SPEAKER SUMMARIES/BIOGRAPHIES

It's Time to Talk About 'Till' – Glacial Sediments and Groundwater

Minnesota Ground Water Association Spring Conference, 2019

Jason Moeckel

Minnesota Department of Natural Resources

Intersection of Groundwater Models, Ecology, and Management

Abstract

Groundwater models are currently being used to inform appropriation management decisions. Model results and interpretations relative to other information like lake ecosystem dynamics and stream ecology and state policy (i.e. statutes and rules) are all part of the decision framework. This presentation will describe how the MN DNR has been applying these in a few settings within Minnesota, including White Bear Lake, Little Rock Creek and Cold Spring.

Biography

March 2011 – Present
Section Manager for the Inventory, Monitoring and Analysis Section Pertinent Section Manager, Inventory Monitoring and Analysis
Division of Ecological and Water Resources, Central Office, St. Paul, MN

June 2006 – March 2011
Fisheries Operations Support Supervisor
Minnesota Department of Natural Resources, Central Office, St. Paul, MN

December 2003 – June 2006
Assistant Regional Fisheries Manager
Minnesota Department of Natural Resources, Southern Region Fisheries, Rochester, MN

April 1998 – December 2003
Natural Resource Specialist Senior - Metro Trout Stream Habitat Specialist
Minnesota Department of Natural Resources, Central Region Fisheries, St. Paul, MN

Education

The University of Montana - Admitted as PhD Candidate Sept 1997, Division of Biological Sciences Organismal Biology and Ecology Program

The University of Montana - Awarded M.S. in Resource Conservation, May 1997, School of Forestry

Thesis Topic: Integrating aquatic ecosystems and ranch management.

San Jose State University - Awarded B.S. in Environmental Studies, May 1994

Emphasis: Water Resource Management

Carrie E. Jennings, PhD, PG

Freshwater Society

Till: Spatially variable, complex and dense
or to quote Dr. H.E. Wright, Jr. **"It's all very complex."**

Abstract

Till is sediment that is the product of erosion, transport and direct deposition by ice. But because glacial processes are highly spatially and temporally variable, till can be variable, both vertically and horizontally, in composition, structure, fabric and therefore hydrologic properties. Tills in Minnesota may have also been subject to several glacial and interglacial cycles over the last two million years. Therefore, to best predict the possible degree and scale of variability of till, four classification strategies can be simultaneously deployed:

-Lithological classification—grain-size distribution and matrix and clast lithology
-Stratigraphic position—to help understand the potential impact of periglacial and non-glacial processes such as weathering, soil development and erosion.
-Mode of deposition—links glacial processes with facies characteristics
-Engineering behavior

In the areas mapped by through County Geologic Atlas program, the first two and often three are adequately described. The last category lies in the arena of hydrogeologic and geotechnical investigations, primarily at the site scale.

Lithologically, tills in Minnesota range from fine-grained, matrix-dominated, exotic tills of ice lobes (e.g. New Ulm Formation) to silty, coarse-grained tills of more local derivation (e.g. Boundary Waters Formation). These vary in their hydrologic and engineering properties because of the nature the matrix and concentration of clasts.

However, it is also possible to have tills with the same lithologic and textural composition but distinctly different hydrologic and engineering properties. The temperature and effective pressure at the glacier bed strongly control the density, fabric and strength of a till. The subglacial environment varies from low to high effective pressure with varying amounts of total strain. This affects the consolidation state of till and the macro- and microscopic orientation of its grains.

Stratigraphic setting imparts an understanding of chemical and physical changes associated with weathering and soil formation such as leaching, oxidation and the addition of carbon. Geochemical changes can alter the concentration and mobility of certain elements. The presence of fractures and development of soil structure alters preferred pathways.

The scale of spatial variability is best anticipated by accurately defining the depositional environment. Facies associations and landforms, where preserved, can help determine if a till was deposited in a subglacial or supraglacial setting. Supraglacial tills are lower density, more variable because they may have been remobilized and sorted.

Tills of obscure depositional setting are best described by testing key properties at an appropriate scale. Carefully reconstituting tills to the same density in a lab may be important for some engineering applications where strength is key. Whereas, the average variability of an *in situ* till at a regional scale may be more important for interpreting hydrogeologic conditions.

Biography

Carrie has taught glacial geology at the U of M for 25 years, following in the footsteps of her PhD advisor, H.E. Wright. She also has an MS from the U of M in glaciology (Roger LeB. Hooke) and a B.A. in geology from Northwestern University in Evanston, Illinois.

She furthered her understanding of glacial sediment during a 24-year mapping and research career, 22 with the Minnesota Geological Survey and two with the DNR, Division of Lands and Minerals. She was also Science Reports Lead for the hydrogeologic portion of the County Geologic Atlas program at the DNR for two years.

Carrie has built and funded collaborative, interdisciplinary teams of scientists to address the impacts of land management and drainage practices compounded by changing rainfall patterns on river and hillslope processes.

Carrie joined Freshwater as Research and Policy Director in 2016. There, she applies her understanding of glacial geology and landscape evolution to bridge the gaps between what science provides and what a policy maker, watershed district, local government official or citizen needs to know. She helps shape state and local approaches to manage surface water and groundwater, avoid hazards, and use geologic resources wisely.

Carrie and her husband live on a 120-acre farm which is primarily in a permanent conservation easement through the Dakota County Farmland and Natural Areas Program. She has twice been elected town board supervisor and served on the planning commission for Eureka Township.

Barbara Lusardi

Minnesota Geological Survey – University of Minnesota

The Old Gray Till—It ain't what it used to be!

Abstract

Hobbs and Goebel's map of the Quaternary Geology of Minnesota was published in 1982. It is still the go-to map for glacial geologists in the upper midwest. In that same year, the Minnesota Geological Survey (MGS) initiated the County Geologic Atlas program, which provides counties a comprehensive map package at 1:100,000-scale. Thirty-seven years later, we have mapped (and remapped, or are in process of mapping) 56 of Minnesota's 87 counties with an emphasis on supporting groundwater management.

Over the years, our thoughts on how to best represent glacial units have evolved from phase terminology to geomorphic expression to ice lobe and moraine association. More recently, we have described glacial sediments by texture, which allows us to infer hydrogeologic properties of those units. In this recent work, as we draw cross sections in order to identify and map subsurface glacial aquifers, it became clear that we needed a more concise and consistent method for discussing Minnesota glacial stratigraphy. So in 2016, after 10 years of effort, the MGS published a volume in which 47 glacial units were formally defined, revised, or redefined. This gave us—geologists, hydrologists, and users in general—a common framework that helps ensure that we're talking about the same units in our maps and models.

In an effort to bring all of our surficial geology maps up to date in terms of common attributes—texture, deposit type, age, provenance, and formal lithostratigraphic name—we have assembled the map legends from all of our previous maps into one database and are working to stitch together all of the individual maps into a single, seamless digital compilation. Incorporating new linework into this compilation will be the final step in each of the future county geologic atlas surficial maps.

Biography

Barbara Lusardi is the new Associate Director of the Minnesota Geological Survey (MGS), taking over from Dale Setterholm who retired in February of this year. Barb has 27 years of experience at the MGS, mapping glacial deposits and serving as outreach coordinator and project manager. She has a M.S. in geology from the University of Maine at Orono.

Bob Tipping

Minnesota Geological Survey – University of Minnesota

Assessing Vertical Recharge Through Minnesota's Glacial Sediments – A mapping perspective

Abstract

Historically, assessments of vertical recharge through Minnesota's glacial sediments have been used for two separate, but overlapping tasks: 1.) estimates of travel times to water table and/or bedrock aquifers; 2.) calculating water budgets for groundwater and groundwater/surface water numeric models. This talk focuses mostly on the former, with emphasis on geologic maps and datasets used to make vertical travel time estimates. The evolution of subsurface glacial sediment mapping methods are outlined, along with their application to texture-based estimates of vertical hydraulic conductivity.

Biography

Bob Tipping is a senior scientist at the Minnesota Geological Survey, and adjunct faculty member in the Department of Earth Sciences and the Water Resources Science program - both at the University of Minnesota. His research interests are in aquifer characterization, groundwater chemistry and groundwater-surface water interaction. Bob has a Ph.D. in Water Resources Science from the University of Minnesota, M.S. in Geology the University of Minnesota, and B.A. in History from Carleton College.

About the Minnesota Geological Survey

The Minnesota Geological Survey is a unit of the Newton Horace Winchell School of Earth Sciences in the University of Minnesota. The Survey is the University outreach center for the science and technology of earth resources in Minnesota. The Survey conducts basic and applied earth science research, conveys that information to the public through publications and service activities, and promotes earth science education. Minnesota is its exclusive focus.

Jared Trost
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Groundwater Flow Through Till: tortoise, hare, or not in the race?

Abstract

How much groundwater flows through till to buried glacial aquifers in Minnesota? This process is poorly characterized, but important for evaluating the sustainability of water supplies. In 2014, the USGS, Iowa State University, Minnesota Geological Survey, and Minnesota Departments of Health and Natural Resources, initiated an Environmental and Natural Resources Trust Fund-supported project to quantify the variability of hydraulic properties and flux of water through till confining beds to buried aquifers at four sites in Minnesota. Study sites were near Cromwell (Superior lobe), Litchfield (Des Moines lobe), the University of Minnesota Hydrogeology Field Camp (HFC) near Akeley (Wadena lobe), and Olivia (Pre-Illinoian lobe of northwestern Minnesota provenance). Analyses of continuous water-level data, slug and aquifer tests, and groundwater geochemistry, along with finite-difference groundwater modeling were used in the investigation. At each site, piezometer nest(s) were installed to monitor water levels and water quality in the confined aquifer, till, and surficial aquifer (if present). The nests were near high-capacity wells pumping from a confined aquifer.

Till hydrology is highly variable within and among sites. Water levels in a subset of till piezometers at each nest, except for one nest at the Litchfield site, responded to pumping from the underlying confined aquifer. Particle size distributions of tills vary from a clay loam (sand:silt:clay of 37:40:23; Good Thunder Formation (Fm) at Olivia) to sandy loam (67:22:11; Hewitt Fm at HFC). Three sites had downward vertical hydraulic gradients through the till, which ranged from 0.05 (HFC) to approximately 1 (Litchfield). The Cromwell site had an upward

hydraulic gradient in till. Slug tests indicated that hydraulic conductivity (K) in the till ranged from 10^{-4} feet per day (ft/d) at the Olivia site to 10^{-1} ft/d at the HFC site. Average linear velocity estimates and $\delta^{18}O$ data indicate no remnant glacial meltwater in till. Enriched ^{3}H concentrations in groundwater suggest bomb-peak, mid-1960s water at the HFC site (105 feet below land surface, ft BLS) and one nest at the Litchfield site, LFO1 (95 ft BLS), whereas pre-bomb groundwater occurs below 50 ft at all other sites. Above-ambient chloride (Cl) concentrations in pore water and groundwater suggest vertical penetration of surface contaminants into till at some sites.

A series of MODFLOW finite-difference groundwater models suggests the proportion of water entering the aquifer from above was influenced by 1) variations in till vertical hydraulic conductivity, 2) the confined aquifer's lateral connectivity to adjacent aquifers, and 3) the areal extent of the confined aquifer. Taken together, multiple lines of evidence strongly suggest that groundwater in till is "in the race" and flows vertically through the tills to the underlying confined aquifers. Whether the groundwater flow rate is at a "tortoise's or a hare's" pace likely depends on the hydraulic properties and the glacial geologic setting and history of the till.

Biographies

Jared Trost is a hydrologist with USGS at the Upper Midwest Water Science Center and has led several investigations on the quality and quantity of water reaching aquifers and the interactions of these groundwater systems with surface-water. Jared holds a B.A. in biology and chemistry from Augsburg College and an M.S. in Water Resource Science from the University of Minnesota.

Bill Simpkins is a professor of hydrogeology in the Department of Geological and Atmospheric Sciences at Iowa State University. His research focuses on till hydrogeology, groundwater recharge estimation, Ames aquifer sustainability, agriculture impacts on groundwater quality, and isotope hydrology. He received a B.A. in geology from Augustana College (Rock Island, IL), M.S. degrees in Geology (Glacial) and Water Resources Management from the University of Wisconsin-Madison, and a Ph.D. in Geology (Hydrogeology/Glacial) from that university.

He is a former Geological Society of America (GSA) Councilor, GSA Fellow, and a 2015 awardee of the George Burke Maxey Distinguished Service Award from the Hydrogeology Division. He is a member of GSA, AGU, NGWA, MGWA, Iowa Groundwater Association, Sigma Xi, and IAH.

Justin Blum

Minnesota Department of Health, Source Water Protection Unit

Leakage is for 'Lumpers' – Lessons Learned from Aquifer Tests in Layered Till

Abstract

The on-going investigation of groundwater flow through till led by the USGS includes traditional constant-rate aquifer testing as one of many ways to estimate hydraulic properties. The Minnesota Department of Health contributed to this effort by performing two tests on public water supply wells during 2017 and analyzing the data from two additional tests conducted by the USGS and MGS in 2018. As expected, analysis showed the heterogeneity of the till. Over the four test sites, values of vertical conductivity of the till ranged from 4.6 to < 6.0e-4 ft/day. One of the challenges of this part of the project was that no response to pumping was observed at two obwell nest sites. From the perspective of aquifer test analysis, the lower limit of the conductivity is not defined. At two of the four sites, only portions of the till section showed a response, not the full thickness of the till. In this circumstance, the conductivity of the till would be overestimated if the full thickness were used in the calculation. Of particular interest to modelers, the vertical conductivity estimated from an aquifer test was slightly larger than geometric mean of the vertical conductivity of the till. Overall, the investigation showed the importance of focused leakage through the till, where conductivity is highest, for maintaining "static conditions" in the flow system.

Biography

Education: BA & MS in Geology, University of California

Currently: Hydrologist, MDH - Source Water Protection

Justin has worked for various state agencies in Minnesota for over 30-years as a Hydrologist and previously as a consultant for some years. Most of his time at the Department of Health has been spent writing wellhead protection plans for community water supplies in southeastern Minnesota. The rocks in that part of Minnesota are clearly arranged in layers. Because of that circumstance, Justin has been thinking about groundwater flow in layered systems for a long time. In particular, how can aquifer tests inform flow models of layered systems?

Paul J. Martin, M.Sc., P.Eng.

President, Aqua Insight Inc.

Groundwater Flow in the Waterloo Moraine – Knowledge Evolution over 125 years

Abstract

The Waterloo Moraine has been a drinking water source for the people of Waterloo Region for over a century and, as such, it has been the subject of numerous geologic and hydrogeologic studies for over six decades. Over that time, the conceptual understanding and characterization of the hydrogeology has evolved considerably. Characterization challenges stem from the complex glacial history, as the Waterloo Moraine is an interlobate moraine sitting at the one-time margins of ice advances from Lakes Huron, Erie and Ontario. Identified till sheets act as marker beds within the thick (> 300 ft) sediment package, and while their properties vary depending on location, they are essential to delineation of multiple aquifer / aquitard deposits. Of particular importance are the erosional features within the till aquitards, which create "windows" of interconnection between shallow and deeper aquifer horizons.

One of the tools being applied to help refine understanding is a regional, three-dimensional numerical model. This model has been in use for over 20-years and has evolved through calibration to long-term water level and geochemistry monitoring data. Beyond the insights gained through model development, the model has been applied for source water protection, water budgeting, and risk assessments to help guide local water management. This presentation will describe the hydrogeologic setting of the Waterloo Moraine and how numerical modelling tools are being used to help quantify and manage local water resources.

Biography

Mr. Martin holds degrees in Civil Engineering (B.Sc., Water Resources; 1991) and Earth Sciences (M.Sc., Hydrogeology; 1994) from the University of Waterloo. He has over 25-years of applied consulting experience focusing on the characterization and assessment of hydrogeologic systems to understand groundwater flow and contaminant transport. Paul works closely with professors from the Universities of Waterloo and Guelph on technical projects and gives lectures regarding application of modeling tools for characterization, source water protection, as well as fate and transport assessment. Paul is a Professional Engineer in several provinces (ON, AB, SK) as well as a member of the National Ground Water Association (NGWA) and International Association of Hydrogeologists (IAH).

Dr. Keith Schilling

Iowa Geological Survey, University of Iowa

Old till is not over the hill for groundwater protection: Hydrogeology of Pre-Illinoian till in eastern Iowa

Abstract

Few hydrology studies have investigated glacial till older than Illinoian time (> 300,000 BP) despite these older tills overlying a large portion of North America. An 8-well and 6-well monitoring well nest installed into a 31 m thick pre-Illinoian till sequence near Cedar Rapids, Iowa was used to characterize till hydrology using traditional hydrologic methods and chemical tracers. The aquitard system consists of about 9 m of fine-grained oxidized pre-Illinoian till overlying 22 m of unoxidized till and Devonian dolomite bedrock. Results revealed that the oxidized and weathered portion of the till profile is a zone of recent groundwater circulation and much of the groundwater protection is provided by the unoxidized portion of the till weathering profile.

Biography

Dr. Keith Schilling is State Geologist and director of the Iowa Geological Survey and Research Engineer at IIHR-Hydroscience and Engineering at the University of Iowa. He is also adjunct assistant professor at both the University of Iowa Department of Earth and Environmental Science and at Iowa State University Department of Natural Resources Ecology and Management. He received a Ph.D. degree in Geology from the University of Iowa, an M.S. degree in Water Resources from Iowa State University and a BA degree from Knox College in Galesburg, IL. His research has focused on a variety of water-related issues in Iowa, including groundwater flow and quality, surface and groundwater interaction, nonpoint source pollution and watershed and floodplain processes.

Ken Bradbury

Wisconsin Geological & Natural History Survey

Interpreting Vertical Hydraulic Gradients in Clayey Aquitards

Summary

Measuring and understanding vertical hydraulic gradients is often the key to deciphering the hydrogeology of clayey aquitards. Observations of radically different water levels in adjacent piezometers often confuse inexperienced hydrogeologists and can lead to erroneous assumptions about perched aquifers, groundwater mounds, and multiple flow systems. In most cases in clayey deposits in humid climates, steep vertical gradients, even gradients exceeding unity, are common and can be expected. These hydraulic gradients, when measured and interpreted correctly, can provide important insights into stratigraphy, heterogeneity, fractures, and solute migration. Multi-level instrumentation that produces vertical hydraulic profiles should be an essential part of groundwater investigations in low-permeability settings.

Biography

Kenneth Bradbury (Ph.D., Hydrogeology, UW-Madison, 1982) is Wisconsin's State Geologist and Director of the Wisconsin Geological and Natural History Survey, University of Wisconsin-Madison, Division of Extension. Prior to becoming the Survey's Director in 2015, Ken worked at the Survey as a Research Hydrogeologist since 1982. His research interests include virus transport in groundwater, groundwater flow in fractured media, aquitard hydrogeology, groundwater recharge processes, wellhead protection, regional groundwater simulation, and the hydrogeology of glacial deposits.