Chippewa County Groundwater Study
Public outreach meeting

Bloomer, WI
02/26/2013
Today’s outline

- Review of hydrogeology *(WGNHS)*
- Overview of study *(WGNHS)*
- The value of a groundwater flow model *(USGS)*
- Data collection example: Streamgaging *(USGS)*
- Questions?
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Groundwater is...

Pore spaces filled with water
Groundwater provides cold, clear water to streams, rivers and lakes.

Baseflow is usually of excellent quality compared to runoff to streams, which contains sediment and nutrients.
Aquifers are very permeable, aquitards restrict the flow of groundwater.

Core of the Wonewoc sandstone

Core of the Eau Claire shale
Groundwater – surface water connections
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• Questions?
Overview of project proposal

• Objectives
  – Develop soil water balance (recharge) and groundwater flow models to evaluate current and future water use and landscapes on the hydrologic system
  – Disseminate the study results to stakeholders and the general public
  – Transfer the study results to similar geologic/hydrologic settings as appropriate

• Limitations
  – Model solution is valid only within the Area of focus
  – Steady state model (simulates average annual conditions)
Overview of project proposal

• Technical investigation and modeling (5 Tasks)
  – Data collection
  – Recharge modeling (SWB model)
  – Groundwater modeling
  – Scenario testing
  – Transferability
Overview of project proposal

Study location
Demand for groundwater from sand mining and irrigated agriculture is projected to increase in western Chippewa Co.
Technical Investigation – *data collection*

- DEM land surface elevation maps – *USGS (2003)*
- Surface water feature maps – *DNR*
- LiDAR data – *Chippewa County Land Information Office (2011)*
- Bedrock Geology of Chippewa County – *WGNHS (1987-88)*
- Hydrogeologic data – *WDNR, WGNHS, and sand mining companies*
- Streamflow measurements – *USGS*
Technical Investigation – data collection

- DEM (Digital Elevation Map) (USGS, 10-m resolution)
- Surface water features (DNR, 1:24,000 scale)
Technical Investigation – data collection

- DEM (Digital Elevation Map) (USGS, 10-m resolution)
- Surface water features (DNR, 1:24,000 scale)

- DEM data used for calculating elevations of features
- Surface water feature locations used for routing rivers and creeks in the groundwater flow model
Technical Investigation – *data collection*

- LiDAR (Light Detection And Ranging)
Technical Investigation – *data collection*

- LiDAR (*Light Detection And Ranging*)
Technical Investigation – data collection

- LiDAR (Light Detection And Ranging)
  - LiDAR data used for calculating elevations of features
  - May allow for topographic comparison before and after mine reclamation
  - Aids with geologic interpretations
Progress to date - Maps / regional datasets

- **Bedrock geology** *(WGNHS)*
  - Northwest WI (1987)
  - West Central WI (1988)
  - 1:250,000 scale
Progress to date - Maps / regional datasets

- **Bedrock geology** *(WGNHS)*
  - Northwest WI (1987)
  - West Central WI (1988)
  - 1:250,000 scale

- Good framework but relatively small scale mapping

- We will improve by using:
  - More detailed geologic data
    - Geologic logs
    - Geophysical logs
    - Rock cores
    - Outcrop descriptions
  - High resolution elevation data to calculate extent of each fm.
Geophysical logs are high quality subsurface data which aid in correlating and delineating regional (hydro)geologic features.
Technical Investigation – data collection

USGS gaging stations

Manual measurements
Overview of project proposal

• Technical investigation and modeling (5 Tasks)
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Recharge

- Recharge (R) is water that enters the groundwater system

\[ R = \text{Precipitation} - \text{Runoff} - \text{Interception} - \text{Evapotranspiration} \]
Estimating Recharge

- The soil-water-balance (SWB) model calculates recharge based on:
  - Land Cover: forest, pasture, row crop, pavement (affects ET)
  - Soil type: water-holding capacity (affects ET)
  - Daily precipitation, temperature (frozen ground, saturation)
  - Land surface slope (runoff)
Overview of project proposal

• Technical investigation and modeling (5 Tasks)
  – Data collection
  – Recharge modeling (SWB model)
  – Groundwater modeling
    • MODFLOW model
    • Incorporate significant features of hydrologic cycle
    • Calibrate to steady state conditions (average annual conditions)
    • Represent water use and landscape conditions prior to frac sand mining
  – Scenario testing
  – Transferability
Overview of project proposal

- **Technical investigation and modeling (5 Tasks)**
  - Data collection
  - Recharge modeling (SWB model)
  - Groundwater modeling
  - Scenario testing
    - Use calibrated model to evaluate impacts for two scenarios
    - Scenario 1 – peak sand mine operations (~ 2030)
    - Scenario 2 – post-mine reclamation (~ 2050)
    - **Scenarios are designed to be illustrative of impacts not predictive!**
  - Transferability
Overview of project proposal

• Technical investigation and modeling (*5 Tasks*)
  – Data collection
  – Recharge modeling (SWB)
  – Groundwater modeling
  – Scenario testing
  – Transferability
    - Apply models to evaluate general system responses to expected changes in groundwater pumping and recharge associated with frac sand mining and irrigation operations
    - These operations are common to west-central Wisconsin
    - These changes may become increasingly common within west-central Wisconsin
Overview of project proposal

- Public outreach and reporting (3 Tasks)
  - Fact sheet – Now available
  - Public outreach and stakeholders meetings – Annual update meetings
  - Interim and final reporting – 2014 and 2017 respectively

Pick up a copy tonight!
Overview of project proposal

• Project budget
  – 5-year cooperative project between WGNHS and USGS
  – $433,223 total cost to Chippewa County
  – WGNHS and USGS report directly to Chippewa County

• Workflow and activities schedule (*major milestones*)
  – Contract signed August 8, 2012
  – Fact sheet – *Now available*
  – Next public outreach meeting – Q1 2014 (*updated annually*)
  – Next stakeholders group meeting – Q1 2014 (*updated annually*)
  – Interim report – Q4 2014 (*data collection and SWB results*)
  – Final report – Q3 2017 (*final model, scenario, and transferability results*)
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Use of Groundwater-flow Models in Mine Permit Evaluations

Michael N. Fienen

USGS Wisconsin Water Science Center

Understanding the Impacts of Mining in the Western Lake Superior Region

September 14, 2011  Bad River Lodge, Odanah, Wisconsin
model

noun

• a simplified description, esp. a mathematical one, of a system or process, to assist calculations and predictions.

ORIGIN late 16th cent. (denoting a set of plans of a building): from French modelle, from Italian modello, from an alteration of Latin modulus (see modulus ).
Models are ubiquitous
Overview of groundwater modeling

Conservation of Mass
Conservation of Energy

Hydrologic Cycle
Calibration to on-site conditions

The importance of calibration and uncertainty analysis

honor the physical/chemical laws

honor the specific site
The value of models

conceptual model
A cohesive framework to consolidate and interpret data

computer simulation
A platform on which to test scenarios, evaluate responses, add margin of safety

decision making
A feedback mechanism to revise interpretation and guide future work
Groundwater in the Hydrologic Cycle

The Water Cycle

- Water storage in ice and snow
- Precipitation
- Sublimation and Desublimation
- Evapotranspiration
- Condensation
- Evaporation
- Water storage in oceans
- Water storage in the atmosphere
- Surface runoff
- Snowmelt runoff to streams
- Streamflow
- Groundwater storage
- Spring
- Groundwater discharge
- Infiltration
- Freshwater lake
- Biological water
- Dew
- Fog drip

Groundwater System
Water Entering the System
Water Exiting the System
An aside: the myth of sustainable yield
Interaction with streams is dynamic

from Alley, Reilly, and Franke, USGS Circular 1186, 1999
Conservation of Mass—Scotty’s Rule

Matter cannot be collapsed—water is incompressible

Must balance water inflow and outflow
Control volume over which to balance inflows and outflows.
Conservation of Energy—Plumber’s Rule

Water flows “downhill”

Energy entering the system must either leave the system or get converted to heat through friction.
“downhill”, pressure, and Darcy’s Law

Flow is a function of:
- Geometry (area)
- Resistance (hydraulic conductivity)
- Energy in/out (boundary conditions)

Manometer image from: http://www.dwyer-inst.com/Products/ManometerIntroduction.cfm
Henry Darcy image from: Wikimedia commons
Falling head experiment image from: http://bioen.okstate.edu/Darcy/LaLoi/basics.htm
Conceptual model and choice of techniques

The choice of modeling technique and data acquisition are motivated by the nature of the question being asked.

- nearby streamflow impact
- groundwater levels
- water quality in mine water
- water supply to wetlands

The results of all models are contingent on conceptual, technique and data choices made.

A model designed to answer one question with a margin of safety may be at odds with another.
Choosing a model

What kind of model is required?

Tools:
- Hand calculations
- Analytic Elements
- Fully Numerical
  - GFLOW
  - MODFLOW
  - FEFLOW
  - FEMWATER

Computational/Accuracy Issues:
- Patience
- Complexity of Geometry
- Node/Element Size

Timing:
- “Steady State” or “Transient”? In all cases, an important consideration is track record/legal history
Parameters controlling the model

Groundwater flow models rely on several parameters

<table>
<thead>
<tr>
<th>Within the groundwater system</th>
<th>Hydrologic cycle connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>hydraulic conductivity</td>
<td>recharge</td>
</tr>
<tr>
<td>water levels at boundaries</td>
<td>precipitation, infiltration,</td>
</tr>
<tr>
<td>geometry</td>
<td>losing streams</td>
</tr>
<tr>
<td>reaction kinetics</td>
<td>discharge</td>
</tr>
<tr>
<td>porosity</td>
<td>springs, gaining streams,</td>
</tr>
<tr>
<td></td>
<td>lakes, evaporation,</td>
</tr>
<tr>
<td></td>
<td>plant uptake,</td>
</tr>
</tbody>
</table>
Parameters cannot be measured – they are inferred. But, the solution is not unique.
Calibration and Uncertainty
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More complex models → many parameters

Beyond Trial-and-Error → robust statistical techniques can help

Each parameter has some uncertainty associated with it

Predictions made using the model and these parameters will also have uncertainty to consider.
“Essentially, all models are wrong, but some are useful.”

We should not expect to perfectly reproduce the measurements with a model.

We acknowledge that the model is imperfect.

We also acknowledge that our measurements are imperfect.

We thus rely on robust statistical techniques to quantify and explicitly consider these uncertainties.
## Summary

### What can GW models do?
- Provide a cohesive framework to interpret data.
- Allow evaluation of potential scenarios.
- Guide the need for further information and *help revise conceptual model of the site*.

### What can GW models NOT do?
- Perfectly simulate “Truth with a capital ‘T’”
- Answer every type of question posed about the GW system.
- A fully objective representation.
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Streamflow to Inform Modeling

**Modeling Needs:**

1. Aquifer Permeability
2. Water throughput (input = output)
   
   - Stream baseflow (output) can inform recharge to aquifers (input)
   - Spatial surveys of baseflow can inform changes in aquifer permeability
Recharge Varies Across Wisconsin
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- Changes in baseflow *can* reflect changes in geology
- Streams often gain or lose water as they flow over geologic contacts
Recharge Varies Across Wisconsin

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Recharge Varies Across Wisconsin

• Changes in baseflow *can* reflect changes in geology
Recharge Varies Across Wisconsin

- Changes in baseflow can reflect changes in geology

Como Creek, flow measurements Oct. 11, 2012
Synoptic Streamflow Measurements

- High spatial resolution
- Adjust one-time measurements to “normal” using regression methods...
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Thank you...
Questions?

USGS
Chippewa County
Extension
Wisconsin Geological & Natural History Survey