Minnesota Ground Water Association

Volume 13, Number 1: April, 1994

President's Column

Changing Course

Change seems to be a constant in our profession, but this seems to be a time of potentially sweeping and far-reaching change. Congress is considering changing Superfund, the Legislature (at this writing) is considering removing municipal landfills from Superfund, and many of us have seen or experienced significant changes in our organizations.

Ground water professionals have learned that we are not immune to the downsizing, restructuring, and reengineering experienced by our customers. With change can come uncertainty and doubts about what the future may hold.

It's been said that the best way to predict the future is to create it. A positive aspect of change is the opportunity to help set a new course. The changes being contemplated in various ground water-related regulatory programs, the organization of those programs, and investments in ground water protection and research should benefit the resource, but won't be successful without your input. Get involved in the debates, comment on rulemaking, voice your opinion about how to improve our collective effort to protect and enhance the resource.

Traditionally, MGWA doesn't take advocacy positions as an organization, but can provide a forum for discussion and debate on ground water-related issues. Let us know if you have ideas or opinions you would like to share with your colleagues.

Change In The Ground Water Association

The Treasurer's report (p. 9) indicates the association is financially strong, largely because of well-attended conferences. Our success as an organization means we have grown to the point that we must address our non-profit status and tax issues. Our income this year was just under $25,000, the trigger for having to prepare a tax return. We will be standardizing and computerizing our bookkeeping practices so that we can easily and accurately develop tax returns in the future. We are also developing plans to change our tax exempt status to a 501(c)(3) organization to more accurately reflect the type of organization the Minnesota Ground Water Association has become and to take advantage of lower postal costs.

We are also evaluating whether we could use the Association's resources to provide additional services to our membership and the public at large. For example, we are continuing our field trip scholarship program for Minnesota institutions, and are looking into other ways we can support ground water education. Our reserves also give us the ability to develop more involved short courses and conferences.

We are beginning to plan our fall conference, tentatively a half-day seminar either on isotope hydrogeology , a topic of importance to the understanding and protection of ground water resources. Let me or any of the officers know if you have suggestions for other ways to fulfill our mission -- we'd be glad to hear from you.

—Doug Connell, Barr Engineering

Spring Conference Report: Landfill Gases

Editor's Note: The April 5th conference on landfill gases was attended by approximately 150 professionals. The following is a brief summary of the afternoon's program:

Landfill gases are known to heighten the risks of fire and explosion. Prolonged exposure to gases may cause health effects as well. Landfill gas has caused the death or injury of many people in the United States, and may also cause chronic illness for others.

The complex and often unpredictable movement of these gases can compound these concerns. Yet, practices that have been successful in investigating, measuring, and controlling landfill gases are not widely known. This information is becoming increasingly important in light of current pressure to re-develop small old dumpsites.

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Landfill Gases, from page 1

The Minnesota Department of Health and the Minnesota Ground Water Association co-sponsored a half-day conference exploring the many factors that affect the movement and control of landfill gases. Six speakers from various fields came together to share information on this important issue.

John Mann, a geologist with the Agency for Toxic Substances and Disease Registry, brought home the public health implications of landfill gases, giving statistics on deaths and injuries caused by explosions and fires. Mann outlined the major constituents of landfill gases: methane, carbon dioxide, methylene chloride, toluene, hydrogen sulfide, benzene, vinyl chloride, trichloroethylene, nitrogen and various other gases.

These gases result from vaporization, biological decomposition, and chemical reactions within landfills. Mann described problems and experiences at sites around the country on which he has worked. He ended his talk by pointing out the many types of information that are needed to predict landfill gas movement and to approach mitigation.

John Nieber, Associate Professor in Agricultural Engineering at the University of Minnesota, addressed some of these issues by describing the physical and chemical processes which govern soil gas movement. Nieber compared processes observed in soil chambers to those expected to be active in landfills, and described the fluid flow process, transport of constituents, and the thermal and density gradients affecting flow of the gas phase in landfill and other subsurface material.

Nieber emphasized that convective processes are much more important than diffusion processes in driving gas movement. He also outlined the mathematical treatment of the general gas-phase transport processes.

Bill Angell, Professor of Housing at the University of Minnesota, addressed the subject of gas movement into structures by comparing the entry of other soil gases (e.g. methane) to his experiences with radon. He described how factors such as air pressure gradients, temperature gradients, weather, diurnal cycles, and mechanical equipment imbalances can all influence soil gas entry into buildings.

Angell concluded that, in cold-weather climates, the stack effect has the greatest influence on gas infiltration into buildings. He also described both active and passive techniques for preventing entry. Gas entry is often most effectively prevented by depressurizing the structure.

Mike Michels, of Camp, Dresser and McKee, Inc., in Milwaukee, described sampling techniques, parameters, and sampling and monitoring devices, based on his experi-

Special Spring Seminar

Possible Effects of a Wetter Climate on The Ground Water Flow System of Yucca Mountain And Vicinity, Nevada-California

Dr. John B. Czamecki, U.S. Geological Survey, Water Resources Division, Lakewood, CO

Monday, May 9, 1994

7:00 pm 110 Pillsbury Hall, reception and refreshments following

University of Minnesota - Minneapolis Campus

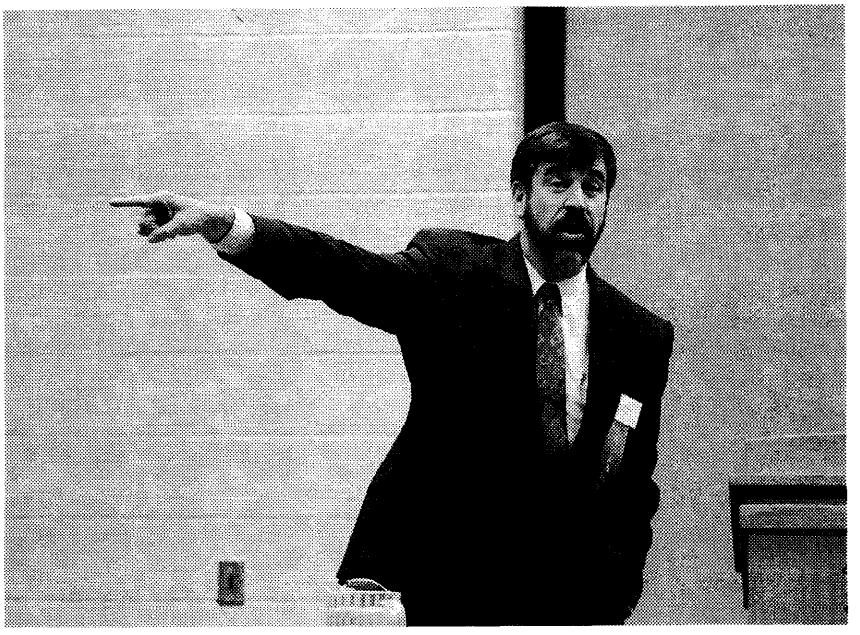
Jointly sponsored by the University of Minnesota Department of Geology and Geophysics and the Minnesota Ground Water Association

Abstract:

Results of simulating the effects of increased recharge with a finite-element model of the ground-water flow system of Yucca Mountain and vicinity, Nevada-California were compared with field evidence to ascertain if model results could be validated. Yucca Mountain is the potential site of a repository for high-level nuclear waste to be constructed 200 meters above the current water table. The water table would rise as much as 130 meters near the design repository area for a simulation involving a fifteen-fold increase in recharge compared to modern-day conditions, which corresponds approximately to doubled precipitation. According to the simulation, the current ground-water discharge at Franklin Lake playa and near Furnace Creek Ranch in Death Valley would increase; upper Fortymile Wash and Beatty Wash would probably have perennial streams; and springs or marshes would exist in the central Amargosa Desert and the western Ash Meadows area. Revisions to this model, that incorporate more recent potentiometric data, modified flow system geometries, and a vertical component of flow, could affect the simulated locations and amounts of discharge for these wetter climatic conditions.

Evidence from drillhole core obtained at Yucca Mountain indicated an absence of glass shards within a zone of about 80 to 100 meters above the modern water table, corresponding well with the maximum simulated rise in water-table altitude. Although a higher water table could account for the alteration of volcanic glass, tectonic uplift of once-saturated rock also could be a cause.

Extensive marsh sediments, possibly younger than 250,000 years, occur in the central Amargosa Desert at locations that generally coincide with areas of discharge under simulated wetter conditions, possibly validating model results. Enhanced satellite imagery shows apparently unique spectral characteristics in a part of the Amargosa Desert, west of Ash Meadows. This area coincides with locations of some of the simulated discharge and hydrogenic deposits, indicating that the imagery may be useful in defining the areal extent of former ground water discharge.



John Mann, Agency for Toxic Substances and Disease Registry geologist, brings home the public health implications of landfill gases.

ences tracking methane movement from landfills. Michels described the influences of landfill design, soil type, and weather on the movement of gases, and emphasized that gas migrates furthest in winter. The volume and concentration of migrating gases increases when barometric pressure is low, or the soil is wet.

Tom Radue of Barr Engineering Company provided a brief overview of gas control methods, outlining the advantages and disadvantages of each type. He stressed that gases may escape to surrounding areas even if gas control systems are used at landfills.

Mark Hibbs, also of Barr, provided a regulatory update on air and water quality issues pertaining to landfills.

Much of the information needed to best monitor landfill gases and design preventive measurer to protect public health is not well understood or always available. However, the concepts described at this conference can be applied to situations where landfill gases may be a threat to the public's health.

For example, since methane moves like radon (another basically inert soil gas), knowledge about the factors that influence entry of radon into buildings can be applied to the understanding of movement of methane from landfills into structures.

The concepts described at the conference should help in making better determinations about where landfill gases can be found, when the concentrations will be highest, and how much variation can be expected. In addition, recording such parameters as temperature, barometric pressure, soil moisture content, and air pressure gradients may be helpful in assessing the usefulness of gas monitoring, and the representativeness of its results.

— by Betsy Gerbec, Supervisor, Superfund Unit, Minnesota Department of Health

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The Water Balance of Abandoned Mine Pits

—John L. Adams, Mining Hydrologist, Minnesota Department of Natural Resources, Grand Rapids

History

The Mesabi Iron Range, the largest and only active mining range in Minnesota, consists of a thick layer of taconite extending from Grand Rapids to Babbitt (Figure 1). Taconite is primarily chert, a form of silica, and magnetite, a black, magnetic iron mineral. Known as the *Biwabik Iron Formation*, it has been altered by geologic processes since its formation. Certain areas of the formation were subjected to solutions which dissolved out portions of the silica, converting the black magnetite to red hematite, or what is known as *natural* ore. Mining of natural ore began on the Range in 1884 with construction of the underground Soudan Mine at Tower. Although many underground mines were initially constructed, most expanded into open pit mining. During the next 70 years or so, natural ore mines provided most of the nation's iron needs, with production peaking at about 65 million tons per year during the war years. Natural ore mining declined sharply after 1955,

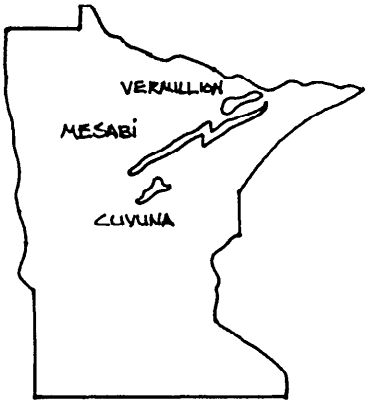

Figure 1. Minnesota's Three Iron Ranges

however, with depletion of the best natural ore grades. More than 175 natural ore mines have been exhausted (Lipp, 1985); scores of others contain marketable reserves, although only one is presently active.

As natural ore mining declined, taconite mining increased, reaching peak production capacity of about 65 million tons per year in the early 1970's. Taconite mining over the past 40 years has consumed many natural ore pits, expanding them into very large pits. It is common for taconite pits to exceed several miles in length and a mile or more across. Although only one of these large pits has been completely abandoned to date (Butler Taconite, 1985), others will eventually be exhausted or abandoned for economic reasons and will be subject to reclamation.

Effects On Hydrology

Many of the natural ore pits are small enough (some less than 20 acres) that they have little effect on local hydrology. Some are comparable in size to taconite pits. Typically, these large pits intercept natural water courses (Figure 2). Prior to or during mining, large streams are diverted around the pits, if possible. Small

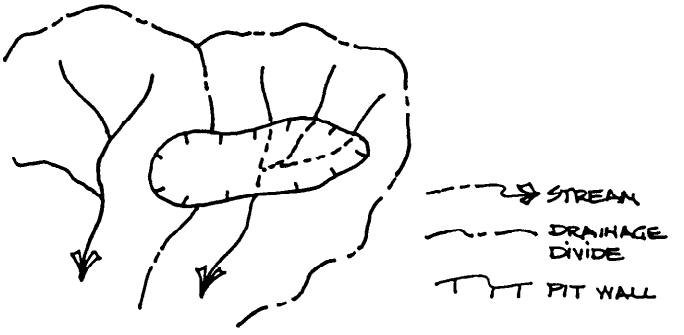

Figure 2. Generalized Mine Pit over-laying Drainage Divide and Intercepting Streams.

streams and those which can't be diverted discharge into the pits where the water flows to sumps and is pumped into a natural channel(s) downstream from the pit. The majority of the water pumped out of the pits, however, is ground water. Prior to mining, the water table is probably not more than 25 feet below the land surface, and in most of the area it is within 10 feet of the land surface (Winter, 1973). Many of the larger pits are 200 to 300 feet deep. Dewatering to these depths over areas the size of the pits requires the discharge of large amounts of water. In many cases, constant dewatering of several thousand gallons per minute is necessary. Normally, most of the ground water inflow comes from the Biwabik Iron Formation since the glacial drift is usually too heavily consolidated, or not thick enough, to contain or release large amounts of water (Cotter, *et al.*, 1965).

During mining, dewatering essentially replaces runoff lost through consumption of watershed area by the pit(s). Once mining ceases, termination of dewatering can negatively affect downstream resources, such as fisheries habitat, water quality, aesthetics, or water appropriators who are dependent on minimal levels of streamflow. Large pits may take 10 to 20 years or more to fill with water. During this time, supplemental pumping may be necessary to protect downstream resources.

Watershed Reclamation

Once mining ceases, not only may supplemental pumping be necessary, but it is also probable that large pits will eventually fill with water to the point where surface

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Mine Pits, cont.

outflow will occur at the lowest elevation on the pit rim. Since many of the larger pits overlay drainage divides, the lowest rim elevation may not occur at a natural channel which can handle the flow or it may occur where there is no channel, resulting in undesirable environmental and legal problems. Minnesota Statute 103G.297, Diversion or Drainage of Water for Mining, establishes the legal foundation for restoring watershed conditions after mining. In addition, the public has proven to be keenly interested in re-establishing natural streamflow where it occurred before mining. The goal of mineland watershed reclamation is to restore natural flow paths and provide for sustained pit outflow, if possible. The question is, how do we accomplish this goal for a huge mine pit which will not be filled with water for many years when we do not know how high the water will rise or what the probable outflow characteristics will be?

Normally, mining companies are required to develop reclamation plans well in advance of anticipated closure. The plans are used to identify closure costs which, in turn, are covered by some form of financial assurance. The plans are typically implemented immediately after closure. In order to accomplish the watershed reclamation goal, an outlet channel, or perhaps modification of an existing channel, may be necessary. The cost of constructing a channel is normally a small part of the total reclamation cost, so acquiring financial assurance should not be a problem. Locating and designing the channel is, however, another matter.

Water Balance Components

Planning for pit outflow is relatively easy if the pit's water balance components can be quantified. What do we know about the water balance of mine pits? The water balance of each pit is unique, as evidenced by large variations in dewatering rates. Figure 3 shows the generalized water balance components for a pit during initial filling, and after the pit has filled with water. Note that during initial filling, evaporation is the only natural water loss; all other water balance components produce inflow to the pit. As the pit fills, the groundwater-in component decreases and, at some higher water level, groundwater-out begins. If groundwater-out becomes large enough to balance all inputs (precipitation, direct runoff and streamflow), the pit water level will stabilize before a surface water outflow becomes established. If groundwater-out is not large enough to balance all inputs, the water will rise until surface water outflows at the lowest elevation on the pit rim. Consequently, the nature of each pit's water balance is dynamic throughout the filling process, especially during the last few years when the outflow components come into play. Quantifying key components, especially during the latter stages of filling, is imperative to achieving the reclamation goal.

Methods to Accomplish the Reclamation Goal

There are several alternative approaches to accomplishing watershed reclamation. We could assume that surface water outflow will be achieved, construct an outlet channel to some safe dimension, and wait to see what happens. This is risky, however, since the pit water level may never rise to the channel bottom, the channel may be improperly sized, and outflow characteristics would be unknown. Sophisticated watershed modeling could be done, although the magnitude of probable error and the cost of collecting the input data may be prohibitive. An alternative approach is being evaluated whereby final decisions would be postponed until site-specific data are collected to quantify key water balance components. This approach involves collecting a minimal amount of data during the period of pit filling, so a definite determination can be made of 1.) whether or not surface water outflow can be achieved, and if so, 2.) what the outflow characteristics would be for any alternative outlet channel design.

Quantifying water balance components may seem difficult, especially given their dynamic nature. There are two key components, however, which can be readily quantified during the period of filling. One component is net ground water or, more specifically, the relationship between the pit water level and net ground water. Groundwater-in and groundwater-out do not have to be quantified since it is the difference between these two which will provide sustained outflow during dry summer periods or winter. During initial filling, net ground water is a large positive input. It decreases as the pit fills, and must become negative if the pit water level stabilizes before a surface water outflow occurs. If the water level rises enough to create surface water outflow, then net ground water could be either positive or negative.

Ground water inflow to the pit is primarily a function of the head differential between the water surface in the pit and the water

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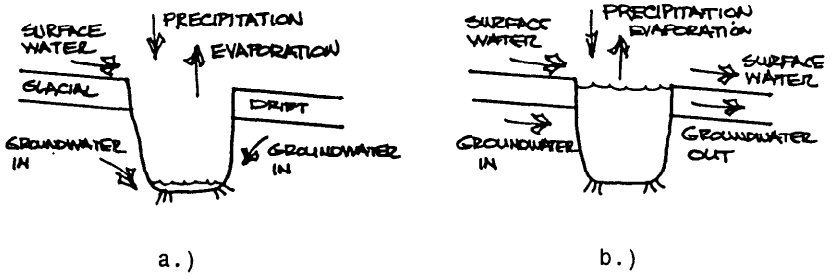

Figure 3. Water Balance Components of a Mine Pit, a.) at Abandonment and b.) Filled with Water.

Mine Pits, cont.

table in the surrounding land; it is generally unaffected by seasonal weather changes. Quantifying water accumulation in the pit during winter months will, therefore, accurately quantify net ground water inflow at the corresponding pit water levels. The more positive net ground water is for the outlet channel design, the greater the probability of sustained outflow during dry summer periods and winter. It is therefore desirable to locate the outlet channel at an elevation where net ground water is as large a positive number as possible, and exceeds maximum daily evaporation loss. Naturally, there will be physical and economic limits to channel construction, so any final design may be a compromise between what is desirable and what is practical. Still, being able to reasonably estimate the outflow characteristics at alternative outlet channel elevations is essential to informed decision making.

The other key water balance component is storm runoff, essential for outlet channel sizing and evaluation of downstream impacts related to flooding, erosion, high water and structural design. The standard procedure for modeling storm runoff involves assigning Soil Conservation Service (SCS) runoff curve numbers to the contributing drainage area. The runoff curve number is a value based on the soil description and is an indicator of the character of the storm runoff produced by the drainage area. Abandoned mineland, with its stockpiles, roads, tailing basins and channel diversions, has runoff characteristics unlike natural terrain. Assigning conservative runoff curve numbers can result in safe runoff estimates. However, if necessary, accurate runoff curve numbers can be back calculated by measuring the rate and volume of runoff water stored in the pit from storms. Such measurements would probably have to be made with a continuous water level recorder in order to accurately separate storm runoff from non storm runoff. On site precipitation data would also be needed. Runoff curve numbers, either assumed or back calculated, can be used with statistically-generated precipitation values to model storm runoff magnitude and frequency.

Study Results

The approach of quantifying key water balance components during pit filling was evaluated using data collected from the abandoned Butler Taconite pit complex near Nashwauk (Figure 4). Butler Taconite closed in 1985, leaving a large complex of pits to fill with water. Data collected during the filling of that part of the pit system east of pit #5, known as the pit #1 complex, was used to quantify the relationship between net ground water and water elevation. Water elevation data at Butler, unfortunately, were not collected with this objective in mind. During some years, the first winter water level reading occurred before freeze up, or the last winter reading occurred during snowmelt, so the data do not truly isolate that time when the only inflow to the pit was ground water. None-the-less, the best available data were used to evaluate the method. When Butler ceased mining, the three eastern pits in the complex had already been mined out and filled with water. Surface water was outflowing from east to

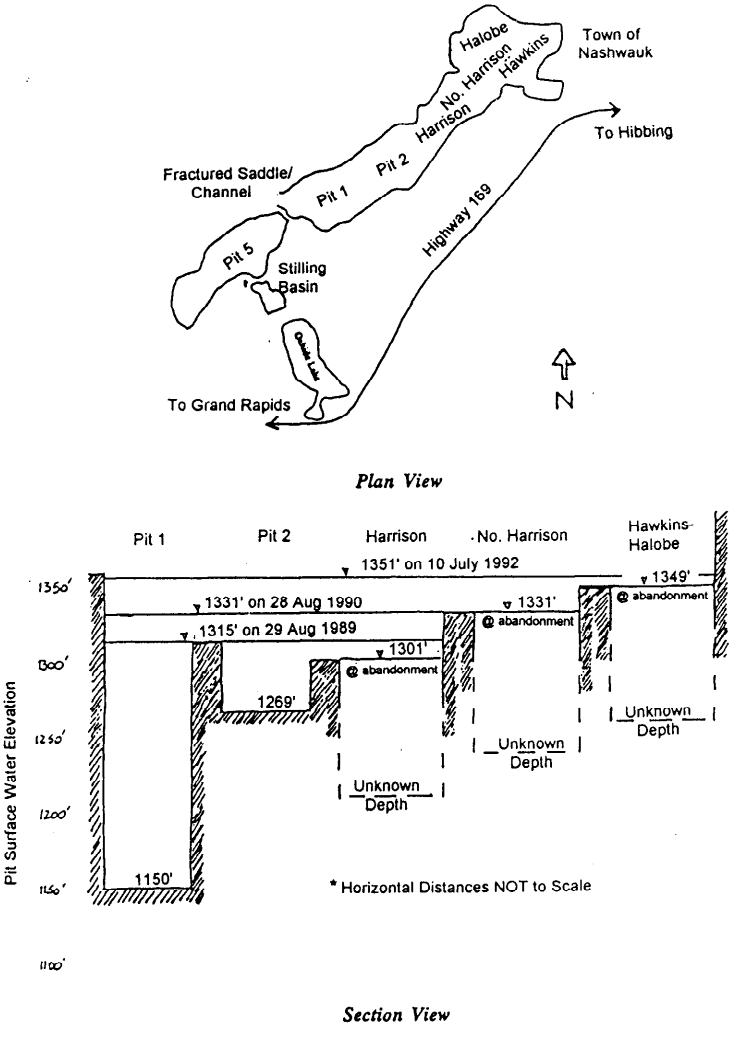

Figure 4. Plan and Section View of the Butler Pit Complex (from Perry and Brooks, 1993)

Mine Pits, cont.

west (Figure 4). The western two pits were being mined and so they were dewatered at the time mining ceased. When dewatering ceased, these two pits rapidly began to fill from ground water rebound and surface water inflow from the three eastern pits.

WATBUDZ, a DNR in-house water balance model, was applied to the pit #1 complex. Since WATBUDZ is not a routing model and deals only with one water body, a "synthetic" pit was developed by combining the volumes of all five pits and the surface areas of all five pits. Elevation/volume and elevation/surface area relationships were developed for the synthetic pit. The synthetic water surface elevation became the actual water surface elevation when the water level rose above elevation 1439 FMSL, where the pit complex became one contiguous body of water. The elevation/volume relationship, along with water level data, was used to determine the net ground water inflow during five winter periods. A regression analysis of the five average winter elevations versus net ground water (Figure 5.) resulted in the following linear relationship:

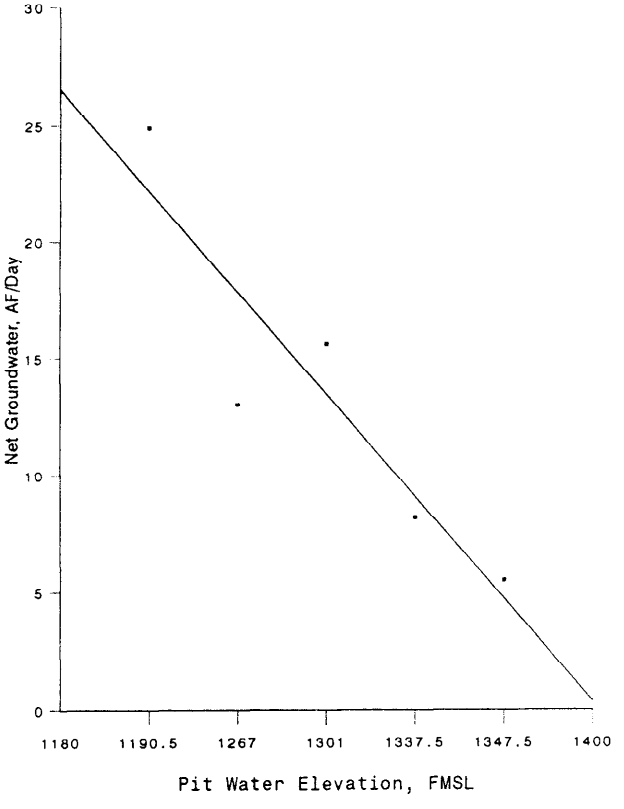

Figure 5. Net Groundwater vs Water Elevation for the Butler Pit #1 Complex

$Y = 158.63 - 0.1127 X$

where Y = Net Ground Water, Acre-Feet (AF)/Day, and X = Water Surface Elevation, Feet above Mean Sea Level (FMSL).

Although the correlation coefficient is reasonably high ($r^2 = 0.90$), the equation is probably not as accurate as it could be since the input data do not isolate that time of the year when net ground water was the only water input to the pit. Similar analysis was done for the Hill Annex pit, located about two miles west of the Butler pits. Water level data were collected several times during the winter of 1993-1994, when ground water was the only inflow to the pit. Consequently, the water level/net ground water relationship is exceptionally well defined for the period of record.

The Hill-Annex data suggest a non-linear relationship. The shape of the curve undoubtedly varies from pit-to-pit, depending on the degree and location of bedrock fracturing, and the depth and characteristics of the glacial drift. This variability emphasizes the importance of gathering site-specific data before making final design plans. Figure 5 also shows the highest regression input elevation of 1352 FMSL for the Butler pit. Extending the best-fit line above the highest input elevation, one would predict that net ground water would go to zero at elevation 1405 FMSL. This is above the lowest rim elevation, however, so the equation is obviously not accurate above the highest input elevation.

The water level in this pit complex, however, has not and will not rise into the drift since it outflows into pit #5 before reaching the drift. If the water level were to rise into the drift, net ground water would likely become negative relatively fast since the water level would have risen to the point where groundwater-in becomes substantially reduced and groundwater-out becomes progressively larger. Yet, this is the portion of the curve that would be critical to define for most pits since it is within the range of alternative outlet elevations. Consequently, for some pits, monitoring may have to be conducted until the water level rises well into the range of alternative outlet channel elevations. If this is necessary, temporary dewatering or diking may be necessary to facilitate channel construction.

The net ground water equation can be used to help evaluate outflow characteristics for alternative outlet channel elevations. For example, the equation predicts net ground water of 6.3 AF/day at elevation 1352 FMSL. Knowing the surface water area at this elevation allows a comparison of net ground water with estimated maximum daily evaporation loss. During dry summer periods, all inputs except ground water will be at or near zero. Using the results from another mine pit study near Babbitt (Perry and Brooks, 1993), maximum daily evaporation was estimated at 6 mm per day or 7.8 AF/day. Since estimated maximum evaporation exceeds calculated net ground water inflow, it is probable that outflow will periodically cease. How often this will happen can be statistically quantified using WATBUDZ or some other water balance model.

For example, WATBUDZ was used to generate the curves in Figure 6. From these curves it can be seen that estimated average daily outflow should remain

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Mine Pits, cont.

above 1 cubic foot per second 90% of the time. These curves were generated using 76 years of local precipitation records as input. The curves are an example of the type of useful hydrologic information which can be generated, given limited site-specific data. The water level data were not collected frequently enough to quantify storm runoff, although this could have been done if included in the site data collection plan.

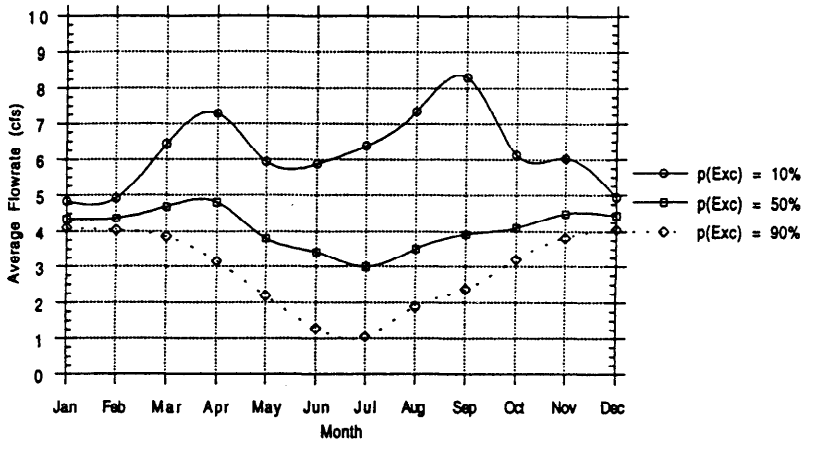

Figure 6. Probability of Exceedance of Average Daily Streamflows (from Perry and Brooks, 1993)

Conclusions

Taconite mining creates large pits which will some day be left to fill with water. These pits, and some of the larger, remnant natural ore pits, are capable of significantly altering local hydrology, both surface water and ground water. A goal of mineland reclamation is to restore natural watershed conditions to the extent practicable. This goal can be accomplished by developing an understanding of the dynamics of each pit's water balance. The two water balance components most critical for accomplishing the reclamation goal are net ground water and storm runoff. An evaluation of hydrologic data from the abandoned Butler Taconite pit complex suggests that these two components can be readily quantified by collecting minimal on-site data during the period of pit filling.

Information which needs to be generated at termination of mining includes accurate elevation/volume and elevation/area curves, and drainage area maps for each pit or pit complex in question. The possible locations for an outlet channel, and the range of alternative channel elevations also needs to be known. During pit filling, local precipitation and an accurate record of the rate of filling, on both a seasonal and storm basis, must be kept. Knowing the water level/net ground water relationship will be imperative to selecting an outlet channel elevation to achieve sustained surface water outflow. Knowing the proper runoff curve number(s) will facilitate channel design and aide in evaluating downstream impacts. With this approach, watershed reclamation would not be accomplished for many years after mine closure. Financial as-

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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 1994. Annual dues are $15 for professional members and $10 for students. Additional donations toward the use of 100% recycled paper will be gratefully accepted.

Just complete the form below and mail to: MGWA, c/o WRI, 4779 126th St. N, White Bear Lake, MN 55110.

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surance would therefore have to cover not only anticipated channel construction, but also the anticipated cost of data collection and analysis, final design, and any temporary dewatering or diking.

There are reasons to understand the water balance of mine pits which go beyond reclamation. Abandoned mine pit lakes are an important local resource with many potential post mining uses. Some of the present uses of mine pit lakes include municipal water supplies, fish farming, and recreation uses such as fishing and boating. Discussion of other uses has included alternative industries and exporting water during drought periods. In Itasca County, a joint powers agreement and associated planning process are being developed to coordinate future use of abandoned mine lands. An important consideration for any pit lake use is the water balance and associated, potential water quality impacts. Understanding the interconnected nature of the ground water and surface water resources of mine pit lakes is imperative to understanding the effects of land use proposals.

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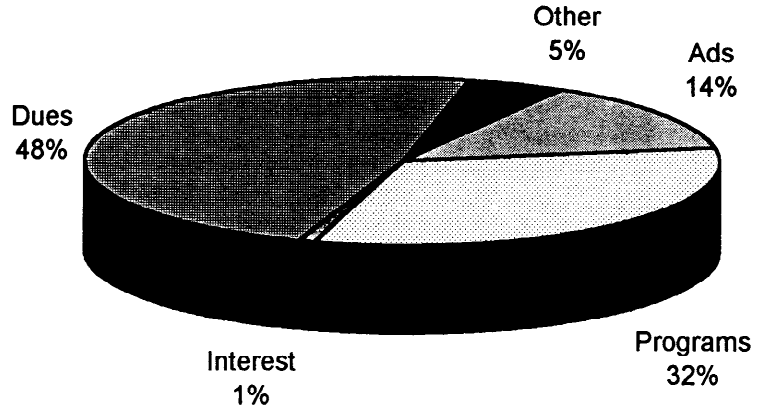
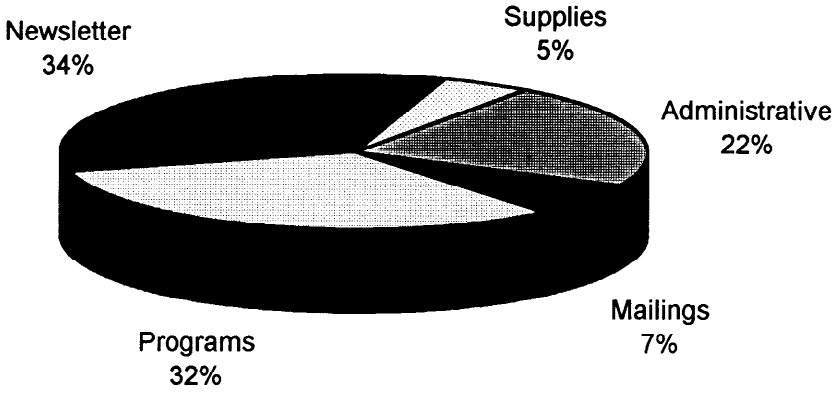
Treasurer's Report

MGWA 1993 Income



Total Income = $23,106.67

MGWA 1993 Expenses



Total Expenses = $20,764.38

MGWA had 16 student members and 541 professional members. Our effort to bring you the newsletter on recycled paper was supported by 59 members who contributed a total of $435 over and above their dues.

The Minnesota Water Information Line

A few months ago I was at a public meeting where we were explaining an upcoming Remedial Investigation (RI) at a landfill near a residential subdivision. A few wells in the subdivision had detectable VOC (volatile organic compound) concentrations and we had developed an RI work plan with the Minnesota Pollution Control Agency (MPCA). We were there to explain the process to the residents. The town hall was packed - people were spilling out into the parking lot. After our presentation a visibly angry and articulate man stood up and said, " I doubt that you understand the difficulty with which ... the regular population understands science and technological fixes. Scientists are one of the most mistrusted groups of people at this point in time in our country. You're going to give us (the residents) a techno-fix and nobody is going to buy it... (applause)."

Most of us have had an experience like this and for many of us it occurs all too frequently. Our business is unique in that we do science, literally, in people's backyards and often their health may be at stake. Experiences like this highlight the need for an accessible, practical and trusted public education resource. Plus, more complex environmental regulations and breakthroughs in technology promise still greater challenges to our ability to communicate scientific ideas to the public. We, as an industry, hold the knowledge that is key to resolving these issues.

The Minnesota Water Information Line, a joint project between the American Ground Water Trust, the Minnesota Extension Service, at the University of Minnesota and the environmental professional community was created to address these issues. The American Ground Water Trust is a national non-profit organization dedicated to public education about ground water. The Minnesota Water Information Line represents a commitment by the project partners to foster an informed dialog among the citizens, government and industry in the management of the State's water resources.

The line will operate as a '1-800' service staffed by a University of Minnesota Extension Educator trained to address questions and concerns about water related issues, especially groundwater. A distinguishing feature of this project is a team of professionals from our industry (hydrogeologists, engineers, drillers etc.) who will be available to return calls and provide follow up information and expertise as volunteers. The Extension educator will draw on this pool of expertise whenever more complete or specialized follow up is needed. Those who volunteer will receive training and guidance to assure consistent public service and that the Line remains a strictly educational resource. In this way the Water Line will bring together the educational expertise of the University with the State's top scientists and engineers to provide clear unbiased information on a variety of water issues. The project has active support from and is endorsed by the MPCA, MN Department of Health, MN Department of Natural Resources, the Minnesota Environmental Initiative, and many others who see the need for a simple comprehensive public education resource. The goal is for the Water Line to become a trusted and objective one-stop resource that empowers individuals and communities facing complex environmental issues.

We invite you to participate in the development and launching of this exiting project. We need ideas, volunteers, and financial support from all segments of our industry. If you are interested in being part of the partnership please call, write or fax me for more information.

Daniel V. Sola
Chairman American Ground Water Trust, MN Committee,
Conestoga-Rovers and Associates Inc.
1801 Old Highway 8 Suite 114
St. Paul, MN 55102
(612) 639-0913 voice,
(612) 639-0923 fax

Focus on Ground Water

Three of five Water Resources Research Center projects which came to a close in 1993 focused on ground water. They are summarized here.

Sampling Network Design for Ground Water Quality Monitoring

Efi Foufoula-Georgiou, Dept. of Civil & Min. Engineering., St. Anthony Falls Hydraulic Lab.

Ground water contamination which infiltrates through the soil over a large area and during a period of time, such as from a landfill, is a challenge to scientists trying to assess its impacts. In such cases, contamination is not uniform over space and its effects may change over time. Additionally, different soil types allow infiltration of contaminants at different rates. Due to those problems, a single ground water monitoring well at a landfill site does not accurately characterize ground water contamination problems. Instead, a network of sampling sites is needed.

This project focused on methodologies for designing ground water sampling networks for landfills and other sources of large scale surface contamination. The project had three main objectives: to develop a framework suitable for analysis and design of a ground water contamination sampling network; to study the spatial and temporal structure of the pollution concentration field by analyzing ground water recharge; and to study the sensitivity of the sampling design to spatial and temporal parameters.

The ground water recharge process was simulated using a model with precipitation considered spatially uniform over the monitored area but variable over time. Results indicate that ground water recharge is spatially uniform except during periods of high rain intensity (Fig. 1). That finding is significant for sampling network design because the large amount of water and pollutants added to ground

—continued on page 12

Calendar

May 3, 1994. *Minnesota Children's Ground Water Festival.* Douglas County Fairgrounds, Alexandria. FFI: Larry Zilliox, Douglas County Extension, (612)762-2381 ext 203.

May 9-13, 1994. *Hierarchical-Multiobjective Approach in Water Resources Planning and Management: Risk Assessment and Management* (short-course), University of Virginia, Charlottesville, VA. FFI S. Gingras, Center for Risk Management of Engineering Systems, University of Virginia, Charlottesville, VA 22903, ph. (804)924-0960, fax (804)924-0865.

May 9-13, 1994. *Principles and Applications of Modeling Chemical Reactions in Ground Water*, Colorado School of Mines, Golden, CO. FFI IGWMC.

May 13-15, 1994. *Midwest Friends of the Pleistocene Annual Meeting*, Cincinnati, Ohio. Information: Tom Lowell, Dept. of Geology, University of Cincinnati, Cincinnati, OH 45226, (513)556-4165, Lowelltv@ucbeh.san.uc.edu.

May 21-22, 1994 *Geologic andHydrologic Considerations for Siting Hazardous and Low-Level Radioactive Waste Disposal Facilities.* FFI NGWA.

May 23-25, 1994. *Eighth National Outdoor Action Conference and Exposition*, to be held in Minneapolis by NGWA.

May 23-26, 1994. Practical Methods for Assessment and Remediation of Hydrocarbon Spills, San Diego. Sponsored by IGWMC.

June 12-16, 1994. *Fifth International Conference on Ground Penetrating Radar,* Kitchener, Ontario, Canada. Information: GPR '94, Waterloo Centre for Ground Water Research, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada, ph. (519)885-1211, fax (519)725-8720.

June 13-17, 1994. *Fundamentals of Stochastic Modeling of Flow and Transport in Porous Formations*, Colorado School of Mines, Golden, CO. Sponsored by IGWMC.

June 15-20, 1994. *GSA Penrose Conference on Fractured Unlithified Aquitards: Origins and Transport Processes*, Racine, Wisconsin. FFI John A. Cherry, Waterloo Centre for Groundwater Research, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada, ph. (519)885-1211x2892, fax (519)746-5644.

June 19-22, 1994. *American Quaternary Association 13th Biennial Meeting.* Topic: Data and Models in Quaternary Research, University of Minnesota, Minneapolis. FFI Dr. Linda C.K. Shane, Limnological Research Center, 310 Pillsbury Drive S.E., Minneapolis, MN 55455-0219, ph. (612)626-7889, fax (612)625-3819, e-mail shane002@maroon.tc.umn.edu.

July 25 through August 19, 1994 *Fourth Annual Technology and Science Clinic.* For grades 7 through 9. A four-week program that gives junior high school students a rare opportunity to examine, "hands-on" some exciting new developments in technology and science. Modules include Architecture, Chemistry, Computer Aided Design & Drafting, Computer Technology, Manufacturing Technology, Electronics, Environment, and Printing/Graphics. FFI Michael O'Laughlin, University of St. Thomas/Dunwoody, (612)962-5765.

August 2-5, 1994. *The Universities Council on Water Resources Annual Conference: Environmental Restoration*, Big Sky, MT. FFI Larry Mays, Dept. of Civil Engineering, Arizona State Univ., Tempe, AZ 85287, ph. (602)965-3589, fax (602)965-0557.

August 10-13, 1994. *Groundwater Modeling Conference*, Fort Collins, Co. Sponsored by IGWMC.

August 17-19, 1994. *Bioremediation Engineering: Principles, Applications, and Case Studies.* FFI General Physics Corporation, Environmental Services, 6700 Alexander Bell Drive, Columbia, MD 21046-2100, ph. (800)395-4516.

October 11-13, 1994 *1994 AIPG Annual Meeting.* Flagstaff, Arizona. FFI Mark Shellhorn 5080 N 40th St. Phoenix AZ 85018, ph. (602)840-3333.

October 25-26, 1994. *27th Annual Water Resources Conference*, University of Minnesota, St. Paul Campus. FFI Bev Ringsak, Professional Development and Conference Services, University of Minnesota, 206 Nolte Center, 315 Pillsbury Drive S.E., Minneapolis, MN 55455-0139, ph. (612)625-6689, fax (612)626-1632.

November 2-4, 1994. *Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Protection, Detection, and Remediation*, Houston, TX. FFI NGWA.

More details available from:

AWRA, Amer. Water Resources Assoc., 5410 Grosvenor Lane, Suite 220, Bethesda, MD, 20814. (301)493-8600, fax (301)483-5844.

NGWA and the Association for Ground Water Scientists and Engineers, 6375 Riverside Drive, Dublin, OH 43017 (614)761-1711.

IGWMC, Institute for Ground Water Research and Education, Colorado School of Mines, Golden, Colorado 80401-1887. (303)273-3103, fax (303)273-3278.

Who gets mugged next?

The Historical Committee of the Hydrogeology Division of the Geological Society of America has produced the second of a series of Hydrogeologist coffee mugs. The 1993 mug featured a likeness of O.E. Meinzer; the first mug featured Henri Darcy. The mugs are given in appreciation for donations to the hydrogeology student research scholarship fund.

A third mug for 1994 is planned. What eminent hydrogeologist would you suggest be celebrated on the next mug? Send or email your suggestions to Bill Back; USGS, WGS Mail Stop 431, Reston VA 22092; wback@usgs.gov.

—The Hydrogeologist, Sept. 1993

water during periods of intense rain requires more wells to be monitored than during periods of low intensity rain.

The scale over which the recharge is correlated is another important parameter in model design. Placing monitoring wells at a larger scale could result in loss of important water quality information, while placing wells at a smaller scale could lead to unnecessary costs as adjacent wells may duplicate information.

Temporal analysis of recharge indicates that the recharge process changes over time due to the filtering process of the unsaturated soil zone, which acts as a reservoir. This information is needed in sampling network design to determine how frequently measurements should be taken to reflect temporal changes of the recharge process and water quality.

The spatial and temporal analysis of the recharge process also identified a means to quantify the sampling

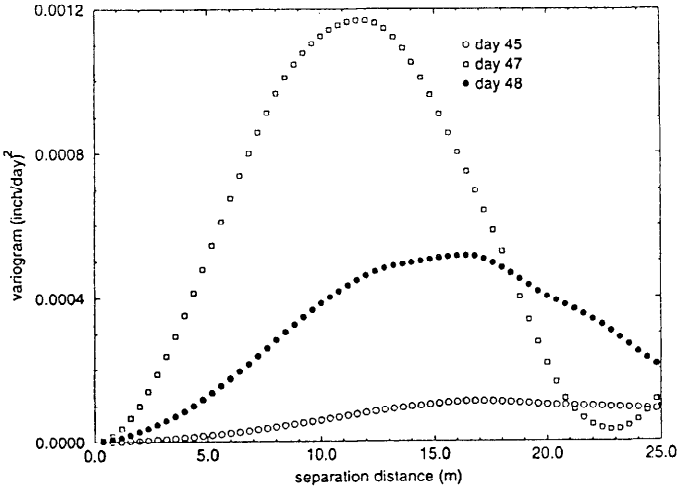


Figure 1. Development of the recharge spatial structure for several rainfall intensities around the peak.

network performance. That allows the network designer to determine optimal well placement and sampling frequency given available resources.

Association of Topography and Layering with Water Storage in a Sand Plain Soil

James Anderson, Dept. of Soil Science, Center for Agricultural Impacts on Water Quality

This project focused on the Anoka Sand Plain, near Princeton, Minnesota. That site is a research area in a major study, the Management System Evaluation Area (MSEA), which is researching the design of crop management systems to minimize ground water pollution.

The purpose of this project was to obtain information on variability of soil-water storage and movement in a sandplain soil. Generally, the movement of water in sand soils is heterogeneous because of such factors as layering of different soil materials, lateral water flow below the surface, and the variability of soil types across an area. Understanding that heterogeneity is crucial in designing cropping strategies that will reduce ground water pollution.

Specific objectives of this study were to characterize the variability of soil water storage over space and time at a selected plot on the Anoka Sand Plain; to correlate observed water storage patterns with distribution of thin clay bands (lamellae), depositional layering, and surface topography; and to develop a survey technique to map soil hydrologic variability, including evaluating the potential of using ground penetrating radar, aerial infrared photographic imagery, and digital elevation models in mapping.

Lamellae in sand soils help water to be retained within upper soil layers, resulting in improved crop productivity. This project concluded that lamellae also contribute to subsurface lateral water movement (Fig. 2).

The lateral flow of water caused by the lamellae slows the downward movement of water, thus retarding the movement of solutes to ground water. Additionally, areas of maximum water storage and potential recharge were successfully predicted using a model based on topography.

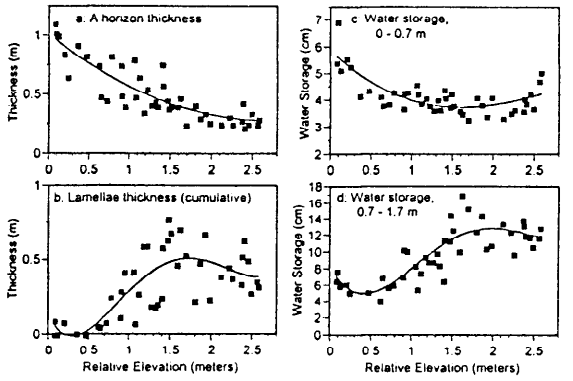


Figure 2. Topographic distribution of soil features and soil-water storage. A horizon (topsoil) thickness is greatest in topographically low areas, and becomes thinner with increasing surface elevation (a). In contrast, lamellae development is dominant in upslope areas (b). Soil-water storage follows this pattern: near-surface (0 to 0.7 m depth interval) water storage is greatest in topographically low areas (c), but deeper soils (0.7 to 1.7 m depth interval) are wettest in higher landscape positions (d).

The use of neutron and capacitance probes for collecting soil water data were compared. The capacitance probe is more sensitive and allows better depth resolution, but its sensitivity makes it difficult to calibrate and adds variability in monitoring results.

For those reasons, it was found that the neutron probe is a better instrument for collecting research data. The capacitance probe is better suited for management uses such as developing irrigation schedules.

Ground penetrating radar (GPR) and aerial infrared photography were evaluated for use in surveying soil layering and water storage patterns. Other researchers have successfully used GPR for the same purposes in coarse to medium sand soils, but it was found to be too complex for use in fine sand soil.

Aerial infrared photography can be useful for indicating patterns of crop yield and nitrogen uptake. Areas of low yield

and nitrogen uptake generally indicate areas of limited water availability. Further study of the application of aerial infrared photography for surveying soil water storage is needed.

A Field Tracer Test Method for Large Soil Samples

E. Calvin Alexander, Dept. of Geology and Geophysics and John Nieber, Dept. of Ag. Engineering

An important aspect of understanding the migration of chemicals to ground water is having the proper instruments to predict hydraulic properties of soil. A lysimeter is an instrument that allows researchers to determine the flow and transport properties of soils.

However, lysimeters are normally too expensive to be installed over a large area. The purpose of this study was to develop a rapid and cost effective procedure for measuring soil hydraulic properties on a large scale. A new type of lysimeter, conical in shape and capable of being installed using a tree planter, was developed and tested (Fig. 3).

The new equipment was tested on three different field soils and on control soil samples in a laboratory. The degree of soil disturbance caused by the installation of the field equipment also was assessed.

The installation of each prototype conical lysimeter took less than one hour and had total material and equipment costs less than $500. Infiltration experiments using water and solutions of Rhodamine WT, fluorescein or bromide ion tracers were then conducted. Seven of the lysimeters were installed in Minnesota over two field seasons in three different soil types. Results of the tests indicate that the conical lysimeter methodology is suitable for wide application in subsurface hydrology. This methodology also has potential value in other areas of research such as studying water balance of plants. Some technological improvements to the conical lysimeter and further tracer experiments are needed to fully define the lysimeter's flow characteristics.

—Minnegram, WRRC, Jan, 1994

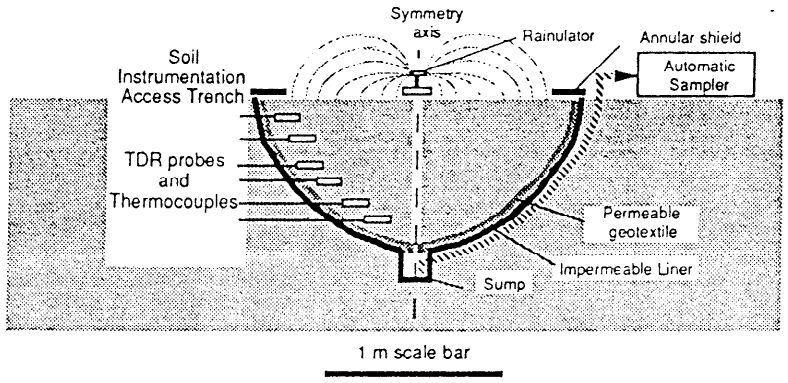


Figure 3. Conical lysimeter design.

Ground Water Guidebook Available

There are still copies of the Metropolitan Council report *Guidance for Local Ground Water Protection in Minnesota* available.

The Minnesota Ground Water Association printed special copies of the report so that it could be made available at the MGWA Fall Conference.

The remaining copies can be purchased for $15 each, including postage (inside the U.S.).

Requests can be sent to: MGWA, c/o WRI, 4779 126th Street North, White Bear Lake, MN 55110-5910. Checks should be made out to MGWA.

BMP's for Sandy Soils

The Minnesota Extension Service recently released a guide to assist farmers in sandy areas of the state in their efforts to protect water quality. "Farming Sandy Soils in Central Minnesota" provides background and explanation of Best Management Practices for this part of the state which is underlain by ground water vulnerable to pollution. The guide includes BMP's for controlling soil erosion, recordkeeping, crop nutrient assessment, pest control, and irrigation management.

For more information, contact David Cooper, Anoka Sand Plain Project Coordinator, at (612)625-27113.

New Books From National Academy Press

Ground Water Vulnerability

Ground Water Vulnerability Assessment reviews the classes of current ground water vulnerability assessment methods, examines the uncertainties associated with various approaches, provides guidance in the selection of an approach, summarizes relevant data bases available in the U.S., and identifies areas of research for the development of future techniques.

Bioremediation

In-situ bioremediation - the use of microorganisms for in-place removal of contaminants - is potentially cheaper, faster, and safer than conventional cleanup methods. But in-situ bioremediation is also clouded in uncertainty, controversy, and mistrust. In-situ Bioremediation: When Does It Work? provides direction for decision makers and offers detailed explanations of the processes of in-situ bioremediation, circumstances in which it is best used, and methods for evaluating the results of bioremediation projects.

These books can be ordered from National Academy Press, 1(800)624-6242.

Visit the MGWA Booth!

The National Ground Water Aswsociation has offered the Minnesota Ground Water Association the opportunity to have a booth at the National Outdoor Action Conference and Exposition which is going to be held by NGWA in Minneapolis on May 23 through 25, 1994.

Look for the MGWA booth and come over, say Hi, and let us know how we're doing.

Ground Water Bookstore

The National Ground Water Association's 1994 catalog is a comprehensive listing of ground water goods and services. Books, slide Sets, videos, and public information pamphlets are available on many topics, including geology, ground water hydrogeology, geophysics, geochemistry, heat pumps, modeling, management, and much more.

Contact NGWA at 6375 Riverside Drive, Dublin, OH 43017

AIPG Update

The Minnesota Section of AIPG has launched a newsletter: *The Minnesota Professional Geologist*. The new editorial board consists of Philip Davis, editor; Terese Miller, advertising editor; Paul Brookner; Thomas Clark; and Jane Willard. The mailing address for the newsletter is: AIPG Newsletter, c/o Phil Davis, Editor, 8600 Wood Cliff Road, Bloomington, MN 55438.

The next meeting of AIPG will be May 3, 1994, 11:45 at the Holiday Inn Roseville. Butch Pendergast will speak on *Searching for Sunken Treasure in the Gulf of Mexico.*

Conference Report: Ground Water Remediation

The successes and failures of ground water remediation efforts were the topic of the "Forum on Remediation of Ground water Contamination" presented by the National Ground water Association in Denver in February. The conference attendees consisted of approximately 50 percent consultants, with the remainder being regulators or other government personnel, industry representatives, and lawyers. The conference was co-sponsored by U.S. EPA, the American Bar Association, Chemical Manufacturers Association, and others. Impressions of some of the major themes discussed at the conference are summarized below:

Remedial Investigations/Feasibility Studies

A common opinion expressed at the conference was that many remedial efforts have not been successful due to inadequate control of contaminant sources. The corollary is that pump-and-treat (i.e., ground water extraction and treatment) cannot be considered a tool for **restoration** until the source has been identified and removed or isolated. There was some disagreement as to the degree of source characterization that is necessary for dense, non-aqueous phase liquid (DNAPL) sites (the type of site that was most often discussed at the conference). The majority view seemed to be that extensive efforts oriented toward source characterization are necessary, since source control is critical to remedial success. However, an alternative position noted that it is typically very difficult to find a DNAPL source (at least for chlorinated solvent DNAPLs) and that money spent on searching for sources is not well advised if it is known that pump-and-treat will be implemented for containment anyway.

The "failure" of pump-and-treat for site restoration was viewed as driving a move toward more *in-situ* solutions. This means that there will need to be more focus on the subsurface as a treatment reactor; water is often not an effective carrier to remove contaminants for subsequent above-ground treatment. The remediation industry will need to more effectively combine the subsurface understanding of geologists/hydrogeologists with the treatment technology knowledge of engineers. And in addition technical professionals will have to broaden their understanding of factors influencing remediation success.

Consultants and industry representatives indicated that inflexibility inherent in work plans often proved a hindrance to effectively completing investigations. Solutions that were discussed included: **phased investigations** (often a lengthy, but controlled, process); **mini-phases**, involving one fairly generic work plan and known checkpoints for brief meetings with involved parties following each step of the investigation; and **dynamic work plans** that emphasize field screening techniques and establish locations only for the first day of sampling, with subsequent sampling driven by the data and approved by an on-site regulatory representative.

Superfund as an Industry Driver

A widely discussed idea at the conference was that the Superfund (CERCLA) program may not encourage or even allow effective site remediation. The program's goals of employing treatment, achieving permanence at every site, and meeting a broad range of requirements that may not be sitespecific may work against attaining the actual overall objective of protecting public health and the environment. The concept was that limited resources are now often spent on: treating for the sake of treating; implementing technologies that are selected because they are 'permanent', even

—Continued on next page

Ground Water Remediation, cont.

if they do not seem appropriate, and trying to meet cleanup requirements that cannot realistically be met. Discussions indicated that a preferred approach would focus on actual risks and would tie expenditures to risk reduction, thereby addressing the worst problems first.

Realistic Objectives for Remediation

The conference attendees were generally pessimistic about the current state of the industry in being able to actually **restore** sites affected by many types of contamination. It was widely viewed that new technologies will be needed for restoration of many types of sites, especially those involving DNAPLs. Most people were optimistic that such technologies can and will be developed. In the meantime, however, realistic objectives for site remediation appear to be source **containment** and plume **removal**. The commonly referenced remedial objective of mass removal was questioned, since DNAPL sources will usually remain a source of ground water contamination even with small fractions of the original mass remaining in place. This skepticism was consistent with the view of pump-and-treat as a **hydraulic control** technology rather than an overall **restoration** technology.

A discussion of ecological risk assessments noted that although it appears that more site remediation will be driven by eco-risk in the future, federal policy on reducing ecological risks may be significantly ahead of science's ability to realistically assess ecological risks.

New Regulatory Approaches to Remediation

Voluntary investigation and cleanup programs were discussed frequently, both as alternatives to Superfund and as models for revisions to Superfund. Minnesota received positive reviews for its Voluntary Investigation and Cleanup (VIC) program. Generic cleanup standards, which are components of some states' voluntary programs, are currently being considered for the revised Superfund program. While the efforts to tie the standards to realistic land uses were generally well received, some viewed generic standards as useful only for smaller, less complex sites. The option of using site specific risk assessments to establish cleanup standards for larger, more complex sites was seen as very important.

Summary

Two recurring themes during the conference were: (1) Professionals involved with ground water remediation need to be realistic and open about current technological limitations on our ability to fully restore sites; and (2) efforts must be focused on developing new and enhanced remedial technologies even as current state-of-the-art remedies are being implemented.

— Mike Relf, Barr Engineering Co.

Discover IT

The Institute of Technology (IT), University of Minnesota, has announced plans for "Discover IT" a day-long event at the Twin Cities campus on Thursday, May 12, 1994. The event will showcase the departments and centers of the Institute of Technology to alumni and friends of the Institute of Technology and will feature presentations on exciting new research, laboratory tours, demonstrations, lunch with department faculty, and an evening banquet at the Radisson Hotel Metrodome on campus. The day's activiites will begin with registration and welcome by the Dean of IT and participants may choose multiple "tracks" of various activities.

Contact Frank Robertson in the IT Dean's Office at (612)626-8282.

Upper Mississippi River Basin Selected for National Water Study

The Upper Mississippi River Basin in Minnesota and Wisconsin has been selected as one of 20 sites in the second set of study areas for the on-going National Water Quality Assessment program of the U.S. Geological Survey, U.S. Department of the Interior.

The Upper Mississippi River Basin study area covers about 21,000 square miles and includes parts of the Minnesota River and upper Mississippi River basins and the entire St. Croix River basin.

The overall NAWQA program describes the status and trends in the quality of the nation's surface and ground waters. The 20 selected study areas include river basins and aquifer systems in parts of 36 states that represent a wide range of environmental settings. the assessment will also provide an understanding of the primary natural and human factors affecting the country's vital water resources.

Water-quality problems in the Upper Mississippi River Basin include potential contamination of ground and surface water from industrial activities, the large number of Superfund sites in the Minneapolis-St. Paul metropolitan area and the use of agricultural chemicals and road de-icing salts.

The NAWQA study will support various federal and state efforts related to agricultural chemicals, long-term monitoring of the Upper Mississippi River Basin and recreational management of scenic rivers.

For more information contact Jim Stark at the U.S.G.S. Water Resources District office , 783-3100.

GEOFLUIDS Program at University of Minnesota

The Department of Geology and Geophysics at the University of Minnesota has received a half-million dollar National Science Foundation (NSF) grant this year to support interdisciplinary doctoral research and training in crustal-scale hydrology (GEOFLUIDS). The GEOFLUIDS program focuses on topics as diverse as mid-ocean ridge processes, sedimentary-basin evolution, tectonics, climate change, ocean history, limno-geology, Quaternary hydrogeology, and the fate of pollutants. The University of Minnesota becomes the third program in the country to receive one of these coveted NSF doctoral training grants for the hydrological sciences. The Massachusetts Institute of Technology and the University of Virginia have received similar training grants emphasizing other aspects of hydrology. The NSF doctoral program is intended to increase the number of U.S. citizens, especially women and minorities, receiving doctoral degrees from the Department of Geology and Geophysics. Doctoral candidates are also expected to earn a doctoral minor in Water Resources. GEOFLUIDS participants will chose a core curriculum from four disciplines: Limnology, Aqueous and Isotope Geochemistry, Hydrogeology, or Basin Tectonics.

In conjunction with the GEOFLUIDS program, a series of short courses and talks will be held at the University over the next five years. This spring, as part of the GEOFLUIDS program, a special seminar course, Coupled Models of Groundwater Flow and Rock-Groundwater Interactions, is being offered by visiting Professor Dr. Ward Sanford from the U.S. Geological Survey, Reston, VA.

For more information on the GEOFLUIDS program and upcoming events, contact Dr. Mark Person, GEOFLUIDS Program Coordinator at 625-7332.

Glacial Terrains Featured

Minnesota's glaciated terrains will be featured at NGWA's Outdoor Action Conference May 23-25, 1994. The difficult hydrogeologic settings found in the glaciated terrains of Minnesota will give a different perspective to the NGWA Outdoor Action Conference on Aquifer Remediation, Ground Water Monitoring and Geophysical Methods. Hands-on drilling and product demonstrations will illustrate appropriate construction, investigative, and sampling techniques for use in Minnesota's heavy gravels, boulders, and sands.

Ten topic tracks are featured:

- Remediation
- Sampling and Analysis of Monitoring Wells
- Direct Push Technology
- Borehole Geophysics
- Surface Geophysics
- Regulations/Compliance
- Drilling Technology
- Management
- Glacial Geology and Hydrology
- Well Testing and Maintenance

This year NGWA will also offer: a workshop on the subject of NAFTA and the ground water industry and opportunities in Mexico, taught by invited authorities, a workshop dealing with the measuring of fuel contamination in ground water with a field fiber optic laser fluorimeter, and an outdoor workshop demonstrating a relatively new drilling method - Rotosonic Drilling.

Don't forget to stop by the Minnesota Ground Water Association's booth at the National Outdoor Action Conference.

Publications

New Techniques: Estimating Aquifer Specific Yield

The volume of water in an aquifer is calculated by through use of a characteristic of an aquifer called specific yield. In a recently completed study, the U.S. Geological Survey, U.S. Department of the Interior, in cooperation with the Colorado Department of Natural Resources, and the Castle Pines Metropolitan District, evaluated several techniques for estimating specific yield from aquifer grain-size data or from geophysical logs. These techniques can enable more accurate estimates of the volume of water in storage.

The recently completed report, "Techniques for estimated specific yield and specific retention from grain-size data and geophysical logs from clastic bedrock aquifers, by S. G. Robson, published as USGS Water Resources Investigations Report 93-4198 is available from the USGS, Earth Science Information Center, Open-File Reports Section, Box 25286, Mail Stop 517, Denver Federal Center, Denver, CO 80225. Call (303)236-7476 for exact cost. Prepayment is required.

Ground Water Protection Tips

Farmers (or those who work with them) might find this book useful. Colorado Cooperative Extension has published "50 Ways Farmers Can Protect their Groundwater." The booklet includes tips on water quality, herbicides, livestock disposal and other issues of concern to farmers. The book is available from Colorado Cooperative Extension for $5. Call (217)333-2007.

— Colorado Ground-Water Association Newsletter, V12(2) Jan.-Feb. 1994

New Applied Earth Sciences Firm

Larry Johnson, Past President of the Minnesota Ground Water Association has formed a new company, Larry L. Johnson and Associates, Inc. His firm will specialize in soil and ground water investigations, water resources planning and development, environmental permitting and construction support. Larry can be reached at (612)825-2091

39th Annual Midwest Ground Water Conference

Call for Papers

The 1994 Midwest Ground Water Conference will be held in Bismarck North Dakota, October 16-18, 1994 at the Radisson Hotel.

Session topics include:

- Effects of 1993 flooding on ground water resources
- Impacts of mining and reclamation on ground water resources
- Wetlands or surface water/ground water interactions
- Effects of agricultural practices on ground water resources
- Regional geohydrology and aquifer evaluation
- Water quality and aqueous geochemistry
- Contaminant hydrogeology
- GIS and data management
- Wellhead protection
- Ground water monitoring
- Ground water modeling and computer applications
- Legal, education, planning or policy issues

Abstracts are limited to 300 words (double-spaced) and will be accepted until June 1, 1994. Authors should state a preference for oral or poster presentation.

The North Dakota Energy and Environmental Research Center will lead a one-day preconference field trip (Sunday October 16) focused on wetland occurrence and function in the Prairie Coteau landscape. If you wish to attend, please send an expression of interest by June 1, 1994.

Abstracts should be sent to: Robert B. Shaver, North Dakota State Water Commission, 900 East Boulevard, Bismarck, ND 58505-0850.

1993 Minnesota Well Construction

The Well Management Unit at the Minnesota Department of Health has compiled totals for the number of wells constructed and sealed in 1993. As of March 1, 1994, construction reports for 13,874 water wells, monitoring wells, and dewatering wells were received; and 11,790 well sealing reports were received. Well construction totals were up 6 percent, and well sealing totals were up 16 percent over 1992.

The leading counties (with total number of wells drilled) were Hennepin (946), Anoka (942), Crow Wing (672), Stearns (590), and Wright (583). Hennepin County tops the list for well sealings (3597), followed by Ramsey (901), Anoka (448), Dakota (294) and Crow Wing (263).

Minnesota Ground Water Association
P. O. Box 65362
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