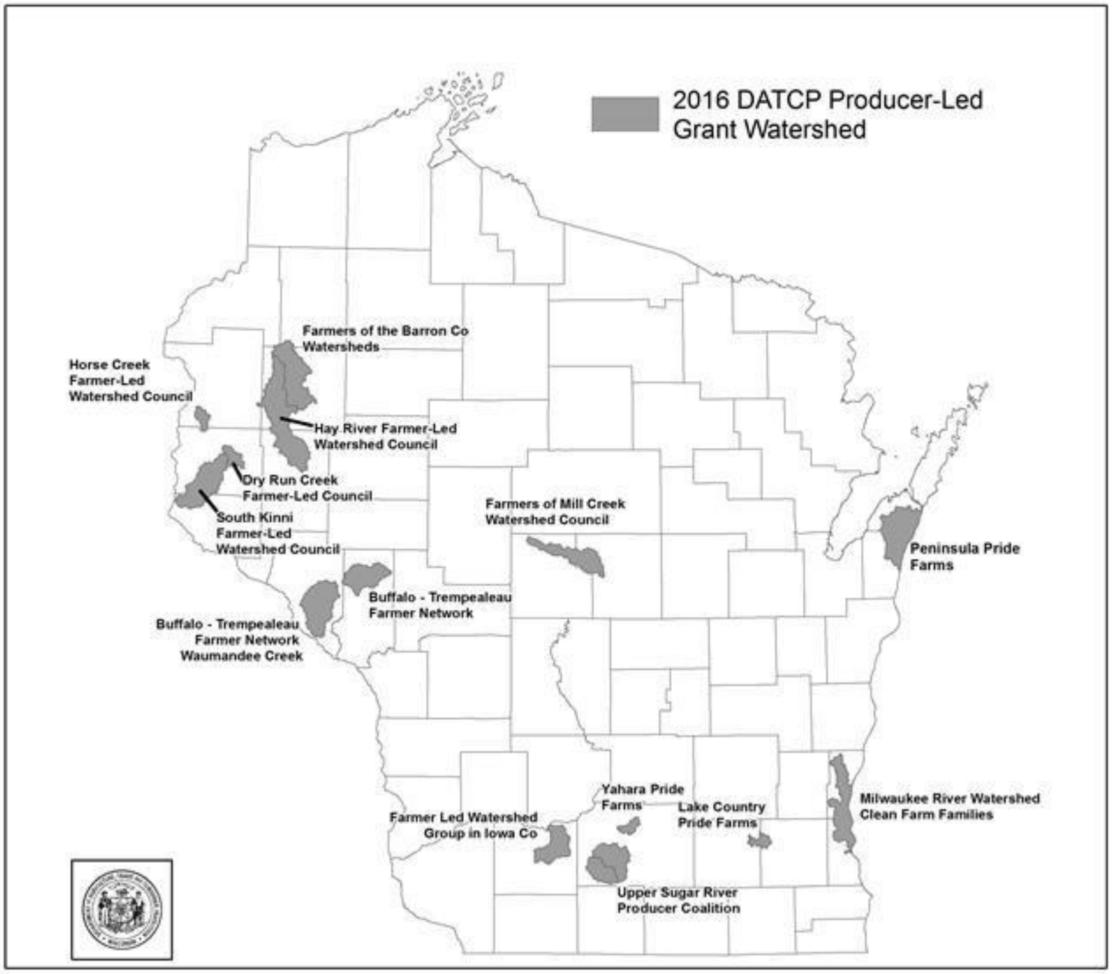


Figure 1. The location of the 14 first-annual Producer Led Watershed Protection Grant recipients for 2016.

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 2015, 87 grants were issued: 25 for agricultural waste, 37 for household hazardous waste and 25 for the collection of unwanted pharmaceutical wastes. There were 869 farmers and 9 agricultural businesses that brought in more than 149,000 pounds of agricultural wastes, an 11 percent increase from 2014. While fewer farmers participated, the weight per farmer increased. Farm participation can vary. Counties may not hold a farm collection each year, preferring to do it every other year or every few years. Farm participation seems to be holding steady overall, ranging between 100,000 and 150,000 pounds in recent years. However, 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 2015 from nearly 56,000 residents. Lead and oil-based paints are the most common waste collected from households. In 2015, nearly 629,000 pounds were taken in for disposal. The next category is solvents and thinners with just over 170,000 pounds. Pesticides are the third-most collected waste with nearly 165,000 pounds. Drug collections netted just over 52,000 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 perform compliance inspections and work with facilities across the state to help 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.

Since 1993, 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 well 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. The agency is currently conducting a statistically random sampling survey of private wells statewide. The results of this survey will be available in 2017, and will provide a comparison of pesticide and nitrate results to earlier statewide random surveys, the last of which was performed in 2008.

Research Funding

Due to budget constraints, DATCP did not have funding for new pesticide research projects in FY 2015. 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. . 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/)

Contact John Petty, Sara Walling or Stan Senger, DATCP

2811 Agriculture Drive, PO Box 8911

Madison, Wisconsin, 53708-8911

Phone: 608-224-4500;

E-mail: john.petty@wisconsin.gov, sara.walling@wisconsin.gov, or stan.senger@wisconsin.gov.

DEPARTMENT OF HEALTH SERVICES

Wisconsin Stat. ch 160 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 Wisconsin Department of Natural Resources (DNR) and are submitted through the rule-making process as amendments to Wis. Admin. Code ch. NR 140. When requested, DHS develops health-based drinking water advisories for substances that do not have an enforcement standard.

DHS Staff present on health implications of arsenic at an Ozaukee County well water informational event attended by over 150 members of the public. *Photo: Ozaukee County Public Health Department*

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 work together to:

- Present water quality information and human health implications of groundwater and drinking water issues to the public through town meetings and conferences, as well as a wide variety of informational materials.
- Provide direct assistance to families via home visits, letters to well owners, and telephone consultations.
- Educate residents with contaminated water supplies on the health effects of specific contaminants and suggest strategies for reducing exposure until a safe water supply can be established.
- Provide supplemental advice and assistance in cases of organic vapor intrusion, when shallow groundwater is contaminated with volatile substances such as benzene and vinyl chloride and the contaminants are released as vapors from groundwater directly into buildings through the building foundation.
- Improve understanding of current and potential groundwater and drinking water issues related to human health in Wisconsin through 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.

FY 2016 Highlights

- In 2015, five local public health agencies (LPHAs) completed projects related to contaminants in drinking water with grants from the Wisconsin Environmental Public Health Tracking (EPHT)

Program. Along with the funding, EPHT staff connected mini-grantees to subject matter experts and provided technical assistance related to epidemiology, communications, and evaluation.

- The Building Resilience Against Climate Effects or BRACE program provided mini-grant funding to 11 LPHAs to increase their capacity to respond to the health impacts of climate and extreme weather. Most communities identified groundwater as a public health priority area during BRACE-facilitated community meetings. These projects have also led funded LPHAs to engage in additional groundwater-related efforts, including:
  - La Crosse County, through a CDC grant, is working to increase public awareness of drinking water hazards and increase testing among private well owners.
  - Wood and Portage Counties have been revising their existing groundwater plan.
- DHS provides technical support for multiple LPHA efforts to increase public awareness of common private well contaminants and the importance of well testing. As an example, in March 2016, DHS staff presented on health implications of arsenic at an Ozaukee County well water informational event attended by over 150 members of the public.

Details of Ongoing Activities

Reviewing Scientific Information to Develop Public Health Recommendations for Groundwater Contaminants

At the request of DNR or LPHAs, DHS reviews technical information on substances that may be found in groundwater to determine whether health-based drinking water advisories or other public health recommendations should be considered. These reviews are typically conducted by the DHS Groundwater Standards Development program. In 2015, DHS reviewed the available scientific literature on 12 substances potentially associated with a handful of contaminated sites in Wisconsin. The outcome of the reviews may help guide future recommendations to residents should these substances be found in their drinking water wells.

In March 2016, the U.S. Environmental Protection Agency (EPA) released new drinking water health advisories for two perfluoroalkyl substances, perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). EPA drinking water health advisories are non-enforceable guidance values for risk assessment purposes. DHS has been helping multiple LPHAs interpret the implications of these new health advisories and determining appropriate public health recommendations should these compounds be found in drinking water.

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

Every year, instances of microbial contamination of drinking water wells follow 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 frequently participate on multi-stakeholder workgroups that examine agricultural practices related to manure storage, handling, and landspreading. These partners include the UW-Extension Understanding Manure Irrigation workgroup, which concluded its work during the spring of 2016 with the release of the workgroup report and accompanying webinar (see: http://fyi.uwex.edu/manureirrigation/). Other participation includes the Department of Agriculture, Trade, and Consumer Protection (DATCP) Livestock Siting Review Committee, which concluded its most recent review during the summer of 2015, as well as 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 LPHAs responding to a broad range of groundwater contamination events, including those related to manure contamination. Such responses may include:

- 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 technical assistance to LPHAs that are responding to issues of groundwater and drinking water contamination.
- Facilitating communications between LPHAs and various state partners (e.g., DNR and DATCP).
- 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 (Agency for Toxic Substance and Disease Registry's Partnership to Promote Localized Efforts to Reduce Environmental Exposures) 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.

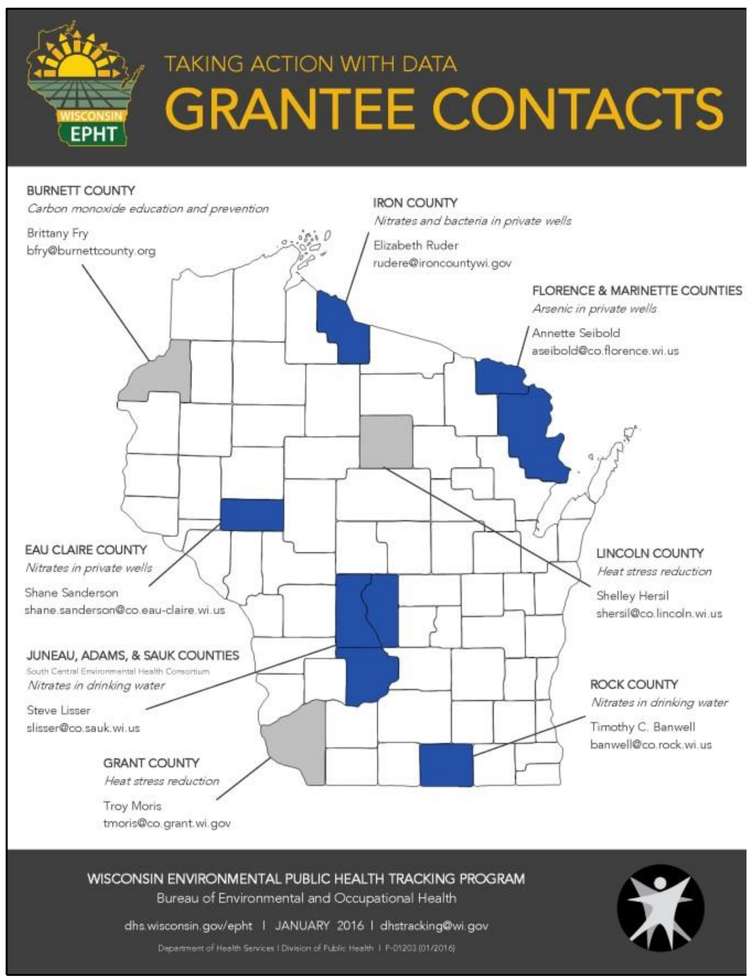
As an example, DHS has been involved in a groundwater contamination investigation in a community near Lake Michigan where approximately 100 drinking water wells have been tested since 2013 because of groundwater contamination from a nearby former dump. About one-fifth of the wells tested had contaminants at high enough levels that residents were advised to not drink their well water or use it for food preparation. A few of these wells had contaminant levels that were high enough that residents were told to not use their water for drinking, food preparation, or showering. Throughout the investigation, DHS has served as a technical resource for DNR and the other city and county agencies involved, helping state and local agencies determine and implement appropriate public health response actions. Some of these actions have included: providing bottled water and bulk water for affected homes, seeking more permanent clean water sources for affected homes, informing residents about the ongoing investigation, and answering residents' questions at several public meetings.

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

As a state partner in the Centers for Disease Control and Prevention's (CDC) 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, the DHS EPHT program has worked with UW–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.

Taking Action with Data: Use of the Environmental County Health Profiles to Improve Environmental Health in a Community

DHS continually seeks to provide data and resources to LPHAs to assist them to make positive public health improvements in their communities. As a state partner in the Centers for Disease Control and Prevention's (CDC) Environmental Public Health Tracking (EPHT) network, the Wisconsin EPHT Program developed a request for applications (RFA) for local and tribal public health agencies to apply for funds for a mini-grant project in 2015. Funds were used by LPHAs to explore data from the Environmental County Health Profiles and identify an environmental health concern in their jurisdiction. Based on the identified concerns, LPHAs developed and implemented a local initiative related to environmental health in their communities.



Local partners in EPHT initiatives across the state.

The Wisconsin EPHT Program and other staff from DHS provided ongoing support, technical assistance, and guidance to LPHAs on epidemiology, communications, and evaluation throughout the project period. Regular conference calls and frequent emails with the LPHAs led to a positive collaboration: LPHAs were empowered to carry out their projects but still had support and assistance from the EPHT Program as needed. Some examples of technical assistance the EPHT Program provided LPHAs included: drafting multiple letters to simplify arsenic testing results to residents, providing guidance on surveys, developing a reverse osmosis fact sheet, and assisting in writing up success stories.

Eight LPHAs were awarded funds to carry out their projects. Of the eight funded LPHAs, five conducted projects related to contaminants in groundwater, clearly showing that groundwater is an important priority for many LPHAs. The five LPHAs conducting groundwater related projects included:

- *Eau Claire County: Nitrate in Private Wells*

  Eau Claire County worked to increase water sampling for nitrate, as well as advance research and collaboration. Mid-project (March 2016), over 25% of samples indicated nitrate concentrations exceeding the maximum contaminant level of 10 ppm. Eau Claire leveraged their working relationship with the Land Conservation Division to achieve higher sampling rates among private well owners and made initial connections to build an Eau Claire Nitrate Taskforce.

- *Florence and Marinette Counties: Arsenic in Private Wells*

  Florence and Marinette counties collaborated to increase well water testing for arsenic to residents of their jurisdictions. Testing kits were distributed using targeted outreach at town board meetings and an intense media campaign. Mid-project, Marinette distributed 153 tests; six wells tested higher than 10 µg/L. The highest arsenic level discovered was 170 µg/L and this individual was connected with the DNR Well Compensation Grant Program. Mid-project, Florence County distributed 97 tests, and about one in every five tests had elevated arsenic levels.

- *Iron County: Nitrates and Bacteria in Private Wells*

  Iron County worked to increase testing for nitrates and bacteria in private wells, specifically focusing on developing resources for a large sampling effort (including sampling, transportation, shipping, and analytics). Iron County contracted with the Environmental Research and Innovation Center at UW-Oshkosh to carry out the testing. They have also developed outreach and resource materials for their community members.

- *Rock County: Nitrates in Drinking Water*

  Rock County worked to identify and characterize nitrate sources in their community using multiple resources (e.g., National Land Cover Database, U.S. Department of Agriculture Crop Data Layers, and Rock County Land Use Maps). They have also identified geologic features that influence nitrates in water, including soil types and characteristics, as well as bedrock depth and type. This led them to create a Local High Capacity Well GIS layer. They are transferring sample results from the Rock County Health Department Well Nitrate Database to the UW-Stevens Point Well Water Quality Viewer.

- *South Central Environmental Health Consortium (Juneau, Adams, and Sauk Counties): Nitrates in Drinking Water*

  South Central Environmental Health Consortium worked to collect groundwater nitrate data for transient non-community (TNC) systems and private drinking water systems, consisting of a total of over 21,000 data points. The data set was then narrowed to only include usable data that fits criteria for the project (2,762 private well data points and 6,760 TNC data points), leading to a project total of 9,522. These data were subsequently formatted, geocoded, and mapped. They will use these maps/data to look for trends, locate potential sources of contamination, and evaluate the statistical validity of the data.

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.

Gaps identified previously by the Climate and Health Profile Report assessment have 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, UW Center for Climatic Research, Wisconsin Emergency Management (WEM), and a number of LPHAs. The findings from these flood-related projects have helped inform the BRACE Wisconsin Climate and Health Adaptation Plan, WEM's Wisconsin Hazard Mitigation plan, as well as LPHA and local emergency management planning processes.

As an example, in 2016, the BRACE program completed a geospatial analysis of the socioeconomic vulnerability and economic impacts of flooding in the Upper Fox River Valley. Study findings and applications of the information were summarized and disseminated to local public health and emergency management personnel.

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/

Contact

Jonathan Meiman: 608-266-1253, Jonathan.Meiman@wi.gov

Roy Irving: 608-266-2663, Roy.Irving@wi.gov

1 W. Wilson St., Rm. 150

Madison, Wisconsin, 53701

WISCONSIN GEOLOGICAL & NATURAL HISTORY SURVEY


Grace Graham and Emma Koeppel of the WGNHS collecting water quality data from a spring near Lulu Lake, WI. *Photo: David Hart, WGNHS*.

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.

FY 2016 Highlights

- Creating an inventory of the springs of Wisconsin
- Studying the potential impacts to groundwater resources from industrial sand mining and irrigated agriculture in Chippewa County
- Developed the Little Plover River groundwater flow model to help people understand the groundwater system and inform management decisions

Details of Ongoing Activities

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 2016, this network consists of 93 long-term monitoring wells, two spring gaging stations and 57 project-specific, limited-term monitoring wells. The 93 permanent wells and 2 spring gaging stations are located in 45 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 evaluation and maintenance of the monitoring network, aids in data collection, 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 a proposal to add new wells, lake, and stream gages to the monitoring network in four areas where high capacity well applications are prevalent and water level data is sparse. These areas include: the Antigo Flats in Langlade Co.; several sites near the groundwater divide on the eastern edge of the Central Sands (Adams, Marquette, Portage and Waushara, Cos.); and in the Southern Rock River Valley in Rock Co. And lastly, in an area in West Central Wisconsin (Dunn and St. Croix Cos.) where we hope to partner with the US Fish and Wildlife Service and potentially use existing wells present on federal or state lands when those properties were acquired.

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 FY 2016 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 FY 2016 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 nearing completion of a multi-year study of the hydrogeology of Wisconsin's National Forests. This effort consists of characterization of the groundwater system and development of groundwater flow models to improve management of forest resources. The project covers four forest units across eight counties in northern Wisconsin. A comprehensive technical report for each forest unit is scheduled for publication in FY17

b. *Hydrogeology of the Agricultural regions in Bayfield County*. In FY 2016, the Large-Scale Livestock Study Committee of the Bayfield County Board requested WGNHS assistance to assess groundwater contamination potential in agricultural areas within the county. Staff compiled and analyzed available geologic and hydrogeologic information and completed a report: http://wgnhs.uwex.edu/pubs/000934/

c. *Hydrogeology of the frac-sand mining district in western Chippewa County*. This five-year study, commissioned by the

View from a frac sand mine in Chippewa County. *Photo: Madeline Gotkowitz, WGNHS.*

Chippewa County Department of Land Conservation and Forest Management in 2012, is a cooperative effort between the USGS and WGNHS. The project evaluates potential impacts to groundwater resources from industrial sand mining and irrigated agriculture. This effort includes development of a groundwater flow model and a series of annual informational meetings to update the public about study results and water resources in this region of Wisconsin.

d. *Groundwater flow in the Mukwonago Basin*. In cooperation with the USGS, and with funding from The Nature Conservancy, the WGNHS is building a groundwater flow model. This model will be used to understand the impacts of possible land use changes and groundwater pumping to the wetlands of the Mukwonago Basin.

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 FY 2016 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. A new computerized groundwater flow and optimization model for the region was developed that can help people understand the groundwater system and inform management decisions.

Drainage in the Little Plover Basin. *Photo: Ken Bradbury, WGNHS.*

b. *Viruses in groundwater*. WGNHS scientists completed a two-year *study* funded by the US EPA that addressed impacts to groundwater quality from leaky sewers. The study found that a combination of factors, including the age of sanitary sewer infrastructure and local climatic conditions, affect the transport of pathogens from sanitary sewers to water supply wells. WGNHS staff continue investigations at the sites used for this study to evaluate use of novel wastewater tracers, such as pharmaceutical compounds, to assess the quality of urban groundwater. A *fact sheet* related to this project describes important implications for Wisconsin's groundwater quality and municipal drinking water supplies.

c. *Radium studies.* In FY 2016, WGNHS scientists received funding to investigate the geologic sources of radium to groundwater in Wisconsin's sandstone aquifer. This two-year study addresses a significant problem for many municipal water supply systems, such as the City of Waukesha, where deep wells produce water with elevated radium.

d. *Nitrate study.* In FY 2016, WGNHS assisted the DNR with source water protection at public supply wells impacted by elevated nitrate. The WGNHS designed, installed and operated monitoring systems at two sites. At one locations, the WGNHS is working with cooperating land managers to quantify nitrate loading to the underlying aquifer under an irrigated corn crop.

Groundwater Data Management and Support

In FY 2016 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. *An updated springs inventory for the State of Wisconsin.* The WGNHS is in year-2 of a 3-year effort to inventory the springs of Wisconsin. This inventory serves as both as database of flow springs greater than 0.25 cfs for use by the WDNR for their high capacity well approvals. It also provides for study of reference springs. These springs are selected in representative hydrogeological and ecological settings for long term monitoring to provide better understanding of springs and potential impacts from land use and groundwater withdrawals.

b. *Properties of Wisconsin aquifers.* The DNR funded a project to compile readily-available storage information and other hydraulic properties for Wisconsin aquifers, particularly in areas where high-capacity well applications are most common. Previous compilations of the storage properties of Wisconsin aquifers have been made, however, these datasets were relatively sparse and lacked of citations for aquifers in many parts of the state. Over 800 records were compiled in database and then made available to the DNR as a spreadsheet, as GIS layers, and through the Hydro Data Viewer application.

c. *Data viewer maintenance.* 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. Many of the geophysical logs are collected for the WDNR in wells where water quality or lack of data is an issue.

d. *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.

e. *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. In FY 2016 WGNHS provided an updated set of these records to DNR for internal use. This update includes corrections to the records made by WGNHS over the past several years.

f. *High-capacity well approval tracking.* In collaboration with the DNR, WGNHS is now tracking high-capacity well approvals in an internal database. This enables a more proactive approach for WGNHS researchers to work with well drillers, pump installers, and consultants to collect samples and borehole geophysical logs from priority areas of the state.

g. *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.

h. *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.

i. *Physical properties of Wisconsin's bedrock aquifers and aquitards.* This database contains porosity, density, thermal conductivity and specific heat of core samples collected from across the state. Data include high-resolution images of core taken from various depths along with a summary table.

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 Farm Technology Days, at the Wisconsin State Fair, at various children's museums and schools, and at UW-Madison events (such as at Science Expeditions and at the Science Festival).

In FY 2016, WGNHS staff members participated in groundwater educational meetings in counties where mapping and/or hydrogeologic studies are in progress, particularly in Bayfield, Chippewa and Columbia Counties. Staff provided groundwater education at several public meetings in Green County in FY 2016. 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. WGNHS geologists and hydrogeologists presented a seminar on trace metals in groundwater during a meeting of the DNR's Advisory Council on Well Drilling, Heat Exchange Drilling & Pump Installing.

Multiple WGNHS staff members gave presentations at the Wisconsin Society of Science Teachers conference helping to increase our efforts to reach teachers in FY 2016. 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. Researchers and consultants also use our core holdings in that collection to better understand the subsurface and its aquifers.

For more information

Visit http://wgnhs.uwex.edu/

Contact Ken Bradbury, Wisconsin Geological & Natural History Survey

3817 Mineral Point Road, Madison, WI, 53705

***Phone: 608-263-7389; Email:* ken.bradbury@wgnhs.uwex.edu**

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.

FY 2016 Highlights

- Equipped county trucks that work on the state highway system with AVL/GPS equipment to better track salt usage across the state.
- Provided customized forecasts using an advanced Road Weather Information System based on pavement and weather sensors for 58 sites across the state.

Details of Ongoing Activities

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 and presentations, teleconferences, and water testing and satellite programs. Activities of several specific programs are described below.

FY 2016 Highlights

- Funded a project to more actively involve citizens and stakeholders in water-use decisions
- Assembled a traveling photography display highlighting the state's wealth of water that has traveled to 14 venues this reporting period.
- Created all-inclusive kits for children in pre-K to fourth grade to teach age-appropriate STEM concepts with a water theme that are booked out for months into the future.
- Researchers leveraged a WRI project on manganese for NSF funding and a student originally funded on this WRI project was also awarded a NSF fellowship

Details of Ongoing Activities

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.

Researches recently leveraged the results of a WRI-funded project to win an NSF grant. The student (Sara Balgooyen, pictured here) who was funded by WRI separately received an NSF fellowship as well. *Photo: UW WRI.*

<u>Research</u>

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 geothermal heat exchange, groundwater-surface water interactions and various groundwater contaminants, including manganese and viruses.

During FY16 (July 1, 2015–June 30, 2016), the WRI directed a wide-ranging program of priority groundwater research consisting of five new projects and three 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 eight 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
- The Wonewoc and Tunnel City: A Potential Natural Source of Groundwater Contamination in Western & Central Wisconsin
- Long-term Alterations in Groundwater Chemistry Induced by Municipal Well Pumping
- Phosphorus & Arsenic Sensors for Real Time Environmental Monitoring
- Engaging Stakeholders to Improve the Use of Groundwater Flow Models for Decision Making
- Predicting the locations of nitrate removal hotspots at the groundwater-surface water interface in Wisconsin streams

For FY17 (July 1, 2016–June 30, 2017), the UWS selected three new groundwater research projects from proposals submitted in response to the Joint Solicitation and will continue four projects selected from the previous year's solicitation. The projects are based at University of Wisconsin-Milwaukee, University of Wisconsin-Stevens Point, University of Wisconsin-Madison, University of Wisconsin-Extension, and University of Wisconsin-Oshkosh, and include:

- Anthropogenically driven changes to the metagenome of a shallow groundwater and its effect on aquifer reactivity (new project)
- Investigating the impact of nitrate-nitrogen contamination on uranium concentrations in Wisconsin groundwater (new project)
- Geologic sources of radium to municipal wells in Wisconsin (new project)
- Long-term alterations in groundwater chemistry induced by municipal well pumping (continued project)
- Phosphorus and arsenic sensors for real-time environmental monitoring (continued project)
- Engaging stakeholders to improve the use of groundwater flow models for decision making (continued project)
- Predicting the locations of nitrate removal hotspots at the groundwater-surface water interface in Wisconsin streams (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 FY16 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 WRI's FY15 and 16 annual federal 104 (B) allocation was used to plan and conduct a workshop to advance the monitoring and analysis of trace metals and address applications in the upper Great Lakes. In FY16, funding was 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. In FY17, this funding will be matched by DNR's Bureau of Water Quality for a full time postdoctoral fellow.

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 put 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, kits on buoyancy and on ponds were completed and joined one related to frogs. 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. In this reporting period, five packs have been checked out 23 times to formal and nonformal educators (the maximum checkout period is two months), reaching approximately 1,135 students. The packs have been used to educate 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 an estimated 50,550 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 the *YouTube channel*, "Testing well water for microorganisms." To date it has nearly 9,500 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. Finally, this reporting period saw the initiation of a new audio podcast series that will be completed in early FY17. The series is called Undercurrents: The Hidden Knowledge of Groundwater.

During this reporting period, WRI staff were also integral to the content-population of *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 an estimated 44,850 visitors in this reporting period.

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 40,000 online visitors to the newsletter.

Traveling Photography Exhibit

One of the traveling photo displays that has made its way to libraries, nature centers, and conferences across the state. *Photo: UW Sea Grant Institute.*

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 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. In this reporting period, there were six presentations that resulted from the photography exhibit and included stops in Port Washington, Delavan, Palmyra, Middleton, Neenah and New Berlin. The display itself has been warmly received. At the conclusion of each month’s installment, an evaluation is solicited and comments are consistently positive.

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 40th conference was 40 Years of Wisconsin Waters: Quantity, Quality, Technology. 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.

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 five journals, and 30 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. 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 and drinking water 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. In this reporting period, 32 individuals used this material.

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 309 Wisconsin residents through eight events conducted at public libraries, Head Start and other early-childhood programs, or as part of other informal learning setups. Library staff also delivered presentations to Head Start and environmental education instructors. This sparked inquiries from 14 teachers from around the state interested in STEM literacy. It demonstrates multiplier effect, that is, if each teacher reached a minimum of 10 students or lifelong learners that is nearly 150 people receiving STEM messages.

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. It is currently being redesigned and is expected to launch early in the next reporting period. During the past 12 months, the library site had about186,750 visitors.

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. Some examples form the past year include, a boat owner inquired about what the best management practices are if the boat is infested with invasive zebra mussels, a student inquired about the diet, behavior and biology of invasive Asian carp, and a patron requested data to support groundwater monitoring.

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 490 "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 1,900 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 and Other WRI-funded Projects

Water Resources Institute Reports

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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.

Ginder-Vogel, M., and C. Remucal. 2016. Effect of source chemistry on Mn-bearing solid dissolution and reactivity in municipal water systems. Final report, Water Resources Institute, University of Wisconsin-Madison. WR15R009.

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.

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Hauxwell, J. 2016. Wisconsin Water Resources Fellowship. Final report, Water Resources Institute, University of Wisconsin-Madison. WR15R006.

Larson, E.R., and S.A. Allen. Establishing the long-term range of variability in drought conditions for southwest Wisconsin. Final report, Water Resources Institute, University of Wisconsin-Madison. WR13R003.

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

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Stelzer, R., T. Scott, and L. Bartsch. 2013. The effects of particulate organic carbon quantity and quality on denitrification of groundwater nitrate. Final report, Water Resources Institute, University of Wisconsin-Madison. WRI11R006.

Thompson, A., K.G. Karthikeyan, R. Stenjem, D. Hyndman, A. Kendall, and A. Parish. 2015. Implications of climate change and biofuel development for Great Lakes regional water quality and quantity. Final report, Water Resources Institute, University of Wisconsin-Madison. WR10R008.

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.

Ventura, S., and S. Cardiff. 2016. Advances in monitoring and analysis of trace metals: a workshop to address applications in the Upper Great Lakes. Final report, Water Resources Institute, University of Wisconsin-Madison. WR14R001.

Wu, C. 2016. Uncertainty and variability of Wisconsin lakes in response to climate change. Final report, Water Resources Institute, University of Wisconsin-Madison. WR11R003.

Xu, S., and L. Feriancikova. 2015. Transport of manure-derived *Escherichia coli* within naturally-fractured dolomite. Final report, Water Resources Institute, University of Wisconsin-Madison. WR12R003.

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Childress, Evan S. 2014. Cross-ecosystem delivery of nutrients to streams: the role of fish migrations and processes. Ph.D. Thesis. Freshwater and Marine Sciences, University of Wisconsin-Madison. 130 pp.

Fields-Sommers, Laura. 2015. Assessing the Effects of Riverbank Inducement on a Shallow Aquifer in Southeastern Wisconsin. Masters Thesis. School of Freshwater Sciences, UW –Milwaukee. 211 pp.

Louison, Michael. 2013. Use of first-order tributaries by brown trout (*Salmo trutta*) as nursery habitat in a central Wisconsin coldwater stream network. M.S. Thesis. Department of Biology & Microbiology, University of Wisconsin-Oshkosh. 56 pp.

Polich, Michael. 2015. Surface runoff, soil, and nutrient fluxes of cellulosic biofuel cropping systems. M.S. Thesis, University of Wisconsin-Madison. 87 pp.

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Other Publications

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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@aqua.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 2015, the Center assisted 3,516 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 1,409 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 2015, nearly 7,000 people used the viewer. The next update for the viewer is scheduled to be completed by 2017; data from additional county health departments will be included in the update.

Central Wisconsin county-based volunteer streamflow monitoring

The Little Plover River, one of the many streams in the pumping stressed region of the Central Sands. *Photo: UW WRI.*

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. Results from this study have been presented at the Wisconsin American Water Resources Association meeting and the American Geophysical Union Annual 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 which is under review.

Chippewa County Groundwater Quality Inventory

The Center was contracted by the Chippewa County Land Conservation and Forest Management Department to collect and analyze samples from 800 private wells from around the county. The county has previously conducted inventories in 1985 and 2007 for nitrate and chloride. Results from samples collected in the summer of 2016 will be compared with previous results to better understand how groundwater quality may have changed through that time. Nitrate source analysis will be performed on a subset of wells to better understand sources of elevated nitrate levels in Chippewa County.

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

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

Recent Publications and Reports

McGinley, P.M, K.C. Masarik, M.B. Gotkowitz and D.J. Mechenich. Impact of Anthropogenic Geochemical Change and Aquifer Geology on Groundwater Phosphorus Concentrations. *Applied Geochemistry* (In Review).

Luczaj, J., K. Masarik. 2015. Groundwater Quantity and Quality Issues in a Water-Rich Region: Examples from Wisconsin, USA. *Resources* 2015 4:323-357. *doi*:*10.3390/resources4020323*

Kraft, G.J., D.J. Mechenich, and J. Haucke. 2014. Information support for groundwater management in the Wisconsin central sands, 2011-2013. Report to the Wisconsin Department of Natural Resources. Center for Watershed Science and Education, University of Wisconsin – Stevens Point / Extension. *http://www.uwsp.edu/cnr-ap/watershed/Documents/kraft_cs_2011_2013.pdf*

Masarik, K. , Norman, J. and Brye, and K. 2014. Long-Term Drainage and Nitrate Leaching below Well-Drained Continuous Corn Agroecosystems and a Prairie. *Journal of Environmental Protection* 5:240-254. doi: *10.4236/jep.2014.54028*.

Kraft, G.J., D.J. Mechenich, K. Clancy, and J. Haucke. 2012. Information Support for Groundwater Management in the Wisconsin Central Sands, 2009-2011. A Report to the Wisconsin Department of Natural Resources, Project NMA00000253.

Kraft, G.J., D.J. Mechenich, K. Clancy, and J. Haucke. 2012. Irrigation effects in the northern lake states – Wisconsin central sands revisited. *Ground Water Journal* 50:308-318. DOI: 10.1111/j.1745-6584.2011.00836.x

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 2015 show that as a result of local delivery of the curriculum, over 6,234 producers farming approximately 1,781,920 acres in 55 counties have received in-depth education on nutrient management planning. In 2015, approximately 874 farmers operating about 227,530 acres in over 30 Wisconsin counties added to this accomplishment list. Data currently being collected for 2016 accomplishments.
- *SnapPlus nutrient management planning software* assistance and refinement in conjunction with the SnapPlus team (UW-Soil Science). NPM staff assist in developing educational tutorial online videos (30 total), updating the SnapPlus online help system, refining output reports to meet the needs of end users, creation of a SnapPlus training manual with over 350 copies requested and delivered.
- *Managing Nutrients on Wisconsin Soils* (MNWS) was an intensive self-paced, seven-hour online video series designed for agency and agriculture industry personnel who desired to gain more knowledge of intermediate to advanced topics in soil fertility and management. The learning objectives were to provide individuals with fundamental understandings of Wisconsin's nutrient application guidelines, advanced soil fertility management tools, and soil management practices to reduce nutrient loss. This workshop was delivered to clients via an online video technique. Use of this delivery mechanism was in response to client concerns regarding costs associated with traditional (face-to-face) workshops. Travel, lodging, meal, hard copy, etc. expenses were greatly reduced or eliminated with this approach.
- *Training for Nutrient Management Planners* (TNMP) was a self-paced seven hour online video series and a one day face-to-face, follow-up workshop. The program is designed for current and potential nutrient management plan writers in Wisconsin - particularly production agronomists and county-based conservation staff. The intent of this workshop is to provide in-depth training on the preparation of quality nutrient management plans.
- *Spring Green-area Nitrogen Management:* In response to degradation of public and private drinking water resources due to nitrate, NPM working with a team of county UW-Extension and UW soil scientists has surveyed farmers in the area on their N management practices. As a follow-up, a series of on-farm demonstrations featuring various N management practices have occurred in the area. Practices features initially include: manure application timing (with and w/o Instinct), irrigation management, and UW recommended nitrogen rates for corn on sands.
- 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. Also, key member of the Farmer-led, performance-based watershed project in Barron, Polk, St. Croix, Pierce and Dunn Counties. The latter project serves as a prototype for managing TMDL watersheds across Wisconsin.
- On-farm demonstrations, field plot research, and subsequent educational programs on various topics (corn N rates, cover crops, conservation tillage, manure treatments, 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.
- *Managing Volunteer Winter Wheat in Summer Alfalfa (RR) Seedings:* NPM, in conjunction with the UW-Madison CALS Dept. of Agronomy (Dr. Mark Renz) is investigating the control of volunteer wheat in summer seeded Roundup Ready alfalfa. Three locations: Grant, Sheboygan, and Columbia Counties. The objective is to compare and contrast the timing of Round Up, Raptor, and Post-Plus on the control of volunteer winter wheat.
- *Profitability of Alternative Management Strategies for Western Corn Rootworm:* A series of large-scale, on-farm demonstrations and management comparisons of various strategies for controlling corn rootworm. At each site, the profitability of alternate management practices versus the standard practice of relying solely on Bt corn varieties is made.

Food Systems:

- *Cover Crops Research, Education, and Outreach* activities include development and instruction of cover crop demonstration and training. Also fielding inquires 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. Activities include a demonstration plot at the 2015 Farm Tech Days site featuring 16 cover crop options, and on-farm demonstrations & research cover crop trials in Sheboygan, Dane, Pierce, Polk, and Dunn Counties.
- *Frac Sand Mining Site Reclamation*: 2015 marks the second year of a frac sand mining reclamation site restoration project. This project, located in Chippewa County, is in cooperation with the county Land Conservation Dept., UW-River Falls, and the mining company. The intent is to investigate the remediation of mining sites to agricultural land use. This year’s site converted to pasture. Plans for next year call for a conversion to corn production on a new site.
- *Healthy Grown / Health Farms:* The Healthy Grown – which was expanded to the Healthy Farm - program has been a national model of sustainable production systems, exemplifying integrated pest management and reduced pesticide systems for potato production. There is also an innovative ecosystem conservation component to restore privately owned landscaped in Wisconsin. Utilizing the Healthy Farm concept, additional commodities are developing sustainability standards. NPM staff are involved in efforts for pea, sweet corn, and soybean.

Outreach and Communication:

- *Mobile Applications*: The NPM Program is creating mobile applications (apps) for hand-held devices. Six apps are currently available: Nitrogen (N) price calculator, Corn N rate calculator, Integrated Pest Management toolkit, Corn crop calculators, Manure and legume nutrient credit calculator, and a Soybean replanting decision aid. 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)

Contact Scott Sturgul, Wisconsin NPM Program

445 Henry Mall, Room 314

Madison, WI 53706

Phone (608) 262-7486, email ssturgul@wisc.edu

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.

WSLH also provides educational and outreach activities related to groundwater and drinking water including, (1) instructional consultations for well owners and well drillers, (2) assistance and consultation for municipal water supply operators, and (3) tours for a variety of international, educational, regulatory, and governmental groups. Staff members have developed 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.

<u>Summary of Groundwater-Related Work at WSLH</u>

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 people, 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* ssp.; 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.
- 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

- 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. Detectable concentrations of arsenic have been more routinely measured in drinking water sourced from Wisconsin groundwater. Recent updates to Wisconsin regulations has increased monitoring requirements under certain scenarios. Arsenic in groundwater and drinking water has received increased attention in general.
- 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 contaminates 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.

For more information on the WSLH:

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

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

2601 Agriculture Drive

Madison, WI 53718

Phone (608) 224-6200, email David.Webb@slh.wisc.edu

DEPARTMENT OF SAFETY AND PROFESSIONAL SERVICES

Effective July 1, 2013, programs within Department of Safety and Professional Services (DSPS), Division of Industry Services were transferred to other departments. Plumbing and Private Onsite Wastewater Treatment Systems (POWTS) remains at DSPS.

The Bureau of Petroleum Products and Tanks was transferred to the DATCP's Bureau of Weights and Measures. The new Petroleum Products and Tanks Section continues to regulate flammable and combustible liquids and hazardous substance liquids. The authority to fund the removal underground petroleum product storage tanks has been transferred from DSPS to DNR.

The Bureau of PECFA was transferred to DNR's Bureau of Remediation and Redevelopment. PECFA continues to reimburse owners and operators of leaking petroleum storage tanks for remediating environmental contamination. The regulatory jurisdiction of petroleum sites determined to be a low or medium risk to the environment has been transferred back to the DNR.

The statutory jurisdiction over stormwater runoff on building sites (Soil Erosion and Sediment Control Program) was transferred to DNR.

Within the Division of Industry Services, two plumbing programs have the responsibility of safeguarding public health and the waters of the State. Graywater reuse and stormwater is regulated by the General Plumbing Program. Private on-site wastewater treatment systems are regulated by the Private Onsite Wastewater Treatment Systems Program.

FY 2016 Highlights

- Over 90% of statewide private on-site wastewater treatment systems (POWTS) have been inventoried and more than a third of counties are operating a maintenance program for all POWTS in their jurisdiction

Details of Ongoing Activities

Plumbing – Reuse, Stormwater and Private Onsite Wastewater Treatment Systems (POWTS)

In addition to public health and safety, the water supply and quality issues facing Wisconsin are a focus of the General Plumbing and POWTS programs in the Department of Safety and Professional Services.

General Plumbing – Reuse and Stormwater Use. The Department plumbing code includes standards for reuse of wastewater and stormwater. Currently, the Chapter SPS 382 stormwater rules create the ability for plumbing to be integrally involved with the design and installation of storm systems complying with Chapter NR 151, Wis. Admin. Code. Currently in Wisconsin there are over 65 approved stormwater use or wastewater reuse plumbing systems.

Private Onsite Wastewater Treatment Systems (POWTS) The Department maintains regular contact with the Department of Natural Resources regarding mutual issues of interest such as large onsite sewage systems, mixed wastewater treatment systems, Underground Injection Control (UIC) regulations, septage disposal and water well regulations. The Department also communicates with the USEPA Region 5 office regarding POWTS related matters. Department staff participates when requested in the development of a regional and national model code related to onsite sewage systems.

Petroleum Product and Hazardous Substance Storage Tanks

The Division of Industry Services continued to maintain regulatory oversight of aboveground and underground petroleum and CERCLA hazardous substance storage tanks in the Chapter SPS 310, Wis. Admin. Code. Underground storage tank regulations include the Federal EPA Underground Storage Tank (UST) requirements, as well as heating fuels, tanks supplying stationary combustion engines such as emergency generators, and other tanks storing regulated liquid products. Chapter SPS 310, Wis. Admin. Code, was revised with an effective date of July 2009, which included the Federal Energy Policy Act of 2005 operator training requirements. A revision of SPS 310 to address additional federal requirements is expected in a future revision.

In order to maintain a federally regulated tank in use (i.e. tanks used for vehicle fueling), the tank must have a valid “permit-to-operate.” Permit renewal administrative review includes compliance assessment of the owner’s financial responsibility. Federally regulated and large fuel oil USTs are subject to periodic inspections involve verification of leak detection, spill and overfill protection, and record keeping. Annual inspections have been performed by Department of Safety and Professional Services (DSPS) employees and private contractors. Due to budget reduction initiatives many of the private contractor inspections have been eliminated with the objective to move these inspections to DSPS inspectors, but extending the time between inspections to no more than two years.

Program tank permit initiatives have resulted in approximately 93% of the tanks required to have financial responsibility being in compliance with the rule. The remaining tanks will not be permitted and will be shut-down if financial responsibility coverage is not verified. Insurance carriers are required to notify when a policy is terminated either by the carrier or by the insured.

The closure of federally regulated tanks will continue, but at a slower pace than experienced over the past few years. Closure of out-of-service residential heating fuel tanks is continuing as realtors and lenders recognize the potential problems and liability. Wisconsin has over 6,000 abandon underground storage tanks (USTs). Many of the tanks are on property of indigent owners. The 2009 Wisconsin Act 28 created ss. 101.1435, Stats, and provided DSPS with $100,000 per year from the Petroleum Inspection Fund (PIF) to contract for the closure of abandon USTs. Internally this program is referred to as the “PIF tank closure” program. The owner must give DSPS authorization to access the property and remove the UST(s); DSPS will procure the contractor via low bid, and subsequently place a lien against the property for the amount of the tank closure. The PIF closure covers the excavation and backfill, removing the islands, scrapping the tank(s) and piping, soil assessment when required, and removal of existing canopy.

The PIF UST Closure funding has helped significantly; but the closure program comes with challenges, such as: locating and communicating with the property owner and the owner agreeing to a lien against the property. On the positive side is the cooperation of the Department of Justice (DOJ) to include authorization for DSPS to remove tanks under the PIF program in judgments served for non-compliance with tank closure requirements. Some owners found the financial means to remove tanks when approached with the possibility of DOJ referral. To date the funding program has provided for the closure of 114 underground tanks at thirty-eight facilities.

Proactive educational outreach efforts and annual inspections by the Department and its agents have resulted in a high level of regulatory compliance, and a reduction of system failures and environmental contamination. Mandates required in the Federal Energy Bill of 2005 that had to be implemented in Wisconsin by August 2012 have a significant positive impact on release reduction as the requirement for secondary containment and owner/operator training was implemented with a revision to the administrative code. The ongoing regulatory challenges are owner operational compliance with leak detection. The department has partnered with trade associations working with the regulated community to provide training related to the revised SPS 310 and the pending operator training.

Petroleum Environmental Cleanup Fund Act (PECFA)

Since 1989, the PECFA program has reimbursed approximately $1.53 billion to petroleum storage tank system owners for costs associated with the investigation and remediation of petroleum contaminated sites. The program, in addition to auditing owner invoices and authorizing payments, performs technical reviews of site investigations, evaluates the feasibility of remedial options, approves funding for scopes of work, and makes decisions regarding closures for the majority of the State's leaking underground storage tank (LUST) sites.

The Petroleum Inspection Fee supports PECFA's spending authority. The spending authority for 2012/2013 is $12.3 million. It is estimated that the PECFA program will reimburse $4.3 million to 430 claimants in FY 13. The Program currently reimburses claimants within two months of receiving a claim. The Program's current bond obligation amount is $188 million.

In addition to administering the PECFA fund, the DSPS PECFA Bureau had the administrative authority for low and medium risk petroleum contaminated sites (which includes both soil and groundwater sites). The Bureau closed approximately 7,750 sites since 1994.

Data Management

DSPS is continuing its data integration information technology (IT) initiative. The database also stores information on activities associated with on-site sewage system design, installation and maintenance. The Department is working with county code administrators and POWTS industry members to upgrade the reporting and recording of inspection, maintenance and servicing events for onsite sewage systems. The department promulgated a rule revision in late 2008 that implements POWTS program related provisions contained in 2005 Wisconsin Act 347 and further modified in 2011 by Wisconsin Act 134. The revised rule requires that counties conduct an inventory by October 1, 2017, to identify all POWTS within their jurisdictional areas. Counties must also initiate new or enhance existing reporting programs related to inspection, maintenance and servicing events by October 1, 2019. Over 90 % of statewide POWTS have been inventoried and more than a third of the counties are operating a maintenance program for all POWTS in their jurisdiction.

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.

Protecting Groundwater from Nonpoint Source Contamination

What's the issue?

Any time rainfall or snowmelt runs across the land surface, this water picks up some amount of soil, nutrients, and other pollutants. Just as this runoff can cause water quality problems in streams and other surface water bodies, it can also carry contaminants to groundwater when it seeps into the soil. On agricultural landscapes, runoff may pick up bacteria, nutrients, or pesticides through contact with soil, manure, or crops. In urban areas, road salt and organic compounds from impervious surfaces are typical nonpoint contaminants.

Flooded fields after manure spreading can quickly carry nitrogen and other nonpoint source pollution to the groundwater. *Photo: Marty Nessman, DNR.*

Protecting groundwater from nonpoint source contamination is a complex management challenge. In contrast to "point source pollution," which comes from an easily identifiable source like a pipe, it is very difficult to sort out relative contributions from sources scattered across the landscape. Even when the contributing areas are well known, the effectiveness of alternative management strategies can be highly dependent on landscape characteristics like soils and slopes that vary considerably from site to site. In addition, many nutrients and other pollutants build up in groundwater and respond very slowly to changes in inputs. Although groundwater sometimes responds within months or a few years, it is not unusual for it to take decades to see environmental results from a change in management strategy.

Because of this high variability and long timescales, long-term monitoring and scientific research that evaluates management practices for nonpoint contaminants are routinely identified as priorities by the Groundwater Coordinating Council (GCC). Approximately 25% of all research projects funded by the Wisconsin Groundwater Research and Monitoring Program since 1984 have been related to nonpoint contaminants. Agricultural contaminants are of particular concern, since nitrate is one of the top drinking water contaminants in the state and pesticides and their metabolites are estimated to exist in one third of all Wisconsin wells (DATCP, 2008).

GCC in Action: *The Atrazine Rule*

The development of the Atrazine Rule (ATCP 30, Wis. Adm. Code) illustrates how the benefits of long term state-funded research and monitoring can build on one another over time to effectively protect public health and the environment while upholding a strong economy.

The herbicide atrazine was first detected in monitoring wells and private drinking water wells in the mid-1980s. This prompted a statewide well sampling program in 1988, which revealed that atrazine was present in 12% of the Grade A dairy farm wells (LeMasters and Doyle, 1989). Follow-up research supported by the GCC notably demonstrated that normal agricultural applications of atrazine, rather

Atrazine is an herbicide popularly used on corn in Wisconsin and across the US. *Photo: DATCP*

than only point spills and mishandling, could lead to groundwater contamination (Cowell and LeMasters, 1992). Armed with the understanding that this was a nonpoint source pollution problem, the Department of Agriculture, Trade and Consumer Protection (DATCP) first evaluated a modeling approach to try to simulate contaminant transport and identify vulnerable areas. However, early results indicated that the behavior of atrazine in the environment was too complex to be reliably predicted by modeling (Muldoon et al., 1994). A more empirical approach, relying on actual well test results and analyses of soils, geology, production intensity, and application practices more successfully identified areas with the highest susceptibility to atrazine contamination (Daniel et al., 1990; Bradbury and McGrath, 1991; Hanson et al., 1996). Critically, these studies showed that areas with highly permeable sandy soils were not uniformly susceptible to contamination and areas with medium textured loamy soils were not uniformly safe – nuanced differences in soil type and regional production intensity had substantial effects on groundwater susceptibility. Ultimately, this allowed DATCP to develop and refine an atrazine rule that limits statewide use of atrazine and prohibits it only in certain highly vulnerable areas where atrazine in wells has exceeded the groundwater enforcement standard. In the atrazine prohibition areas, atrazine levels generally drop below the MCL in 2 to 7 years (DATCP, 2010).

The intensive monitoring and research efforts supported by the GCC allowed for a more tailored rule to be developed. This resulted in a rule that benefited both the agricultural economy by allowing continued uses of an inexpensive herbicide in most areas of the state, while also protecting groundwater and public health in environmentally sensitive areas of the state by prohibitions on use where data showed a need.

Other Projects in Other Places

DATCP Statewide Survey of Agricultural Chemicals

An integral element of nonpoint monitoring in Wisconsin is the statewide statistical survey of agriculture chemicals that is periodically performed by DATCP. As agricultural practices have evolved and laboratory methods have improved, the number of pesticide compounds analyzed in this study has grown from one compound (atrazine) in 1994 to 31 compounds in 2007 and will include close to 80 compounds in 2016. According to the last survey conducted in 2007, an estimated 9% of wells exceed the nitrate standard (10 mg/L) and 33% of wells contain a detectable level of at least one pesticide or pesticide metabolite (DATCP, 2008). As demonstrated by the development of the Atrazine rule, regular assessment of the extent of nonpoint source contaminants is critical to prioritizing issues and making fair and effective management decisions.

Reducing Nitrate Inputs to Groundwater

Nitrate is Wisconsin's most widespread contaminant. Agriculture accounts for about 90% of the nitrate in Wisconsin groundwater (Chern et al., 1999), so efforts to address this problem overwhelmingly focus on management of manure and fertilizer application. Nutrient management plans specify the amount and timing of all nutrient sources applied to a field as well as other best practices that both optimize economic input and reduce groundwater quality impacts. Not all farms have a nutrient management plan, but DATCP provides free resources and training for farmers to encourage total coverage across the state.

While there is still significant potential to reduce statewide nitrogen inputs with increased adoption of NMPs, improvement in nitrate levels in groundwater has remained frustratingly elusive after years of efforts. In light of this, the Department of Natural Resources (DNR) began a new program to work with communities on a nitrate demonstration project. This is a long-term program targeted at reducing nitrate levels in groundwater by making the most efficient use of nitrogen in agricultural production. At agricultural fields in selected demonstration communities, activities include measuring all current nitrogen inputs and baseline groundwater nitrate levels, calculating agricultural input and production costs, determining and implementing best nitrogen management practices that optimize groundwater conditions and agricultural production efficiency, and measuring whether predicted results are achieved. After several years of monitoring and modeling, costs of nitrogen management will be compared to water treatment costs for nearby wells to identify optimal nitrogen management systems.

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Understanding Natural Geochemistry

What's the issue?

As groundwater flows through rock formations and past mineral deposits, it dissolves metals and other elements into the water. Even groundwater that looks clear typically has many substances in it. Often, these chemicals are dissolved at non-toxic concentrations and do not affect how safe the water is to drink. Some of them – such as iron and sulfate – we remove for aesthetic reasons. Occasionally, natural elements do dissolve at high enough concentrations that they can affect the safety of humans and the environment.

Natural geologic formations are sources of trace elements that can be released to groundwater under certain circumstances. *Photo: WGNHS*

A complex combination of geochemical factors affects whether or not an element will leach into groundwater at dangerous levels. For any element that exists in a rock formation, the stability of the mineral in which it is incorporated as well as the temperature, pH, and oxygen dissolved in the groundwater strongly control the degree to which it mobilizes. Identifying where and why naturally occurring substances are released to groundwater requires detailed local information about all of these factors as well as extensive understanding of when small changes in one property might cause large changes in another. Developing this basic scientific knowledge is the critical first step toward developing recommendations for public water systems, homeowners, and well drillers that effectively protect the health and safety of the people of Wisconsin.

GCC in Action: *Discovery of Naturally-Occurring Arsenic in Wisconsin Groundwater*

An early example of advances in geochemical understanding in Wisconsin leading to protection of public health is the story of arsenic. Naturally-occurring arsenic was unexpectedly discovered in 1987 during a feasibility study for a proposed landfill in Winnebago County. Follow up sampling by the Department of Natural Resources (DNR) and reports from nearby homeowners indicated the problem appeared to be widespread in the region, more likely due to natural sources than industrial contamination. As a result, in 1992 the DNR, the Department of Health Services (DHS), and local health officials teamed with researchers funded by the Wisconsin Groundwater Research and Monitoring Program (WGRMP) to sample thousands of private wells in the Winnebago and Outagamie counties and later surrounding counties to analyze where and why arsenic levels were elevated (Burkel, 1993; Burkel and Stoll, 1995). These initial studies confirmed that the arsenic was naturally occurring and isolated the geologic formations acting as sources. Further geochemical studies linked arsenic mobilization to oxidation of pyrite and associated it with low pH and fluctuating groundwater levels. This information helped the DNR outline a Special Well Casing Depth Area (SWCDA) and develop well construction guidelines to protect drinking water wells in this area from exposure. Simultaneously, DHS worked with local health officials to inform residents of health risks, provide low-cost testing of private wells, and gather information about people with long-term exposure to arsenic in one of the largest epidemiological studies ever conducted in Wisconsin (Knobeloch, 2002; Zierold et al., 2004).

In the early 2000s, the Environmental Protection Agency (EPA) lowered the maximum contaminant level for arsenic from 50 ppb to 10 ppb (the current standard), which raised concerns for schools and residents in southeastern Wisconsin that had been observing arsenic levels in the 10-50 ppb range. Initial testing by the DNR and WGNHS revealed that the geochemical explanations for arsenic contamination in northeastern Wisconsin could not explain the problem in southeastern Wisconsin (Gotkowitz, 2002), so the WGRMP funded further research to analyze the sources and mechanisms of arsenic release in the region and develop more appropriate guidelines (Sonzogni et al., 2003; Bahr et al., 2004; West et al., 2012). One of the important outcomes of more recent studies has been improved understanding of how chlorine disinfection, which is often used to treat microbial biofilms (slime) in wells, can affect the release of arsenic (Gotkowitz et al, 2008). While chlorination must be limited in much of northeastern Wisconsin since it has a similar effect as oxygen on sulfide-bound arsenic, it does not affect arsenic bound to iron compounds in southeastern Wisconsin and may in fact help reduce arsenic levels in those areas by controlling microbes that contribute to iron dissolution.

DHS and DNR staff presenting on health implications of arsenic at an Ozaukee County well water informational event attended by over 150 residents. *Photo: Ozaukee County Public Health Department*.

Understanding the occurrence of arsenic in Wisconsin's groundwater is a classic example of interagency cooperation. Initial work with DHS and local health departments and town boards in the early 1990s effectively defined the problem and raised awareness. Research supported by the joint solicitation helped define the extent and mechanisms of release in northeastern Wisconsin. With assistance from well drillers, the DNR used this scientific information to identify drilling methods that reduce arsenic in the SWCDA. Importantly, when evidence emerged that southeastern Wisconsin is also vulnerable to high arsenic, the solutions that were effective in northeastern Wisconsin were not simply applied to the area. Rather, careful study informed more appropriate and effective solutions for the new region of concern, leading to better protection of drinking water and public health.

Other Projects in Other Places

Radium in Southeastern Wisconsin

Another well-known example of natural contamination in Wisconsin is radium in southeastern Wisconsin. By the late 1990s, drawdown in this region due to decades of large-scale pumping was causing concerning increases in radium levels in drinking water. Initial links between radium and geologic formations in eastern Wisconsin had been drawn by GCC researchers in 1990 (Taylor and

Mursky, 1990), but the source of radium was poorly understood, making it difficult to know how to manage drinking water sources. Research funded by the WGRMP in the late 1990s more clearly demonstrated that high radium is most common near the edge of the Maquoketa shale, which runs from Brown County in the north to Racine County in the south (Grundl, 2000). A remaining puzzle was why radium levels were elevated to the east of the Maquoketa shale boundary but not to the west – conventional understanding of the sources of radium did not seem sufficient to explain observations. In the early 2000s, researchers at the University of Wisconsin and the Wisconsin Geological and Natural History Survey (WGNHS) leveraged new models and knowledge about groundwater flow patterns in the Waukesha area to elucidate the relationship between radium and sulfate minerals in the area, collecting much needed information on the geochemical backdrop of the region in the process (Grundl et al., 2003). Today, there are still unanswered questions about the precise geochemical processes that control radium activity, but our improved understanding of radium sources helps water managers in eastern Wisconsin define their options: treat water from deep aquifers, blend with water from shallow aquifers, or find alternate surface sources for drinking water.

Chromium in Dane County

More recently in Dane County, residents were surprised to learn in 2011 that hexavalent chromium (Cr [VI]) is present in Madison drinking water in very low concentrations. While trivalent chromium (Cr [III]) is an essential trace nutrient in low concentrations, Cr (VI) is a suspected carcinogen. As DHS responded to questions about the health effects of Cr (VI), WGNHS quickly embarked on a sampling study to determine whether there was a naturally occurring source of chromium in the local bedrock formations (Gotkowitz et al., 2012). Findings indicate that chromium naturally occurs in all formations, but only the upper aquifers seem to have the geochemical conditions to promote mobility of aqueous Cr (VI). WGRMP-funded researchers at UW-Madison and the Wisconsin State Laboratory of Hygiene followed up with a project to explore what geochemical environments create ideal conditions for Cr (VI) mobility in key geologic formations across the state (Gorski et al., 2015). Work like this helps Wisconsin communities prepare for a federal drinking water standard for Cr (VI), which does not currently exist but is expected to in the future.

Sampling irrigation wells for Cr(VI). *Photo: Patrick Gorski*

Discovery triggers geochemical questions, science improves understanding and helps GCC agencies better protect human health – this pattern is repeated by GCC agencies and researchers whenever natural contaminants are identified in groundwater in unexpected amounts in a new location. This continues today with ongoing investigations that are exploring the occurrence of strontium near Green Bay and the presence of heavy metals in geologic formations near LaCrosse, among others.

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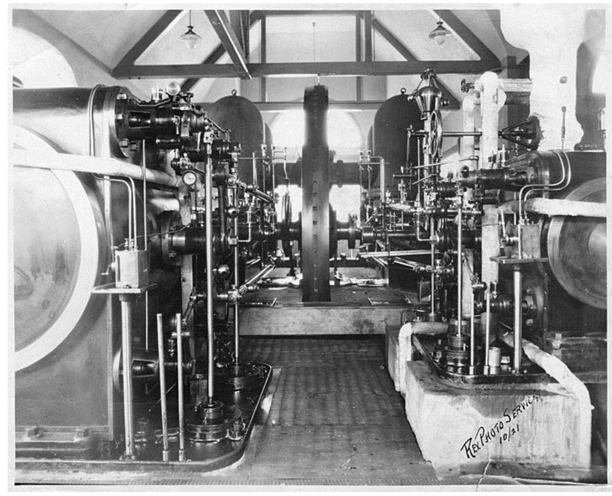
Tracking Pathogens to Their Source

What's the issue?



Early photo of the interior of the Janesville Water Works, ca. 1921. Around this time, many American municipalities were adopting practices that dramatically improved drinking water quality. *Photo: Bill Tunstead*

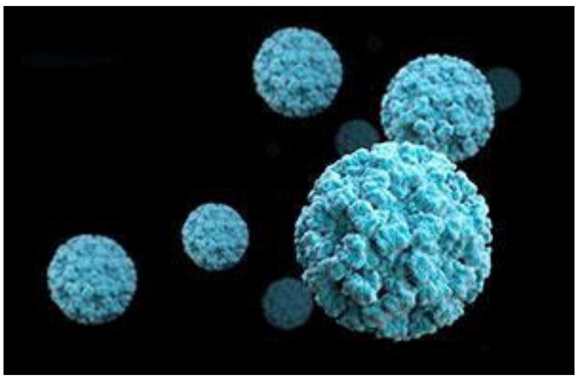
Pathogens from human sewage and animal waste are among the oldest and most ubiquitous drinking water contaminants. In the late-1800s, the advent of modern epidemiology and germ theory led to the understanding that many diseases are caused by waterborne microorganisms rather than harmful "miasmas" (vapors) in the air. By the early-1900s, many American municipalities had taken steps to keep drinking water sources separate from sewage sources and were adopting basic filtration and disinfection techniques. These actions improved the microbial quality of drinking water so dramatically that it is still considered one of the greatest global advances in public health. Half of the decline in mortality from 1900 to 1940 – the largest recorded decline in mortality in United States history – is attributed to the introduction of these basic wastewater and drinking water practices (Cutler and Miller, 2005).

Today, public sanitary sewer systems, private septic systems, and drinking water disinfection are well established so the risk of illness and mortality from waterborne disease in the United States is greatly reduced compared to 100 years ago. Protecting groundwater from microbial contamination remains a top public health priority since outbreaks of gastrointestinal illness related to well water still occur periodically. A notable example is the 2007 outbreak of norovirus caused by contaminated well water which sickened 229 diners and staff at a Door County restaurant (Borchardt et al., 2011). Because effects can be acute and severe, multiple barriers are the best defense.

In general, waterborne disease outbreaks like this are related to how quickly pathogens travel through the soil. Often, pathogen movement is slow enough or occurs over sufficiently great distances that natural attenuation and degradation make the pathogen ineffective by the time it has traveled from a fecal waste source (e.g., septic field, leaking sanitary sewer, or manure at the land surface) to a drinking water well. However, this is not always the case, particularly in areas with thin soils or shallow water tables. Furthermore, different pathogens move through the soil differently, so the presence or absence of one pathogen (e.g. a type of bacteria) does not always correlate with the presence or absence of others (e.g. viruses). Because of the complicated nature of pathogen transport and the serious consequences of waterborne disease outbreaks, the Groundwater Coordinating Council (GCC) regularly prioritizes research that evaluates how, when, and where pathogens in groundwater may pose a threat to public health.

GCC in Action: *Viruses in Drinking Water*

It is difficult and expensive to comprehensively test for all harmful pathogens, so water samples are typically tested for "indicators" – microbes that are not necessarily harmful themselves, but are a warning sign that other, potentially harmful microbial agents may be present. Traditionally, the presence of coliform bacteria is assumed to be a reasonable indicator of the presence of most harmful microbial agents, including viruses. Since 2000, groundbreaking work by GCC agencies related to the occurrence of viruses in drinking water and the impact on human health have challenged these assumptions.



Norovirus, one of the human enteric viruses detected in drinking water by GCC researchers. *Image: CDC*

An early indication of the significance of the problem came in the early 2000s, when researchers at the Marshfield Clinic Research Foundation demonstrated that viruses in private wells do not exhibit strong seasonal trends and are not correlated with commonly used indicators such as total coliform and fecal enterococci (Borchardt et al., 2003a and 2003b). A subsequent study with the U. S. Geological Survey (USGS) looking at LaCrosse municipal wells drew similar conclusions and further concluded that nearby surface waters were not the source for the viruses; rather, viruses in LaCrosse wells were likely coming from leaking sanitary sewers (Borchardt et al., 2004; Hunt et al., 2005). This was not shocking in a city like LaCrosse, where municipal wells are located in a shallow sand and gravel aquifer, relatively close to underground pipe infrastructure. However, municipal wells completed at depth – below confining layers of shale that separate shallow from deep aquifers – were presumed to be well-protected. The geology in the Madison area meets this description, yet collaborators from the Marshfield clinic, the Wisconsin Geological and Natural History Survey (WGNHS), and the University of Waterloo discovered human enteric viruses in Madison municipal wells in 2007, indicating that all aquifers are potentially vulnerable to microbial contamination (Borchardt et al., 2007; Bradbury et al. 2013).

In recognition that disinfection with chlorine or ultraviolet light can dramatically reduce virus populations, a subsequent study compared drinking water quality and illnesses in Wisconsin communities that do not disinfect. This work concluded that 6% to 22% of gastrointestinal illness incidents were directly attributable to viruses in drinking water in these communities (Borchardt et al., 2012). Results were so compelling that the Department of Natural Resources (DNR) quickly developed a rule mandating disinfection of municipal drinking water, although this was repealed by the state legislature in 2011.

This series of studies exemplifies how work by GCC researchers positions Wisconsin at the cutting edge of protecting the environment, economy, and public health. Nationally, the Environmental Protection Agency (EPA) included virus types found in the Wisconsin studies on the list of 30 unregulated contaminants that were monitored from 2013 to 2015 in 6,000 public water systems across the United States in order to gather information to support future drinking water protection. Continued research along these lines follows in the footsteps of the great public health advances of 100 years ago to ensure that drinking water, a basic human need, is not jeopardizing public health.

Other Projects in Other Places

Tracking the source of bacteria

Until recently, definitively identifying the cause of bacterial contamination in drinking water wells was not always possible. Many projects funded by the Wisconsin Groundwater Research and Monitoring Program have developed new techniques for detecting, quantifying, and monitoring microorganisms in groundwater and soils. Impressive results include a rapid molecular method to identify contamination from human waste without culturing organisms, a reliable method for detecting *Heliobacter pylori* in environmental samples, and an assay that distinguishes fecal pollution from grazing animals like cows from other sources like pigs or chickens. Improved laboratory methods enhance the ability of GCC agencies to quickly understand the root causes of bacterial contamination and identify appropriate solutions.

Laboratory methods that can distinguish fecal pollution from grazing animals vs. human or other animal sources are among of the cutting edge research supported by the GCC. *Photo: DNR*

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Predicting and Responding to Drought and Flood

What's the issue?

During times of drought, local water tables can decline due to decreased recharge and increased demand for groundwater supplies. This puts shallow drinking water and irrigation wells at risk of going dry, which can lead to reduced drinking water availability or crop yield. These water table declines also affect water levels in streams, lakes, and wetlands, with important consequences for aquatic life and recreational value. Even where groundwater quantity remains sufficiently high to meet demands, declines in water table level can alter water chemistry and expose residents using groundwater for drinking water to more heavy metals, organics, and other contaminants.

Too much groundwater can also be a problem. Groundwater flooding occurs when extremely intense and frequent rainfall leads to excessively fast recharge of local groundwater levels, causing the water table to rise above the land surface. This type of flood can be very long-lasting because water table decline requires drainage of an entire aquifer. For the months that it takes for this drainage to occur, flood waters cause significant property loss, human displacement, and disruption of transportation. Seepage lakes may also experience flooding of shoreline beaches and buildings due to a rise in the water table elevation and the related long-term increase in lake levels.

Floods and droughts are part of life in Wisconsin and elsewhere, but they come with significant economic, public health, and environmental costs. Being able to predict where these events are likely occur, how often they may take place, and probable impacts is critical to reducing the damage. The Groundwater Coordinating Council (GCC) encourages the development of data and analyses of likely scenarios for quantity and quality of Wisconsin's groundwater supply.

GCC in Action: *June 2008 Flooding in Spring Green*


Flooding in Spring Green, WI in June 2008. *Photo: WI ASCE*

A dramatic example of groundwater flooding in Wisconsin occurred when Southern Wisconsin experienced record amounts of precipitation from August 2007 through July 2008. 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. In Spring Green, about 4,400 acres of land several kilometers away from the floodplain of the Wisconsin River remained flooded by high groundwater for over five months. Recovery in the Spring Green area included a $5.4 million Federal Emergency Management Agency (FEMA) grant in 2009 to acquire and demolish 28 flood damaged homes (Moynihan, 2009).

Groundwater flooding is rare and little studied in Wisconsin. Given the extent of the damage to agricultural, residential, and commercial properties caused by the 2008 flooding, questions about the future likelihood of groundwater inundation naturally arose. Researchers at the Wisconsin Geological and Natural History Survey and UW-Madison funded by the Wisconsin Groundwater Research and Monitoring Program (WGRMP) responded by developing a series of models that simulated groundwater hydrology in the low-lying areas near Spring Green under a range of climate scenarios through 2100. Findings suggest that years of extremely high water table conditions may still occur but will remain relatively rare in this century (Joachim et al., 2011). Higher evapotranspiration is likely to reduce groundwater recharge overall.

The 2008 floods also highlighted the need for improved mitigation, preparation, response, and recovery practices. Capitalizing on momentum, a GCC-sponsored conference, “From Sandbags to Sanity,” brought together policy experts, state and local officials, and nonprofit organizations in April 2009 to discuss the policy approaches that can minimize the risks associated with this type of hydrologic disaster (Moynihan, 2009).

These two responses to the June 2008 floods – investment in research to improve scientific knowledge and enhanced coordination among federal, state, and local actors – exemplify how the GCC carries out its core missions to enhance the effectiveness and efficiency of groundwater management.

Other Projects in Other Places

Agricultural management in the Central Sands

Corn suffering in July 2012, one of the worst droughts on record in Wisconsin. *Photo: DATCP*

In times of drought, the demand for agricultural irrigation increases substantially, especially in the Central Sands region of the state. For immediate relief, the Department of Natural Resources may approve emergency high capacity wells for irrigation or livestock supply, as it did during the 2012 drought. On a long-term basis, a more reliable strategy for farmers and water systems requires understanding water balance dynamics and crop biophysics at higher spatial and temporal resolutions so that process-based models can be used to evaluate the effects of different irrigation strategies and climates on water demand. To this end, a recent study funded by the WGRMP conducted an intense field measurement campaign to refine models and evaluate how climate and land management have impacted groundwater recharge and evapotranspiration in the Wisconsin Central Sands over the past 60 years (Kucharik et al., 2015). Initial results indicate that irrigation increases the demand for water for evaporation and plant use (potential evapotranspiration), which has important implications for regional estimates of water demand.

Building Resilience Against Climate Effects (BRACE)

The Department of Health Services BRACE program has worked with seven local public health departments, or consortiums of health departments, to facilitate a climate and health community engagement process. Two of the seven local health department pilot projects have chosen to address public health impacts related to groundwater in a changing climate. One such consortium of local health departments (Eau Claire Co., Dunn Co., Pepin Co., and Buffalo Co.) is developing better policy regulating nutrient contaminants (e.g., nitrates, phosphorous). Activities will include increased testing and a collaborative group to problem-solve public health interventions. Another local health department pilot project in La Crosse County is working to increase public awareness of drinking water hazards and increase testing among private well owners. This project successfully received funding from the CDC for private well water testing.

Another aspect of the BRACE framework focuses on projecting disease burden related to a changing climate. One projected disease burden the BRACE program is investigating is gastrointestinal illness related to increases in precipitation from a changing climate in Marshfield.

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Evaluating Pumping and Drawdown Scenarios

What's the issue?

As the world population continues to grow, more people than ever before are living in and around cities. Today, over half of the world lives in urban areas and two thirds of the world will by 2050. In Wisconsin, this global trend is evident near Milwaukee, Madison, and Green Bay. Between 1980 and 2010, the population in Waukesha, Dane, and Brown counties increased by over 40% – more than double the statewide rate of population increase.

Changes in where people live leads to changes in the distribution and amount of groundwater pumped from aquifers to support homes and businesses. In southeastern Wisconsin as well as in the Lower Fox Valley near Green Bay, groundwater demands lowered the water table by several hundred feet over the past few decades. In the Madison area, drawdowns have been around 50 feet.

As population increase in urban areas, so does the demand for public water supply from distribution systems in cities like Milwaukee, Madison (pictured), and Green Bay. *Photo: David Nevala for UW Water Resources Institute*.

Wisconsin's urban centers are not the only places experiencing dramatic drawdowns. About 20% of the state's groundwater pumping occurs in the Central Sands region, predominately for irrigation. While wells in Wisconsin's urban areas typically draw from confined aquifers not well connected to surface waters, wells in the Central Sands draw from an unconfined aquifer that is a critical source of water for lakes, streams, and wetlands in the area.

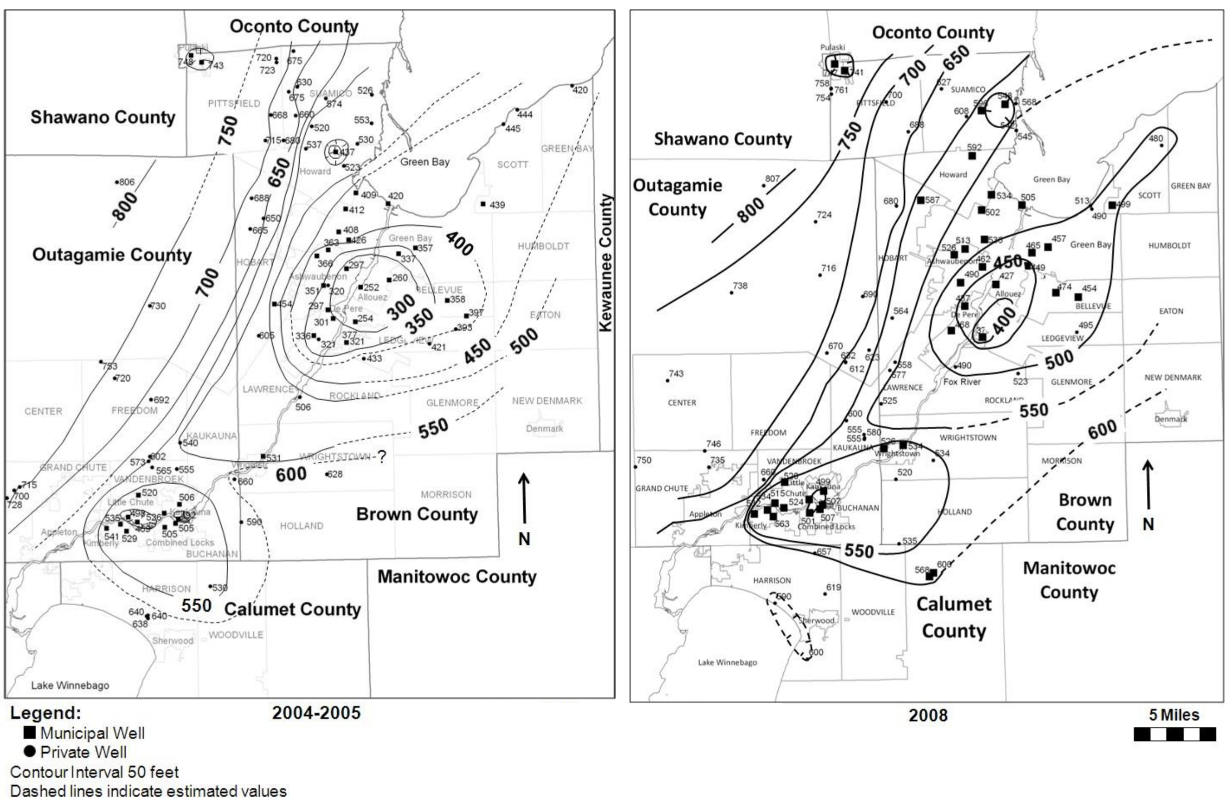
Wisconsin is water-rich overall, but these long-term drops in groundwater levels can create local scarcity in water resources. Drawdowns can cause the water level in wells, lakes, streams and wetlands to drop or dry up entirely. Additionally, water level declines can trigger geochemical reactions that cause the levels of arsenic, radium, and salinity in drinking water to increase. These consequences of long-term drawdown have a serious impact on the environment, economy, and public health.

GCC in Action: *Green Bay Recovery*

Due to concerns about the magnitude of drawdown in recent decades, the Lower Fox River Valley near Green Bay was labeled a Groundwater Management Area under Act 310 in 2003. The intent of this designation is to encourage a coordinated management strategy among the state, local government units, regional planning commissions, and public and private users of groundwater to address the problems caused by overpumping the deep aquifer. To facilitate management, GCC agencies assisted these stakeholders by undertaking research and planning related to groundwater management. GCC projects in the Lower Fox River Valley have notably improved our understanding of groundwater flow patterns, high salinity, high arsenic, and increasing radium in the area (Grundl, 2000; Grundl and Schmidt, 2002; Gotkowitz et al., 2003; Hooyer et al., 2007 and 2008).

In response to groundwater quantity and quality issues in the Lower Fox Valley, eight suburban communities near Green Bay reduced consumption of groundwater in 2007 by switching to surface water supplied by pipeline from Lake Michigan. This created a unique opportunity to observe changes in water levels due to *decreases* in pumping rates, rather than increases.

The effect of the switch was rapid and remarkable, as demonstrated by researchers at UW and WGNHS funded by the Wisconsin Groundwater Research and Monitoring Program (WGRMP) (Luczaj et al., 2009). Within the first two years, groundwater levels in the deep confined sandstone aquifer rose by over 100 feet in areas that had experienced the greatest drawdown. Today, rates have tapered off but groundwater levels in the deep aquifer continue to rise slowly. In some cases, these levels have risen above the surface, creating flowing wells and a need to deal with excess water. At the same time, a small region of the Groundwater Management Area centered in the southeastern corner of Outagamie County has remained unaffected by the decreased pumping to the north – the cone of depression around Little Chute, Kaukauna, and Kimberly has not experienced any notable improvement.



Pumping withdrawals and water table levels (in feet above mean sea level) before and after reduction in pumping. Groundwater levels rose over 100 feet in the cone of depression near Green Bay. *Figure: John Luczaj*

This research illustrates the importance of monitoring the resource after key groundwater management decisions. Because of these projects, we now know that the pumping in southeast Outagamie does not impact the cone of depression closer to Green Bay. We also know that a further decrease in pumping in the Green Bay area will cause more wells to flow above the surface in the communities northwest of Green Bay. Yet as long as pumping rates remain near their current levels, the higher water table may reduce the risk of arsenic and radium release. Each of these conclusions helps GCC agencies and stakeholders better understand which management decisions are likely to have a positive effect on groundwater supply and groundwater quality for the people, businesses, and environment of Wisconsin.

Other Projects in Other Places

Southeastern Wisconsin is also designated as a Groundwater Management Area under Act 310. As in the Lower Fox Valley, WGRMP-funded research has advanced our understanding of the geology, hydrology, and geochemical conditions contributing to similar groundwater issues in this region (Cherkauer and LaCosse, 2003; Grundl et al., 2003; Skalback et al., 2008). One of the biggest concerns for the southeastern communities is the increasing concentration of radium with drawdown, also a focus of WGRMP-funded studies (e.g., Grundl, 2000). Several communities are facing a regulatory deadline related to radium and must look for alternate drinking water sources. The main surface water alternative is Lake Michigan, but use of this water outside the Great Lakes Basin requires approval from all of the other Great Lakes states, as well as Canadian provinces. The city of Waukesha applied for this option in 2011 and the Compact Council made an unprecedented decision to approve Waukesha's application (with conditions) in 2016. All alternatives to the deep aquifer have their own obstacles and challenges, but as more communities opt to avoid it in favor of sources with lower concentrations of radium, water table declines have leveled off and are starting to recover in some wells.

In the *Central Sands*, the study of groundwater flow and its complex interactions with stream flows and lake levels dates back to historical experiments [video link] by the USGS, WGNHS, and the Wisconsin Conservation Department (precursor to the DNR) in the 1960s. Decades of continued study by GCC agencies and GCC-supported researchers, all summarized in a recent white paper, have further described the hydrogeology, climatology, and impacts of groundwater pumping on lakes, rivers, and wetlands in this region (Kniffen et al., 2014). This research, specific to the Little Plover River watershed, confirms that the Little Plover River is closely connected to the groundwater system, making it vulnerable to impacts from nearby high capacity well groundwater withdrawals.

The Little Plover River, the site of decades of research on the links between groundwater stress and surface water response. *Photo: David Nevala for UW Water Resources Institute.*

Since 2013, GCC agencies including the DNR, WGNHS, UW Extension, and the USGS have worked to bring stakeholders together in support of a new state-of-the-art groundwater flow model that builds on past modeling to assess current conditions and evaluate potential solutions. The Wisconsin Potato and Vegetable Growers Association Groundwater Task Force, an initiative of the agricultural industry in cooperation with members of GCC agencies, has been a strong supporter of this work. This project has all the hallmarks of a classic GCC initiative: GCC agencies collaborating on cutting edge science and building on decades of knowledge in order to provide information that communities can use to solve problems.

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Fostering Public Awareness

What's the issue?

Most Wisconsin residents interact with and use groundwater on a daily basis. Around 70% of residential drinking water, one third of industrial and commercial water and nearly all agricultural irrigation water comes from groundwater (Maupin et al., 2014). Yet if you were asked, "What does groundwater look like?" would you feel confident in your answer?

If you answer "no," you are not alone. Wisconsin's "buried treasure" is largely out of sight beneath the ground, so it can be very difficult for people to visualize the resource and understand our relationship with it. Often, people apply what they know about surface water to the groundwater beneath our feet and picture underground lakes, rivers, and "veins of water." But actually, groundwater is stored in the pores between soil particles and cracks in rocks and is below us everywhere we walk.

Similarly, it is common to believe that groundwater is very old, very pure, and filtered from what humans do on the land surface. In fact, the water in many wells is only a few years to a few decades old and the quality of that water can be vulnerable to what occurs on the land surface during that time. The quality of groundwater drawn from deep aquifers can also be highly variable depending on the natural geochemistry of the rock that water is drawn from.

Members of the Groundwater Coordinating Council have been national leaders in developing creative ways to present consistent educational messages about how groundwater flows and how our actions can affect the quantity and quality of that water. From sand tank visualization models to investigations into the barriers to private well testing, Wisconsin residents have benefited from the GCC's dedicated efforts to foster public awareness of how to protect the water that sustains our environment, powers our economy, and keeps us healthy.

GCC in Action: *Teacher Training Workshops*

How do GCC agencies help people understand how groundwater works? Make it visible! The groundwater sand tank model, first produced in the early 1980s in a basement by two UW-Madison professors, does exactly that. The model represents a slice or cross-section view of the earth so students can "see" groundwater and interactively explore how water and contaminants flow through different geologic materials. Concepts such as water table levels, groundwater recharge, and the effects of pumping on groundwater flow come alive when students see the model. Today, this model is so popular that is has been patented and is sold widely across the United States through Ward Scientific Catalogue, with a portion of the proceeds returning to groundwater education in Wisconsin.

To get these sand tank groundwater models [video link] into the hands of educators, the Wisconsin DNR, the Wisconsin Geological and Natural History Survey and the UW-Stevens Point Center for Watershed Science and Education collaborate to host teacher training workshops every year. Using funding from an EPA grant, educators from schools or nature centers around the state apply and are selected to receive a one-day training session, a groundwater flow model and instructions on using it, classroom exercises designed to meet state academic standards, and reimbursement for substitute teachers while at the training.

Since 2001, educators from over 500 schools or nature centers have received training and a free model through this program. Response from these workshops is always overwhelmingly positive, with 90% agreeing that the sand tank model is a necessary instructional tool for teaching about groundwater. By the time they leave, educators are better prepared to pass on to students, parents, and their community knowledge of how groundwater moves, how groundwater contamination happens, and ways to protect the resource.

Students eagerly waiting to see how "contamination" flows from a seepage pond. *Photo: Doug Gouff*

Successful groundwater management depends on dispelling myths and fostering public understanding of the resource. Through the cooperation of these GCC agency partners, a new generation of students, parents, and teachers are more aware of the complex relationship we have with groundwater, our valuable buried treasure.

Other Projects in Other Places

An ongoing focus of the GCC is promoting consistent messages about groundwater in publications from member agencies. The magazine, "Groundwater: Wisconsin's Buried Treasure" is published by the Wisconsin DNR with enormous input from other GCC agencies and is the most successful of these publications. Thousands of copies are requested each year and distributed free of charge to Wisconsin students, homeowners, and community groups. As with the sand tank model and teacher training workshops, the focus of "Buried Treasure" is on demystifying what groundwater is, how it works, and what the relationship is between groundwater and the people, economy, and environment of Wisconsin.

One of the most compelling reasons to foster public awareness about groundwater is that about half of the Wisconsin residents who get their drinking water from groundwater rely on private wells. While public water systems are regulated by state and federal safe drinking water legislation, the protection and maintenance of a private well – including regular testing of water quality – is largely up to the owner. To protect the health of their families, it is important that these owners know that they should test, what to test for, and how to obtain and interpret results. Surveys by researchers funded through the Wisconsin Groundwater Research and Monitoring Program (WGRMP) find that statewide, no more than 10%-16% of private well owners have tested their well water for *any* contaminant within the past year (Knobeloch et al., 2013; Schultz et al., 2015).

In order to improve the effectiveness of GCC agency outreach efforts, a recent WGRMP-funded research project explored the barriers to testing private wells (Schultz et al., 2015). Survey results reveal that a critically important predictor of well testing is whether owners feel that they have sufficient knowledge about what to test for. When asked to identify more specific reasons why they did not test, the most common barriers included:

- Perceptions that well water is safe to drink
- Lack of previous problems identified in a community
- Feelings of security after drinking water for years

This indicates that knowledge sharing about groundwater at a local level is key to encouraging the testing behaviors that protect human health. Findings like these underscore the importance of fostering public awareness of groundwater and help GCC agency members continue to adjust their outreach messages to target the most prevalent sources of confusion. Tools such as the Wisconsin Well Water Quality Viewer, the Environmental Public Health Tracking county profiles, and targeted testing programs by local public health departments are some of the ways GCC partners are working to bring knowledge about local groundwater quality risks to residents.

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Developing and Sharing State-of-the-Art Tools

What's the issue?

Good groundwater management decisions depend on good information about the state of Wisconsin's groundwater resources. This includes long-term data on groundwater levels and groundwater quality for all regions of the state as well as the tools to predict responses of the current system to changes in pumping rates, climate, and land use change.

One of the challenges of having eight state agencies responsible for some aspect of groundwater protection is that it is possible for similar datasets and tools to be generated and stored in eight different places. At the other extreme, it is possible for one very useful dataset or tool to be generated in one place without being distributed to the other seven and their partners. Each agency works with different sets of data users, such as researchers, well drillers, consultants, or farmers. One of the central functions of the Groundwater Coordinating Council (GCC) is ensuring coordination in both the development and the distribution of state-of-the-art groundwater tools and data.

GCC in Action: *Springs Inventory*


Pheasant Branch spring in Middleton, WI. *Photo: WGNHS*

Groundwater springs [video link] are special places where the water table reaches the land surface and overflows into streams and wetlands. Springs are critical natural resources since they supply cool, oxygen-rich water for trout and often harbor threatened and endangered species. Springs are also a window into the groundwater below the surface and they can provide a great deal of information about the chemical composition and flow of local groundwater. Springs are often well loved for their scenic beauty at public parks.

Because these special natural resources are vulnerable to groundwater pumping, the Department of Natural Resources (DNR) carefully reviews high capacity well applications involving wells constructed near springs for adverse environmental impacts. There are over 10,000 known springs in Wisconsin and it is not a simple task to determine, given a proposed high capacity well, which nearby springs need to be assessed. Correct information about the location and flow rate of each spring is critically important to have, but existing data come from many sources – some as old as 1905 – with varying levels of quality and accuracy. Springs can also be used as easy sampling points for indicators of groundwater quality.

In keeping with the stated mission of the GCC to assist in the efficient management and exchange of groundwater data, GCC agencies and researchers have worked together to gather data about Wisconsin's springs into a centralized inventory for Wisconsin. In 2007, the establishment of a statewide springs database (Macholl, 2007) was a major step forward in pulling together data from disparate sources, but unfortunately it was incomplete for large areas of the state (e.g., northeastern WI) and the accuracy of the information is unknown. New research is currently underway to systematically fill these gaps and improve the accuracy and quality of location and hydrology information. During this project, researchers are also identifying "reference springs" which can be used to identify trends in spring discharge due to climate change and nearby land use management. Accessibility to scientists, water resources managers, and the general public will be greatly enhanced by the inclusion of the springs inventory in the Wisconsin Geological and Natural History (WGNHS) web browser interface, Hydro Data Viewer.

Other Projects in Other Places

Other statewide databases

Geotechnicans at WGNHS install a new well for the Wisconsin Groundwater Monitoring Network. *Photo: Jeff Miller, UW-Madison*

The longest-running example of cooperative groundwater data collection is the Wisconsin Groundwater-Level Monitoring Network, which has been operated jointly by the WGNHS and the U.S. Geological Survey (USGS) since 1946. Currently, the network consists of 153 wells that are actively measuring groundwater levels in 53 counties. The consistent, long-term record of groundwater levels is critical to track the impacts of high-capacity well pumping, the response of groundwater levels to droughts, the effects of land use changes in groundwater systems, and the impacts of climate change. Long-term data are also essential for calibration of regional groundwater flow models. Thanks to cooperation between multiple municipal, county, state, and federal agencies, recent network upgrades in 2012-2014 went much further than anticipated. For example, two stations in Kettle Moraine State Forest (Southern Unit) now include an interactive display which allows "citizen scientists" (park visitors) to make flow measurements using staff gages and submit the data via text message. In addition to field truthing official flow measurements, the interactive displays help engage the public and demonstrate the value of the statewide monitoring network.

Another well-established GCC database is the Groundwater Retrieval Network administered by the DNR. This system reports groundwater quality data that is required or voluntarily reported to the DNR from public and private drinking water supply wells, non-point source priority watershed projects, special groundwater studies, landfill wells, wastewater treatment facilities, and land spreading sites. DNR's revamped GRN webpage is just one of the data sources from GCC agencies that can be accessed by searching "groundwater" at www.dnr.wi.gov and clicking the "Look Up" button.

Another source of data is the Department of Health's Environmental Public Health Tracking program, which pulls data from several sources and combines them into one public portal. The portal is free to use and accessible to everyone. Users can explore environmental health issues such as air quality, water quality, asthma, cancer, and childhood lead poisoning via tables, charts, and maps.

A recent Wisconsin Tracking initiative led to targeted environmental health outreach for the significant proportion of Wisconsinites – two out of every five households – that rely on private wells to supply their water. Until recently, many homeowners were unable to access data on the quality of well water through a centralized database. In response to this need, the Wisconsin Well Water Quality Viewer was developed and released in 2012 by UW-Stevens Point to provide a portal to display these well water data. While the portal provided rich data for much of the state, subsequent review of the portal's maps revealed data were scarce for several counties – particularly those where labs run by local health departments provided most well testing services. To investigate this issue, the Wisconsin Tracking Program convened stakeholders and the State Laboratory of Hygiene facilitated discussions among UW-Stevens Point and members of the Wisconsin Association of Local Health Departments and Boards. As a result of these efforts, staff from Eau Claire City-County Health Department were able to add their data to the portal and create maps of well water quality in their jurisdiction.

Groundwater flow models

Groundwater flow models are essential for predicting hydrologic change due pressures such as groundwater pumping, climate, or land use change. The WGNHS regularly partners with the USGS to develop and update groundwater flow models to ensure that management decisions are made using the best possible science. Recent releases include an updated version of the Dane County model and a new model for the Little Plover River in the Central Sands. These models are relied upon by both public and private practitioners as state-of-the-science products to support sound management of groundwater quality and quantity.

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Creating Community Based Solutions

What's the issue?

Whether we realize it or not, most of us in Wisconsin interact with groundwater on a daily basis. Around 70% of Wisconsinites rely on groundwater for drinking water and over 97% of agricultural irrigation water in the state is drawn from below ground (Maupin et al., 2014). While communities across the state are united in this dependence on groundwater, hydrogeologic settings and pressures on groundwater resources are unique to each locality. As Groundwater Coordinating Council (GCC) agencies advance groundwater science and exchange information with one another, an equally large emphasis is placed on communicating this information to the public and empowering local communities to design groundwater solutions that make sense for them.

GCC in Action: *Comprehensive Planning*

By Wisconsin law, as of 2010 all cities, villages, towns and counties that adopt or amend zoning, land division or official mapping ordinances must do so consistent with a comprehensive plan. Communities that rely on groundwater as their sole source of water need to assess the magnitude and limits of their water source, but many need additional expertise to quantify and plan for their water supply. The Wisconsin Groundwater Research and Monitoring Program has funded several projects to help communities locate, evaluate, and incorporate good groundwater information and data in their plans.

For example, researchers partnered with Richfield, WI to determine what kinds of groundwater supply information are most relevant and usable for planning from a community's perspective (Cherkauer, 2005). They determined that good basic understanding of geology, sources, sinks and water balance of its aquifer system is 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.

A related project evaluated whether and how Wisconsin communities address groundwater in their comprehensive plans and what tools would help them do so (Markham et al., 2005). This led to the creation of a statewide website with relevant groundwater information for use in comprehensive planning and a suggested process for integrating this information in plans (Markham and Dunning, 2007). All of Wisconsin's 72 counties have a dedicated page that includes a snapshot of local data about groundwater susceptibility, sources of drinking water, groundwater quality, potential sources of contaminants, groundwater quantity, and money spent on cleanup and groundwater protection strategies. Long term hosting and maintenance of the site is undetermined, but the emphasis on getting groundwater information into the hands of local decision makers in ways that are most useful to them remains an important focus of GCC work.

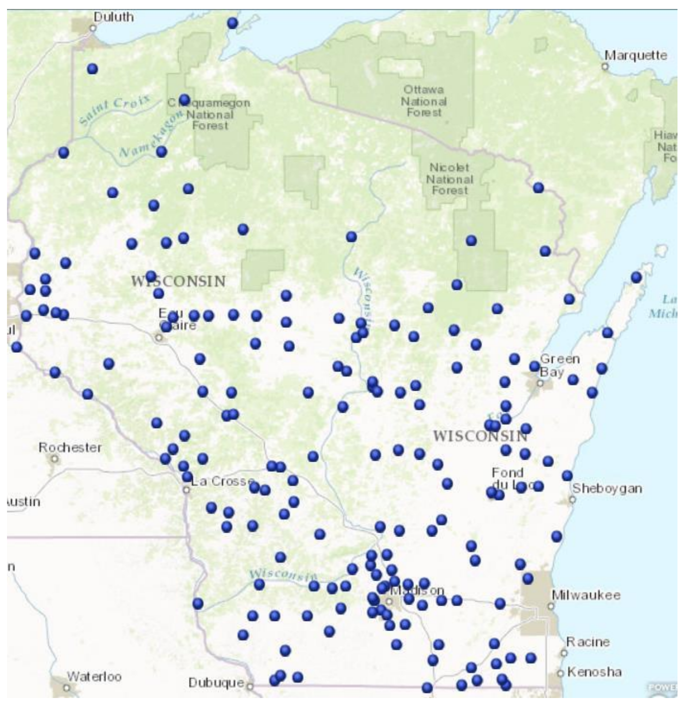
Other Projects in Other Places

Environmental Public Health Tracking

Environmental health data, including information on groundwater and drinking water supplies, is not always easy for local leaders to access and interpret. To assist with this, the Department of Health's Environmental Public Health Tracking program pulls data from several sources and combines them into one public portal. Community leaders and residents can explore environmental health issues such as air quality, water quality, asthma, cancer, and childhood lead poisoning via tables, charts, and maps designed specifically for their county.

In fall 2015, the Wisconsin Tracking team announced a new mini-grant program, *Taking Action with Data.* Five Wisconsin counties used data from their County Environmental Health Profile to propose projects addressing drinking water-related environmental public health issues in their communities. Staff from the Wisconsin Environmental Public Health Tracking program provided technical assistance on epidemiology, communications, evaluation, etc. Using these funds, these five counties have been able to achieve tangible results, such as increased private well testing or the creation of tools that can be used to better understand groundwater quality within the county. After the success of the first year, a second round of funding was announced in July 2016. Additional information about these projects can be found on the Wisconsin Tracking website.

Source Water Protection



Communities with protective plans for all wells that supply public drinking water as of August 2015. *Figure:* *DNR*

The DNR, in partnership with Wisconsin Rural Water Association (WRWA), Wisconsin Land and Water Associations, Wisconsin Geologic and Natural History Survey, USGS and several UW departments, is making what they call "strategic interventions" to support community based solutions. As examples, the City of Waupaca and the Villages of Spring Green and Fall Creek are receiving technical and financial support to try innovative methods of working with neighboring landowners to tackle rising nitrate in public supply wells. In a different corner of the state, the Village of Luck recently updated its wellhead protection plan with assistance from WRWA and is considering a range of management possibilities that DNR groundwater programs are available to support. Luck is on a short list of communities with susceptible wells and active interest in water supply protection that DNR and partners are working with in order to provide new examples of local innovation for others to emulate. These examples and additional resources are available on the DNR's recently revamped Source Water Protection webpage, which seeks to link communities with information they need to develop source water protection plans, as well as recognize communities that already have plans and ordinances in place.

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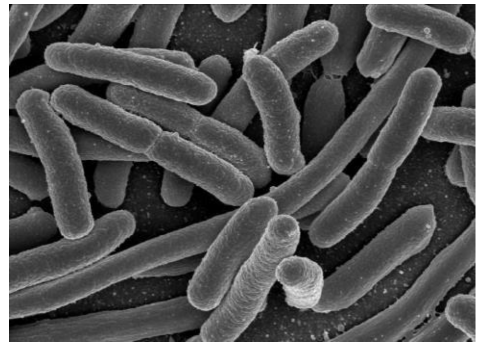
Pathogens

What are they?



E. coli, an indicator of fecal contamination.
Photo: NIAID

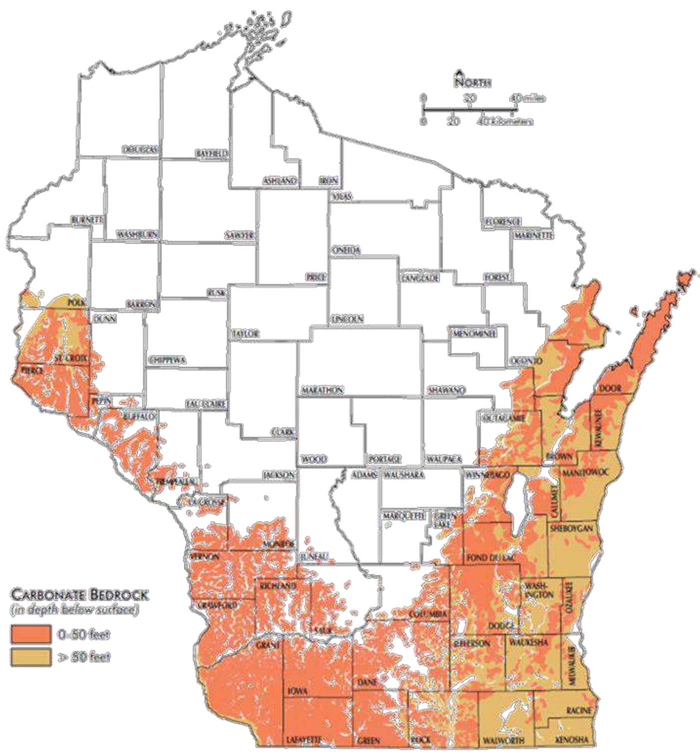
Pathogens are organisms or other agents that can cause disease, including microorganisms such as bacteria, viruses, and protozoa that can cause waterborne disease. Groundwater contamination by pathogens can usually be traced to human or livestock fecal wastes that seep into the ground from sources such as septic systems, leaking sanitary sewers, or manure. Since it is difficult and expensive to test for all pathogenic microorganisms, water samples are usually tested for microbial “indicators” – microbes that are not necessarily harmful themselves, but are a warning sign that other, potentially pathogenic, microorganisms may be present.

There are no groundwater standards for pathogenic microorganisms in Wisconsin, but pubic drinking water systems are regularly monitored for total coliform bacteria (WI NR 809.31-809.329). These systems may also be tested for fecal indicators such as *E. coli*, enterococci, or coliphages if coliform bacteria are found. Coliforms are a broad class of bacteria that are naturally present in the environment and are used as an indicator that other, potentially harmful, microorganisms may be present. Fecal indicators are microbes whose presence more specifically indicates that water may be contaminated with human or animal wastes. Pathogenic microorganisms in drinking water can make people very sick and can result in death. Common symptoms include diarrhea, cramps, nausea, and headaches. Microbial contamination may pose a special health risk for infants, young children, some of the elderly, and people with severely compromised immune systems.

Such contamination is of particular concern in public water systems, because a large number of people can be exposed to contamination in a short amount of time. In 1993, pathogen contamination at Milwaukee’s surface water-sourced drinking water system resulted in 69 deaths and more than 403,000 cases of illness before the epidemic and its source were recognized. A 2007 outbreak of norovirus, caused by contaminated well water, sickened 229 diners and staff at a Door County restaurant (Borchardt et al. 2011).

Occurrence in Wisconsin

In Wisconsin, it is well known that groundwater in areas with karst geology – soluble rocks with many large fractures through which water flows rapidly – is vulnerable to microbial contamination and needs special consideration and protection. In these areas, particularly where there is also thin soil cover and shallow groundwater levels, there is little opportunity for soil to slow and attenuate the transport of microbes. This results in a greater risk that pathogens will remain viable when they reach the groundwater. Karst geology can be found across much of the state. Door and Kewaunee Counties are especially vulnerable since these areas additionally have very thin soils. Around 34% of private well samples test high for total coliforms in these areas, as opposed to 17% in the state overall (Knobeloch et al., 2013).



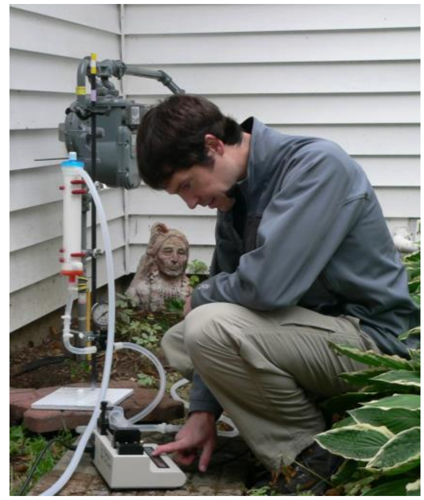
Karst potential in Wisconsin. Areas with carbonate bedrock within 50 feet of the land surface are particularly vulnerable to groundwater contamination. *Figure*: WGNHS

A more recent, emerging concern is the presence of viruses in drinking water wells, including norovirus, adenovirus, and enterovirus. This contamination does not necessarily correlate well with total coliform bacteria (Borchardt et al., 2003b) because viruses have different transport properties than bacteria. Recent research studies have detected human enteric viruses in both public and private wells in Wisconsin (Borchardt et al., 2003a, 2004, and 2007), but there is limited statewide data since testing for viruses is expensive, not routinely performed, and levels cannot be reliably inferred from total coliform results. In cities where such studies have been conducted, such as La Crosse and Madison, transport of viruses from municipal sewer systems to groundwater supplies is known to occur very rapidly – on the order of weeks rather than years – and accurate detection requires frequent sampling and testing specifically for viruses (Hunt et al., 2010; Bradbury et al., 2013). Results suggest that viral contamination of groundwater may occur at other municipal water systems because such wells are generally completed in areas with sanitary sewers.

The risk of finding pathogens in groundwater is seasonably variable but typically highest following spring snowmelt or large rainstorms that generate runoff, since these events create large pulses of water that move quickly through the ground, potentially carrying microbes from septic systems, sewer mains, and manure sources (Uejio et al., 2014). Nutrient management plans can help reduce the risk of contamination due to manure spreading, but even with the best management practices it is difficult to eliminate occurrences. Over 60 private wells have had to be replaced due to manure contamination at a cost to the state of over $500,000 since 2006 (Source: DNR Well Compensation Fund records).

It is important to note that there is very clear evidence that disinfection with chlorine or ultraviolet light can dramatically reduce the risk of illness from viruses and other microbial sources (Borchardt et al., 2012; Lambertini et al., 2012; Uejio et al., 2014). Continuous disinfection is not dependent on indicator tests to protect human health. However, this is not required by law for public water systems that source their drinking water from groundwater. About 60 municipalities in Wisconsin do not disinfect their public water supplies.

GCC Agency Actions



Dr. Sam Sibley, UW-Madison Department of Soil Science, collects a well water sample from a residential home to analyze using new MST tools. Video story at: https://youtu.be/dpE58Rd4i4E. *Photo*: *Carolyn Betz, UW ASC*

Homeowner complaints about private well *bacterial* contamination events, which often correspond with manure spreading, are an ongoing concern for GCC agencies. Unfortunately, the standard methods for testing for bacteria do not show whether the bacteria are derived from human or animal sources and until 2007 there were no readily available methods for testing for manure. Funding from the Wisconsin Groundwater Research and Monitoring Program (WGRMP) has supported the development of laboratory techniques that have made it possible to discern whether bacteria are from human, animal or other sources (Pedersen et al., 2008; Long and Stietz, 2009). These microbial source tracking (MST) tools include tests for *Rhodococcus coprophilus* (indicative of grazing animal manure), *Bifidobacteria* (indicative of human waste) and *Bacteroides* (indicative of recent fecal contamination by either humans and/or grazing animals). A more recently developed analysis can successfully detect bovine adenoviruses to indicate bovine fecal contamination of groundwater (Sibley et al., 2011). The DNR has been using these tools as they become available to determine the source of fecal contamination in private wells. MST results since 2007 indicate that the majority of well water samples are contaminated with grazing animal waste, less than 10% of samples indicate microbial contamination from human sources, and approximately 20% of samples have no indication of microbial contamination (Laura Chern, personal communication). DNR's Drinking Water & Groundwater and Runoff Management programs are working with the DATCP nutrient management program to find ways of controlling this major source of contamination.

Over the past 15 years, GCC agencies and collaborators have carried out groundbreaking work on *viruses* in drinking water and the impact on human health. An early indication of the significance of the problem came in the early 2000s, when researchers at the Marshfield Clinic Research Foundation demonstrated that levels of viruses in private wells do not exhibit strong seasonal trends and are not correlated with commonly used indicators such as total coliform and fecal enterococci (Borchardt et al., 2003a and 2003b). A subsequent study with the USGS looking at LaCrosse municipal wells drew similar conclusions and further concluded that nearby surface waters were not the source for the viruses; rather, viruses in LaCrosse wells were likely traceable to leaking sanitary sewers (Borchardt et al., 2004; Hunt et al., 2005). This was not shocking in a city like LaCrosse, where municipal wells are located in a shallow sand and gravel aquifer, relatively close to underground pipe infrastructure. However, municipal wells completed at depth, below confining layers of shale that separate shallow from deep aquifers, were presumed to be well-protected. The geology in the Madison area meets this description, yet collaborators from the Marshfield clinic, WGNHS, and the University of Waterloo discovered human enteric viruses in Madison municipal wells in 2007, indicating that all aquifers are potentially vulnerable to microbial contamination (Borchardt et al., 2007; Bradbury et al. 2013). In recognition that disinfection with chlorine or ultraviolet light can dramatically reduce virus populations, a subsequent study compared drinking water quality and illnesses in Wisconsin communities that do not routinely disinfect their water (Borchardt et al., 2012; Lambertini et al., 2012). This work concluded that 6% to 22% of gastrointestinal illness incidents were directly attributable to viruses in drinking water in these communities. This figure may be as high as 63% among children under 5 years old during periods when norovirus was abundant. In response, the DNR developed a rule mandating disinfection of municipal drinking water but this was repealed by the state legislature in 2011. Nationally, the EPA included virus types found in the Wisconsin studies on the list of 30 unregulated contaminants that were monitored from 2013 to 2015 in 6,000 public water systems across the United States in order to gather information to support future drinking water protection.

Future Work

Improving best practices for well construction in the vulnerable karst areas of the state is an ongoing topic of concern. In addition to significant threat to health posed by manure sources, there are indications that current requirements for septic systems and leach fields may be inadequate to protect public health and the environment in areas where wells draw from shallow carbonate aquifers. This points to a need to revise the requirements for the construction of private water wells in these areas.

Most of the current data on bacterial contamination in Wisconsin is derived from private well samples. However, public drinking water systems that disinfect their water supplies are also required to sample quarterly for bacteria from the raw water (before treatment) in each well. The DNR recently began tracking total coliform detects in the raw water sample through its Drinking Water System database, so evaluation of this monitoring data from public wells may enhance understanding of statewide bacterial contamination. This understanding would be further enhanced by an analysis of the equivalence and positive predictive value of the laboratory methods (PCR kits, testing protocols) used to measure concentrations of bacteria and bacterial indicators in groundwater.

Pumping test at one of Madison's municipal wells, part of a WGRMP-funded study to enhance understanding of fractures and virus transport. *Photo*: *Jean Bahr*

There are unanswered questions about viruses in drinking water as well. While previous work has clearly demonstrated where viruses in municipal wells come from (sanitary sewers) and how fast they travel (on the order of weeks), the exact mechanism of entry in cities like Madison is unknown and cannot be explained by normal assumptions about hydrogeology. A study funded by the WGRMP is currently exploring whether the rapid transport of viruses between the shallow and deep aquifers in Madison can be explained by vertical fractures in the shale layer that separates them. More research is also needed on the survival times of various viruses in groundwater aquifers.

Finally, additional public health studies where clinical samples and water samples are collected simultaneously, such as those conducted by GCC researchers in La Crosse, are needed to better describe the relationship between cause of illness and groundwater pathogens.

Further Reading

DNR overview of bacteriological contamination in drinking water [link]

DNR overview of cryptosporidium in drinking water

DHS fact sheet on manure contamination of private wells [link]

WGNHS overview of karst landscapes [link]

WGNHS report on municipal drinking water safety [link]

DNR list of municipal drinking water systems that disinfect

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Nitrate

What is it?

Flooded field after manure spreading. Nutrient application on agricultural fields accounts for 90% of nitrate in groundwater. *Photo*: *Marty Nessman, DNR.*

Nitrate (NO_3) is a water-soluble molecule that forms when ammonia or other nitrogen rich sources combine with oxygenated water. Since the nitrogen in nitrate is a health and environmental concern but the oxygen is not, the concentration of nitrate in water is often reported as "nitrate-N" which reflects only the mass of nitrogen in the nitrate (ignores the mass of oxygen). Nitrate levels in groundwater are below 2 ppm (as nitrate-N) where pollution sources are absent. Higher levels indicate a source of contamination such as agricultural or turf fertilizers, animal waste, septic systems, or wastewater.

The health-based enforcement standard (ES) for nitrate-N in groundwater and the maximum contaminant level (MCL) for nitrate-N in public drinking water are both 10 ppm (WI NR 140.10, WI NR 809.11). Everyone should avoid long-term consumption of water containing nitrate above this level.

Infants below the age of 6 months who drink water containing nitrate in excess of the MCL are especially at risk, and could become seriously ill with a condition called methemoglobenemia or "blue-baby syndrome". This condition deprives the infant of oxygen and in extreme cases can cause death. The DHS has associated at least three cases of suspected blue-baby syndrome in Wisconsin with nitrate contaminated drinking water (Knobeloch et al., 2000). In children, there is also growing evidence of a correlation between nitrate and diabetes (Moltchanova et al., 2004; Parslow et al., 2007).

Birth defects have also been linked to nitrate exposure. Several epidemiological studies over the past decade have examined statistical links between nitrate exposure and neural tube birth defects (e.g., Brender et al., 2013). 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. Further work, including a clear animal model, would be needed to conclusively demonstrate causation. Nonetheless, these studies collectively indicate an ongoing need for caution in addressing consumption of nitrates by pregnant women and support the continuation of private well testing programs for these women.

In the human body, nitrate can convert to nitrite (NO_2) and then to N-nitroso compounds (NOC's), which are some of the strongest known carcinogens. As a result, additional human health concerns related 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).

Adverse environmental effects are well described as well. A number of studies have shown that nitrate can cause serious health issues and can lead to death in fishes, amphibians, and aquatic invertebrates (Camargo et al., 1995; Marco et al., 1999; Crunkilton et al., 2000; Camargo et al., 2005; Smith et al., 2005; McGurk et al., 2006; Stelzer et al., 2010). This is significant because many baseflow-dominated streams (springs, groundwater-fed low-order streams) in agricultural watersheds in Wisconsin can exhibit elevated nitrate concentrations, at times exceeding 30 ppm.

Occurrence in Wisconsin

Nitrate is Wisconsin's most widespread groundwater contaminant. Nitrate contamination of groundwater is increasing in extent and severity in the state (Kraft, 2003; Kraft, 2004; Kraft et al., 2008; Saad, 2008). A 2012 survey of Wisconsin municipal water-supply systems found that 47 systems have had raw water samples that exceeded the nitrate-N MCL, up from just 14 systems in 1999. Increasing nitrate levels have been observed in an additional 74 municipal systems. Private water wells, which serve about one third of Wisconsin families, are at risk as well. Statewide, about 10% of private well samples exceed the MCL for nitrate-N, although one third of private well owners have never had their water tested for nitrate (Knobeloch et al., 2013; Schultz and Malecki, 2015). In agricultural areas, such as the highly cultivated regions in south-central Wisconsin, around 20%-30% of private well samples exceed the MCL (Mechenich, 2015). Nitrate concentrations are poised to further increase as nitrate pollution penetrates into deep aquifers and migrates farther from original source areas (Kraft et al., 2008).

Nitrate is Wisconsin's most widespread contaminant, yet 33% of private well owners have never had their water tested for it. *Photo*: *DNR*

To mitigate nitrate contamination, municipal systems surveyed in 2012 collectively spent over $32.5 million, up from $24 million in 2004. 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. Owners of nitrate-contaminated private wells do not qualify for well compensation funding unless the nitrate-N level in their well exceeds 40 ppm and the water is used for livestock. In order to establish a safe water supply, these private well owners 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. In a survey of 1,500 families in 1999, the DHS found that few took any action to reduce nitrate exposure (Schubert et al., 1999). Of those who did, most purchased bottled water for use by an infant or pregnant woman. More recently, it appears that some private well owners in rural Wisconsin are installing reverse osmosis filter systems at considerable cost to obtain safe drinking water (Schultz and Malecki, 2015).

GCC Agency Actions

Nitrate has always been a core concern for GCC agencies. Over 40 projects funded by the Wisconsin Groundwater Research and Monitoring Program (WGRMP) (10% of the total portfolio) have investigated the occurrence, transport, removal, or management of nitrogen in Wisconsin. In addition, multiple sampling programs have been carried out by the DNR, DATCP, and the WGNHS to characterize the extent of contamination.

Since the early 1990s, it has been well-accepted that around 90% of nitrogen inputs in Wisconsin can be traced to agricultural sources including manure spreading and fertilizer application (Shaw, 1990). In addition to regular well sampling surveys, one of the key ways that DATCP assists in addressing this problem is by supporting the development of nutrient management plans (NMPs). These plans specify the amount and timing of all nutrient sources applied to a field as well as other best practices that both optimize economic input and reduce groundwater quality impacts. Currently, about 31% of the agricultural land in Wisconsin is covered by an approved management plan (DATCP, 2015). Not all farms are required to have a nutrient management plan, but DATCP provides free resources and training for farmers to encourage total coverage across the state.

A concerning pattern in many areas has been the continued increase of nitrate levels in groundwater and streams even after reduced regional use of nitrogen-based fertilizers. Several recent studies by WGRMP-funded researchers illuminate possible reasons for this. For one, long groundwater travel distances in some geologic settings mean that it can take decades for nitrate to travel to streams and wells situated deep in thick aquifers, so it will take at least that long to see a response from more recent management changes (Kraft et al., 2008). Until then, increases in nitrate levels due to historical agricultural practices are likely. More concerning are the various studies which indicate that NMPs are questionably effective at reducing nitrate levels to below the MCL. Even in the best managed agricultural systems, over the long-term (7 years) nearly 20% of nitrogen fertilizer bypasses plants and is leached to groundwater, which makes it likely that groundwater concentrations of nitrate-N at or above the MCL will continue to be a concern for Wisconsin residents (Brye et al., 2001; Masarik, 2003; Norman, 2003). That said, there is still significant potential for improvement through increased adoption of NMPs. DATCP estimates that in 2007, over 200 million pounds of nitrogen were applied to agricultural lands in excess of UW recommendations, a number that would be substantially reduced with broader adoption of NMPs.

Exploring best nitrogen management practices in on agricultural fields is a key research priority for the GCC. *Photo*: DNR

The DNR recently began a new program in 2012 to work with stakeholders on the "Wisconsin Safer Drinking Water Nitrate Initiative". This is a long-term program 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, calculating agricultural input and production costs, determining and implementing best nitrogen management practices that optimize groundwater conditions and agricultural production efficiency, and measuring whether predicted results are achieved. Project areas include agricultural fields in Rock and Sauk Counties within watersheds where large numbers of public drinking water systems are approaching unsafe levels of nitrate contamination. DNR is currently working with stakeholders to determine and apply optimal nitrogen management systems to project areas. Monitoring of nitrogen inputs, groundwater nitrate levels, and production costs will continue and costs of nitrogen management will be compared to water treatment costs.

Future Work

Given the pervasiveness of nitrate contamination in groundwater and the seriousness of suspected human health impacts, there is a need for a better understanding of the health effects of high nitrate in drinking water. The DHS will continue to monitor and review the literature on this topic, particularly with regards to links with birth defects.

Improved management strategies, technical tools, and incentives to promote efficient use of nitrogen are another top priority. The Wisconsin Safer Drinking Water Nitrate Initiative is designed to address many of these issues and will hopefully expand beyond initial project areas in future years. Manure digesters are also emerging as an increasingly popular way to control nutrient fate and generate power.

Enhancing our ability to definitively link trends in groundwater nitrate levels to activities at individual locations is also the theme of three recently funded WGRMP projects. One study is designing a field based approach that captures the spatial and temporal variability of nitrate below agricultural fields of different soil textures. This project should help untangle variations in nitrate levels due to natural drivers and those due to management practices. Another in Dane County will develop a numerical model that can be used to test the potential of alternate management strategies to reduce nitrate levels. A third study will investigate under what conditions microbes remove nitrate from water, which will help identify hotspots for nitrogen removal in streams across Wisconsin. Throughout all of this, continued groundwater monitoring is also needed to assess existing problem areas and identify emerging areas of concern.

Further Reading

DNR overview on nitrate in drinking water [link]

DNR overview on nutrient management planning [link]

DATCP overview on nutrient management [link]

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Arsenic

What is it?

Arsenic is an odorless and tasteless, naturally occurring element present in soil and rock. Under certain environmental conditions, arsenic can dissolve and be transported in groundwater. It can also be released as a by-product from agricultural and industrial activities. Everyone is exposed to small amounts of arsenic since it is a natural part of the environment, but under some geologic conditions elevated amounts of arsenic can be released to groundwater.

Arsenic-rich minerals, such as arsenic-rich pyrite (pictured), are natural sources of arsenic in groundwater in Wisconsin. *Photo: JJ Harrison.*

The health-based enforcement standard (ES) for arsenic in groundwater and the maximum contaminant level (MCL) for arsenic in public drinking water are both 10 parts per billion (ppb) (WI NR 140.10, WI NR 809.11). Some people who drink water containing arsenic in excess of the MCL over many years could experience skin damage or problems with their circulatory system, and have an increased risk of getting cancer.

Occurrence in Wisconsin

In Wisconsin, most arsenic found in groundwater is naturally occurring, released from minerals in bedrock and glacial deposits. Arsenic has been detected above the ES in the groundwater in every county in Wisconsin. Arsenic contamination of groundwater is common in northeastern Wisconsin in areas around Winnebago and Outagamie County and moderately high levels of arsenic (10 ppb – 30 ppb) are also common in some parts of southeastern Wisconsin.

Arsenic is common in northeastern Wisconsin (regions 1 and 3) and southeastern Wisconsin. *Figure*: *Luczaj and Masarik, 2015*.

In *northeastern Wisconsin*, a geologic formation called the St. Peter Sandstone contains arsenic-rich minerals. When sulfide minerals common in this rock are exposed to oxygen in the air – either at the water table elevation or from drilling activity – chemical reactions solubilize these minerals and lead to very high levels of arsenic in water (exceeding 100 ppb, or 10 times the ES). In low-oxygen groundwater environments, arsenic can be released from the St. Peter Sandstone at lower concentrations which may still exceed the ES. This more moderate contamination may result from the same sulfide minerals or from arsenic that is bound to iron oxide minerals.

In *southeastern Wisconsin*, most wells draw from glacial sand and gravel deposits or Silurian dolomite formations. While oxidizing conditions tend to release arsenic from sulfide minerals in northeastern Wisconsin, reducing conditions (where dissolved oxygen is low) tend to release arsenic from iron compounds in the glacial deposits and dolomite of southeastern Wisconsin.

GCC Agency Actions

Naturally-occurring arsenic was unexpectedly discovered in Wisconsin in 1987 during a feasibility study for a proposed landfill in Winnebago County. Follow up sampling by the Department of Natural Resources (DNR) and reports from nearby homeowners revealed a pressing need to determine the distribution and frequency of the problem. As a result, over the next several years the DNR, the Department of Health Services (DHS), and local health officials teamed with researchers funded by the Wisconsin Groundwater Research and Monitoring Program (WGRMP) to sample thousands of private wells in the Winnebago and Outagamie County area and analyze where and why arsenic levels were elevated (Burkel, 1993; Burkel and Stoll, 1995). As researchers identified first the geologic formation, then the chemical reactions responsible for the situation (Pelczar, 1996; Simo, 1995 and 1997; Gotkowitz et al., 2003), the DNR outlined a Special Well Casing Depth Area and developed well construction guidelines to protect drinking water wells in this area from contamination. Simultaneously, the DHS worked with local health officials to inform residents of health risks, provide low-cost testing of private wells, and gather information about people with long-term exposure to arsenic in one of the largest epidemiological studies ever conducted in Wisconsin (Knobeloch et al, 2002; Zierold et al., 2004).

In the early 2000s, the US EPA lowered the MCL for arsenic from 50 ppb to 10 ppb (the current standard), which raised concerns for schools and residents in southeastern Wisconsin that had been observing arsenic levels in the 10-50 ppb range. Initial testing by the DNR and the Wisconsin Geological and Natural History Survey (WGNHS) revealed that the geochemical explanations for arsenic contamination in northeastern Wisconsin could not explain the problem in southeastern Wisconsin (Gotkowitz, 2002), so the WGRMP funded further research to analyze the new situation and develop more appropriate guidelines (Sonzogni et al., 2003; Bahr et al., 2004; West et al., 2012). One of the important outcomes of these studies was improved understanding of how chlorine disinfection, which is often used to treat microbial biofilms (slime) in wells, can affect the release of arsenic (Gotkowitz et al, 2008). Shock chlorination of private wells should be limited in much of northeastern Wisconsin because it has a strongly oxidizing effect that encourages release of arsenic from sulfide minerals. Well chlorination does not similarly affect arsenic bound to iron compounds in groundwater environments such as southeastern Wisconsin. In these settings, well disinfection may in fact reduce arsenic levels by controlling microbes that contribute to iron dissolution.

The extensive research completed in Wisconsin over the past 20 years illustrates the highly variable nature of Wisconsin's geologic sources of arsenic to groundwater. A well with no detectable arsenic can be right across the street from a well that tests well above the MCL. Arsenic concentrations can vary over time, too. This makes regular testing – with efficient, accurate, and affordable methods – critical. WGRMP-funded researchers have been important partners in this and have designed portable field sampling kits, improved upon existing laboratory methods, and are currently working on sensors that can immediately detect arsenic levels in groundwater.

Future Work

Sampling and testing private wells remain important priorities for understanding and managing arsenic contamination in Wisconsin. To encourage private well sampling, local health departments continue to offer fee-exempt testing to low income families. The DNR and some county governments are also working to both promote well sampling programs and explore impediments to private well sampling.

In the areas of the state that are known to be vulnerable to arsenic contamination, there is a focus on reducing exposure. Several communities have expanded the service area for public water systems and moving homes from private wells to public supplies has been effective in reducing exposure in towns like Algoma in Winnebago County.

Areas outside the original region of concern in northeast Wisconsin and the more recent area of concern in southeast Wisconsin have not been as well described. Recent revisions to NR 812 now require wells to be tested for arsenic, in addition to bacteria and nitrate, during pump installation or when testing is requested during property transfers involving existing private wells, which may help to fill this data gap. In addition, researchers from the WGNHS funded by the WGRMP are currently working to understand the mineralogy of the Tunnel City rock formation in western Wisconsin, which may help define the risk of arsenic contamination in that region.

Further Reading

DNR overview of arsenic in drinking water wells [link]

DNR special well casing depth areas for arsenic [link]

DHS overview of arsenic health effects [link]

WGNHS report on arsenic release due to well disinfection [link]

WGNHS report on preliminary investigation near Lake Geneva, Wisconsin [link]

DHS report on arsenic in Wind Lake Private Wells, Town of Norway, Racine County [link]

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Pesticides

What are they?

Pesticides are a broad class of substances designed to kill, repel, or otherwise disrupt living things that are considered pests. They include insecticides, herbicides, fungicides, and anti-microbials, among other types of biocides. Normal field applications, spills, misuse, or improper storage and disposal can all lead to pesticide contamination in groundwater. As pesticides breakdown in soil and groundwater or are absorbed and metabolized by the target pest, some are converted into related compounds called **metabolites**, which may also be harmful to the pest or other living things.

Pesticide application sign. *Photo*: DATCP.

The health effects of exposure to pesticides or pesticide metabolites vary by substance. About 30 pesticides (and some additional pesticide metabolites) currently have a health-based enforcement standard (ES) in groundwater (WI NR 140.10). A smaller number have a maximum contaminant level (MCL) in drinking water (WI NR 809.20). However, at least 90 different pesticides are used on major crops in Wisconsin (WASS, 2006). Occasionally, pesticides and pesticide metabolites that do not have a groundwater ES or drinking water MCL are detected in drinking water, in which case information on health effects may be very limited or difficult to evaluate. It is also difficult to predict the health effects of multiple pesticides in drinking water; several studies indicate that pesticide mixtures can have different health effects than exposure to individual pesticides at the same concentrations (Porter, 1999; Hayes et al., 2006). A few commonly detected pesticides which do have groundwater or drinking water standards in Wisconsin include atrazine, alachlor, and their metabolites.

Atrazine is an herbicide popularly used on corn. The groundwater ES for atrazine and its three chlorinated metabolites is 3 parts per billion (ppb). The drinking water MCL for atrazine (does not include metabolites) is also 3 ppb. Some people who drink water containing atrazine well in excess of the MCL over many years could experience problems with their cardiovascular system or reproductive difficulties. A number of epidemiological and animal studies support this (Hayes et al., 2002; ATSDR, 2003; Hayes et al., 2003; Hayes et al., 2006; Hayes et al., 2011; Craigin et al., 2011; Agopian et al., 2012; Agopian et al., 2013).

Alachlor is another herbicide used on corn and soybeans. While use of alachlor in Wisconsin is being replaced by other herbicides in the same family (e.g., *metolachlor, acetochlor*) (NASS, 2015 and 2016), its metabolites still linger in groundwater. Both the groundwater ES and drinking water MCL for alachlor are 2 ppb and one of its metabolites, *alachlor ESA*, has a groundwater ES of 20 ppb. Some people who drink water containing alachlor in excess of the MCL over many years could have problems with their eyes, liver, kidneys, or spleen, or experience anemia, and may have an increased risk of getting cancer.

Occurrence in Wisconsin

In Wisconsin, the main source of pesticides in groundwater is agricultural herbicide and insecticide application. For this reason, detection is more common in highly cultivated areas where agriculture is well established, notably in the southcentral, central, and west-central parts of the state.

As of 2007, the last time DATCP conducted a statewide statistical survey of agricultural chemicals in groundwater, an estimated 33% of private wells in Wisconsin contain a pesticide or pesticide metabolite (DATCP, 2008). For wells where at least one agricultural chemical was detected, on average there are 2 to 3 pesticide compounds found in the water. The primary metabolites from alachlor and metolachlor, alachlor ESA and metolachlor ESA, respectively, are the two most common compounds. Each is found in about 22% of wells. Atrazine and its family of metabolites (total chlorinated residues, TCR) are also prevalent and occur in about 12% of wells. About 4% of well samples with atrazine TCR detections have atrazine TCR levels that exceed the groundwater ES.

GCC Agency Actions

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 concerns by implementing monitoring programs and conducting groundwater surveys, initially testing exclusively for aldicarb (Rothschild et al., 1982; Kraft 1990) but soon expanding to other pesticides and eventually pesticide metabolites as well (Postle and Brey, 1988). DATCP also developed rules to restrict aldicarb use in areas vulnerable to groundwater contamination.

When findings from these sampling surveys in the late 1980s and early 1990s showed that atrazine, a popular corn herbicide, was particularly prevalent in groundwater across the state (LeMasters and Doyle, 1989; Cowell and LeMasters, 1992), special projects were conducted to investigate how and why it reaches the groundwater. Notably, researchers funded by the Wisconsin Groundwater Research and Monitoring Program discovered that normal field application of atrazine – not just point spills and misuse – was an important source of atrazine in groundwater (Chesters et al., 1990; Chesters et al. 1991). This knowledge, combined with other findings regarding the roles of soil, geology, and agricultural management (Daniel and Wietersen, 1989; Lowery and McSweeney, 1992; Levy and Chesters 1995; Levy et al. 1998), allowed the DNR and DATCP to effectively and fairly design both groundwater standards and the atrazine rule.

A plane sprays pesticides on a field. *Photo*: DATCP.

Where atrazine use has been prohibited by the atrazine rule, follow-up studies demonstrate there is a clear reduction in atrazine levels, which generally drop below the groundwater standard in 2 to 7 years (DATCP, 2010). Many farmers would like the option to use atrazine in these areas, but they have adapted well to growing corn without it. A 2010 DATCP survey found that the vast majority of farmers in atrazine prohibition areas have not observed a decrease in yield, most believe it is not more difficult to control weeds with other alternatives, and there is an even split in those who think weed control is more vs. less costly without atrazine (DATCP, 2011a). By far, the most popular alternatives to atrazine are glyphosate-containing products such as Roundup. From a groundwater perspective, this is fortunate since glyphosate binds very tightly to soil and thus is generally not a groundwater threat. There are concerns, however, that overuse of glyphosate may lead to glyphosate- resistant weeds.

Many sampling surveys initiated by DATCP, the DNR, and other agencies in the mid-1980s to early 1990s are still ongoing today. The longest running survey on pesticides in Wisconsin began in 1985 and is designed to evaluate the potential impact of agriculture on groundwater quality by sampling monitoring wells near selected agricultural fields in areas with high groundwater contamination potential. Current results confirm that alachlor and metolachlor are the two most common pesticides in Wisconsin, followed by atrazine. Another study that has been repeated annually since 1995 focuses on re-sampling wells that have previously exceeded a pesticide standard. Over 160 wells have been sampled a second time in this survey, and over time, atrazine levels have declined in about 80% of the wells (DATCP, 2010). Many of these wells are located in what are now atrazine prohibition areas. DATCP has also conducted a statewide, statistically designed survey of agricultural chemicals in Wisconsin groundwater four times since the early 1990s (1994, 1996, 2001, and 2007). In the latest survey, nearly four hundred samples from private drinking water wells were analyzed for 17 pesticides and 14 pesticide metabolites (DATCP, 2008). Health standards have been established for 11 of the parent compounds and four of the metabolites. In addition to capturing the current picture of agricultural chemicals in groundwater, this series of studies relates these findings to land use and compares results over time to detect trends.

Future Work

In addition to continuing existing annual surveys, the statewide statistical survey of agricultural chemicals in groundwater will be repeated by DATCP in 2016 for the first time in 9 years. The new survey will analyze for close to 80 pesticide compounds, a dramatic increase over the 31 compounds tested during the last survey in 2007 and the 17 compounds tested in 2001. This reflects both changes in agricultural practices and improvements in laboratory methods capable of detecting these compounds.

One of the benefits of organic farming is the significantly decreased potential for pesticides in groundwater where organic practices are followed. As the organic market continues to expand due to increased consumer interest in organic food and reports of increased profits by organic producers (DATCP, 2011b), this may help manage the amount of pesticides reaching groundwater.

Further development of health standards and laboratory methods is of paramount importance for keeping pace with the evolving use of agricultural chemicals in order to ensure that the agricultural success that is so crucial for our state is fairly balanced with the protection of groundwater and human health.

Further Reading

DHS resources for contaminants in drinking water [link]

DNR overview of pesticides in drinking water wells [link]

DATCP water quality reports [link]

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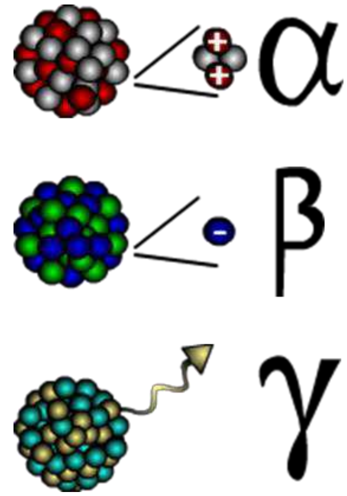
Naturally-Occurring Radionuclides

What are they?

Radionuclides are radioactive atoms. It is possible for radionuclides to be manmade, as is the case with some materials from nuclear power reactors, but they also occur naturally in rock formations and are released to groundwater over millions of years by geochemical reactions. Common naturally-occurring radionuclides in groundwater include uranium and thorium, which both decay to different forms of radium, which in turn decays to radon.



Alpha, beta, and gamma types of radiation. *Figure:* *US EPA*.

There are no groundwater standards for radionuclides in Wisconsin, but drinking water at public water systems is monitored for general indicators of radioactivity (alpha, beta, gamma activity) as well as for specific radionuclides (uranium, radium). The maximum contaminant levels (MCLs) in drinking water are 15 pCi/L for alpha activity, 4mrem/yr for beta or gamma activity, 5pCi/L for total radium, and 30 ug/L for uranium (WI NR 809.50-809.51). Some people who drink water containing alpha, beta or photon emitters, radium, or uranium in excess of the MCL over many years may have an increased risk of getting cancer. In the case of uranium, an increased risk of kidney toxicity is possible as well. There is no drinking water standard for radon, although the US EPA has proposed that radon levels be no higher than 4,000 pCi/L (where indoor air programs for radon exist) or 300 pCi/L (where indoor air programs do not exist).

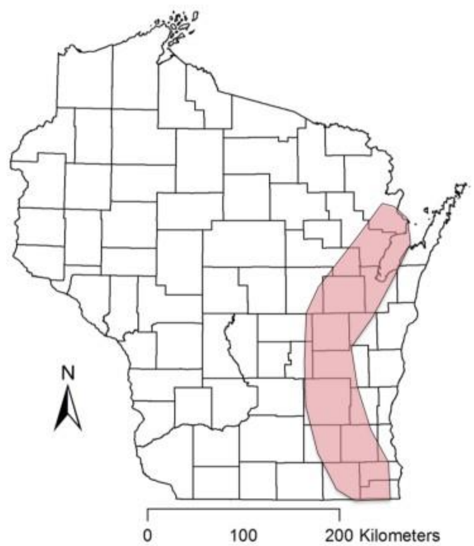
Occurrence in Wisconsin

Since radionuclides occur naturally in rock formations, every well in Wisconsin contains some level of dissolved radionuclides. In many places these levels are not concerning, but some areas of the state tend to have notably high concentrations of radium, radon, and/or gross alpha activity.

In *northern Wisconsin*, there are notably high levels of both radon and gross alpha activity. Here, the geologic source is usually granite bedrock or, in some cases, granitic sand and gravel deposits.

In *eastern Wisconsin*, wells that draw from a very deep sandstone aquifer, the Cambrian-Ordovician, to the east of where it intersects with another geological formation, the Maquoketa shale, often have levels of radium above the MCL. This band of high radium activity stretches from Brown County in the north to Racine County in the south and primarily affects public wells, since drilling deep enough to reach this aquifer is usually prohibitively expensive for smaller private systems. The geochemical explanation for the high levels is that the solubility of radium is related to the solubility of sulfate minerals in this aquifer, and the sulfate minerals that are common to the east of the Maquoketa shale are more soluble than those to the west.

About 80 public water systems have exceeded a radionuclide drinking water standard at some point in time. The DNR has been working with these systems since 2003 to ensure that they develop a



Area of Wisconsin where most of the wells that exceed the drinking water MCL for radium are located. This band coincides with where the Cambrian-Ordovician sandstone aquifer intersects the Maquoketa shale. *Figure*: *Luczaj and Masarik, 2015*.

compliance strategy and take corrective action, so currently less than 10 remain that are providing water in exceedance of the standards.

GCC Agency Actions

By the mid-1980s, regular monitoring of public water supplies in north central Wisconsin seemed to indicate that there was an increased risk of radionuclide contamination in wells drawing from the granite bedrock aquifer. This raised concerns since, at the time, drilling to this deeper granite aquifer was viewed as the best alternative if wells in the shallow sand and gravel aquifer became contaminated by manmade sources. After collecting and analyzing nearly 500 samples from this area in the late 1980s, the DNR showed that the granite bedrock aquifer is indeed a significant source of radionuclides, especially *radon*, and the DNR began taking steps to educate well owners and expand the investigation. Follow up work in other regions of the state by the DNR, WGNHS, and DHS also showed that while nearly all aquifers in the state contain some amount of radon (at or above 300 pCi/L), exceedingly high levels (over 4,000 pCi/L) are only found in granite or in sand and gravel deposits derived from granite (Mudrey and Bradbury, 1993). A few studies by University of Wisconsin researchers at this time also noted that unusually high levels of *radium* in eastern Wisconsin seemed to be related to the Maquoketa shale formation (Taylor and Mursky, 1990; Weaver and Bahr, 1991).

In the early 2000s, the flow patterns and geochemistry of groundwater in southeastern Wisconsin became of great interest as large-scale pumping driven by growing communities outside Milwaukee began to dramatically change groundwater conditions. One puzzle to scientists was why *radium* levels were elevated to the east of the Maquoketa shale in this region but not to the west – conventional understanding of the sources of radium did not seem sufficient to explain observations. Leveraging new models and knowledge about groundwater flow patterns in the Waukesha area, researchers at the University of Wisconsin and WGNHS funded by the Wisconsin Groundwater Research and Monitoring Program (WGRMP) elucidated the relationship between radium and sulfate minerals in the area, collecting much needed information on the geochemical backdrop of the region in the process (Grundl and Cape, 2006; Grundl et al. 2006).

The Wisconsin State Laboratory of Hygiene and other WGRMP-funded researchers have also made advances in sampling techniques and laboratory testing for radionuclide parameters, which tend to be very sensitive to collection and analysis methods. These studies have demonstrated how simple differences in approaches can cause one analysis to conclude a water sample is below the MCL while another can conclude the opposite about the same sample (Sonzogni et al., 1995; Arndt and West, 2004). Following these findings, researchers have developed corrections and guidelines to ensure reported test results are as accurate as possible.

Future Work

The DNR continues to work with public water systems that exceed drinking water standards for radionuclides to bring them into compliance. Options include blending water high in radionuclides with water from sources containing lower levels of radionuclides, finding an alternative water supply or constructing a new well in a low radionuclide aquifer, and softening or applying another effective radionuclide removal treatment technique to the water supply. The need for compliance with radium drinking water standards is the main reason the city of Waukesha is seeking approval for a Lake Michigan Diversion with Return Flow, the first major test of the Great Lakes Compact.

Further Reading

DHS resources for contaminants in drinking water [link]

DNR overview of radium in drinking water wells [link]

DNR overview of radon in drinking water wells [link]

WGNHS report on distribution of radionuclides in groundwater [link]

WGNHS report on radon in private wells in SE Wisconsin [link]

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Volatile Organic Compounds

What are they?

Volatile Organic Compounds (VOCs) are a group of common industrial and household chemicals that evaporate, or volatilize, when exposed to air. Examples of products containing VOCs include gasoline and industrial solvents, paints, paint thinners, drain cleaners, air fresheners, and household products such as spot and stain removers. Chemical names for the VOCs in these products include benzene, TCE, toluene, and vinyl chloride, among others. Improper handling or disposal of VOCs is often the reason why they occur in groundwater.

Collection of household products containing VOCs including paints, stains, and paint thinners. *Photo: Tom Murphy VII*

Health risks vary depending on the VOC. Short-term exposure to high concentrations of many VOCs can cause nausea, dizziness, anemia, fatigue, or other health problems. Long-term exposure to some VOCs may cause cancer, liver damage, spasms, and impaired speech, hearing, and vision. For more on the health effects of specific VOCs, see the resources listed by the Wisconsin Department of Health Services (DHS) at https://www.dhs.wisconsin.gov/water/index.htm

Occurrence in Wisconsin

At least 59 different VOCs have been found in groundwater in Wisconsin, although only 34 of those have health based standards (groundwater WI NR 140.10, drinking water WI NR 890.24). The main sources of VOCs in Wisconsin groundwater are landfills, leaking underground storage tanks (LUSTs), and a variety of facilities that use VOCs in their regular operations, including gas stations, bulk petroleum and pipeline facilities, plating facilities, dry cleaners, and other industrial facilities. The Department of Natural Resources (DNR) currently tracks about 700 current or former landfills, 20,000 LUSTs, and 8,000 other facilities which are required to monitor groundwater. The DNR also tracks approximately 33,000 spills, some of which are also sources of VOCs. Given how common potential sources of VOCs are, these substances are more frequently found in groundwater near urban industrial and commercial areas. However, exceedances of groundwater standards for VOCs have been reported in every county in the state.

Installation of a compacted clay and geotextile liner at a landfill site in Wisconsin. *Photo*: DNR

GCC Agency Actions

Drilling to monitor for VOCs near a Wisconsin landfill. *Photo*: DNR

Early studies by the DNR and DHS in the late 1980s and early 1990s focused on VOC contamination from landfills, specifically from those without linings to protect groundwater from leachate. DNR scientists found that VOCs contaminated groundwater at 60% of unlined industrial landfills and 80% of unlined municipal solid waste landfills (Friedman, 1988; Batista and Connelly, 1989). Further review of monitoring data showed that while VOC levels typically decrease following the closure of unlined landfills, concentrations remain high and do not always show continued improvement with time (Battista and Connelly, 1994). In the late 1990s, this knowledge raised concerns since increasing numbers of residential developments were located close to old, closed landfills. In 1999, the DNR and DHS designed targeted sampling of private wells near old, closed landfills to investigate and address the problem. For wells where VOCs were detected above drinking water standards, residents were given health advisories not to drink water and the DNR took follow-up measures at the nearby landfills. Much more stringent engineering standards have guided the design of modern landfills (those built after the 1980s), so these have a much better record in terms of VOC contamination, but older landfills continue to remain a concern (US DHHS, 2006).

A critical role of GCC agencies is identifying and monitoring all known sources of VOCs, not only landfills. The Department of Agriculture and Consumer Protection (DATCP) keeps track of all underground storage tanks (USTs) with a capacity of 60 gallons or greater; this registry has identified over 180,000 USTs since 1991. Hazardous waste treatment, storage, and disposal facilities must be licensed by the DNR and are subject to corrective action authorities in the event of spills or releases. The DNR's Bureau for Remediation and Redevelopment oversees investigation or remediation at approximately half of the 140 sites that fall into this category. More broadly, the Hazardous Substance Spill Law requires immediate notification to the DNR when any hazardous spills or discharges occur and requires that all necessary actions be pursued to restore the environment to the extent practicable. The spills program also 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.

Future Work

Continuing to identify and monitor known sources of VOCs is key to continued protection of drinking water. Each year, several hundred contaminated sites, some of which involve VOCs, are reported to the DNR and each year, cleanup begins at another several hundred sites. Continuing to track and respond to this ongoing issue remains an important objective for GCC agencies.

Further Reading

DHS resources for contaminants in drinking water [link]

DNR overview of VOCs in private drinking water wells [link]

DNR map of open and closed contaminated sites [link]

DNR database of contaminated soil and groundwater [link]

DHS overview of vapor intrusion [link]

USGS report on VOCs in the nation's groundwater and drinking water wells [link]

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Emerging Contaminants

What are they?

An emerging contaminant is a substance that has not historically been considered a contaminant, but for which there is increasing evidence that it is present in the environment and may cause adverse human and environmental health effects. Some emerging contaminants have been present in the environment for a long time but could not be detected until the development of new testing methods. Others are of concern due to recent changes in synthesis, use, or disposal practices. Research on the occurrence and health effects of these contaminants is important to characterize the nature of the risk and decide what actions may be required to protect human and environmental health.

Pharmaceuticals, including antibiotics, birth control pills and other prescription medicines are one class of contaminants of emerging concern. *Photo: US Department of Defense*

Emerging contaminants often enter the groundwater from wastewater from municipal, industrial, or agricultural sources, although some come from naturally occurring sources. Pharmaceuticals, such as antibiotics, birth control pills, or other prescription medicines, are a large group of emerging contaminants from human-generated waste streams. Another is personal care products (PCPs), which include shampoos, detergents, and “over-the-counter” non-prescription medicines. Other broad classes of emerging contaminants include viruses and agricultural pesticides and their metabolites.

Health effects vary and are not always well understood. Some emerging contaminants, including some pesticides, pharmaceuticals and PCPs, act as endocrine disrupting compounds (EDCs), which adversely affect the behavior of natural hormones in animals and humans. EDCs include both anthropogenic chemicals, such as pesticides and plasticizers, and naturally occurring compounds like steroids and plant-produced estrogens. Scientific studies suggest these compounds may cause developmental, reproductive, neurologic, and immune problems as well as cancer (NIH, 2010), but more research is needed on many of them.

Occurrence in Wisconsin

The occurrence of emerging contaminants in Wisconsin is not easily generalized, but several studies supported by the GCC have investigated the potential for certain emerging contaminants to enter groundwater from specific sources.

Wastewater effluent. Antibiotics have been detected in treated wastewater effluent from facilities across the state, with very low concentrations of tetracycline and sulfamethoxazole detected in one groundwater monitoring well directly adjacent to a groundwater discharge site (Karthikeyan and Bleam, 2003). In treated effluent from private on-site wastewater treatment systems (POWTS), acetaminophen (Tylenol), paraxanthine (a caffeine metabolite) and the hormones estrone and β-estradiol have been detected in Dane County (Bradbury and Bahr, 2005) and estrogenic EDCs have detected in southeast Wisconsin (Sonzogni et al., 2006). Neither study detected compounds in groundwater monitoring well samples. However, a follow up study at the Dane County site ten years after development of a subdivision found a number of contaminants that may have moved from POWTS into groundwater: artificial sweeteners were found in seven of ten monitoring wells and two domestic wells, human enteric virus indicators were found in three monitoring wells, and pathogenic bacteria indicators were found in one monitoring well (Bradbury et al., 2015). Other studies also suggest human enteric viruses from wastewater may be present in private and public drinking water wells across the state (Borchardt et al., 2003a, 2003b, 2004, 2007; Bradbury et al. 2013).

Pete Chase and Jacob Krause, WGNHS, install well casing during a WGRMP-funded experiment designed to improve understanding of virus transport from wastewater to drinking water wells. *Photo: Blake Russo-Nixon*.

Agricultural sources. Due to the expense of testing and the limited analytical methods available, only a fraction of the pesticides applied to agricultural fields and their metabolites have been tested for in groundwater. However, DATCP's most recent statewide statistical survey of agricultural chemicals in groundwater found that approximately 33% of private wells in Wisconsin contained at least one of the 31 pesticides and pesticide metabolites analyzed (DATCP, 2008). The most commonly detected compounds do have health-based groundwater standards, but the potential health effects of others are less well understood. Hormones from livestock operations were detected in runoff and tile drain water from one agricultural field in a study funded by the Wisconsin Groundwater Research and Monitoring Program (WGRMP), but they were not found in nearby groundwater monitoring wells (Hemming et al., 2013). A different study evaluated wells in northeastern Wisconsin that were suspected of being impacted by agricultural activities due to nearby land use and contamination with bacteria and/or nitrate (Bauer-Dantoin, 2009). These researchers identified estrogenic activity in some groundwater samples from these wells.

Industrial sources. Municipal and industrial landfills and hazardous waste clean-up sites are always sources of concern for both known and emerging contaminants. One example of emerging contaminants suspected to originate at these sites are perfluoroalkyl substances (PFASs), organic molecules that have a number of industrial applications including use in firefighting foams and as a carpet, upholstery, and fabric protector. These compounds were detected in three public water supply wells during monitoring for unregulated contaminants required by the US EPA from 2013-2015. It is suspected they may be present in groundwater at other locations near firefighting training sites and facilities that manufacture products containing PFASs.

Natural geologic formations. The susceptibility of groundwater to contamination by natural trace elements depends on the geochemical environment, which can be highly variable spatially and temporally and is not always well described. Strontium is emerging as a trace element of concern in eastern Wisconsin, particularly in the Brown and Outagamie county areas. A recent study detected strontium above the US EPA's health advisory limit in about 63% of well samples from this area (Luczaj et al., 2013) but the full extent of groundwater with high strontium levels is not well documented, nor are the potential health effects.

GCC Agency Actions

By definition, much is unknown about emerging contaminants, so an important role of the GCC is supporting research studies that further scientific understanding of these substances. In addition to the many studies mentioned above that tested for occurrence of emerging contaminants, other WGRMP-funded projects have explored pathways of contaminant transport. One group of these studies investigated factors that affect the mobility and fate of antibiotics in the subsurface (Gao and Pedersen, 2005 and 2010; Gu and Karthikian, 2005a, 2005b, 2008; Gu et al., 2007; Sibley and Pedersen, 2008; Pedersen et al., 2009). This body of work has helped describe under what conditions specific antibiotic compounds bind to soil, which is important for assessing the risk to groundwater from antibiotics in wastewater sources.

Nested piezometers installed for monitoring groundwater levels and sampling for groundwater contaminants near Spring Green. *Photo: Blake Russo-Nixon*.

Ongoing groundwater monitoring in areas known to be vulnerable to emerging contaminants is another way in which GCC agencies coordinate efforts to understand emerging contaminants. DATCP's regular statistical survey of agricultural chemicals and DATCP's targeted monitoring programs in agricultural areas are good examples of this. The DNR also regularly reviews groundwater data from near active and closed landfills, mining operations, and hazardous waste remediation sites.

Future Work

In Wisconsin law, there is an established process that facilitates regular review of groundwater monitoring data and identification of contaminants of emerging concern (WI 160.27). A fundamental component of this process is the long-term groundwater monitoring data itself, so maintenance and expansion of current networks is an ongoing priority for the GCC.

The US Environmental Protection Agency (EPA) also has a process for regularly gathering data on emerging contaminants and assessing potential risks nationwide. The Unregulated Contaminant Monitoring Rule (UCMR) provides for monitoring of no more than 30 unregulated contaminants every five years in all large (serving >10,000 people) public water systems and a representative sample of small (serving <10,000 people) public water systems. The Third UCMR (UCMR3) monitoring period was completed in 2015 and monitoring for the Fourth UCMR (UCMR4) will occur from 2018-2020. Data collected at Wisconsin public water supply systems during UCMR monitoring supplements data from other GCC-supported monitoring and occurrence studies.

The US EPA also maintains a Contaminant Candidate List (CCL) of physical, chemical, biological and radiological substances that might potentially be found in drinking water. Potential contaminants listed on the CCL are substances not currently subject to federal Safe Drinking Water Act (SDWA) regulation but are known, or anticipated to be, present in public water supply systems. The US EPA evaluates occurrence data on these unregulated contaminants and this information assists with identification of potential emerging contaminants in Wisconsin groundwater.

Further Reading

DNR overview of pharmaceuticals and PCPs in the environment [link]

Wisconsin Contaminated Lands Environmental Action Network [link]

DATCP Water Quality report [link]

NIH factsheet on endocrine disruptors [link]

US EPA Third Unregulated Contaminant Monitoring Rule (2012-2016) fact sheets [link]

US EPA Third Unregulated Contaminant Monitoring Rule (2012-2016) data summary [link]

US EPA Fourth Unregulated Contaminant Monitoring Rule (2017-2021) information [link]

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Water Use

Chapter 281 of the Wisconsin Statutes requires annual reporting to the Wisconsin Department of Natural Resources (WDNR) of monthly withdrawals from all wells and surface water withdrawal systems capable of supplying water at a rate of 100,000 gallons per day or more. This includes water uses such as public supply systems, energy production, paper manufacturing and agricultural irrigation. Reporting data is spatially located such that inquiries can be customized to specific locations, withdrawal types and water uses. The annual collection of these reports facilitates understanding of spatial and temporal trends in water withdrawals.

Results from 2014 reporting show that the largest category of groundwater withdrawals was municipal public water supplies, accounting for 98 billion gallons in 2014, a increase of 6% from 2013 (WDNR 2015). The second largest category of groundwater withdrawal in the state was agricultural irrigation, totaling 77 billion gallons-a decrease of 24% from 2013.

Reference:
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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.

With financial support from the DNR, the Wisconsin Geological and Natural History Survey constructed a groundwater flow model for the Little Plover River watershed in Portage County. This model is a scientific tool for understanding the complexities of geology, groundwater recharge and discharge, surface-water flow, well development and use, and water balance. The model simulates the complex temporal and spatial interactions among streamflow, pumping, and climate and also provide users "what-if" evaluations of possible decisions involving management of water use or land-use changes. The Little Plover River Basin was chosen for this pilot study because the river has been the focus of recent management concern and because a great deal of hydrogeologic data already exists for this area. (https://fyi.uwex.edu/littleplovermodel/files/2014/08/Little-Plover-River-handout.pdf)

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, 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.

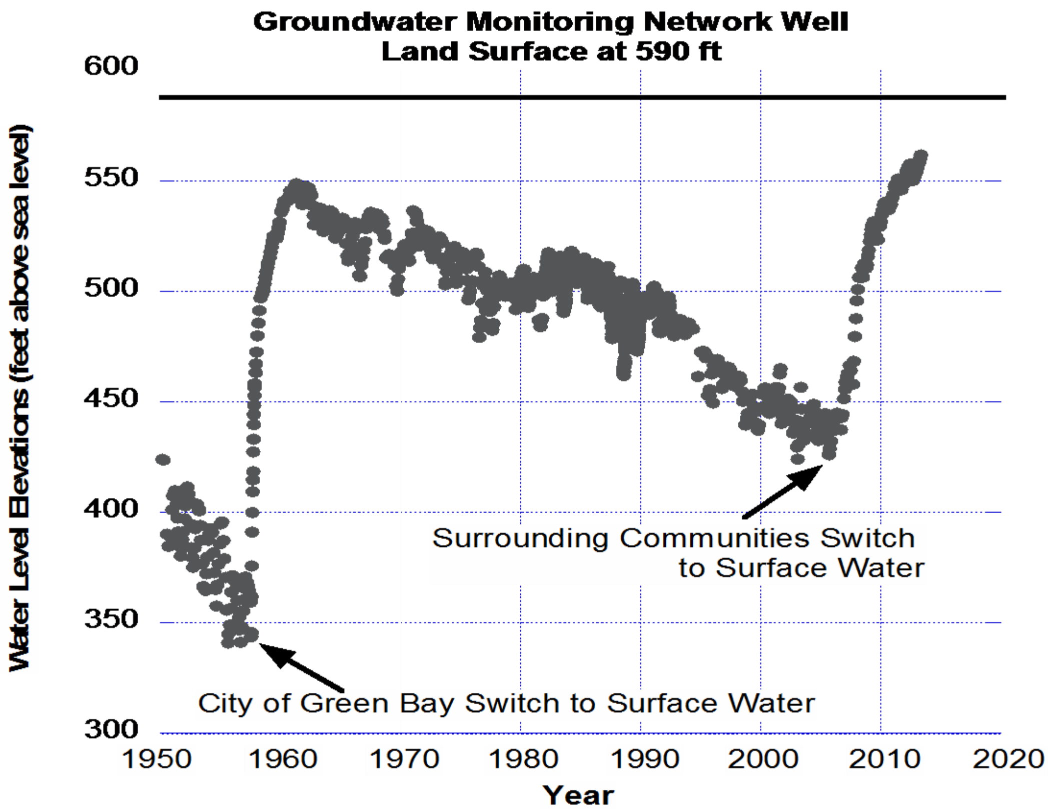

Figure 1: Changes in groundwater levels in a groundwater level monitoring well in Green Bay, Wisconsin (WGNHS)

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.

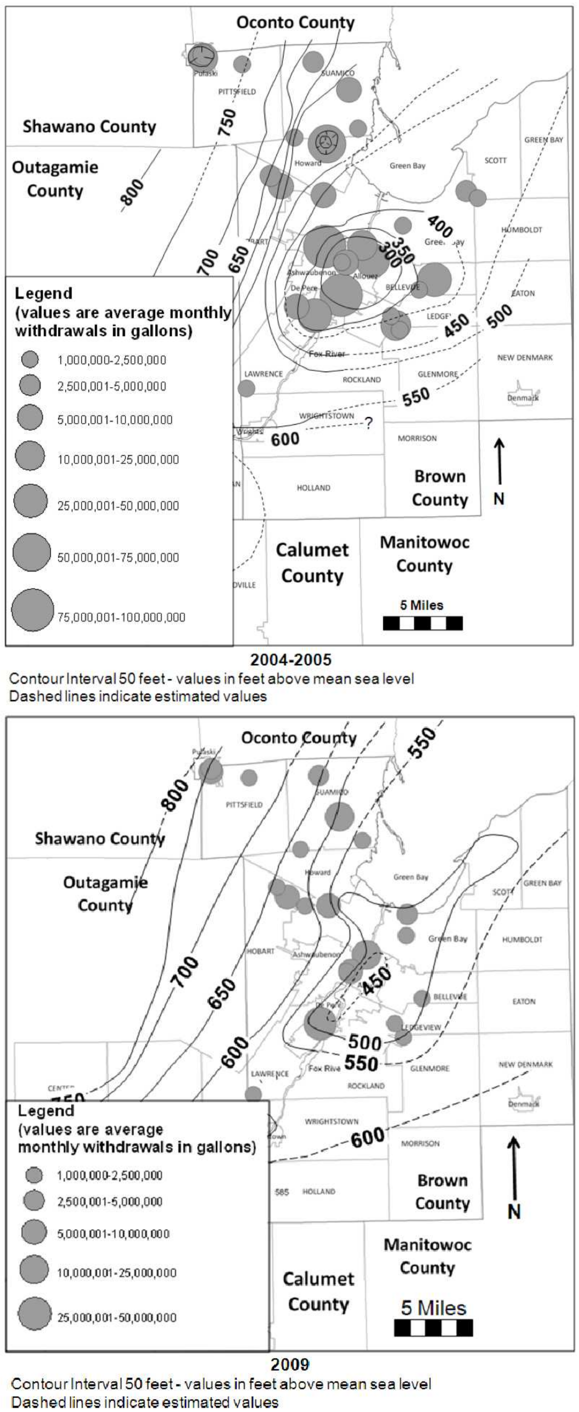

Figure 2: Water table elevations in Brown County (WGNHS).

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 pC/l. Treatment of that water can be costly, leading some communities to look at other water sources.

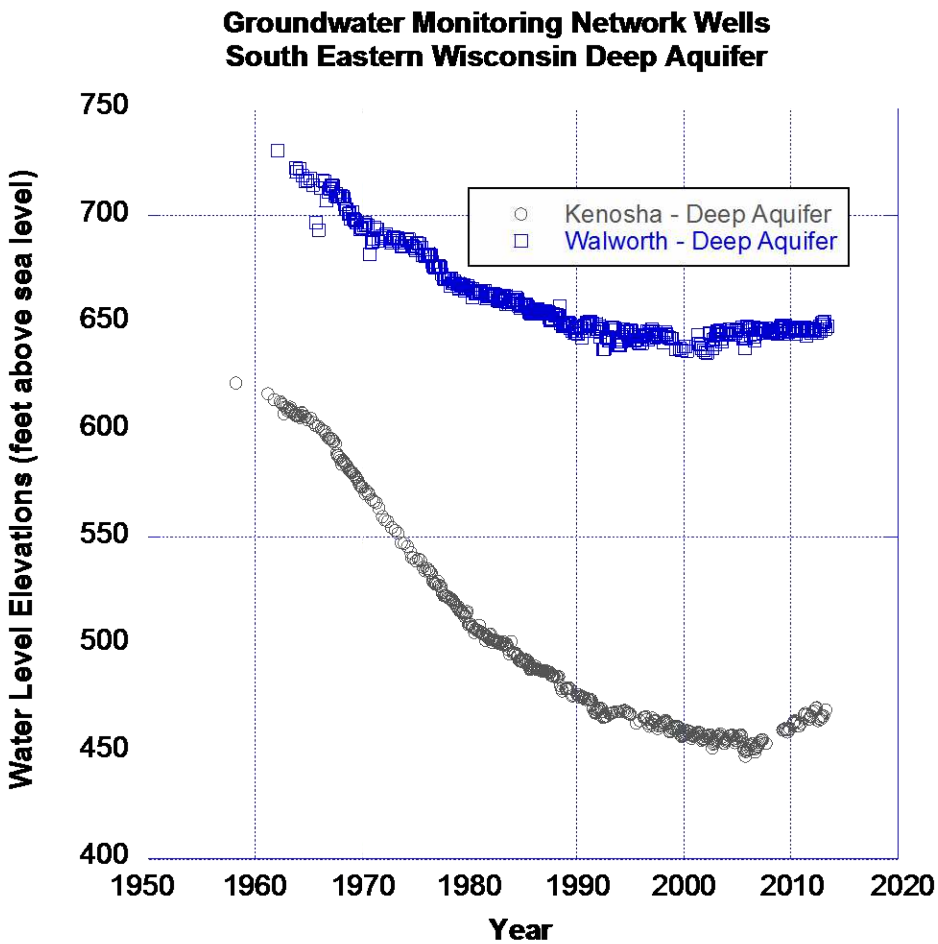

Figure 3: Water levels in a groundwater level monitoring wells in Kenosha and Walworth counties (WGNHS).

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

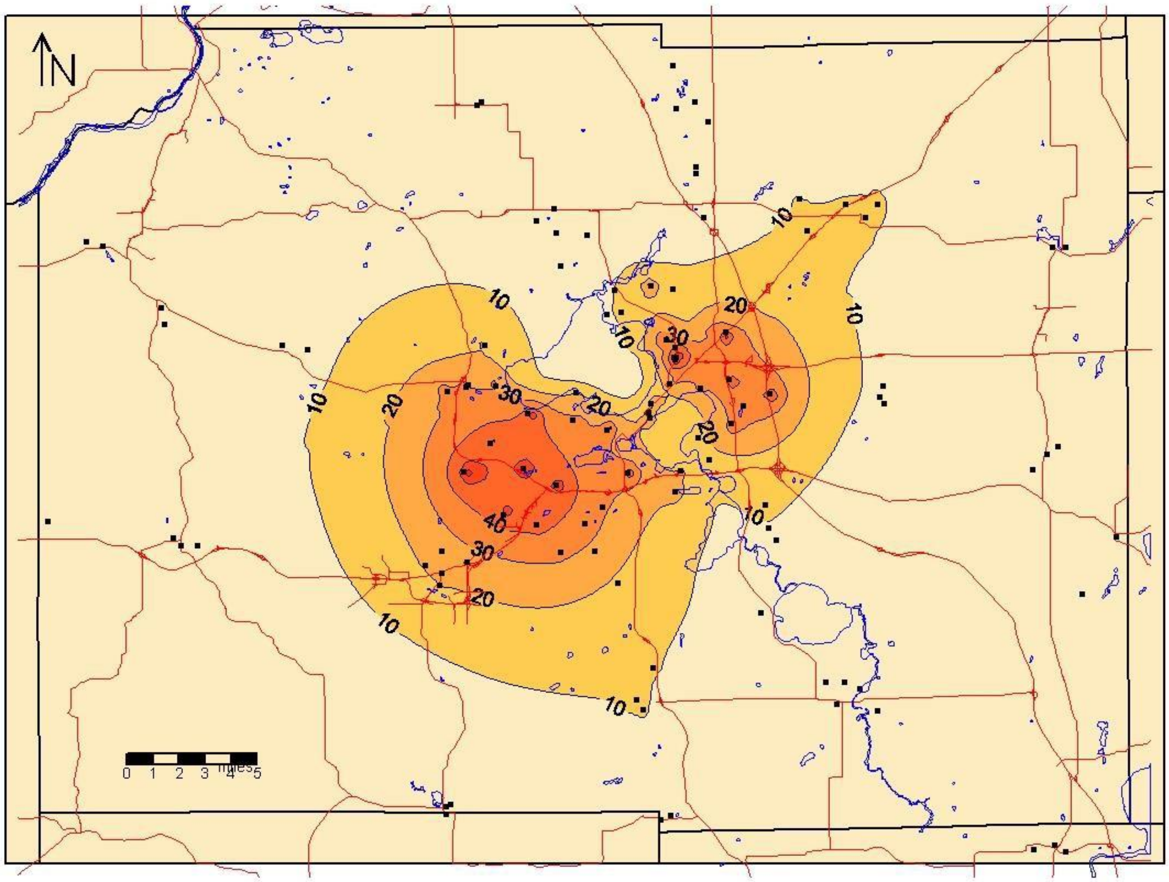

Figure 4 - Simulated drawdown (feet) in the Mount Simon Sandstone; predevelopment to 2000. The Mount Simon Sandstone, located several hundred feet below land surface and up to 800 feet thick, is the lowermost aquifer unit within Dane County. This porous sandstone is a highly productive aquifer which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

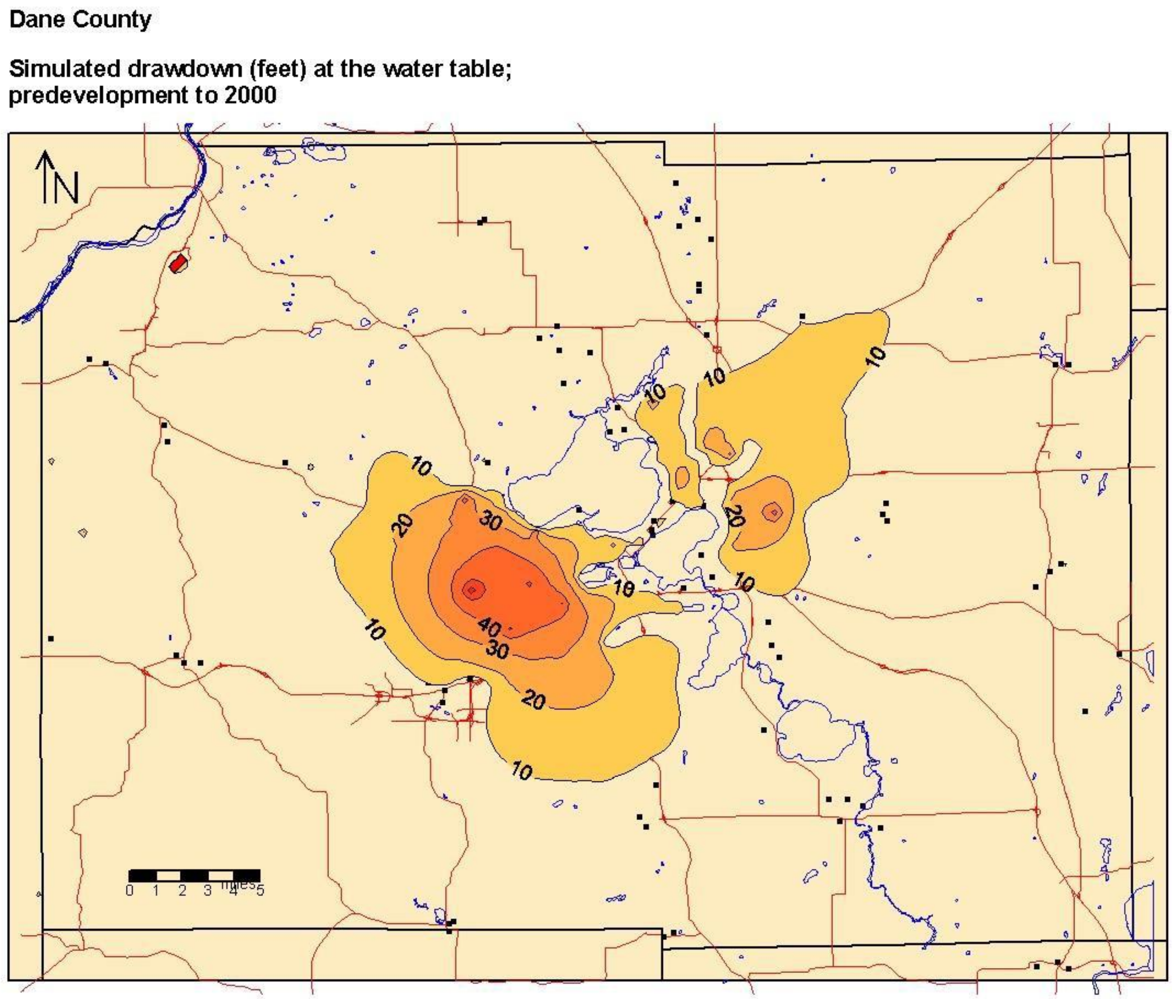

Figure 5 - Simulated drawdown (feet) at the water table; predevelopment to 2000. Drawdowns from the lower Mount Simon aquifer system propagate upwards to the shallow sand and gravel and upper bedrock aquifer systems to create drawdowns at the water table.

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:
Joachim DR, Gotkowitz MB, Vavrus SJ, Loheide SPI, Bradbury KR. 2011. Forecasting Impacts of Extreme Precipitation Events on Wisconsin's Groundwater Levels, Wisconsin Geological and Natural History Survey, Open File Report 2011-03

Wisconsin Groundwater-Level Monitoring Network

Wisconsin's statewide 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, working in close cooperation with the Wisconsin Department of Natural Resources (WDNR). As of June of 2016, this network consists of 93 long-term monitoring wells, two spring gaging stations and 57 project-specific, limited-term monitoring wells. The 93 permanent wells and 2 spring gaging stations are located in 45 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 also routinely used in the development of regional groundwater flow models, as long-term water-level measurements serve as reliable calibration targets.

On a day-to-day basis the USGS and WGNHS continue to support the evaluation and maintenance of the monitoring network, aids in data collection, interpretation, and provides information to public and private clients through dedicated webpages. The WGNHS provides a general overview of the monitoring network (*http://wgnhs.uwex.edu/water-environment/groundwater-monitoring-network*), while the USGS maintains an interactive portal for viewing and downloading data (*http://wi.water.usgs.gov/data/groundwater.html*).

The WGNHS and USGS, at the request of the DNR, have recently completed a proposal to add new wells, lake, and stream gages to the monitoring network in four areas where high capacity well applications are prevalent and water level data are sparse. These areas include: the Antigo Flats in Langlade Co.; several sites near the groundwater divide on the eastern edge of the Central Sands (Adams, Marquette, Portage and Waushara, Cos.); and in the Southern Rock River Valley in Rock Co. And lastly, in an area in West Central Wisconsin (Dunn and St. Croix Cos.) where we hope to partner with the US Fish and Wildlife Service and potentially use existing wells present on federal or state lands when those properties were acquired.

Over the past year, the USGS and WGNHS have partnered with Chippewa, Dunn, and Eau Claire counties to begin a pilot deployment of Wellntel (*www.wellntel.com*) water-level monitoring equipment. Wellntel is a private-sector company that has developed an inexpensive, remotely operated, groundwater-level monitoring system that can be readily installed in wells to obtain real-time groundwater-level data. This pilot study seeks to evaluate the suitability of Wellntel systems for collecting water-level data in a variety of groundwater settings and compare the results to existing monitoring techniques. Provided the Wellntel systems meet testing requirements, the hope is that they could be rapidly deployed to collect groundwater-level data in key areas across the state.

The WGNHS is also pleased to report that a recent grant application to the USGS National Ground-Water Monitoring Network (NGWMN) program has been approved for funding. The grant amount is for nearly $90,000 and will allow for several repairs to the long-term monitoring network, including the redevelopment of existing wells and the drilling of replacement wells.

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.