A High Resolution Vertical Gradient Approach for Delineation of Hydrogeologic Units at a Contaminated Sedimentary Rock Field Site

Jessica Meyer

2013 - Solinst Symposium
High Resolution, Depth-Discrete Groundwater Monitoring - Benefits & Importance

Georgetown, Ontario
November 7, 2013
DNAPL Fractured Rock Site in Southern Wisconsin

Contamination in a fractured sandstone

- Multicomponent **DNAPL** source zone

- **Dissolved phase** plume ~ 3 km long
Mixed Organic Contaminants Plume in Fractured Sandstone

- 154 monitoring locations
- 20 multilevel systems
- Total of 558 monitoring points
- Flow generally toward east to southeast

DNAPL Source Area
~ 72,000 L DNAPL

Plume ~ 2.8 km long in 2003
Pleistocene Unconsolidated Sediments
Cambrian/Ordovician Sedimentary Bedrock

Most laterally extensive dissolved phase plume

Regional Aquitard

Regional Aquifer

Local Aquifer

DNAPL

Horicon Member Unconsolidated Deposits

Prairie du Chien Group Dolostone

St. Lawrence Formation Dolostone

Tunnel City Group Sandstone

Wonewoc Formation Sandstone

Eau Claire Formation Sandstone with Siltstone/Shale Interbeds

Mt. Simon Formation Sandstone
Objectives

• High resolution hydraulic basis for delineation of hydrogeologic units

• High resolution characterization of the mass distribution
Hydrogeologic Units (HGUs)

Represent partitions of the groundwater flow domain with contrasting hydraulic conductivities
Why are HGUs Important

Used as a framework for **ALL** conceptual and numerical models of groundwater flow and contaminant transport
All Groundwater Studies
Require Delineation of HGUs

• Position

• Thickness

• Lateral Extent/geometry
High resolution head profiles identify the position / thickness of $K_v$ contrasts that can be used to delineate HGUs.
Discrete Fracture Network (DFN) Approach to Site Characterization

- Drill Corehole
  - Core
    - Geology / Fractures
    - Contaminant Analysis
    - Physical / Chemical Properties
  - Corehole
    - Geophysics / Hydrophysics
    - Hydraulic Tests
    - Multilevel Systems

Parker et al., 2012, AQUA mundi
**Multilevel System (MLS)**

**Definition:**
A single device assembled on surface and then installed in a borehole or a multi-screened casing to divide the hole into many separated intervals for data acquisition from many depth-discrete segments of the hole.
High Resolution MLS Design Objectives

- Avoid blending HGUs
  - Position monitoring zones and seals based on complimentary data sets
  - Use short monitoring zones
  - Seal un-monitored sections of the borehole

- Maximize the number of monitoring zones
High Resolution Design

Multilevel System

- Monitors 129.5 m of bedrock
- 46 monitoring zones
- 3.6 zones per 10 m
- 32% sealed
Schematic Head Profile

- Litho-Stratigraphy
  - Unit 1
  - Unit 2
  - Unit 3

- Hydraulic Head
  - Sharp change in head (inflection)
  - Monitoring Interval
  - Packer Seal

- Depth
  - No to minimal change in head

Meyer PhD, 2013
Schematic Vertical Gradient Profile

Litho-Stratigraphy

Unit 1
Unit 2
Unit 3

Hydraulic Head

Vertical Gradient

Depth

Upward Gradient
Unresolvable Vertical gradients
Downward Gradient

Meyer PhD, 2013
Head Profiles are Geometric

Thin sections of large vertical gradient (inflections)
- Relatively low $K_v$

Thick sections of unresolvable vertical gradient
- Relatively high $K_v$

Meyer et al. 2008, Meyer PhD 2013
Head Profiles are Repeatable

- Dec 2003
- Jun 2009
- Aug 2011

Meyer et al. 2008, Meyer PhD 2013
Comparison to Lithostratigraphy

Lithostratigraphy is not predictive of the position/thickness of $K_v$ contrasts

Meyer et al. 2008, Meyer PhD 2013
Research Questions

• Do the vertical gradients correlate between locations

• What is the geologic basis for the shape of the head/vertical gradient profiles?
DNAPL Source Area ~ 72,000 L DNAPL

Plume ~ 2.8 km long in 2003

Flow

Approximate Extent of Observed DNAPL

2003 L5 Plume 10 ppb TVOC Contour

Research Wells
- UW/UG Multilevel Wells

Preexisting Monitoring Network
- Barrier System Wells
- Multilevel Wells
- DNAPL Recovery Wells
- Monitoring and Other Wells
- Staff Gauges
- Village Wells

Other Features
- Creeks and Drainage Ditches
- 3.05 m (10 ft) Elev. Contours
High Resolution MLS Transect
Key Points

- Vertical gradients occur at similar stratigraphic positions across the site (they correlate!)
- Indicate laterally extensive contrasts in K
- K contrasts are not coincident with lithostratigraphy
New Basis for Numerical Models
Vertical Gradient Based Bedrock HGUs
How Much Resolution is Enough?

Lower resolution profiles

- do not accurately identify the position and thickness of K contrasts
- do not identify thin but important contrasts in K
- provide inaccurate (blended) heads and gradients
Acknowledgements

The research presented is a portion of Jessica Meyer’s PhD dissertation.

Dr. Beth Parker: Supervisor
Dr. John Cherry: Collaborator and committee member
Dr. Emmanuelle Arnaud: Collaborator and committee member

Funding and In Kind Support
Dr. Beth Parker’s NSERC IRC and the University Consortium for Field Focused Groundwater Contamination Research

Westbay – Schlumberger Canada Ltd., Solinst, FLUTe, Stone Environmental, Golder


