PLENARY SESSION
The Waters of Wisconsin Initiative: Update, Results and Next Steps
Thursday, February 27, 2003
12:45 – 2:15 p.m.

Abstract

For the last three years, the Waters of Wisconsin (WOW) initiative, organized by the Wisconsin Academy of Sciences, Arts and Letters, has involved hundreds of the state's leading water experts and concerned citizens. This effort has sought to foster informed discussion of the status and trends that characterize our state's waters, to consider the sustainability of our water resources and aquatic ecosystems, and to focus thinking on long-term policy and educational needs to ensure a healthy future for our waters and all that depends on them. The report of the WOW committee is being completed. In this session, Dr. Curt Meine, director of conservation programs at the Wisconsin Academy, will lead a panel of WOW committee members in a discussion of the report's findings and recommendations and next steps in carrying out the work of the initiative. Invited speakers are committee co-chair Pat Leavenworth, state conservationist for the USDA Natural Resources Conservation Service; Dr. George Kraft, director of the Center for Watershed Science and Education at UW-Stevens Point and UW-Extension; and Todd Ambs, newly named administrator of the Water Division of the Wisconsin Department of Natural Resources.

Biographies

Todd Ambs is the administrator of the Water Division, Wisconsin Department of Natural Resources. He brings more than 20 years of experience working for nonprofit and governmental agencies to this position, including serving as executive director for the River Alliance of Wisconsin and executive director of Rivers Unlimited, a statewide river protection organization in Ohio. Ambs also has an extensive management background, having coordinated numerous public policy, regulatory and legislative projects at the state and national levels. He also played a key role on Governor Jim Doyle's transition team.

George Kraft is a professor of Water Resources and director of the Center for Watershed Science & Education at UW-Stevens Point and UW-Extension. His position is largely dedicated to serving the citizens, businesses and governments of Wisconsin through UW-Extension outreach. Some of his recent outreach activities have included reforming Wisconsin's groundwater pumping laws and assisting stewardship groups in organizing and managing their water resources. Dr. Kraft's research interests revolve around issues of water resource sustainability, particularly questions about profitable agriculture and water impacts.

Pat Leavenworth has served as the Wisconsin State Conservationist for the U.S. Department of Agriculture Natural Resources Conservation Service since September 1994. Since then, she has overseen implementation of the federal farm bill, agency restructuring and the metamorphosis of the former Soil Conservation Service into the new Natural Resources Conservation Service. She holds a BA degree from Mount Holyoke College in Biological Sciences and received a Masters degree in forest science from Yale University. Pat places a high priority on the development of partnerships with organizations and individuals to achieve voluntary, incentive-based conservation on private lands.

Curt Meine is director of conservation programs at the Wisconsin Academy of Sciences, Arts and Letters. He received his graduate degrees from the Institute for Environmental Studies at the University of Wisconsin-Madison. He is author of the biography *Aldo Leopold: His Life and Work* (1988), editor of the collection *Wallace Stegner and the Continental Vision: Essays on Literature, History, and Landscape* (1997), and co-editor with Richard L. Knight of *The Essential Aldo Leopold: Quotations and Commentaries* (1999). He is also active in local conservation as a co-founder and member of the Community Conservation Coalition for the Sauk Prairie in Sauk County, Wisconsin.

SESSION 1A:
Surface Water Studies
Thursday, February 27, 2003
2:45 – 3:45 p.m.

Hydrogeologic and Vegetative Gradients Across a Wetland Transect in South Central Wisconsin

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The temperate, semi-humid climate of Madison, Wisconsin, supports productive and diverse wetlands. Cherry Island, located in Cherokee Marsh, is surrounded by a relatively undisturbed area of wetland consisting of plant communities common within the prairie landscape. The study area includes a fen, sedge meadow and shallow marsh. These distinct communities are hydraulically connected, providing an unusual opportunity to characterize the hydraulic, vegetative and chemical gradients to determine patterns relating to landscape changes. Cherry Island is located in a glaciated area with a variable subsurface composition of till and peat. The lateral variation in subsurface stratigraphy influences the resulting hydrology and, quite possibly, the vegetation pattern. Continuous sampling of water levels with in situ loggers; field chemical analyses characterizing alkalinity, total iron, dissolved oxygen, and conductivity; as well as lab analyses of major ions, oxygen and hydrogen isotopes are some of the methods employed—in addition to two vegetative surveys. Vegetation analysis revealed a transition of dominant sedge species, which appear to correspond to changes in hydrology from a groundwater-to-surface water-dominated system. The preliminary results of this study indicate that the presence of wetland-defining plant communities is dependent not only on hydrology, but also on water chemistry and subsurface stratigraphy in a unique combination that may vary from site to site.

Keywords: hydrogeology, wetland, geochemistry, prairie landscape, vegetation

*Note: This is a student presentation.

Stream Assessments, Restoration and Watershed Management: An Automated Approach Using GIS

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Watershed development and changes in land use modify the landscape and alter the natural pathways of surface water and groundwater. Increased development results in an increase of stormwater runoff and flood potential, a decrease in groundwater levels, and ultimately results in the degradation of stream stability and its ability to support aquatic ecosystems. Stream restoration is intimately connected to the watershed and requires a watershed-based management approach to support a healthy and functional surface water system.

Stream assessments are one of the first steps to a successful stream restoration program. The assessment inventories each reach where site-specific habitat and infrastructure metrics can be used to 'rank' each reach based upon these metrics. Inventorying and ranking streams based on their restoration need and habitat condition can allow watercourse managers to effectively allocate capital improvement project budgets, manage/maximize mitigation banking credits, effectively target 303d listed streams, and implement stormwater, BMP, and watershed management programs.

The development and application of GIS-based tools to collect, analyze, and present land use, stormwater infrastructure, and field (stream survey) data, and to automate quantification of stream and watershed quality and integrity will be presented. A stream assessment and quantification protocol has also been incorporated into the GIS system and will be discussed.

Keywords: stream assessment, stream restoration, GIS, watershed management, rapid bioassessment protocols

Sources and Variability of Cryptosporidium in the Milwaukee River Watershed

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Recent well publicized, waterborne Cryptosporidium outbreaks involving large numbers of people and some deaths have been attributed to possible treatment deficiencies linked with watershed contamination. Understanding the occurrence and variability of Cryptosporidium in a watershed is critical to the production of a safe drinking water supply. Essential to this understanding is the ability to characterize potential sources of Cryptosporidium and predict their occurrence in a watershed. The purpose of the work described in this report is to define the relative magnitude and contributions of Cryptosporidium from major non-point sources defined by urban and rural land uses and point-source wastewater discharges, and to characterize contributions of each source by factors such as hydrograph timing, climatic effects and seasonal variations. An urban subwatershed, a rural subwatershed, a CSO in Milwaukee, and three publicly owned sewage treatment works (POTW) wastewater outfalls were examined. Each of the sites was continuously monitored for streamflow and precipitation. Cryptosporidium and turbidity samples were collected using both a fixed-interval and a runoff event-based schedule. The researchers estimate that the largest source of Cryptosporidium oocysts in a large diverse watershed was from urban streams, followed by rural/agricultural streams and finally, almost insignificantly from wastewater effluents. The largest concentrations of oocysts at both subwatersheds occurred during runoff events. For this reason, automated or other intensive sampling methods are necessary for reliable evaluation of Cryptosporidium concentrations during runoff event periods.

Keywords: pathogen loading, event monitoring, statistical model, land-use

SESSION 1B:
Agriculture and Groundwater
Thursday, February 27, 2003
2:45 – 3:45 p.m.

Atrazine in Shallow Groundwater of the Western Lake Michigan Drainages: Looking for Trends

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The Western Lake Michigan Drainages (WMIC) is a study unit of the National Water-Quality Assessment (NAWQA) program. The objectives of the NAWQA program are to describe the status and trends in the water quality of the nation's streams and aquifers. In 1994, 30 shallow groundwater wells were installed in the glacial deposits of the southwest part of the WMIC study unit. The network of wells was designed to study long-term agricultural effects on shallow groundwater quality. The wells were screened near the water table and located adjacent to fields that primarily have a corn and alfalfa rotation. The wells were sampled during the summers of 1994 and 2002 for a wide range of constituents, including pesticides. Additionally, the recharge date of the 1994 samples was determined using chlorofluorocarbons (CFCs).

The most commonly detected pesticide for both sample periods was atrazine or one of its metabolites, deethyl atrazine; detected in 28 of 30 samples from 1994, and 22 of 26 samples from 2002. Median concentrations of the atrazine plus deethyl atrazine decreased slightly from 0.166 μg/L in 1994 to 0.163 μg/L in 2002. This difference was not statistically significant. CFC-based ground-water recharge dates indicate that collected samples span the entire period of atrazine use in Wisconsin from the 1960's to present. Temporal trends in atrazine concentration roughly correspond to trends in historical atrazine use.

Keywords: atrazine, groundwater, trends

Nitrate and Pesticide Loading, Fate and Origin in a Wisconsin Groundwater Basin

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Nitrate and pesticide residues are the major pollutants of Wisconsin's groundwater. An estimated 14% of Wisconsin's wells exceed the nitrate drinking water standard and 38% contain the residues of at least one pesticide. Agriculture is by far the largest source of these pollutants. The rise of nitrate and pesticide groundwater pollution coincides with the increase in commercial fertilizer and pesticide use that began in about 1960 and leveled off in the 1980s.

A key need is to determine long-term nitrate and pesticide trends for Wisconsin aquifers. Are they increasing as older, clean groundwater discharges and is replaced by younger, pollutant-laden recharge? Or do denitrification and degradation processes limit the penetration of agrichemicals into aquifers? We investigated these questions by monitoring along a flowpath in a groundwater basin near Whiting, Wisconsin. Groundwater was analyzed for general geochemistry, major ions, nutrients, metals, pesticide, nitrate ^{15}N and ^{18}O, and CFCs for determining groundwater age.

Preliminary results indicate that groundwater originating from modern agricultural practices contains nitrate concentrations of 14-41 mg L^{-1} NO3-N. Residues of the pesticides atrazine, alachlor, and metolachlor were common, with summed concentrations ranging up to 42 μg L^{-1}. Denitrification does not seem to be an effective nitrate-sink. Further investigation will answer questions regarding nitrate steady-state conditions and examine pesticide fate issues.

Keywords: groundwater, nitrate, pesticide, agriculture, land-use

*Note: This is a student presentation.

Denitrification in Shallow Groundwater: Management-intensive Grazing Versus Annual Cropping on Sandy Soils

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Dung and urine patches can impair groundwater quality beneath management-intensive grazing (MIG) operations by leaching nitrogen. However, pasturing can also increase the supply of soluble or mobile organic compounds to microorganisms in shallow groundwater, and can therefore stimulate denitrification. In this paper we show that denitrification improved groundwater quality to a greater extent under a MIG site than a corn cropping site.

A grid (n=91) of shallow miniature wells was established within a MIG paddock. In addition, three wells were installed in a radial pattern around dung (n=6) and urine (n=6) patches within the paddock. At a nearby physically similar cornfield a grid (n=26) of shallow miniature wells was established for the comparison. Potentionmetric head, dissolved solutes and dissolved gases in shallow groundwater were mapped at the paddock and cornfield.

Total dissolved nitrogen, nitrate and nitrous oxide were nearly tenfold higher in concentration beneath the cornfield. Groundwater was generally oxygenated at both study sites but the incidence rate of anaerobic grid nodes was higher at the MIG site. Both dissolved organic carbon and dissolved carbon dioxide were higher in groundwater at the MIG site. Denitrified N as a percentage of total nitrate (NO_3-N + excess N_2-N) was about tenfold higher at the MIG site (based on median denitrification rates of about 60% of total nitrate beneath the MIG site and 5% of the total nitrate beneath the cornfield). Denitrified N varied directly with recharge temperature for the MIG site but was unrelated to temperature for the cornfield, suggesting different processes at the two sites.

Keywords: nitrous oxide, excess nitrogen gas, denitrification, dissolved organic carbon, recharge temperature

SESSION 2A:
Surface Water Chemistry
Thursday, February 27, 2003
4:05 – 5:25 p.m.

Calcium and Phosphorus in a Hardwater Eutrophic Lake

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Hardwater lakes are common in Wisconsin because the groundwater inflow often contains high concentrations of dissolved calcium and magnesium. Calcium precipitation in these lakes has been studied because of the influence on algal and aquatic plant growth. Phosphorus reaction with calcium solids has been suggested as a means to reduce the amount of available phosphorus. A reduction of phosphorus typically limits plant and algae growth in lakes.

McGinnis Lake is a 33-acre hardwater, yet eutrophic, lake in southeastern Adams County, Wisconsin. Despite evidence of calcium precipitation, this groundwater-fed lake has high concentrations of phosphorus. The calcium precipitation appears to be significantly influenced by the hydrology and morphology of the two lobes of the lake and the pattern of groundwater inflow. Phosphorous concentrations appear related to the heavy stands of macrophytes, dominated by *Potamogeton crispus,* and their senescence. In this study, we monitored surface water and groundwater, paying close attention to calcium, magnesium and phosphorus concentrations to understand the impact of calcium removal and macrophytes on phosphorus concentrations.

Keywords: calcium carbonate, phosphorus, hardwater lakes, eutrophication

*Note: This is a student presentation.

An Overview of In-Lake Results from the Mercury Experiment to Assess Atmospheric Loading In Canada and the United States (METAALICUS)

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In response to considerable evidence that atmospheric transport, deposition and re-emission of mercury are key to its global cycle, researchers are studying the fate of newly deposited mercury on a watershed in northwest Ontario, Canada. Stable isotopes are used to differentiate between the newly deposited and the standing pool of mercury. These techniques will provide the first direct evidence of a watersheds' response to changing atmospheric inputs, and will inform pending controls on mercury emissions that may cost more than several billion dollars to implement.

Stable isotopes of mercury were applied to three watershed compartments totaling 60 hectares: the upland, the wetland and the surface of a dimictic lake. Each compartment received ~ 5 times the annual background atmospheric deposition for the region.

Results from two years of data show that new mercury is extremely particle-reactive. There has been little transport of the terrestrial spike to the lake. In the water column, the isotopic amendment ranged from 0 to 0.8 ng L^{-1} in the filtered phase compared to 1.5 to 4 ng L^{-1} native mercury. At times, the isotopic amendment was up to 40% of the native pool. Methylation of the isotopic mercury was first noted two weeks after the initial spike and reached 50% of the native MeHg concentration on hypolimnetic particles. Implications for the availability of newly deposited mercury for methylation will be presented, along with a summary of the major study findings to date.

Keywords: isotopes, methylation, bioaccumulation, hypolimnion, partitioning

Factors Controlling the Fate and Transport of Mercury and Methylmercury in Hypolimnetic Lacustrine Environments

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As part of the Mercury Experiment To Assess Atmospheric Loading in Canada and the United States (METAALICUS), the biogeochemical cycling of mercury and methylmercury (MeHg) (Hg) is being investigated to better understand the relationship between atmospheric loading and bioaccumulation. Lake 658, an 8-hectacre first-order boreal lake, was dosed bi-monthly with stable ^{202}Hg nine times during each summer of 2001 and 2002 at a loading 4 to 5 times the annual wet deposition (3 ug/m^2/year). Preliminary results from deployed sedimentation traps indicated that both inorganic ^{202}Hg and ^{202}MeHg were being delivered to sediment-water interface by settling particulate matter from the water column and that newly-deposited Hg was being recycled in the water column.

The hypolimnetic cycling Hg and MeHg is hypothesized to be controlled by organic and inorganic aqueous phase speciation (e.g. sulfide, S-containing DOC) and solid-phase partitioning. However, the relative role of iron/manganese oxides to organic thiols, and sulfide species in hypolimnetic cycling of Hg and MeHg is poorly understood. Isolated settling particulate matter and surficial sediments were sequentially extracted (1M KOH, 6M HCl, 12M HNO_3, Aqua Regia) to better understand the association of Hg and MeHg to solid organic and inorganic phases. Investigating iron speciation in dimictic Lake 658 and intensive sampling at the iron(II)/iron(III) redoxcline allows a better understanding of the role of active iron transport as a delivery mechanism and as a vector for remineralization of Hg and MeHg across the sediment-water interface.

Keywords: mercury, methylmercury, cycling, transport

*Note: This is a student presentation.

Polybrominated Diphenyl Ethers: The Saga Continues

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Polybromodiphenylethers (BDEs) and other brominated organic compounds continue to be in the environmental limelight. Although partially banned or controlled in Europe, the US continues to use these compounds unabated. They are mainly used as flame retardants in such things as electronic equipment, plastics, building materials, fabrics and carpets. About 300,000 tons of brominated flame retardants are consumed annually. Production is concentrated in the US and Israel. Polyurethane foam, a common component of furniture, contains about 30 % by weight brominated flame retardant. Moreover, penta PBDE, generally thought of to be among the more toxic PBDEs, is widely used in foam. PBDEs continue to be found in just about all matrices, and an increasing number of reports have documented the presence of PBDEs in, for example, lake sediment, forage fish, bird eggs, marine invertebrates, phytoplankton, freshwater oligochaetes and Atlantic dolphins. Recent sewage sludge (biosolids) data from around the US, including Wisconsin, show that US sludge contains much higher PBDE levels than sludge from European and other countries. Sewage sludge spread on land may be a significant source of PBDEs to water bodies (due to overland runoff). Air, even in remote areas, has been shown to contain various levels of PBDEs. Overall, there are no signs that the rate of increase of PBDEs in environmental matrices is slowing down. Toxicity information is still limited, but some data suggests an association with thyroid disruption. Some interesting new data suggest that some PBDEs may alter enzyme systems in fish resulting in complex patterns of endocrine disruption and, ultimately, diminished reproduction.

Keywords: polybrominated biphenyls, toxic substances, Great Lakes, PCBs, water quality

SESSION 2B
Groundwater Chemistry
Thursday, February 27, 2003
4:05 – 5:25 p.m.

Comparison of Solute Concentrations Collected from Experimental and Field Data at the Reclaimed Flambeau Mine, Ladysmith, Wisconsin

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The Flambeau Mine, located near Ladysmith, Wisconsin, is the only example of a metallic mining operation that has been permitted, operated and reclaimed under the state's current regulations. The open-pit, copper-gold mine began operations in July 1991, and reclamation activities were completed by the end of 1999. During reclamation, stockpiled waste rock was blended with a prescribed amount of limestone and used as backfill for the mine pit. Limestone was used to provide supplementary buffering capacity to minimize the potential for the development of acid conditions prior to reflooding.

Monitoring data indicate that groundwater levels have nearly rebounded and closely parallel pre-mining conditions. Current analysis suggests an approximate correlation of dissolved manganese concentrations measured in laboratory column tests with groundwater quality sampled within the pit, and may correspond with the transition from oxic to anoxic conditions. Within the pit, it was expected that wells screened in backfilled waste rock exposed for longer periods of time (due to surface stockpiling and/or delayed reflooding) would contain only slightly elevated solute concentrations. However, dissolved iron concentrations within the pit show greater iron concentrations in the two deeper-pit wells (0.84-15 mg/L) than in the three shallow-pit wells (<0.01-1.2 mg/L). This may be explained by the reduction of ferric oxyhydroxide particles to the more soluble ferrous ion at one deeper-pit well (increasing Fe), and formation of more stable iron-bearing phases at the second deeper-pit well (decreasing Fe).

Geochemical modeling software will be utilized to determine phases that may be supersaturated/undersaturated under existing conditions, in order to determine potential solute concentrations of backfill pit pore-water quality.

Keywords: mining, geochemistry, modeling, Flambeau mine, water quality

Geochemical Controls on High and Low Arsenic Concentrations in Residential Well Water, Fox River Valley, Wisconsin

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In the Fox River valley, arsenic concentrations in well water exceed 10 μg/L in about 20% of wells sampled; concentrations exceed 100 μg/L in about 1% of the wells. Higher concentrations are from wells in which the static water level intersects a sulfide-mineral-rich horizon located at the base of the Platteville Formation and the top of the St. Peter sandstone, suggesting that a primary mechanism for arsenic release to groundwater is introduction of oxygen at the borehole and subsequent oxidation of arsenic-bearing sulfide minerals. In wells with lower arsenic concentrations, there is no clear correlation between water level elevation and the elevation of the sulfide horizon.

A field-based experiment was conducted to investigate the conditions resulting in the release of low (less than 50 μg/L) concentrations of arsenic to well water in this region. Groundwater arsenic concentrations are spatially heterogeneous within the 1500 ft^2 field site and correlate to the concentration of arsenic associated with the marcasite, pyrite, and iron oxides distributed throughout the aquifer. The geochemical environment within a well borehole alternates from reducing to oxidizing conditions as consequence of pumping, and groundwater arsenic concentrations appear to be a function of residence time in the well. Under pumping conditions typical of residential water use, arsenic concentrations remain below 10 μg/L and are predominantly in the As^{3+} oxidation state. In this setting, reductive dissolution of arsenic-bearing iron oxides, entrainment of colloidal arsenic-bearing iron oxides, and oxidation of arsenic-bearing sulfide minerals may play a role in contributing arsenic to well water.

Keywords: arsenic, groundwater, geochemistry

Delineation of High Salinity Conditions in the Cambro-Ordovician Aquifer of Eastern Wisconsin

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The salinity and major ion content of the water contained within the deep sandstone aquifer of eastern Wisconsin was investigated. Data obtained from the Wisconsin Department of Natural Resources Drinking Water Database, in conjunction with stratigraphic data obtained from the Wisconsin Geologic and Natural History Survey, was used to compile an overall view of the geochemical conditions within the aquifer. All data was entered into GIS format (ArcView 3.2). Salinity of water pumped from the aquifer averages 473 ppm and is more saline to the north and east. The spatial variance in salinity is almost entirely due to a 1:1 molar increase in calcium and sulfate, probably due to dissolution of gypsum. In spite of this increase in calcium-sulfate character, the aquifer is dominated by calcium-bicarbonate water except in isolated locations within Calumet and Outagamie Counties where the water is calcium-sulfate in character. An attempt was made to correlate the percentage of the well open to a particular stratigraphic interval and salinity, however no correlation was found. Most wells within the study area do not exhibit large changes in salinity over time. Only 10 wells have salinity changes that exceed 10 ppm/year and of these, 5 exhibit decreasing salinities.

Keywords: sandstone aquifer, geochemical, salinity

*Note: This is a student presentation.

Insights into Radium Occurrences in the Deep Sandstone Aquifer of Eastern Wisconsin

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Deep sandstone wells that produce elevated levels of radium are located in a band that is roughly coincident to the Makoqueta Shale subcrop pattern. It is at this location that the aquifer transitions from unconfined to confined conditions. This band is also the locus of several high pumpage centers including Green Bay, Fond du Lac and Waukesha. A detailed study of aquifer geochemistry within Waukesha County shows that to the west of the unconfined-confined boundary radium can be correlated directly to barite dissolution. Solubility calculations indicate that barite has a constant radium concentration of approximately 10 ppb. East of the unconfined-confined boundary an additional source of radium is indicated. The source of this additional radium is unclear but data will be shown that indicates colloidal transport of radionuclides may be in operation. There is no indication of the presence of a low redox boundary capable of mobilizing excess radium.

Keywords*:* radium, deep sandstone aquifer, water quality

POSTER SESSION
Thursday, February 27, 2003
5:30 – 7:00 p.m.

Arsenic Removal During Iron Treatment

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Arsenic is present in groundwater at low concentrations in many areas of Wisconsin. Studies of the negative health effects of arsenic exposure suggest reductions in arsenic concentrations in drinking water are desirable. The recent reduction in the arsenic standard to 10 ug/l may require arsenic removal at some water facilities. Unfortunately, the cost of treating water to remove arsenic may be prohibitive, particularly for smaller water treatment facilities. This study examined arsenic removal incidental to treatment for iron at small water systems in Wisconsin.

More than seventy-five water systems in Wisconsin may have arsenic concentrations exceeding 3 ug/l, and most of these systems also have iron concentrations in excess of 0.1 mg/l with more than half exceeding the secondary standard for iron of 0.3 mg/l. The removal of arsenic during iron treatment was examined at several facilities currently removing iron. Treatment for iron at those facilities employed oxidation of the iron and the removal of the precipitated iron in a pressure filter. Removal of arsenic with the iron was observed. While the removal of arsenic with iron is consistent with previous studies, several oxidation methods followed by pressure filtration were examined in this study. The successful removal of arsenic after oxidation and pressure filtration suggests that iron removal methods offer opportunities to reduce the arsenic concentrations and improve the aesthetic qualities of the water.

Keywords: arsenic, water treatment

*Note: This is a student presentation.

Development of a Tribal Fish Consumption Advisory Based on Interagency Data Sharing

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Many walleye in Wisconsin waters contain elevated levels of methylmercury in their tissues that can pose a significant human health risk. The spring spearing and netting of walleye is the largest off-reservation harvest activity of the Ojibwe tribes in inland waters. Walleye fillets are a staple of the diet for tribal members of all ages and the harvest activity is an important cultural activity for tribal members. To address the potential health problems associated with methylmercury in walleye, the Great Lakes Fish and Wildlife Commission (GLIFWC) has developed a walleye consumption advisory that is designed to reflect the specific consumption patterns of tribal members. The advice is provided through GIS maps identifying high and low mercury lakes. These maps are provided to member tribes that harvest fish within the 1837 and 1842 ceded territories.

Data used in the development of the advisory is collected annually by GLIFWC and the WDNR using a variety of funding sources. The mercury data is shared between the agencies and is not only used by GLIFWC to develop the tribal advisory, but is also used by the WDNR for development of a state fish consumption advisory. This cooperative approach to data collection and data sharing was formalized through an inter-agency memorandum of understanding developed in 1996.

Keywords: Ojibwa tribes, mercury, fish, walleye, consumption advisory

Importance of Disinfection on Arsenic Release from Wells

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One of the more perplexing groundwater problems currently facing Wisconsin is the high concentrations of arsenic (exceeding EPA's new MCL of 10 µg/L) found in many northeastern Wisconsin drinking-water wells. High levels of arsenic in drinking water are a concern because of the relatively high level of risk to human health. Chlorine disinfection of wells containing sulfide-bearing minerals may accelerate the release of arsenic. The purpose of this study was to evaluate whether alternate disinfection techniques will minimize arsenic release. In the first phase of this study, three disinfection processes were evaluated on a test well in the Town of Algoma. The test well, which had an existing iron bacteria infestation, was treated by: (1) the Wisconsin Department of Natural Resources' recommended method for this Arsenic Advisory Area with a low dose of chlorine (100 mg/L); (2) a commercially available acid surfactant method; and (3) the shock chlorination method (1000 mg/L). Although a relationship between the level of chlorine used and arsenic release was expected, one was not found on the initial disinfection experiments. All disinfection processes reduced heterotrophic plate counts and iron bacteria levels. However, heterotrophic plate counts returned after the low-dose chlorination and acid surfactant treatments but remained low after shock chlorination. Iron bacteria levels returned after all treatments. Phase two of the study is evaluating whether a relationship exists between the drilling method and the method of disinfection with respect to the release of arsenic. Samples for arsenic and coliform bacteria are being taken from 84 private wells that have been drilled in the last five years and which were previously tested for arsenic. At this point, it is still not clear what disinfection approach is least likely to promote arsenic release.

Keywords: arsenic, bacteria, disinfection, drinking water

Cooperative Mercury Sampling of Surface Waters Near the Site of the Proposed Crandon Mine

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As part of a monitoring program in the vicinity of the proposed Crandon Mine in Forest County, Wisconsin, we developed a cooperative sampling project to assess water quality of small local streams. Water quality is important to local Indian tribes because of direct use of the waters as well as the wild rice and other aquatic resources that occur in the watershed. Results from 1999 water quality monitoring using bryophytes in Swamp Creek suggested that there may be variation among tributaries in the input of metals to Swamp Creek. To further investigate the observed metal levels, in 2001 and 2002 the USGS and Great Lakes Indian Fish and Wildlife Commission sampled water of tributaries in the Swamp Creek watershed and adjacent Rolling Stone Lake watershed for total and methyl mercury. Tributaries flow from lakes, groundwater-fed wetlands and perched wetlands in the watershed. Results of testing show large variation in levels of total and methylmercury among tributaries and among sampling dates.

Keywords: Indian tribes, mercury, methylmercury, Swamp Creek, water quality, wetlands

Monitoring Contaminant Flux from a Stormwater Infiltration Facility to Groundwater

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State of Wisconsin administrative code NR 151 became effective in October 2002. This code, in part, defines performance standards for infiltration of storm water from new developments. These infiltration standards are intended to preserve recharge to groundwater and stream baseflow. However, depending on the characteristics of the contributing watershed, infiltrated storm water may introduce to groundwater significant amounts of contaminants including hydrocarbons, pesticides, bacteria, and chloride. Therefore, it is imperative to quantify the relationship between the quality of infiltrated storm water and the flux of contaminants to the groundwater system. Developing an understanding of this complex relationship will provide a scientific basis for satisfying the goals of NR 151, while still meeting Wisconsin groundwater standards.

To investigate the relationship between storm water quality and contaminant flux, hydrologic and water quality data is being gathered at a detention/infiltration facility in the Stonefield Neighborhood in Middleton, Wisconsin. Storm water flowing into the detention/infiltration facility may infiltrate into the pond bottom, flow into an injection well with spill point about 1 foot above pond bottom, or flow to the storm-sewer system over a sharp-crested weir with spill point about 4 feet above pond bottom. Sediment coring reveals that the soil profile to 43 feet below ground level at the Stonefield site comprises soil and organic sediments to about 3 feet, clay and clay loam from about 3 to 4 feet, and uniform, clean, fine sand to 43 feet. Coarser grains and pebbles are present between 40 and 43 feet.

The watershed has been defined and contributing areas calculated. Data showing the relationship between precipitation and ponding depth has been collected for about nine months. Recent installations comprise 2-inch stainless steel casing for neutron logging (soil moisture content), nested piezometers for sampling and measuring hydraulic head, and suction lysimeters for sampling the unsaturated zone. Baseline water-quality analyses have been conducted on samples taken from ponded storm water during 2002 events. Sampling for water quality analyses will be conducted at regular intervals and during events from ponded storm water, suction lysimeters, and piezometers. Changes in unsaturated zone moisture content and water table elevation in response to stormwater events will be monitored.

Keywords: infiltration, contaminant flux, storm water, groundwater

Eutrophication in Wisconsin Lakes During the Last 150 Years

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The landscape in Wisconsin was largely unaffected by Europeans until after the 1830s in the southern part of the state and after the 1880s in the northern part. Early impacts included plowing of the prairies for subsistence farming and clear-cut logging in the central and northern part of the state. During the twentieth century the landscape underwent dramatic changes. Agriculture greatly expanded from early dairying operations to large-scale cash cropping. During about the 1920s, cottages began to become common on lakeshores. This shoreline development has greatly increased since the 1960s, with many cottages converted into permanent homes, resulting in larger structures and maintained lawns along with increased density of homes. These changes have impacted lakes in a variety of ways.

Sediment cores have been collected from 61 lakes. Full cores from 43 lakes have been analyzed for diatoms, geochemistry and radiochemistry, while in an additional 18 lakes the top and bottom of the cores were examined.

The mean mass accumulation rate (MAR) during the last 150 years was greatest in hardwater lakes that contained intensive agriculture in their watersheds, while the lowest MARs generally occurred in softwater lakes where the principal watershed landuse was shoreline development and forestry. The few hardwater lakes that had relatively low MARs were either seepage lakes with shoreline development or large, deep lakes.

In a majority of the lakes, the peak MAR occurred during the period 1950-1980 and rates at the top of the cores were reduced. Exceptions to this are lakes that currently continue to have intensive agriculture in their watersheds, or where urbanization continues to increase. In nearly all cases, present-day MARs were higher than rates prior to European settlement.

In many lakes, diatom-inferred phosphorus values at the top of the cores were lower than previous decades. Peak values generally occurred during periods of intensive agricultural activity and values have declined as land use in the watershed has been converted from agriculture to homes, e.g. shoreline development. Lake types have responded differently to shoreline development. Initial development during the first half of the twentieth century resulted in reduced impacts in both softwater and hardwater lakes. With redevelopment that generally began during the 1960s, there was increased MARs and higher phosphorus levels. In hardwater lakes, MAR and phosphorus levels generally declined following this construction phase. This was not the case with softwater lakes. Since these lakes do not have the natural buffering capacity, i.e. $CaCO_3$ precipitation, they are less able to assimilate the increase in phosphorus input.

In nearly all lakes, the first impact of increased land disturbance—either from plowing of the prairie or from logging—was the expansion of macrophyte growth. Also in lakes where the trend in anoxia could be determined, there has been a decline in oxygen levels in the bottom waters during the last 50 years, even when phosphorus values have not significantly increased.

Keywords: phosphorus, diatom, lakes

Trinity Creek Multi-Feature Restoration Project: Stream Enhancement, Wetland Rehabilitation, Northern Pike Spawning Habitat and Flood Mitigation

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This project has demonstrated high levels of cooperation and coordination with local, state and federal agencies, and private businesses, along with providing public education and outreach. Building consensus with the many stakeholders has been imperative throughout the design and construction process because the project will provide many varied benefits.

The project has been partially funded by three Wisconsin Department of Natural Resources (WDNR) grants, a coastal management grant, a Great Lakes grant, a Milwaukee Metropolitan Sewerage District (MMSD) grant, and private business cost-sharing. Funding sources for future phases will be considered from these groups, the U.S. Army Corps of Engineers, and potential wetland bank credits (one of the first projects in Wisconsin to use new wetland banking laws). The site will be monitored and studied by University of Wisconsin-Milwaukee biological science students.

A design team with a diverse background of expertise was responsible for the success of this project. The multi-feature facility consists of 3,000 feet of stream enhancement, creation of northern pike spawning habitat, 30 acre-feet of flood storage, a hiking trail and interpretive/educational signage. The project will maximize flood storage and water quality benefits at this site by restoring existing farmed lands and drainage ditch with wetland/marsh habitat.

Keywords: Diverse cooperation, grant funding, restoration

Urban Storm Drainage in Hilly Areas

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Waterways, land and receiving waters near urban areas are often adversely affected by urban storm runoff. The significance of storm water runoff in affecting soil structure and water quantity in many developing countries has become an increasing concern in recent years. A wide variety of structure and non-structural, urban storm runoff drainage and management practices, are available to handle urban storm runoff discharges. The present paper focuses on current managing and draining water runoff practices.

Keywords: storm water runoff, urban runoff drainage practices

*Note: This is a student presentation.

Maintaining Continuity in Chlorophyll Trend Data While Improving the Analytical Method

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The Wisconsin State Laboratory of Hygiene (WSLH) has been performing chlorophyll analyses for the Department of Natural Resources (DNR) with the spectrophotometric approach (Trichromatic method) for close to three decades. The DNR has been tracking trends in chlorophyll data from Wisconsin lakes and streams for about the same period of time. These data provide invaluable information regarding the trophic status of Wisconsin's waters and afford a way to evaluate the effectiveness of improved water quality management practices. However, changes in analytical techniques must be evaluated to ensure there is little affect on data, thus maintaining the continuity of future trend analysis.

In Spring 2002, the WSLH implemented a semi-automated fluorescence technique to perform chlorophyll analysis. The new technique has a detection limit of 0.26 μg/L, which is about four times more sensitive than the spectrophotometric method (detection limit of 1 μg/L) that had been used for close to thirty years. However, before proceeding with the change, the WSLH performed a comparability study to ensure the integrity of trend data would not be sacrificed once the new method was implemented.

Samples submitted from April through June 2002 by DNR staff, from lakes and streams throughout Wisconsin, were tested with both the spectrophotometric and fluorescence methods. Randomly selected samples submitted in the spring, summer and fall were also tested with both techniques to assess method comparability during the growing season. In addition, replicate analyses of pure chlorophyll cultures and of compounds containing chlorophyll *b* were performed by both techniques to evaluate the methods under controlled conditions. Natural surface water samples containing pheophytin were also tested using the fluorescence and the monochromatic spectrophotometric (pheophytin corrected chlorophyll) method. These tests were conducted to determine how well the fluorescence method performed in the presence of pheophytin.

In general, the results indicate the two methods are comparable based on results of the students' *t*-test and regression analyses. Consequently, the new fluorescence method will enhance Wisconsin's already extensive chlorophyll database by providing better quantification of chlorophyll in the spring and fall when chlorophyll levels are low. In addition, the data will be less influenced by pheophytin levels, which tends to cause a high bias in the spectrophotometric

method. Furthermore, since the fluorescence data are generally comparable with historical data, environmental managers and researchers should expect to continue chlorophyll trend analysis of Wisconsin's waters for decades to come.

Keywords: chlorophyll, comparability, fluorescence, spectrophotometric

Monitoring Update for Argonne National Laboratory Sanitary Landfill, Argonne, Illinois

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The Argonne National Laboratory-East (ANL-E) Sanitary Landfill (21.8-acres) began operation in 1966 and ceased in September 1992. The post-closure requirements of the landfill, including gas and groundwater monitoring, are conducted in accordance with Illinois Environmental Protection Agency (IEPA) permits. The landfill received general refuse, construction debris, boiler ash, and 29,000 gallons of liquid organic waste. The presence of volatile and other toxic organic compounds has been confirmed by soil gas surveys and leachate sampling, but not groundwater. Radioactivity in the form of hydrogen-3 (tritium) has also been noted in surface and ground water measurements.

Twenty-five stainless steel wells comprise the IEPA-approved groundwater monitoring program at the landfill. Quarterly sampling entails assessing field parameters and routine indicator parameters. Three gas wells placed into the waste area and 10 perimeter gas wells are monitored quarterly.

Quarterly groundwater monitoring reveals that iron, manganese, total dissolved solids and chloride routinely exceed the corresponding Illinois Class I Groundwater Quality Standards, although organic parameters are occasionally identified. Very low concentrations of hydrogen-3 has been detected in some wells, and has been recorded in monthly surface water samples at the landfill. The presence of hydrogen-3 allows information to be obtained on the subsurface water flow pathway in the landfill area. Results of quarterly gas monitoring for methane, carbon dioxide, nitrogen and oxygen indicate that methane is generated but no migration has been noted.

Long-term monitoring is a proactive approach to ensuring the protection of our groundwater resource. Although there is evidence of non-hazardous materials migrating from the landfill, no hazardous materials have been noted. Extensive long-term monitoring will continue to provide the necessary information for ANL-E and surrounding communities. The current monitoring program should detect any changes which might possibly lead to a hazardous release.

Keywords: long-term monitoring, groundwater, gas

Validating the Ammonia Analysis Technique Used in Surface Water and Wastewater Monitoring

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The automated phenate method is widely used by environmental laboratories as a direct measurement technique for the analysis of surface waters and wastewater for ammonia. The technique is precise, accurate, relatively free from interference and sensitive enough to provide a detection limit of 0.013 mg/L, which is adequate for most surface water monitoring. However, environmental wastewater monitoring rules prohibit the direct measurement technique unless the lab has data on file that shows preliminary distillation is not required. The Wisconsin State Laboratory of Hygiene (WSLH) evaluated the necessity of preliminary distillation to confirm the validity of the direct automated phenate method for the analysis of ammonia in surface water and wastewater samples.

Representative effluent samples from warm and cold water fish hatcheries and domestic wastewater treatment plants were selected for the validation tests. Fish hatchery samples were selected for the evaluation because they are fed by surface waters. Consequently, they serve a dual purpose for use in validating the method for surface waters as well as in discharges regulated under Wisconsin wastewater rules. Background concentrations of ammonia were determined prior to the distillation experiments. Ammonia was added to samples with background levels below 0.4 mg/L. Sample aliquots were distilled, in triplicate, along with a procedural blank, a 0.60 mg/L quality control sample and a 0.80 mg/L standard. In addition, aliquots of each sample were filtered, in triplicate, through 0.45 µm membrane filters. Both the distilled and filtered (direct) replicates were analyzed for ammonia with a Lachat model-8000 flow injection analyzer with the automated phenate method.

Regression analysis was used to compare the mean concentrations of ammonia from both the distilled and direct triplicate analyses. The coefficients of determination for fish hatcheries and domestic wastewater were 0.980 and 0.987, respectively, which show generally good comparability between the distilled and direct analyses. Precision was evaluated by comparing the percent relative standard deviations (%RSD) determined from the replicate analyses. The WSLH criteria for acceptable precision of replicate analysis is ±10%. The mean %RSD was 2.62% and 0.89%, respectively, for the distilled and direct measurement. Although the precision of both techniques met or exceeded WSLH criteria, the results obtained with the direct measurement technique were clearly better.

In general, the direct ammonia concentrations were 3.79% higher than the distilled samples for the fish hatchery effluents while the direct measurements were 0.14% lower than the distilled on

domestic wastewater samples. These results indicate that preliminary distillation is not required prior to analysis for ammonia when using the automated phenate method. Moreover, the data clearly demonstrates that the direct measurement technique provides better precision, while being more cost-effective and less labor intensive than the preliminary distillation approach. Consequently, the direct automated phenate method is the preferred method for monitoring ammonia in surface water and wastewater studies.

Keywords: ammonia, fish hatcheries, wastewater

Arsenic in Groundwater in Southeastern Wisconsin: Sources of Arsenic and Mechanisms of Arsenic Mobilization

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Moderately high arsenic concentrations occur in groundwater wells throughout southeastern Wisconsin. Arsenic-impacted drinking water wells are especially common near the city of Lake Geneva in Walworth County. Approximately 10% of the wells in the Lake Geneva area have arsenic concentrations above the new U.S. Environmental Protection Agency drinking water standard of 10 ppb. Maximum arsenic concentrations are on the order of 80 ppb. This paper summarizes the status of an ongoing project, the objectives of which are 1) to identify sources of arsenic and 2) to characterize geochemical controls on arsenic mobility.

Review of existing well logs and water chemistry data has shown that wells open to the glacial aquifer and the Silurian dolomite have elevated arsenic concentrations. Groundwater sampling has shown that the arsenic is dominantly As (III). There is no evidence of anthropogenic sources of arsenic in the area. Geochemical analysis of core collected during sonic drilling shows above background concentrations of arsenic in an organic horizon in the glacial aquifer (21 ppm) and in weathered bedrock (15 ppm) at the top of the Silurian dolomites. Future work will include mineralogic analysis and selective extractions to determine the solid phase associations of arsenic in these core samples. Laboratory leaching experiments will be conducted to determine what environmental conditions promote the release of arsenic to groundwater.

The results of this study will be useful to individuals, municipalities and regulators—all of whom have an interest in maintaining safe drinking water supplies. An understanding of the mechanisms controlling arsenic contamination will be useful in modifying well construction methods and placing new wells to prevent contamination and in designing mitigation measures for already contaminated wells.

Keywords: arsenic, groundwater, contamination, southeastern Wisconsin

*Note: This is a student presentation.

Spatial and Temporal Variability of Groundwater Chemistry Beneath Agricultural Land: Implications for Assessing Environmental Impacts of a New Unsewered Subdivision

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Population growth and urban expansion around many Wisconsin cities has resulted in residential development on formerly agricultural land. Currently, little information is available about how conversion of agricultural land to residential use might change groundwater quality. To document these effects, we initiated a monitoring program in 2001 to collect groundwater-quality data before, during and after construction of a new, unsewered rural subdivision located on agricultural land several miles east of Madison, Wisconsin. We installed a dense groundwater monitoring network with frequent sampling intervals designed to identify temporal and spatial variability in groundwater quality. Almost a full year of background data was collected before subdivision development began in the fall of 2002. During this time, several key parameters, including nitrate, chloride, and atrazine, showed significant spatial and temporal variability. Seasonal recharge variations appear to control the temporal trends, while local loading, groundwater flow paths, surface topography, and small-scale heterogeneities are responsible for the current spatial distribution of chemical constituents in the groundwater.

Results from the pre-construction stage of this project demonstrate the importance of collecting an extensive background data set to adequately characterize groundwater conditions resulting from previous land use. Continued monitoring once development begins, combined with the knowledge of pre-existing conditions, will allow conclusions to be drawn about the effects of replacing agricultural land with unsewered residential subdivisions.

Keywords: land use, nitrate, agriculture, subdivisions

*Note: This is a student presentation.

BANQUET SPEAKER
Larry Wawronowicz
Lac du Flambeau Tribal Natural Resource Department
Thursday, February 27, 2003
7:00 p.m.

Abstract

This presentation will describe the natural resource base of the Lac du Flambeau Indian Reservation and highlight the programs designed to protect and conserve these precious resources for present and future generations. The activities and accomplishments of the Water Resource Department will be highlighted.

Biography

Larry Wawronowicz is the Deputy Administrator of Natural Resources for the Lac du Flambeau Band of Lake Superior Chippewa Indians. He has held this position for five years and has been employed by the Band since February 1984. Mr. Wawronowicz received his Master of Science degree in fisheries with an emphasis in fish culture, from Southern Illinois University, Carbondale in 1978. From 1978 to 1984, he worked as a researcher for the Fisheries Research Laboratory at Southern Illinois University, where he wrote and published reports on the effects of secondary sewage on the fish populations of receiving streams. In his current role as Deputy Administrator of Natural Resources, he is responsible for the management of 14 natural resource programs, including the Lac du Flambeau Water Resource Department.

SESSION 3A
Groundwater Remediation
Friday, February 28, 2003
8:30 – 9:30 a.m.

Three Seasons of Phytoremediaton of VOCs in Soil and Groundwater

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RMT installed a full-scale phytoremediation system to treat soil and groundwater contaminated with chlorinated solvents and petroleum hydrocarbons. Soil and shallow groundwater at the site contain high concentrations of petroleum and chlorinated VOCs (100s of mg/kg total CVOCs and total PVOCs in soil, 10s of mg/L total CVOCs and total PVOCs in shallow groundwater).

The system consists of 485 deep-rooted hybrid poplar trees. The trees grew from an initial height of 1.5 to 2 meters to a height of 7 to 9 meters after three growing seasons. In the second growing season, tree roots extended more than 1.3 meters laterally, and to depths of 3 meters below grade, suggesting that tree roots have propagated through most of the treatment area. Tree root development appears to be retarded in areas where free product was present. The results of soil monitoring (chemistry and soil moisture) are inconclusive to date.

Water levels in on-site wells showed diurnal changes in water levels associated with transpiration after the first growing season. The groundwater treatment zone is transpiring an estimated 100% to 700% of the annual pre-remediation groundwater discharge to the river after three growing seasons. Evaluation of half-lives of contaminant mass in shallow groundwater, since construction of the phytoremediation system suggests that mass removal is accelerated over natural attenuation by 20% to 45% for PVOCs, and by 60% to 80% for CVOCs. Data from the first three growing seasons indicate that the phytoremediation system is significantly reducing the mass flux of VOCs to the river, and the total mass of VOCs in groundwater.

Keywords: phytoremediation, VOCs

Response of Redox Conditions to Air Sparging in a Geochemically Heterogeneous Groundwater System

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The shallow groundwater aquifer at Fort McCoy, WI, contaminated from leaking petroleum tanks, shows elevated BTEX concentrations (2-10mg/L). The study area is geochemically heterogeneous with groundwater moving through an originally aerobic upland into an anaerobic wetland, and then discharging into Tarr Creek. Terminal electron accepting processes along the contaminated flow path range from iron and sulfate reduction to methanogenesis, and along the uncontaminated path from oxygen and nitrate reduction to iron reduction (Schreiber and Bahr, 1999). An air sparging system, activated 11/8/01, injects air into the subsurface to remove VOCs and to possibly aid in biodegradation. This study assesses the effects of subsurface aeration on redox reactions involving dissolved iron and oxygen, the efficiency of BTEX-remediation, and the microbial degradation of contaminant. Seasonal and weekly sparging cycles allow for spatial and temporal analyses of the migration of oxygen-iron reactions from the source area to the discharge point.

Results show that at shallow (most contaminated) depths, high dissolved oxygen is present only during periods of active sparging, indicating rapid consumption by microbially mediated oxidation of organics. At deeper, less contaminated depths, oxygen concentrations persist suggesting potential for down-gradient migration of the oxygen plume. Iron concentrations increase rapidly after sparging has stopped, indicating a remaining BTEX source and continued viability of the iron-reducing consortium. Continued monitoring is planned to distinguish between permanent and transient changes to the groundwater chemistry after sparging is terminated.

Keywords: geochemically heterogeneous, air sparging, BTEX, groundwater, redox reactions

*Note: This is a student presentation.

Surfactant-Enhanced Oxidative Dechlorination of Chlorinated Solvents by Permanganate: Proof of Concept

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Oxidative dechlorination of chlorinated solvents by permanganate is an emerging technology for remediation of groundwater contaminated with dissolved chlorinated contaminants such as trichloroethylene (TCE). In this study, the enhancement of present surfactant in solution on TCE degradation by permanganate was evaluated using a continuous stir test reactor (CSTR) system with the permanganate as the limiting reagent. The surfactants used include a cationic (hexadecyltrimethylammonium bromide), an anionic (sodium dodecyl sulfate), and a nonionic (triton X-100). The degradation of TCE was quantified by measuring the increase in chloride concentration with time. It was found that the consumption of permanganate, an indication of TCE degradation, in the presence of free phase TCE and 0.75 mM $KMnO_4^-$ followed a zero-order reaction kinetics with a half-life ($t_{1/2}$) of 8 min for MnO_4^-. The $t_{1/2}$ stayed the same as the MnO_4^- concentration increased to 1.5 and 3.0 mM. In the presence of surfactant, the consumption of MnO_4^- followed pseudo first-order reaction and the reaction rates increase significantly. At 0.42 and 4.2 times the critical micelle concentration of sodium dodecyl sulfate, at which surfactant molecules associate to form micelles and the TCE concentration can be significantly increased, the $t_{1/2}$ values were reduced to 2, and 1 min, respectively. The results indicate that it is feasible to achieve a synchronized 'pump-while-treat' for soils and groundwater contaminated with free phase DNAPLs when surfactant-enhanced pump-and-treat is combined with permanganate oxidation.

Keywords: enhancement, permanganate, solubilization, surfactant, trichloroethylene

SESSION 3B
Hydrogeologic Characterization
Friday, February 28, 2003
8:30 – 9:30 a.m.

Flow Across the Maquoketa Shale Aquitard in Southeastern Wisconsin

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Flow across an aquitard might occur through several different pathways: the matrix, vertical joints or faults, depositional or erosional windows in the aquitard, or short-circuiting wells that are open to aquifers above and below the aquitard. Understanding the different pathways and their relative importance allows us to determine how recharge and contaminants might enter an underlying aquifer.

The Maquoketa Formation is a regional aquitard in southeastern Wisconsin. Calibration of a regional groundwater flow model for southeastern Wisconsin suggests that the vertical hydraulic conductivity (Kv) of the Maquoketa shale must be approximately $5x10^{-6}$ ft/day. This regional-scale estimate stands in stark contrast to field-scale measurements of $1x10^{-9}$ ft/day and core-scale measurements ranging from $7x10^{-9}$ to $4x10^{-7}$ ft/day.

Flow along the different pathways through the shale could explain the apparent increase of bulk Kv at the regional scale. Because well logs show the Maquoketa shale to be relatively uniform, thick and extensive, it seems unlikely that significant porous media flow occurs through windows or high conductivity zones. Instead, we believe that hydraulic discontinuities, either fractures or open boreholes, cause the higher regional Kv. Fractures spaced 6 miles apart with an aperture of 50 microns could provide enough flow across the aquitard to match that provided by an equivalent bulk Kv of $5x10^{-6}$ ft/day. In a similar fashion, 50 12-inch diameter wells open to both aquifers and evenly spaced 7 miles apart across southeastern Wisconsin can match the model Kv.

Keywords: aquitard, Maquoketa shale, scale, short-circuiting well, fracture, hydraulic conductivity

Use of the Time-Domain Electromagnetic Method for Determining the Presence and Depth of Aquitards

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The purpose of this research is to develop guidelines for the use of the time-domain electromagnetic method (TDEM) for determining the presence and depth of aquitards. The guidelines will be based on TDEM surveys that use the shaley facies of the Eau Claire formation as the test case. The TDEM method produces current in the earth by induction from time-varying current through a loop on the surface. A receiver located in the center of the transmitter loop measures the resultant secondary magnetic field at the surface. The secondary magnetic field decays more slowly in highly conductive bodies, such as the Eau Claire shale, than in poor conductors. The TDEM data are then inverted into a layered conductivity model.

We have conducted TDEM surveys at six sites where the Eau Claire shale is constrained by well logs. The inversion results thus far indicate that the TDEM method can determine the presence of the Eau Claire shale at a depth of 200 feet and a thickness of 20 feet. If the electrical conductivity is known a priori, the inversions place the conductor at approximately the correct depth with the correct thickness. The method has good repeatability, based upon repeated surveys conducted in Dane County. Due to the non-uniqueness of the problem, smaller loops must be used to better constrain the structure near the surface. Preliminary results indicate that a 20m loop, along with a 100m loop, will provide enough data overlap to better constrain the inversion.

Keywords: time-domain electromagnetics, geophysical methods, electromagnetic methods, aquitard, Eau Claire formation

*Note: This is a student presentation.

Time-Domain Electromagnetic Induction Survey of the Sandstone Aquifer in the Lake Winnebago Area of Eastern Wisconsin

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The Cambrian and Ordovician sandstone aquifer of eastern Wisconsin is a major source of water for municipalities and industry in eastern Wisconsin. This aquifer has been developed heavily in the Lake Winnebago area, particularly along the northern and southern ends of the lake. The rate of development has intensified over the last decade in response to strong economic growth and an increase in the population of the City of Fond du Lac along with the developed corridor from Neenah to Kaukauna and surrounding areas (The Fox Cities). Declining water levels and deteriorating water quality has created concerns over the long-term viability of the aquifer.

The objective of this study was to perform the first regional time domain electromagnetic induction survey (TEM) of the sandstone aquifer around Lake Winnebago. The goal was to map the thickness of the Cambrian and Ordovician sandstone aquifer and identify areas of saline ground water. This study provides critical information needed by several water utilities to make informed water supply planning decisions. Fifty-five Time Domain Electromagnetic Induction (TEM) soundings were conducted using a Geonics EM57 system. The TEM data detected significant changes in the salinity and geometry of the sandstone aquifer. The patterns detected in the Fond du Lac County portion of the study area are different than the pattern detected in the Fox Cities area.

Significant topography was found on the Precambrian surface in the Fond du Lac area. Steep sided mounds and steep walled basins were found. The sandstone adjacent to the mounds or within the basins was found to be significantly more electrically conductive, suggesting more saline water in those areas. Areas with anomalously high resistivity in the sandstone section were also detected. These areas may represent thick carbonate sequences with relatively thin sandstone sections.

In the Fox Cities area, most TEM soundings detected high electrical conductivity in the sandstone section, indicating elevated total dissolved solids levels in the ground water. A few areas with higher resistivity in the sandstone section were detected. These areas could represent areas with better water quality. The pattern of the conductive zones in the sandstone indicates that saline water is migrating upward from the lower portion of the aquifer in response to heavy pumpage and declining head. The trend toward higher salinity with depth in the aquifer is consistent with changes in water quality experienced during well rehabilitation projects in Kaukauna and Little Chute.

In some areas, the vertical contact between fresh water and more saline water in the aquifer appears to be relatively sharp. In many areas, the contact could not be detected by the TEM data. This could indicate the transition is more gradational, possibly as a result of vertical migration after decades of heavy pumpage. Only a few soundings detected Precambrian rock, probably due to signal attenuation in the high conductivity sandstone section and from higher noise levels due to the developed nature of much of the survey area. The data indicated that two previously unknown mounds on the Precambrian surface may be present.

The results of the TEM survey strongly suggest the presence of saline water in the lower portion of the sandstone aquifer in portions of both areas. Saline water seems to be associated with structural features on the Precambrian surface in Fond du Lac County. Saline water appears to be migrating upward in response to heavy pumpage in the Fox Cities area.

Keywords: time-domain electromagnetic induction, saline water, total dissolved solids, Fond du Lac county, Outagamie county

SESSION 4A
Water Policy and Management
Friday, February 28, 2003
10:00 – 11:40 a.m.

How the Wisconsin River Watershed has Benefitted from Three Decades of Clean Water Act Programs

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October 18, 2002, marked the 30th anniversary of the Clean Water Act. The governor has declared 2002-2003 the "Year of Water" in Wisconsin to commemorate the occasion and to plan for the future management of this important resource.

The Wisconsin River is the largest river in the state and is known as "The Hardest Working River in America." In its 430 miles and over 1,000 feet of gradient, this river has experienced almost all the major problems facing aquatic resources in Wisconsin. Over the past three decades, Clean Water Act programs have allowed us to address point and nonpoint source pollution, acid rain, groundwater contamination, spills, dam issues, toxic materials in sediments and fish contaminants.

In an era of environmental challenges, the Wisconsin River story illustrates examples of many successful solutions (and a few failures) in the water resources management field. This paper will describe the progression of water resources improvements in the Wisconsin River Watershed over the past three decades.

Keywords: Wisconsin, river, water quality improvement

Meeting NPDES Phase II Requirements: A Demonstration of the Benefits of Infiltration Practices in Wisconsin, 1999-2002

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As part of the NPDES Phase II rules, operators of regulated small storm sewer systems must develop, implement and enforce a program to reduce pollutants from development projects that result in land disturbance of greater than or equal to 1 acre. Part of this program includes the development and implementation of structural and non-structural best management practices (BMPs).

Many planners use hydrologic models to predict post-development runoff scenarios using strategically placed BMPs. In an effort to calibrate one such model, SLAMM, the USGS, in cooperation with the Wisconsin DNR, is monitoring a 68-acre residential development in Cross Plains, WI. Construction at the site incorporates low-impact development techniques in an effort to reduce stormwater runoff. BMPs at the site include grassed swales, narrow street widths, a wet detention pond, and an infiltration basin that has been designed to eventually receive all runoff generated within the basin.

After four years, the subdivision is over 50% developed. However, all BMPs were in place prior to lot development. The majority of smaller storm events (<0.7") do not produce measurable runoff at the basin outfall. However, for larger storm events, the infiltration basin consistently reduces stormwater volume by 40-50%. Of the 56 precipitation events in water year 2002, only 11 produced sufficient runoff to be measured at the basin outfall. Prior water years, including pre-development, show similar results highlighting the potential benefits of infiltration practices as development continues.

Keywords: infiltration, best management practices, low-impact development, stormwater

Efforts to Manage Aquatic Invasive Species in Wisconsin

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An Advisory Task Force, created by Governor Scott McCallum in May 2001, developed the framework for Wisconsin's future efforts on invasive species. The recommendations of the Advisory Task Force were incorporated into new legislation that was passed in August 2002 as part of Wisconsin Act 109, which created a statewide invasive species program and mandated an Invasive Species Council to oversee it. Act 109 describes the DNR's responsibilities in implementing the program, establishes a watercraft inspection program and develops a control program for nuisance aquatic weeds. The annual base funding of $300,000 for aquatic invasive species currently supports the following efforts:

- Information and education/outreach (staff, Public Service Announcements, publications, exhibits, displays, etc.)
- Monitoring (primarily for zebra mussels)
- Watercraft inspections (DNR staff educating boaters to prevent the spread of invasives and posting signs at boat landings)
- Purple loosestrife biocontrol program

Full implementation of the provisions in Wisconsin Act 109 will require additional funding at the federal and state level. The DNR has identified this as a key issue for increased funding in its 2003-05 budget. In addition, the DNR is seeking federal funding through the U.S. Fish and Wildlife Service to help implement Wisconsin's aquatic invasive species program.

Keywords: aquatic invasive species, advisory task force, invasive species council, watercraft inspection, purple loosestrife, biocontrol

Great Lakes Water Use Following the Ecosystem Improvement Principles of Annex 2001

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The Great Lakes harbor twenty percent of the world's freshwater resources. Faced with the management of this treasured resource, the governors of the Great Lakes states and the premiers of the Canadian provinces put forth an ecosystem improvement-based approach to water use in a document titled Annex 2001. The goal of the new water management system is to protect, conserve, restore and improve the waters and water-dependent natural resources of the Great Lakes Basin.

Inherent to the ecosystem improvement approach is identifying the effect a water withdrawal has on the ecosystem. This presentation will focus on the importance of understanding how the hydrology change of a water withdrawal can influence ecology. Potential local ecosystem improvement examples will be discussed in light of overarching basin goals.

Keywords: Annex 2001, ecosystem improvement, hydrology, ecology

Modernizing Groundwater Quantity Management in Wisconsin: Needs and a Potential Approach

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Groundwater contributes to both Wisconsin's economic and environmental vitality. Aside from supplying human needs (domestic, agricultural and industrial water), groundwater supports lakes, streams, wetlands and the ecosystems that depend on them. Though Wisconsin's groundwater is abundant, uncontrolled extraction can harm both users and the environment.

Groundwater quantity management concerns have resource- and management-related dimensions. Resource concerns are (1) surface water depletion (reduced streamflows, spring flows, lowered water levels in wetlands); (2) large, regional water-level drawdowns (such as in the southeast and in the lower Fox River Valley; and (3) groundwater quality deterioration (arsenic, salinity, radioactivity increases). Management related concerns are (1) "flying blind" – the lack of a monitoring system that is sufficient for identifying potential trouble spots, and (2) a lack of management mechanisms.

What should an improved groundwater quantity management system accomplish, and how should it be developed? A unique partnership of consisting of economic interests (Wisconsin Potato and Vegetable Growers Association), environmental interests (River Alliance of Wisconsin), and scientists (University of Wisconsin System and USGS) met over an 18 month period to forge recommendations for improving Wisconsin's groundwater quantity management. The result is a workable system that protects the environment while allowing reasonable amounts of groundwater to be extracted. The system allows for periodic review of permits, adaptive management and some certainty for groundwater users. The system was designed with a view toward minimizing regulatory overhead and cost.

Keywords: groundwater quantity, legislation

SESSION 4B
Groundwater Modeling
Friday, February 28, 2003
10:00 – 11:40 a.m.

Using Characteristic Leakage Length as a Guide to Model Design: Application to the Grindstone Springs Area, Lac Courte Oreilles, Wisconsin

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The Lac Courte Oreilles Tribe is concerned that groundwater withdrawal from a basal sandstone aquifer may reduce the amount of groundwater available to downgradient springs fed primarily by a surficial sand and gravel aquifer. The US Geological Survey, in cooperation with the tribe, initiated a study in 2002 of the groundwater/surface-water system, and plans to evaluate the effect of pumping on the springs by using a groundwater flow model. Mathematical models can be useful tools for understanding groundwater flow and the effects of pumping. Appropriate use of simple models and the stepwise approach to incorporate complexity can reduce setup and calibration time, yet still maintain the power and functionality that models provide. Knowledge of the appropriate level of detail (such as vertical resolution) necessary to adequately simulate the groundwater flow system is critical for efficient model implementation. Calculation of the characteristic leakage length (the square root of the transmissivity of an aquifer multiplied by the vertical resistance) suggests that a single-layer model can adequately represent the groundwater flow system at the study site. Comparison of regional capture zones generated from a single-layer model and a multiple-layer model show close agreement under both natural and perturbed conditions. Conductivity contrasts that would require simulation as a multiple-layer system were identified by comparing capture zones.

Keywords: groundwater models, characteristic leakage length

Delineation of Five-Year Zones of Contribution for Municipal Wells in La Crosse County, Wisconsin: Methodology and Results

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Municipal wells in La Crosse County draw water from either the sand and gravel deposits along the Mississippi River Valley or the deep Mount Simon sandstone, which underlies the entire county. The Wisconsin Geological and Natural History Survey, in cooperation with the U.S. Geological Survey (USGS), has delineated five-year zones of contribution (ZOC) for these wells, with funding from the county and the Wisconsin Department of Natural Resources Source Water Assessment Program.

To delineate the ZOCs, we used a series of refined-mesh flow and particle-tracking models extracted from a recently developed USGS county-wide three-dimensional groundwater flow model. The shape and extent of ZOCs for municipal wells in the sand and gravel aquifer varied significantly depending on the value of hydraulic conductivity (K) chosen. Delta deuterium and oxygen-18 data collected by the USGS helped identify wells that were likely capturing surface water. This information, combined with K estimates from specific capacity data and pumping tests, enabled us to assign an average K value of 420 ft/day to the sand and gravel aquifer.

The largest ZOCs extend up to 1.5 miles and are associated with municipal wells in the sand and gravel aquifer beneath the Cities of La Crosse and Onalaska and the Village of Holmen. In contrast, much smaller ZOCs are associated with municipal wells in the Mount Simon aquifer and do not extend more than 1,500 feet.

Keywords: La Crosse, zones of contribution, groundwater modeling, isotopes

Hypothesis-Testing by Groundwater Flow Modeling: The Maquoketa Aquitard

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Flow modeling is a way of testing hydrogeological conceptual models that are hypotheses for explaining observed field data. Not all hypotheses can be tested because construction of individual flow models is time consuming. But which conceptual model is the "correct" one for testing? Geological inference and field observations can be used to narrow down the possible conceptual models and construct an appropriate flow model. In this way, hypotheses were tested about the distribution of hydraulic head with depth within the Maquoketa aquitard in southeastern Wisconsin.

Multi-level well data suggest that head in the Maquoketa aquitard has not yet equilibrated to over 120 m (400 ft) of drawdown in the underlying Cambrian-Ordovician aquifer during the 20th century. Therefore, the hypothesis that significant fracture flowpaths traverse the aquitard and increase effective vertical hydraulic conductivity is not supported. Instead, downhole geophysical logging and field testing indicate lateral flow along bedding-plane fracture zones in the upper part of the aquitard. Interbedded dolomitic and shale lithology, and dissolution along bedding planes favor laterally-extensive flow zones over vertical flowpaths.

Results from a representative anisotropic, transient, groundwater flow model are consistent with field data, and show sensitivity to boundary conditions at the edge of the aquitard a few kilometers away. The hypothesis that head values at the field sites are controlled by shallow aquifer heads at the aquitard subcrop was tested by changing parameter values of the thin model layers representing bedding-plane fracture zones. Flow model results and field data suggest that laterally-extensive bedding-plane fractures, not throughgoing vertical fractures, play a predominant role in the hydrogeology of the Maquoketa aquitard.

Keywords: Maquoketa, confining unit, hydrogeology, hypothesis-testing, flowpaths

Using Diverse Data Types to Calibrate a Watershed Model of the Allequash Creek Basin, Northern Wisconsin

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The term "watershed model" is used to describe a wide variety of modeling approaches. In this work, a deterministic groundwater flow model was constructed using MODFLOW2000 to simulate a groundwater-dominated watershed in a northern Wisconsin lake district. The parameter estimation UCODE was used with traditional calibration targets (head, lake stage, and flux observations), but also used targets that included groundwater flows to and from lakes, depth of a lake plume, streamflows from outside the watershed of interest, and time of travel. These latter data types were important for constraining the optimization comprising over 40% of the top five observations for the 11 parameters estimated. Independent estimates of groundwater inflow into lakes were most important for constraining lakebed leakance, and the depth of the lake plume was important for determining hydraulic conductivity and conceptual aquifer layering. The use of parameter estimation significantly eased the calibration process by providing a quantitative assessment of the model's ability to simulate disparate observed data types and a "best fit" for the particular model conceptualization. The model calibration shown here required the use of a "universal" parameter estimation code to include all types of observations in the objective function while incorporating the more sophisticated modeling packages. The methods described here help address issues of watershed complexity and non-uniqueness common to deterministic watershed models of groundwater-dominated stream systems.

Keywords: groundwater model, parameter estimation, UCODE, inversion, diverse data types