

# Minnesota Ground Water Association

Volume 16, Number 4: December, 1997

## President's Letter

I've really enjoyed my year as MGWA's president. The one thing I've liked most about this job is the opportunity to write this quarterly letter. As my final offering, I thought I'd share with you my take on some common axioms and how they might apply to the study of ground water.

One of the most important things I learned in graduate school was "The Principle of Least Astonishment," a.k.a. "Occam's Razor" or "The Principle of Parsimony." Basically, this principle states that when faced with multiple explanations, chose the simplest (or the "least astonishing"). Some salient examples include: "TCE in a monitoring wells, downgradient of a chemical factory, probably came from that factory" and "lowering of water levels in domestic wells is probably due to your client's nearby high-capacity production well." Fighting the Principle of Least Astonishment is like fighting entropy - it takes a lotta work and money.

Now, I've learned that the simplest explanation depends on your point of view and your experience. At face value, which explanation for a particularly productive well seems simpler: a thick sequence of gravelly sand or two underground rivers intersecting at the well location? As a ground-water scientist, you'll probably pick the first explanation, but "that's your education that makes you think that way."

The geologist T.C. Chamberlain knew that Occam's Razor sometimes held a trap for ground-water scientists. Ground water has this nasty habit of flowing through geologic units that are not homogeneous, isotropic, or completely predictable. He advocated the use of "Multiple-Working Hypotheses" when evaluating ground water. I like to think of it as the principle of "keep your options open 'cause your

probably wrong." Multiple-Working Hypotheses are a great prophylactic for "pounding a square peg in a round hole" syndrome (I'm gonna prove my preconceived notions are right, even if it kills me!).

One of my favorite expressions is: "When your only tool is a hammer, every problem looks like a nail." I guess it's a variant on the "square peg-round hole" syndrome but I've found it particularly applicable to ground-water modeling. For a time, I was fond of using one particular model to the exclusion of all others, mainly because it was a great model. However, it had one drawback - it was limited to steady-state conditions. It's amazing how unimportant transient effects become when you can't model them. That leads me to a related expression (courtesy of Calvin Alexander): "Don't let a model limit the scope of your experiment."

Every once in a blue moon, I think I've come up with a new way of doing something, such as calibrating a model or analyzing aquifer test data (rarely, as it turns out, is it really new). Some folks fondly call this process "innovation" but I'm here to tell you that it takes a lot of work to get others to buy into a new approach. I usually persevere because, "only the lead mule gets a change of scenery." Then again, "the earliest Christians met the hungriest lions."

Finally (and because nothing ever goes as planned), I am fond of the expression, "when life gives you lemons, make lemonade." When your pumping test is screwed up because someone forgot to fill the generator with diesel fuel, use that unexpected recovery to your advantage. Squeeze those lemons, but remember, "you gotta lay in a good supply before the hoarders get there."

— Ray Wuolo, MGWA President

## Managing Subsurface Geologic Information In Minnesota — A 25-Year Status Report

— G.B. Morey, Dale R Setterholm, and Robert G. Tipping, Minnesota Geological Survey

Twenty-five years ago Minnesota was in the midst of planning a statewide ground-water quality information system. The lead author of this article represented the Minnesota Geological Survey through much of that planning process (Morey, 1973). Although I am no longer directly involved with the program, I have had the opportunity to observe how it has grown over the past 25 years. Today my co-authors, Dale Setterholm and Bob Tipping, have management responsibilities for various parts of the program.

Those attending a conference convened by the Water Resources Research Center in August 1972 (Walton, 1973) recognized that Minnesota had a large ground-water resource. Consequently, ground-water exploration was not thought to be an important issue. The management plan that evolved from the conference focused on two issues:

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## The Capillary Fringe

In an effort to involve our membership more in the newsletter, we're starting a new opinion column, **The Capillary Fringe**. In our first installment below, Joe Otte of the Minnesota Pollution Control Agency bemoans the cookie-cutter approach we seem to have adopted to site investigation and cleanup. Have a look. Better yet, why not consider contributing to the March 1998 column? This is your newsletter and what better place to vent your spleen or simply comment on just about any aspect of ground water management and protection.

### Joe Spews

by Joe Otte, acting supervisor,  
MPCA's Voluntary Investigation and  
Cleanup (VIC) Program

#### Three wells and a Big Black Arrow on a map.

That's what we regulators really like. The Big Black Arrow tells you with near absolute certainty which direction ground water is flowing. And if the Big Black Arrow says it's going left to right across your site and you want a downgradient well, then put a big X on the right side of your site map, because *no matter where you're standing*, ground water is flowing left to right — just like the Big Black Arrow indicates. Never mind that there's a six foot difference in head between monitoring wells number 1 and 3, and the site's only 150 feet wide. Or that the Big Black Arrow points in a direction entirely contrary to what common sense might indicate. Since three points determine a plane, and water flows downhill, the Big Black Arrow is just the kind of information a good regulator needs. Though sometimes, mostly for effect, it's best if the lines perpendicular to the Big Black Arrow are slightly curvy.

Exaggerating? Maybe a bit. Generalizing? Guilty. Frustrated? Daily.

But then, in many ways, we government dweebs brought it on ourselves. We promulgated cleanup guidance in various MPCA programs with the intent of providing a consistent approach to site characterization, and instead created an approach to hydrogeology that removes nearly all the

geology and most of the hydro. What we've ended up with is the technological equivalent of a world that has only one size bathing suit. And because of economic considerations, it's a thong. And it's never polite to suggest that some folks need a bit more coverage than that.

Oh, I know. It's easy to sit in the bureaucrat's chair and whine that we're not getting the quality of investigation we need to resolve site issues, or to get snotty about an excess molecule or two of vinyl chloride. Believe it or not, I really am sympathetic with those that have to convince their clients that the problem is maybe much bigger than they might care to admit (are there really seven stages of DNAPL denial?). Or to have to argue that a better Phase I might lead to a cheaper Phase II. Or a better investigation might yield a less expensive cleanup. But I would really like to point out FOR THE RECORD that we live in a state where, despite Joe Soucheray's contention that "absolutely nothing is allowed," here at the agency we *encourage* consultant's creativity. We *celebrate* new approaches. We're *thrilled* by conceptual models. We *welcome* geophysics (though we admit to being somewhat skeptical of GPR). We get positively *giddy* when we can see aerial stereo photographs (emulsion, not Xerox, please). We *love* a new challenge. Hey, it's still a young science. We're learning, developing, pushing ourselves and growing every day.

And it's so sad to think that just as we're getting better at solving these problems, we're beginning to rely more and more on avoidance techniques and legal solutions. If I had a nickel for every No Association determination I reviewed, I'd... Well, I'd have about four bucks. But still — I could get almost two designer coffees for that!

Oh well. Maybe I'm worked up over nothing. Sad thing is, we're working on more guidance. Pretty much every day. Maybe it will be OK, I don't know. In the meanwhile, do me a favor: Just remember — It's only *guidance*. If I wanted rules, I'd work in RCRA. And if I wanted big black arrows, I'd work in signage at MnDOT.

## MGS Subsurface Data, cont.

- (1) How to match the ground-water needs of specific users with available resources, in terms of both quality and quantity, and
- (2) how to protect the ground-water resources from pollution. The first issue received little subsequent attention, but the state has worked very hard to prevent degradation of its existing resources.

Looking back, we now recognize the importance of the 1972 conference in that it was formally recognized there, perhaps for the first time in the state, that the quantity and quality of any ground-water regime are governed by two related but distinct systems. The geologic system is relatively static, at least within a time scale of years to hundreds of years, whereas the subsurface fluid system is dynamic and changes over time. The geologic system provides a fixed datum within which the subsurface fluid system operates. The importance of understanding the geologic framework cannot be overemphasized if the distribution, quantity, and quality of ground water are to be understood. The geologic framework was poorly defined and even more poorly understood in much of Minnesota 25 years ago. This was true for several reasons:

- (1) Geologists and others did not always know what subsurface data existed;
- (2) the data that did exist were not always available in a usable form;
- (3) data were sparse, particularly in out-state areas; and
- (4) there was no readily acceptable way to distinguish good data from bad.

At the time of the conference the Minnesota Geological Survey had already begun to address the first two issues with the development of an electronic data storage and retrieval system for geologic information, which was described in Minnesota Geological Survey Information Circular 9 (Mossler et al., 1971).

The scarcity and uneven distribution of valid geologic data were not easily —continued on facing page

solvable problems. In May of 1972, there were only 750 sets of well cuttings housed at the Minnesota Geological Survey. Two hundred and seventy-five of those sets were from the Seven County Metropolitan Area; 19 counties lacked any data. Those numbers contrasted with North Dakota, Iowa, and Wisconsin, where 10,000, 23,000, and 16,000 sets of well cuttings, respectively, were available. At the same time, the Survey had only several hundred drillers' logs in its files, many of which were compromised by inaccurate locations. Thus, in 1973 it was generally agreed that the subsurface geologic data base in Minnesota was totally inadequate for planning and management purposes, and that the state must expand its efforts to collect subsurface geologic data.

How well have we done in the intervening 25 years? Programs such as the Water Well Contractors Licensing Act of 1971 have made it much easier to systematically collect cuttings,

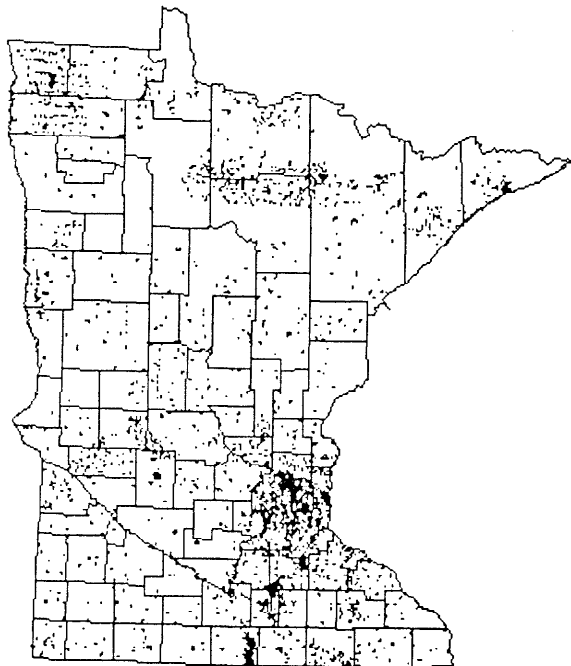


Figure 1. Locations of water wells having cuttings stored at the Minnesota Geological Survey.

cores, and other data. As of March 30 of this year, the survey had 3,800 sets of water-well cuttings in its files. All but two counties now have at least one set of cuttings (Fig. 1). However, much of the collection is still focused on the Seven County Metropolitan Area and on southeastern Minnesota, where a variety of geologic studies has been completed. Other than selected areas in northwestern Minnesota in the Red River lowland, and in northeastern Minnesota along the north shore of Lake Superior, the cuttings collection in out-state areas remains inadequate for modern geologic interpretations.

The lack of an adequate collection of cuttings has been mitigated somewhat by the availability of other kinds of data, most importantly down-hole geophysical logs. As of March 30, the Survey had approximately 3,250 geophysical records in its files (Fig. 2). Of those, 1,184 records were derived from wells where cuttings also are

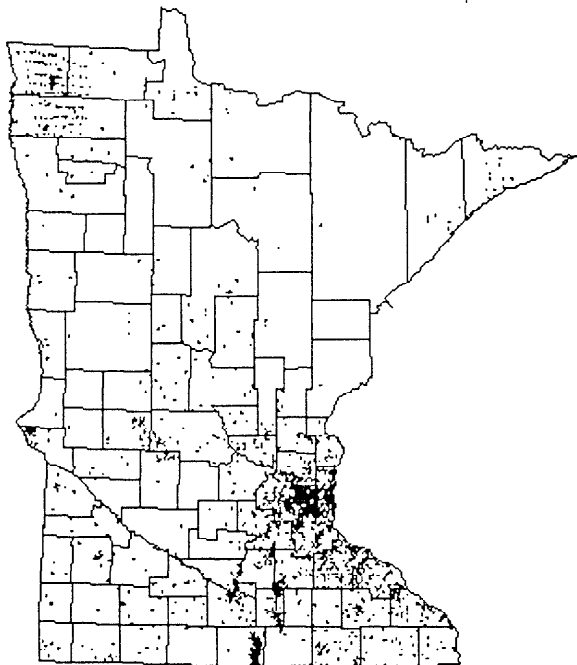


Figure 2. Locations of water wells having down-hole geophysical logs in the files of the Minnesota Geological Survey.

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## MGS Subsurface Data, cont.

available. Geophysical logs are important because they record actual physical measurements rather than subjective descriptions skewed by observer bias. The geophysical logs provide points of high-quality stratigraphic information that enhance the value of lower-resolution drillers' logs by serving as a guide when interpreting nearby well logs.

The importance of geophysically logged holes as stratigraphic control for interpreting well records that lack both geophysical logs and cuttings is underscored by the raw numbers. As of March 30, 1997, our County Well Index (CWI) contained the records of approximately 228,000 drill holes. We do not have the time, money, or staff to locate all of the drillers' logs submitted to us, consequently, the backlog of unlocated logs continues to grow. Of those in the system, approximately 83,000 logs contain interpreted geologic information and are located to within the area of a 2.5-acre or smaller cell. Approximately 38,000 of the located and interpreted wells are finished in bedrock (Fig. 3), and 45,000 are finished in glacial materials (Fig. 4). The remainder are so-

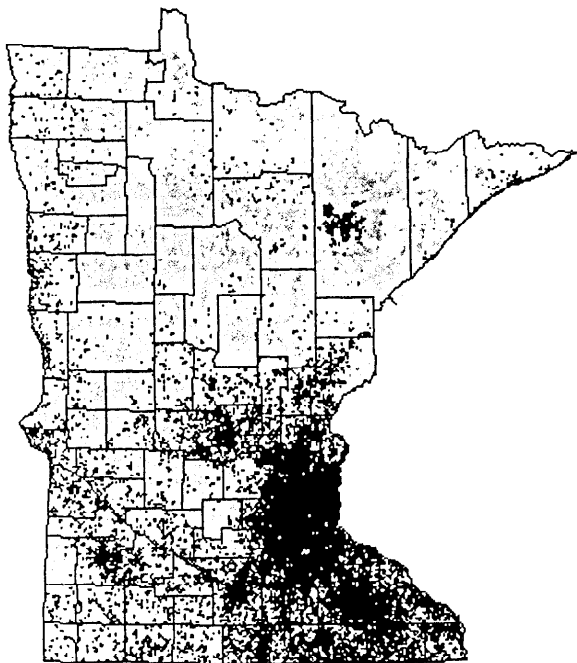


Figure 3. Location of water wells and other kinds of holes recorded in CWI (County Well Index) that are finished in bedrock. Black, located; gray, unlocated or wells that have less than four quarter-section letters (2.5-acre cell).

called unlocated logs that are in the descriptive language of the driller and have not been verified as to geographic location.

CWI records are derived from copies of drillers' logs submitted to the Minnesota Department of Health as part of a reporting protocol mandated by the Licensing Act of 1971. At the Minnesota Geological Survey we enter the drillers' logs into a desk-top computational system that facilitates the storage, retrieval, and manipulation of the contained information (Wahl and Tipping, 1991). As an organization, we are concerned with locating and interpreting the logs so that they can be used in geologic studies. Today, much of that work is done as part of our portion of the County Atlas Program and other mapping activities.

What difference does it make to planners and resource managers that drillers' logs are located and interpreted professionally? Today the

state is engaged in developing a comprehensive geographic information system that starts with a well-constrained georeferenced base. Adding digital locations to well data allows users to compare geologic or hydrologic attributes with other kinds of data generated for public-health, land-use, or planning purposes. These comparisons increase the value of all sets of data. Additionally, geologic data obtained from drillers' logs represent the foundation upon which hydrogeologic interpretations are built. Competently interpreted well records build a useful geologic framework by providing a transition from point data to mappable geologic units. The delineation of carefully defined geologic and hydro-

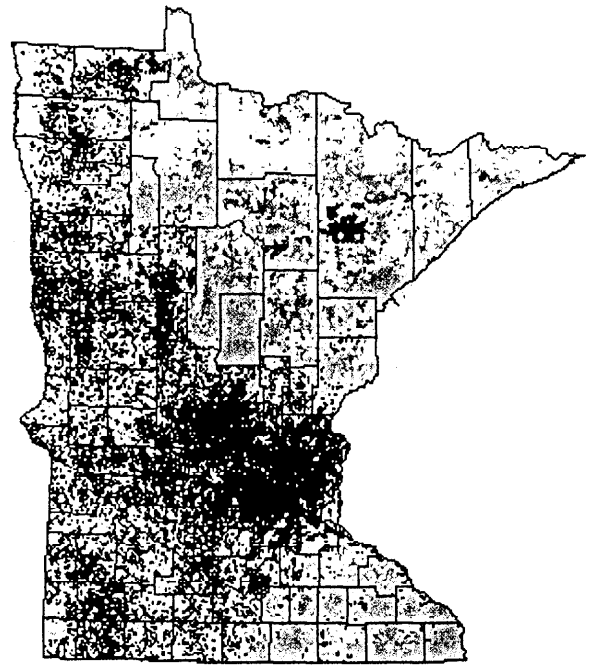


Figure 4. Location of water wells and other kinds of holes recorded in CWI (County Well Index) that are finished in Quaternary material. Black, located; gray, unlocated or wells that have less than four quarter-section letters (2.5-acre cells).

geologic units is the essential first step in understanding the availability of ground-water, mechanisms of contaminant transport, changes in the physical parameters that define an aquifer, and many other attributes that are important in managing the resource.

Experience over the years has taught us that some well records lack validity, but distinguishing the good from the bad logs is not always easy. This judgment is best made in the context of preparing a map, where the individual logs are integrated into geologic syntheses or "working models" that are continually modified as new data are added. Questions continually arise about the validity of individual data points, especially those that depart from the synthesis provided by the model. Should the model be modified to reflect the discordant data or should the data be disregarded? Clearly the experiences and the bias of the geologist making such decisions are important factors in deciding which approach to follow. Regardless, poorly located or inaccurate data cast doubt on the reliability of

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## MGS Subsurface Data, cont.

any geologic synthesis to a point where it becomes unbelievable.

Although we have learned how to use drillers' logs effectively, an evolving problem of considerable significance remains to be solved. (Figs. 3-4) Approximately 135,000 or 59 percent of the wells recorded in CWI are unlocated according to currently accepted standards, or they lack geologic interpretation. Furthermore, over the past 3 years an average of 14,900 new well records per year was received by the Survey. We have been able to locate and interpret only 3,500 of these wells each year. Consequently, our backlog of unlocated and uninterpreted logs grows larger and larger. The state, counties, and the other planning districts, as well as the community of earth science professionals, must recognize that it is not enough just to have the original data. We must all assume some of the responsibility in data management for the common good. As a first step, we should critically ask if the Minnesota Geological Survey is the appropriate place to store drillers' records electronically or manually? Should we store all of the data or focus on the geologic logs? Should all of the data be located to currently acceptable standards? Do all of the water wells need a geologic interpretation beyond the descriptions provided by the drillers? If the answer to either of the last two questions is no, what criteria should be used to determine which wells are located and interpreted? Regardless of specific answers to these and similar questions, it is clear that we have a massive task ahead of us. If we do nothing or continue along the same path, the problems will only get worse with time. Now is the time to implement changes that will move the geologic information system 25 years into the 21st century.

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## MGWA Board Meeting Minutes

**August 7, 1997, Egg & I, University and 280, 7:30 a.m.**

**Attending:** Ray Wuolo, President; Paul Bulger, Treasurer; Jan Falteisek, Secretary; Tom Clark, newsletter editor; Jim Almendinger, advertising; Paul Putzier.

**Approval of Minutes** — Ray Wuolo called the meeting to order at 7:40 a.m. Minutes for June were approved.

**Fall Field Trip** — Paul Bulger and Jan Falteisek reviewed progress on Fall Field Trip. Generally, plans were well underway and nearly on schedule. Pay asked what plans had been made for breakfast on Saturday. Question would be forwarded to Bill Johnsen for follow-up.

**Newsletter/Directory Update** — Tom Clark provided a newsletter update. Jan Falteisek, issue editor, noted that material was being assembled and developed on schedule. Tom noted that both newsletter and directory will be published before the fall field trip. Jim Almendinger, advertising manager, noted again the need for a replacement. There were no inquiries from notice in June Newsletter.

**Fall Conference** — Ray said that he had talked with Randy Hunt, USGS in Madison, who has indicated definite interest in a fall program on wetlands. Dates were discussed, possibly two weeks after GSA: November 13, or 14<sup>th</sup> were suggested as first choice.

**Spring 98 Meeting** — A joint spring meeting with the Wisconsin Chapter AWRA was discussed and is likely it

## Minutes, cont.

will be arranged, possibly held in La Crosse, WI.

**Election of Officers** — Nominations and schedule for election of 1998 officers were discussed.

**Other business** — Paul Putzier noted that he continued to hold the key for the Post Office Box and checked the contents regularly.

Meeting adjourned 8:30 a.m.

**September 4, 1997, Egg & I, University and 280, 7:30 a.m.**

**Attending:** Gretchen Sabel, Past-President; Ray Wuolo, President; Paula Berger, President-Elect; Paul Bulger, Treasurer; Jan Falteisek, Secretary; Tom Clark, newsletter editor; Jim Almendinger, advertising; Jennie Leete, Sean Hunt, WRI.

**Approval of Minutes** — Ray Wuolo called the meeting to order at 7:30 a.m. Minutes for August were approved.

**Fall Field Trip** — Sean Hunt, Paul Bulger and Jan Falteisek reviewed progress on Fall Field Trip. Logistics were reviewed and a variety of questions on lodging, registration, and transportation were addressed.

**Newsletter/Directory Update** — Tom Clark indicated the September newsletter was ready to print and would be mailed next week.

**Fall Conference on Wetlands Hydrology** — Ray asked for a volunteer to make meeting place arrangements for either November 13 or 14 (full day). Jennie said that she would pursue meeting room arrangements. Gretchen asked about using schools, public agencies, etc. for meeting. Jennie said she would check with those places as meeting rooms and work with Gretchen on a meeting place.

**Election of Officers** — Nominations are needed for president-elect and secretary. Jan said that she would run for another term as secretary. Ray encouraged Board members to make personal calls or other contacts with potential Board candidates. Paula suggested making an announcement on the bus at the beginning of the field trip. It was noted that

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## Minutes, cont.

the ballot needed to be inserted in the December newsletter. Gretchen drafted a brief "want ad" for open positions for the September newsletter.

**Spring 98 Meeting** — A joint spring meeting with the Wisconsin Chapter AWRA was discussed. It was noted that the MN chapter of AWRA has been inactive.

Meeting adjourned 8:25 a.m.

## October 2, 1997, Egg & I, University and 280, 7:30 a.m.

**Attending:** Gretchen Sabel, Past-President; Ray Wuolo, President; Paula Berger, President-Elect; Jan Falteisek, Secretary; Tom Clark, newsletter editor; Jim Almendinger, advertising; Jennie Leete, Sean Hunt, WRI; Leigh Harrod.

**Approval of Minutes** — Ray Wuolo called the meeting to order at 7:50 a.m. Minutes for September were approved.

**Fall Field Trip** — A short update of the field trip was given by those who attended. Leigh Harrod mentioned a conversation with Calvin Alexander regarding working with mortgage bankers by approaching them informally.

As another approach, Ray said he would check with Ken Haberman at Barr, who works with property purchasers, conducting phase 1 investigations and identification of existing hazards.

**Newsletter/Directory Update** — The board approved and welcomed Leigh Harrod as new advertising manager, who will take over from Jim Almendinger.

**Fall Conference: Seminar of Surface Water/Ground Water Interaction** — Confirmed date of November 14<sup>th</sup>. Ray said he would get mailing information to Sean Hunt by October 9<sup>th</sup>. Gretchen said she had the MPCA Board room reserved for the day. Jennie said she had the USGS conference room signed out, but there was a question whether it was large enough for the expected number of attendees.

After some discussion, the MPCA Board Room was chosen, with the understanding that the room could hold

a maximum of 60 comfortably. Jennie said she would double check the maximum and that would limit the registration. Gretchen said she had catering organized. Ray said the USGS would provide material for a conference booklet — MGWA would provide copying. A brochure would be prepared and mailed separately as an announcement.

**AIPG Lobbyist** — Paula noted that the AIPG was planning to hire a lobbyist and asked whether the MGWA would be able to. Jennie explained that although the current tax status would allow it, the preferred tax status would not.

**Legislative Open House** — It was asked whether the MGWA would sponsor another open house for the legislature this winter. Continued to January meeting.

**Scholarships** — Paula asked about funds available for scholarships. Jennie said that budgeted funds had been awarded. Paula said she would send out 1998 scholarship letters in the next week or two.

**Corporate Memberships** — Jan asked whether corporate memberships were possible. Jennie described how some organizations charged for corporate memberships. Jennie also mentioned tax implications and voting issues. Issue continued to January.

A "corporate sponsorship" category was suggested in which an amount (e.g. \$300) would go into the scholarship fund and would then be awarded in their name. MGWA would provide a certificate to the sponsor. Consensus was that it could be done, but needs additional discussion.

**Election of Officers** — Bob Beltrame and Jim Piegat were mentioned as candidates for President-Elect. Jan Falteisek said she would run again for Secretary. Ballots need to reach members in December.

Meeting adjourned 8:45 a.m.

*Respectfully submitted, Jan Falteisek, MGWA Secretary*

## The primary objectives of the MGWA are:

- Promote and encourage scientific and public policy aspects of ground water;
- Establish a common forum for scientists, engineers, planners, educators, attorneys, and other persons concerned with ground water;
- Educate the general public regarding ground water resources; and
- Disseminate information on ground water.

## Reminder to Vote for New Officers and Renew Your MGWA Membership

Please remember to vote for a President-Elect and a Secretary by completing the 1998 Officer Ballot which will be enclosed in a separate mailing with your invoice for your 1998 MGWA membership dues. Your annual member dues will again be \$20 for professionals and \$15 for students. The MGWA Membership Directory, a valuable reference and networking toll for those interested in ground water issues in Minnesota, is available for an additional \$7 and is mailed in late Spring to members who order it.

We again solicit your donations in two areas: donations to help cover the extra cost of recycled paper, and donations to help fund scholarships for students studying in hydrogeology and related fields. There is a convenient place at the bottom of your dues statement to elect either or both these options.

Please get your dues in as soon as possible after receiving your invoice to make our business manager's job a little easier and help speed production of the 1998 directory.

**Thanks, and don't forget to vote!**

## 1997 AIPG – MGWA — AWG Fall Field Trip Report

With the American Institute of Professional Geologists (AIPG), Minnesota Chapter, taking the lead, the MGWA and Association of Women Geoscientists (AWG) joined in sponsoring this year's fall field trip, September 26-27, featuring the karst hydrogeology of southeast Minnesota. Again this year, the weather gods smiled on the 75 field-trippers who filled two buses for the two-day tour which featured stops in Olmsted, Mower, Fillmore and Winona counties. The trip was co-led by noted karst authority Dr. Calvin Alexander of the University of Minnesota's Department of Geology and Geophysics and Jeff Green, area ground water specialist with the Minnesota Department of Natural Resources (DNR) Rochester office. The trip was joined by Bob Libra of the Iowa Geological Survey and Maureen Muldoon of the Wisconsin Geological and Natural History Survey, who provided

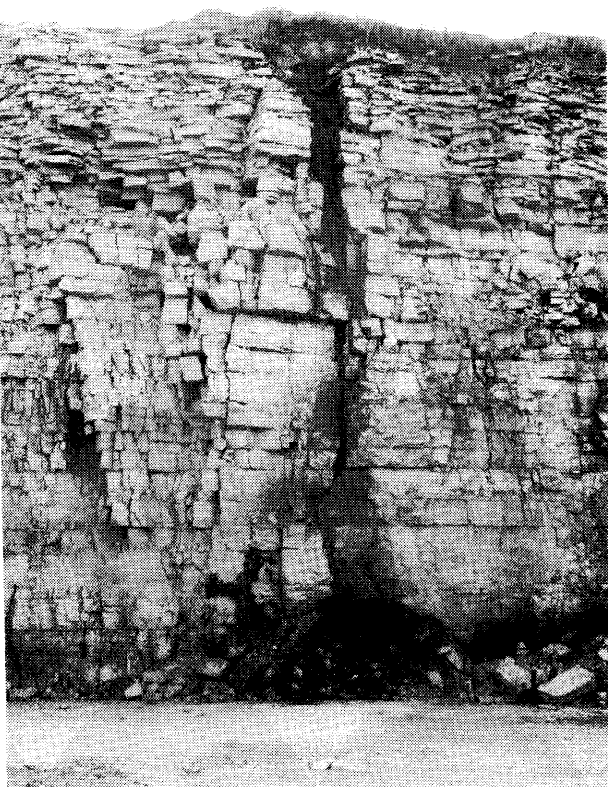
the perspective of karst hydrogeology studies from their respective states. Jeff Broberg of McGhie and Betts Environmental Services in Rochester added valuable insights to the trip from his years of travelling the highways and back roads of southeast Minnesota.

### Day 1

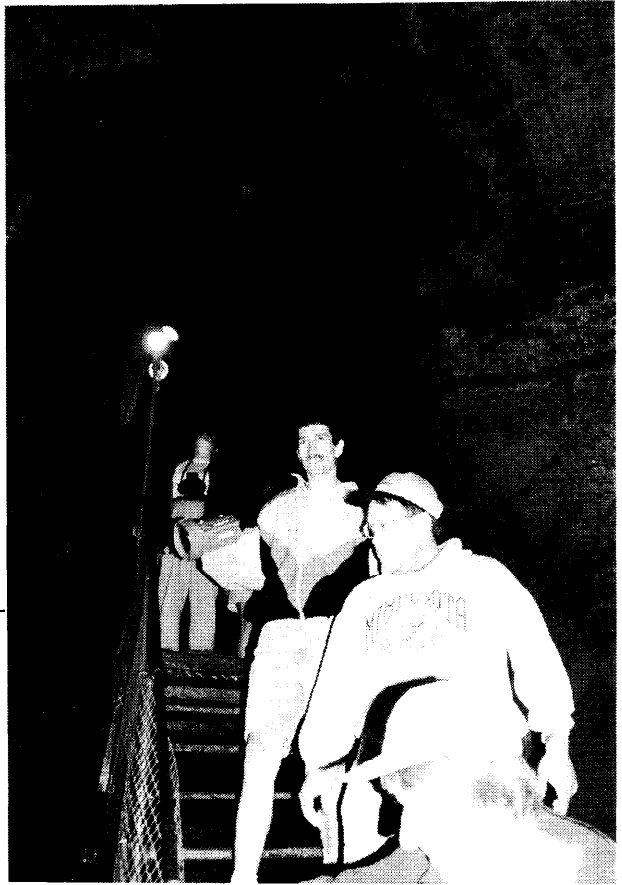
The first stop Friday morning was at the offices of Rochester Public Utilities (RPU), where Joe Hensel welcomed us and summarized his company's activities relating to ground water assessment and wellhead protection. RPU serves a population of 79,000 and is responsible for two dozen wells which pump close to four billion gallons a year. Ground water quality and quantity

data are maintained in a geographical information system (GIS), essential to the company's wellhead protection strategy.

Tony Runkel of the Minnesota Geological Survey then summarized the results of ongoing investigations of the hydrogeology of the Paleozoic strata of southeast Minnesota. Tony's work has shown that traditional beliefs about the aquifers of the area may not apply when the "microhydrostratigraphy" of the units is examined in detail. In the Rochester area, for example, the Platteville Limestone within the Decorah-Platteville-Glenwood sequence has many characteristics of an aquifer, and should be considered as such, at least when it is the first encountered bedrock. Further down the section, the Jordan Sandstone, long



*Paleokarst feature of the Big Spring Quarry near Harmony. Photo: Sean Hunt*



*Mark Bishop (with flashlight), owner of Niagara Cave, leads a cave tour. Photo: Tim Thurnblad*

considered an aquifer throughout its saturated thickness, has many confining characteristics in its upper part in this area. This kind of understanding is important to decisions about wellhead protection and where to locate new wells.

Terry Lee, Olmsted County Water Planning Coordinator, illustrated with slides the importance of focused ground water recharge to the St. Peter-Prairie du Chien-Jordan aquifer complex at the edge of the Decorah Shale, along the wooded hillsides that surround Rochester. New development encroaching on these recharge areas needs to be carefully evaluated in terms of its potential impact to water quality in the underlying aquifers.

Jeff Broberg, McGhie and Betts Environmental Services, discussed field identification of ground water discharge zones and edge-effect wetlands using vegetative indicators and soil types. Small linear wetlands on

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slopes between upper and lower Paleozoic aquifers have high plant diversity and are important in encouraging recharge rather than runoff and can be effective filters of nutrients such as nitrate and phosphate, which can impact ground water quality.

Next, Chris DeMattos, hydrologist with the Department of Health, Rochester office, discussed general well construction requirements and special concerns relative to the geology of southeast Minnesota. The department is developing "50-foot of cover" maps to help well drillers locate areas where the protective cover over the upper carbonate aquifer is greatest. The upper carbonate aquifer is much more likely to be contaminated if the overburden is less than 50 feet thick. Deeper bedrock wells in this area can be very expensive to install. Wells finished in the Prairie du Chien, for example, can cost upwards of \$15,000.

The final session at the Rochester Public Utilities offices was presented by Larry Landherr, Regional Manager for the Pollution Control Agency's Rochester office. Larry discussed how the agency's operations relate to karst geology, surface



Part of the educational display on sinkholes along the DNR's Root River Recreational Trail. Photo: Sean Hunt

water/ground water interaction, and projected population growth in the Rochester area.

Since the morning session ran long, the stop at the Golden Hills roadcut on US 52 south of Rochester was shortened to a rolling stop. Here, the lower part of the Cummingsville Formation (Galena Group) is exposed atop the Decorah Shale, the

most important aquitard in southeast Minnesota. The soil zone is very thin at Golden Hills, and recharge from lawns, septic systems and farms moves through the soil quickly, reaches fractures in the Cummingsville on the ridges adjacent to the cut faces, and then

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		Annual Rate 4 issues	Annual Rate 1 issue
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## Fall Field Trip Report, cont.

moves down to the top of the Decorah where it emerges in springs. During freezing weather, the top of the Decorah is marked by spectacular ice accumulations at the Golden Hills cut.

We stopped for lunch at Lake Florence Park in Stewartville, site of a Department of Natural Resources riverine ecosystem restoration project. The project includes removal of an old dam on the North Branch of the Root River and restoration of the river channel.

The buses then headed south to the LeRoy karst area. This is one of the few areas in Minnesota where the Devonian karst is exposed. Several recent sinkholes have opened adjacent to a corn field on the road to Osmundson's quarry, our next stop. Here, the large, blocky, smooth limestone of the Lithograph City Forma-



*Climbing up from the depths of the sinkhole along the Root River Recreational Trail at Saturday's first stop. Photo: Lee Trotta*



*Hydrogeologist Steve Robertson and others observe a large solution fracture in the Prosser Formation. Photo: Lee Trotta*

tion is exposed. Earlier this century, the stone was quarried here and further south in Iowa for use in the printing industry.

The next stop, in the town of LeRoy, featured a leaking underground storage tank site. The sensitive geology of this location, 20 feet of silty sand over the same Lithograph City Formation exposed at the quarry, made a hydrogeologic investigation of the site a high priority. Four shallow monitoring wells to the top of the weathered bedrock and one double-cased deeper well to 50 feet, then open-hole to 70 feet have been installed. Petroleum-contaminated ground water extends offsite from the source area (the former tank basin) toward the south. Two wells onsite have shown significant contamination, however, a well across Minnesota Highway 56 and down-gradient has shown only trace amounts of product. The deep well has had no detections of petroleum compounds. Remediation activities at the site in-

clude the removal of 150 cubic yards of heavily contaminated soils from the tank basin, baseline and event sampling of the monitoring wells and the water supply well at the adjacent creamery, and sampling of springs identified along the nearby Upper Iowa River.

From there, it was on to the feature stop of the day, Niagara Cave, near the town of Harmony. Niagara Cave is one of two commercial show caves in Minnesota, Mystery Cave being the other, in Forestville State Park. Niagara Cave is a fine example of the karst plumbing system in action, connecting points of surface infiltration primarily through sinkholes, with resurgent springs. Mark Bishop, the cave owner, led one of the tours and his first-hand knowledge of the cave history and features was impressive. Niagara Cave has been mapped extensively over the years, however submerged passages accessible only to divers have only just recently been explored. One encouraging sign of improvement in the cave's environment is that recent soil conservation efforts appear to have reduced the sediment input to the cave's passages during floods and the cave is actually starting to clean itself out. Dr. John Nosek, a professor of re-

— continued on next page

**Fall Field Trip Report, cont.**

source analysis at St. Mary's University in Winona plans to have several of his students study the water quality of the cave to assess differences in water input to the cave compared to that in emergent springs.

The final stop of the day was at the Big Spring Quarry, northwest of Harmony, which demonstrates the Galena karst of southeastern Minnesota. The depth of the quarry is limited by water-filled conduits below the quarry floor. In the southeast corner of the quarry, discharge from the conduits was readily observed on the quarry floor. The quarry also exposed several interesting paleokarst features, including sediment-filled conduits and sinkholes in cross-section.

The evening's dinner speakers featured Bob Libra of the Iowa Geological Survey and Maureen Muldoon of

the Wisconsin Geological and Natural History Survey. Bob took us on a geological tour down into Iowa to explore the Iowa karst and see how nomenclature and geologic exposures differ from Minnesota's. Contrary to common perceptions, Iowa like Minnesota, has a wide variety of rock types from Precambrian to Quaternary. Maureen then zeroed in on the fractured Silurian dolomite aquifer of Door County, Wisconsin, including detailed fracture flow studies and water budget analyses of two quarries in the northern part of the Door peninsula.

**Day 2**

The second day began with a stop at the Department of Natural Resources (DNR) sinkhole display along the Root River Recreational Trail. (See also the December 1996

MGWA Newsletter for a picture and discussion of the display.) Here, the DNR has taken the opportunity to raise public awareness of how karst hydrogeology works and the need to protect lands in and around sinkholes.

It was a short drive to Kapper's Quarry, just northwest of Fountain for the second stop of the day. This is another Galena quarry, providing crushed limestone and dolomite for road construction. During heavy rainfall events, the quarry floods from below as water backflows through karst conduits. When this occurs, all the operators can do is wait for the springs to catch up



*Spring at the Laneboro Fish Hatchery. Photo: Tim Thurnblad.*



*Dr. Calvin Alexander at the discharge point for Fountain Big Spring, Fillmore Co. Photo: Sean Hunt.*

with the sinkholes and drain the quarry.

A short way down an adjoining township road led us to the Fountain Spring Group, a complex of four distinct springs, which collectively are the discharge for the Fountain Springshed. Depending on recent rainfall events, these springs can be either babbling and clear or roaring and muddy. During our visit, the water emerging was surprisingly clear and cold. Jeff Broberg took a few minutes at this stop to acquaint us with some of the vegetation indicative of the cold ground water of emergent springs in this part of the state.

A fine stratigraphic section is exposed along the west side of Fillmore County 17 as it descends off the Galena Plateau into the valley of Watson Creek and this was our next field trip stop. This cut exposes the

— continued on next page

## Fall Field Trip Report, cont.

stratigraphic section from the Cummingsville Formation of the Galena Group down through the Decorah Shale, Platteville Limestone, Glenwood Shale, St. Peter Sandstone, and finally to the Shakopee Formation.

Our lunch stop at the Lanesboro State Fish Hatchery provided a welcome break and left us with a sense of appreciation for keeping karst springs clean. The ponds fed by the hatchery spring produce nearly half of all the trout stocked in the state's public waters, so important to Minnesota's tourist economy. During the early 1990's, a field investigation by DNR and subsequent grant from DNR and the Board of Water and Soil Resources (BWSR) led to excavating and filling a sinkhole over two miles from the hatchery that was sending agricultural runoff and sediment into the conduit system feeding the hatchery spring. Since this work was completed, the hatchery spring has stayed clear and sediment is no longer a factor in inhibiting trout production.

The next-to-last stop featured another example of the impact of spilled petroleum products on karst terrain, this time, 8700 gallons of unleaded gasoline from a tanker truck rollover near the town of Amherst in Fillmore County. Despite the distinctly rural nature of the area, two private wells in the Prairie du Chien aquifer had to be sealed and replaced with deeper wells. In addition, one of the residences, directly across the county road from the site of the accident, was affected by gasoline vapors, necessitating active remediation which continues today (the spill occurred in May 1995). Trace levels of petroleum have periodically been detected in the South Fork of the Root River, nearly a quarter-mile downgradient of the release.

The final field trip stop was at the Lewiston Country Club, west of Lewiston in Winona County. Construction of a dam on the golf course to create a water hazard resulted instead in the formation of multiple sinkholes behind the dam so the intended impoundment never held water. The



Field trip group at the last stop, Lewiston Golf Course. Photo: Sean Hunt

golf course is located in the area of Prairie du Chien karst, which is also the bedrock at the site of the Lewiston wastewater treatment plant, where one of the lagoons failed catastrophically several years ago.

Thanks to the many who helped make this year's field trip a success, especially coordinator Bill Johnsen of AIPG and his committee of Paul Bulger, Jan Falteisek, Sean Hunt (representing AWG) and Andrew Nichols.

Calvin Alexander and Jeff Green led the trip and wrote the excellent field trip guidebook and MGWA's publisher, Watershed Research Incorporated, produced it.

Thanks also to the photographers whose pictures appear with this article. If you have ideas for next year's trip or would like to help out, just let any of the MGWA, AIPG or AWG officers know.

A few extra copies of the guidebook are available for \$20 each through MGWA, c/o Watershed Research, 4779 126th St. N., White Bear Lake, MN 55110-5910, (612) 426-8795. Checks should be made out to MGWA.

— Tom Clark, Newsletter Editor

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## Enpro has a New Address

Enpro Assessment Corp is celebrating their 10<sup>th</sup> year with a new home and fax number. The telephone number is the same.

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## Leigh Harrod: New MGWA Advertising Manager

Leigh has accepted the assignment of Advertising Manager from Jim Almendinger. Leigh received a BS in Geology from LSU, a MS in Environmental Management of Natural Resources from the University of Texas, and studied hydrogeology in the Professional Degree Program at the Colorado School of Mines. Her work history includes both the private and public sector in oil & gas and in the environmental industry. Leigh's focus for the past six years has been on Minnesota hydrogeology, with her primary work in the areas of ground water planning, ground water modeling, aquifer management and GIS systems.

## Over 100 Attend Fall Conference on Ground Water-Surface Water Interaction

The interaction of ground water and surface water proved to be a popular topic as over 100 jammed the Minnesota Pollution Control Agency's Board Room on Friday, November 14, for the MGWA's Fall Conference. The featured speakers for the day-long conference were Drs. Randy Hunt and Dave Krabbenhoft of the U. S. Geological Survey Office in Madison, WI, and Dave Dahlstrom of Barr Engineering, Minneapolis.

After introductions by MGWA President Ray Wuolo, Randy Hunt began with a fascinating overview of the hydrogeology of natural and constructed wetlands, using the USGS's constructed wetland site near Wilton, WI as an example. Through detailed site instrumentation, use of isotopes and ground water flow modelling, he demonstrated some of the differences between natural and constructed wetlands. One of the problems with wetland management policy, he said, is that until recently, definition of wetlands was driven by regulation, rather than science. His data showed that many of the chemical characteristics of a created wetland are inherited from the materials used to create it. Although a created wetland may appear aesthetically pleasing next to a natural or restored wetland, its hydrogeochemistry, flow characteristics, and the diversity of plant communities it supports may be vastly different from an undisturbed system.

Dave Krabbenhoft next discussed the role isotopes play in defining ground water-lake interactions. For examples, he cited his work instrumenting Sparkling Lake in northern Wisconsin, and Nevins Lake in the upper peninsula of Michigan. The lakes both lie in outwash plains, but Sparkling Lake is characterized by high permeabilities with considerable ground water-surface water interaction, while Nevins Lake is very shallow and receives very little ground water input. Because of this, Nevins Lake never receives a source of alkalinity from incoming ground water and is subject to acidification. Dave pointed out that the lake is acidifying because of hydrology, not chemistry. Ground water immediately under the lake is isotopically similar to the lake water, and very different from surrounding ground water 15 feet away. At Sparkling Lake, the system is much more dynamic, with summer surface water loss to ground water and a winter reversal, with ground water inflow near shore.

The first two afternoon talks by Dave Dahlstrom and Randy Hunt discussed analytical approaches for evaluating ground water-surface water interactions. The advantages and disadvantages of analytical element and finite difference models were discussed. New analytical element model (AEM) screening methods can be used to save time and costs over running a full-blown model.

Dave Krabbenhoft finished the day describing his work analyzing for mercury in ground water and surface water systems. He described his work on Palette Lake in northern Wisconsin, and his part on an interdisciplinary team working on the Aquatic Cycling of Mercury in the Environment in the Florida Everglades.

The popularity of the conference underscored the need of hydrologists and others in the ground water field to understand more about ground water interactions with surface water and these three scientists each gave lively and interesting discussions featuring examples from their many years of experience.

— Tom Clark, Newsletter Editor



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## New Publications

### USGS

U.S. Geological Survey Water-Resources Investigations Report 97-4085 — "Nitrate and pesticides in surficial aquifers and trophic state and phosphorus sources for selected lakes, eastern Otter Tail County, west-central Minnesota, 1993-96." by J.F. Ruhl.

### Flood Publications

Climatic Conditions and the Resulting 1997 Record Spring Floods on the Upper Minnesota River and Red River of the North in Minnesota, Minnesota DNR Waters, June 1997, St. Paul.

Managing Minnesota's Floodplains for the Future of Our Communities, Minnesota DNR Waters, August 1997, St. Paul.

The Floods of 1997: A Special Report, North Dakota State Water Commission, June 1997, Bismarck

Flood Disaster of 1997 (special issue): North Dakota Water, Vol. 5, No. 5, June 1997, (by the North Dakota Water Education Foundation, 1501 North 12th St., Bismarck 58501)

### 1995 — 1996 Water Year Data Summary Available From DNR Waters

The report provides a review and summary of basic hydrologic data gathered through DNR Waters programs. The four major areas of data collection include climatology, surface water, ground water, and water use. The focus of the report is the distribution and availability of Minnesota's water resources. The report is filled with maps, graphs, and summaries of data gathered during the period October 1994 to September 1996.

*For more information on MN DNR publications call DNR Waters (612)296-4800. Additional climate information, see also the climatology section of the MN DNR web site: <http://www.dnr.state.mn.us>. For North Dakota publications, write the North Dakota State Water Commission, 900 East Boulevard Avenue, Bismarck, ND 58505-0659.*

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## Wellhead Protection Rules Finalized

The well head protection rules are now final! The rules (Minnesota Rules, part 4717.7000 and parts 4720.5100 to 4720.5590) were open for public comment for 30 days in late summer, were adopted without a public hearing, and went into effect on November 3, 1997. The wellhead protection program will be administered by the Minnesota Department of Health (MDH). The rules have been around in draft form for over three years and in the process of making it to final form have been tried out on many public water suppliers (mostly municipalities) that expressed an interest in getting started on wellhead protection on a voluntary basis in advance of the promulgation of the rule. Demand to get started has been strong and a wait list of 10 to 20 communities has existed for over a year. However, now that the rules are finalized, participation will no longer be voluntary. Public water suppliers across the state will be steadily phased into the wellhead protection program over the next 10 years.

The effect of the rule will be noticed by all public water suppliers in the state, especially those ranked by MDH staff high on the phasing list (i.e., potentially vulnerable water

supply systems) or those that commence drilling of a new well. Those highest on the MDH's phasing list will get an announcement early in 1998 in which they will be put on notice that they will need to begin wellhead protection planning in the subsequent 12 month period. Others will be phased in later according to their placement on the phasing list or when they add a new well. Once a new well is added to the distribution system, the public water supplier must initiate wellhead protection. For more information on the wellhead protection rules, see the August 4, 1997 issue of the State Register or contact the Minnesota Department of Health.

— Steve Robertson, Newsletter Team

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## EPA Issues Final Guidance Regarding Source Water Assessment

As required by Congress, EPA issued final guidance on state Source Water Assessment and Protection Programs (EPA 816-R-97-009) in August. The assessment process outlined in the guidance defines Federal, State, and local roles in identifying public drinking water sources, assessing water system's susceptibility to contamination, and inform-

ing the public of the results. The source water assessment and protection program is the centerpiece of the Safe Drinking Water Act's focus on prevention.

Minnesota now has 18 months (from August 1997) to submit its plan for source water assessment to EPA for approval. The source water assessment program must contain the following elements:

- 1) strategic approach towards conducting the assessments,
- 2) delineation of the boundaries of the areas providing source water for public water systems, and
- 3) identification of origins of regulated and certain unregulated contaminants in the delineated areas to ascertain the susceptibility of the systems to such contaminants.

After EPA approves Minnesota's Plan, the assessments for all affected public water supplies must be completed within 2 years. More will become clear about how source water assessments will be implemented in Minnesota, and how it will be reconciled with the existing wellhead protection program, as the Minnesota Department of Health, who will administer the program, develops the plan.

— Steve Robertson, Newsletter Team

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## Join the Minnesota Ground Water Association!

If you are reading this newsletter second-hand, we'd like to take this opportunity to invite you to become a member of **MGWA** for 1998. Annual dues are \$20 for professional members and \$15 for students. Members are entitled to purchase the annual membership directory for \$7. Additional donations toward our scholarships and/or the use of recycled paper will be gratefully accepted.

*Dues paid to MGWA are **not** deductible as charitable contributions for federal income tax purposes. However, dues payments are deductible as ordinary and necessary business expenses to the extent allowed by law.*

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## The Southwest Metro Ground Water Workgroup: A Subregional Approach to Water Supply Planning

— by Marcia L. Honold and Gary L. Oberts, Metropolitan Council

The Metropolitan Council convened the Southwest Metro Ground Water Work Group (SMGWG) in April 1997 to address water supply issues in northern Scott and northwest Dakota Counties.

Concerns over water supplies have developed because population forecasts indicate significant growth for this area, with associated demand for water. There are also some indications that surface water bodies are negatively affected by current ground water withdrawals. Therefore, state agencies, local units of government, counties, the Shakopee Mdewakanton Sioux Community and others are working together on a long-term strategy that addresses options for adequate and reliable water supplies while protecting sensitive environmental features.

The Metropolitan Council projects that the population in the study area (Burnsville, Lakeville, Prior Lake, Savage, Shakopee, Credit River and Spring Lake Townships) will increase by 91,000 by the year 2020. This represents a 67% increase in population over the next 25 years. Currently, the cities of Shakopee, Savage, Prior Lake, Burnsville and Lakeville have 43 municipal wells. By 2020, the communities are planning to add at least 24 additional municipal wells to meet projected water demands. Most of the forecasted commercial, industrial and residential growth in the communities will be served by municipal water supplies.

Recent declines in ground water levels in the study area raise concerns about the long-term availability of water from the Prairie du Chien-Jordan aquifer and the viability of impacted surface water resources. Recent studies suggest that municipal ground water withdrawals from the Prairie du Chien-Jordan aquifer are contributing to a lower piezometric head in the Savage Fen wetland complex. This wetland complex, which

sustains one of the largest calcareous fens in Minnesota, relies on cold, calcium-rich ground water to sustain unique and rare vegetation. Decreasing piezometric heads are evident in other surface water features fed from upwelling ground water, such as Boiling Springs, Eagle Creek (a trout stream), Minnesota River Valley seeps and springs, and low-lying valley bottom lakes.

The Prairie du Chien-Jordan aquifer is the main source of water for most of the study area participants. If the cities are not permitted to withdraw water from the Prairie du Chien-Jordan, their ground water source alternatives are limited. New or increased water use requests from the deeper Mount Simon-Hinckley aquifer, must meet the requirements of Minnesota Statutes, Article 103G.271, which requires applicants to employ demand reduction measures, demonstrate that there are no feasible alternatives, and use the water for potable purposes only.

The Franconia-Ironton-Galesville aquifer in this area has yet to be evaluated and limited surficial aquifers may not be usable because of nitrate concerns and hydraulic connection to surface water bodies.

The SMGWG has been meeting for several months, and has spent a great deal of time reviewing existing data collection and modeling efforts, identifying gaps in the data, discussing priorities, and developing short and long-term action plans. In the

short-term, the Minnesota Department of Natural Resources (DNR) has responded to applications for permits for new city wells by conditioning them as follows: cities must continue to participate in the SMGWG; they must implement conservation techniques to improve water use efficiencies and reduce peak use; they must investigate water supply alternatives and institute a monitoring program; and, for the present time, they must restrict installation of wells into the Prairie du Chien-Jordan so as to have no net increase in the amount of water appropriated from the aquifer.

Long-term strategy efforts are geared to address regional aquifer management and sustainability questions. The long-term plan will have two main components: a monitoring program to determine trends and impacts on water resources, and a ground water modeling initiative to develop a model to estimate impacts from various options for long-term water supply alternatives.

As more information becomes available (better geologic information, pumping data, historic water levels), the group has found that existing models have become obsolete. Better monitoring data are necessary in many locations to adequately describe the hydrogeology and help verify the accuracy of any new modeling effort. As a part of this effort, the Min-

— continued on next page

### This Newsletter brought to you by:

*Tom Clark, Editor-In-Chief and Issue Editor*

*Jan Falteisek*

*Steve Robertson*

*Jim Lundy*

### MGWA Newsletter Deadlines for 1998

Issue	Copy to Editor	Final Copy to Publisher
March (v. 17, no. 1)	2/6/98	2/13/98
June (v. 17, no. 2)	5/8/98	5/15/98
September (v. 17, no. 3)	8/7/98	8/14/98
December (v. 17, no. 4)	11/6/98	11/13/98



nesota Department of Health (MDH) is working with Prior Lake, Shakopee, Savage, and the Mde-wakanton Sioux Community to develop a subregional ground water model designed to be used in the preparation of wellhead protection plans. MDH plans to issue a request for proposal (RFP) for this project in February 1998.

The data collection and monitoring plan, which is available in draft form, will contain a number of components, some of which will be continued as long-term monitoring sites. Both ground water and surface water will be measured. Key areas will include: stream flow, wetland and lake levels, baseflow contributions to priority surface water bodies, geochemical analyses, pump tests, ground water levels and withdrawals, better definition of stratigraphy in the Prairie du Chien-Jordan, and identification of significant recharge areas. As this effort proceeds, a water budget will be prepared for the major aquifer units. The end result will be a long-term water resources management plan which will include a thorough analysis of alternative water sources such as inter-community connections, reuse of water resulting from dewatering of quarries in the area, purchase of water from Minneapolis and St. Paul, and alteration of pumping cycles and level of use of the various aquifers.

It is important to note that the success of this process depends on the willingness of the participants to work together and engage in long-term water resources planning. The cities and agencies have entered into a working partnership to address protection of high-value water resources while acknowledging local issues. It is this commitment that makes this process different from many others.

The Council hopes this group and its cooperation in resolving difficult issues will be a prototype for similar efforts in the future.

## MGWA Calendar

**Contact information for the major event-holders is listed at the end of the column.**

**December 8-10, 1997.** Principles of Ground Water—Fate, Transport and Remediation. Salt Lake City, UT. NGWA

**December 15-19, 1997.** Princeton Remediation Course. Las Vegas, NV.

**January 13-17, 1998.** PC Applications in Risk Assessment, Remediation and Modeling. Orlando, FL. NGWA

**January 25-28, 1998**

Minnesota Water Well Association 1998 Convention and Hazmat Conference. St. Cloud Civic Center, St. Cloud, Minnesota. Contact MWWA at (612)290-6270, or Kelly Inn at (320) 253-0606 or 1-800-528-1234.

**February 9-13, 1998.** Princeton Ground Water Pollution and Hydrology Course. Orlando, FL.

**February 10-12, 1998**

Managing Manure in Harmony with the Environment and Society. Soil and Water Conservation Society, Iowa State Center, Scheman Building, Ames, Iowa. Contact: Bob Ball, chair, Program Task Force, Natural Resources Conservation Service, (573) 876-0900, email bobb@mo.nrcs.usda.gov

**February 15-19, 1998.** Princeton Ground Water Pollution and Hydrology Course. San Francisco, CA.

**February 23-27, 1998**

Princeton Groundwater and Hydrology Course, San Francisco, CA.

**March 12-14, 1998.** Visual MODFLOW: The Standard Modeling Software Package for the USGS's MODFLOW/MODPATH and MT3D. Denver, CO. NGWA

**April 6-10, 1998**

Princeton Remediation Course, Orlando, FL.

**May 18-21, 1998**

First International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA. Contact: The Confer-

ence Group, 1989 W. Fifth Avenue, Suite 5, Columbus, OH 43212-1912, (800) 783-6338.

**September 20-24, 1998**

Fluid Flow in Carbonates: Interdisciplinary Approaches. SEPM Research Conference. Egg Harbor, Wisconsin. Preregistration due March 15, 1998; contact Maureen Muldoon, Wisconsin Geological and Natural History Survey (608) 262-1580, or email muldoon@facstaff.wisc.edu. Abstracts due June 15, 1998.

**October 12-14, 1998**

43rd Annual Midwest Ground Water Conference, Lawrence, Kansas

### Contacts:

#### for NGWA events:

1-800-551-7379 or  
<http://www.h2o-ngwa.org>

#### for GSA events:

<http://www.geosociety.org>

#### for Princeton's events:

<http://www.princeton-groundwater.com> or email:  
[info@princeton-groundwater.com](mailto:info@princeton-groundwater.com)

#### for Wright State University events:

WSU, Center for Ground Water Management, 3640 Colonel Glenn Hwy, 056 Library, Dayton, OH 45435. (513) 873-3648, [IRIS@desire.wright.edu](mailto:IRIS@desire.wright.edu); [http://biology.wright.edu/cgwm/cgwm\\_home.html](http://biology.wright.edu/cgwm/cgwm_home.html)

#### for AIH events:

AIH, 2499 Rice Street, #135, St. Paul, MN 55113-3724. (612)484-8169. (612) 484-8357 (fax). e-mail: [AIHydro@aol.com](mailto:AIHydro@aol.com)

#### for Midwest Geosciences events:

Midwest GeoSciences Group, Suite 137-137, 931 West 75th Street, Naperville, IL 60564.

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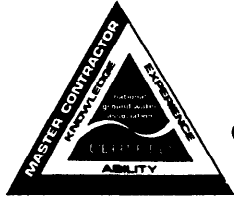
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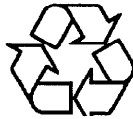
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