Groundwater Occurrence & Movement: An Introductory Discussion with Application to East-Central Illinois

East-Central Illinois Regional Water Supply Planning Committee
July 27, 2007

Allen Wehrmann, P.E., P.H.(GW), D.WRE, Director
Center for Groundwater Science, Illinois State Water Survey
Special thanks to:

Ed Mehnert, Ph.D.  
Hydrogeology Section  
Illinois State Geological Survey

Steve Burch & George Roadcap, Ph.D.  
Center for Groundwater Science  
Illinois State Water Survey
East-Central Illinois Water Supply Planning Area
Topical Presentation Outline

Basic Concepts and Definitions

- The Hydrologic Cycle
  What is groundwater?
- Concepts & Definitions
  Porous Flow vs. Fractured Flow
  Aquifers vs. Aquitards
  Artesian vs. Water Table Conditions
- Regional Groundwater Flow Systems
- Well & Aquifer Hydraulics
- Groundwater Modeling
The Hydrologic Cycle

Climate, surface water, and groundwater are linked
Porous Systems

Porosity = \frac{\text{volume of pore space}}{\text{total volume of porous material}}
Fractured Systems
Fractured Limestone or Dolomite
<table>
<thead>
<tr>
<th>Material</th>
<th>Porosity (%)</th>
<th>Eff. Porosity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silt</td>
<td>34 - 61</td>
<td>0.1 – 10</td>
</tr>
<tr>
<td>Clay</td>
<td>34 - 60</td>
<td>0.1 – 10</td>
</tr>
<tr>
<td>Sand/Gravel</td>
<td>24 – 55</td>
<td>10 - 55</td>
</tr>
<tr>
<td>Limestone/dolomite</td>
<td>5 - 15</td>
<td>0.1 – 5</td>
</tr>
<tr>
<td>Shale</td>
<td>1 - 10</td>
<td>0.5 – 5</td>
</tr>
<tr>
<td>Sandstone</td>
<td>5 - 15</td>
<td>0.5 – 10</td>
</tr>
</tbody>
</table>
Aquifers vs. Aquitards

An **aquifer** is a saturated bed, formation, or group of formations which yields water in sufficient quantity to be of consequence as a source of supply.

An **aquitard** yields *inappreciable* quantities of water to wells compared to an aquifer but through which *leakage* of water is possible. Aquitards often act as confining beds.
Unconfined vs. Confined Groundwater

An unconfined aquifer is one in which groundwater possesses a free surface open to the atmosphere. The upper surface of the zone of saturation is called the water table.

A confined aquifer is one in which groundwater is confined under pressure by overlying and underlying aquitards or aquicludes and water levels in wells rise above the top of the aquifer. Also called an artesian aquifer.
Confined Aquifers

- Land Surface
- Unsaturated (Vadose) Zone
- Unconfined Aquifer
- Water Table
- Saturated Zone
- Confining Layer - Aquitard
- Confined Aquifer
- Potentiometric Surface
- Bedrock
Regional Groundwater Flow Systems
Groundwater – Stream Interaction
Groundwater – Stream Interaction
Groundwater – Stream Interaction
Groundwater – Stream Interaction
# Groundwater Flow Velocities

<table>
<thead>
<tr>
<th>Material</th>
<th>Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel</td>
<td>5-10 feet per day</td>
</tr>
<tr>
<td>Clean sand</td>
<td>1 – 5 feet per day</td>
</tr>
<tr>
<td>Clayey sand</td>
<td>0.1 – 0.5 feet per day</td>
</tr>
<tr>
<td>Clay</td>
<td>&lt; 0.1 feet per day</td>
</tr>
<tr>
<td>Sandstone</td>
<td>&lt; 0.5 feet per day</td>
</tr>
<tr>
<td>Highly fractured limestone</td>
<td>10 – 1000’s feet per day</td>
</tr>
</tbody>
</table>
Regional Bedrock Topography
Green = higher elevations
Light violet = lower elevations
The Mahomet Aquifer Region

Proposed ethanol plants using Bedrock "high" – aquifer absent
Mahomet Aquifer as principal source
Glacial Depositional Processes
Major Sand & Gravel Aquifers
Geology of the Mahomet Aquifer
Withdrawals from Sand & Gravel Aquifers

Total use ~ 400 mgd
+ ~200 mgd for irrigation
# Regional Community Groundwater Use

<table>
<thead>
<tr>
<th>Location</th>
<th>2004 Water Use (gpd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gibson City (not Mahomet Aquifer)</td>
<td>730,000</td>
</tr>
<tr>
<td>IL-American Water Co.</td>
<td>21,000,000</td>
</tr>
<tr>
<td>Mahomet</td>
<td>500,000</td>
</tr>
<tr>
<td>Monticello</td>
<td>700,000</td>
</tr>
<tr>
<td>Normal</td>
<td>4,100,000</td>
</tr>
<tr>
<td>Paxton</td>
<td>650,000</td>
</tr>
<tr>
<td>Rantoul</td>
<td>1,600,000</td>
</tr>
<tr>
<td>Stone Ridge Dairy (near Bellflower)</td>
<td>~1,200,000</td>
</tr>
<tr>
<td>White Heath</td>
<td>50,000</td>
</tr>
</tbody>
</table>
Cone of Depression

Well/Aquifer Interactions
Overlapping Cones of Depression

Well/Aquifer Interactions
Overlapping Cones of Depression: Well Interference
Overlapping Cones of Depression: Well Interference

Well/Aquifer Interactions
Overlapping Cones of Depression: Well Interference

Well/Aquifer Interactions
Overlapping Cones of Depression: Well Interference

Well/Aquifer Interactions
Mahomet Aquifer Groundwater Levels

10-foot contour
Flow direction
Mahomet Water Levels by the Illinois River

Land Surface = 485’ MSL elevation

Great Flood of 1993

1988-1989 Drought
Potentiometric Surface of Eastern Mahomet Aquifer, 2005
Mahomet Potentiometric Heads near Champaign

Groundwater elevation, feet

Water Use Trend at Champaign
Impacts of pumping on water levels (head)

- Mahomet aquifer pumping heads
- Mahomet aquifer nonpumping (artesian) head

P Pump settings

Glacial till

High-capacity well

Low-capacity well

Mahomet aquifer
Impact of pumping hydraulically linked aquifers

- Mahomet nonpumping
- Mahomet pumping
- Glasford nonpumping
- Glasford pumping

Glacial Till
Glasford Aquifer
Mahomet Aquifer

Dewatered aquifer

Legend:

- Blue: Mahomet nonpumping
- Red: Glasford nonpumping
- Dotted blue: Mahomet pumping
- Dotted red: Glasford pumping
Model-Predicted Drawdown

$Q = 23 \text{ mgd at Champaign}$
Thanks!

Visit us on the web for updates:

http://www.sws.uiuc.edu

Or Google: Illinois State Water Survey