Hydrogeology of Wisconsin’s National Forests
AWRA – Wisconsin, March 2017

Anna Fehling, Ken Bradbury, Pete Schoephoester, & Steve Mauel, Wisconsin Geological and Natural History Survey, Madison, WI
Randy Hunt, Andy Leaf, & Paul Juckem, U.S. Geological Survey, Middleton, WI
Aaron Pruitt, Geoscience Department, UW-Madison, Madison WI
Greg Knight, Dale Higgins, & Sara Sommer, Chequamegon-Nicolet National Forest, Park Falls, WI
Background

- First comprehensive groundwater study in Chequamegon-Nicolet National Forest (CNNF)
- Collaborators
  - Wisconsin Geological and Natural History Survey
  - U.S. Geological Survey
  - U.S. Forest Service
Study drivers

• Groundwater important for USFS
  • Streams, springs, ecosystems
  • Water supply

• Future stressors...
  • Climate change, high-capacity wells, mining, logging

One potential effect of climate change
Objectives

• Characterize groundwater system

• Products
  • Well geodatabase, aquifer & recharge maps, groundwater flow models

• Create framework for resource management & foundation for site-specific studies
Study area

- 4 units (& technical reports)
- 11 counties
- 1.5 million acres
Regional geology - simplified

- Till
- Crystalline bedrock
- Sand and gravel
- Glacial deposits
- Bedrock outcrops at surface
Approach: 4 study components

1. **Hydrogeologic data**
   Data inventory and aquifer characterization

2. **Groundwater potential recharge**
   Soil-water balance model

3. **Geochemistry**
   Water sampling

4. **Groundwater flow model**
   GFLOW – 2D regional flow
1. Hydrogeologic data – inventory

- Assembled geodatabase of well construction reports & other available data
- Wells moved to best location in GIS
- Used for analysis in rest of study
- Sparse in many areas!
Hydrogeologic data - aquifer characterization

- Bedrock outcrops at surface
- Glacial deposits
- Sand and gravel
- Till
- Crystalline bedrock
Hydrogeologic data - aquifer characterization

Primary aquifer; absent where glacial deposits thin or fine-grained

Glacial deposits

Till

Sand and gravel

Secondary aquifer; used where sand & gravel is absent. Water flows through fractures.

Crystalline bedrock
<table>
<thead>
<tr>
<th>Description</th>
<th>Sand and gravel</th>
<th>Crystalline bedrock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surficial glacial deposits</td>
<td>75% of wells</td>
<td>25% of wells</td>
</tr>
<tr>
<td>Fractured rock below glacial deposits</td>
<td>30-40 ft/day</td>
<td>2-4 ft/day</td>
</tr>
<tr>
<td>Mean hydraulic conductivity</td>
<td>100-300 gpm</td>
<td>&lt;20 gpm</td>
</tr>
<tr>
<td>Potential well yield</td>
<td>2-4 ft/day</td>
<td>&lt;20 gpm</td>
</tr>
</tbody>
</table>

Aquifer characterization maps

- Saturated thickness of sand and gravel (shown)
- Bedrock elevation
- Depth to bedrock
High-capacity well pumping 2014

• 40 high-capacity wells in CNNF

Dot size shows relative pumping magnitude
Data source: WDNR
Monitoring groundwater levels

- Baseline conditions to evaluate future impacts
- Interpret changes: low water levels from regional drought or local pumping or...?
2. Groundwater potential recharge

- Soil-water balance (SWB) model
- Produces a grid of potential recharge
- Varies with space and time

- Grid input to groundwater flow model & calibrated using a multiplier of the grid
Mean annual potential recharge
Potential recharge vs. surficial geology/soil

Potential recharge vs. surficial geology/soil

3. Geochemistry – water quality

- Sampled wells, lakes, streams, springs
  - Ions, isotopes, alkalinity, pH
- Water quality generally unimpaired by humans - some places affected by road salt

Photo credit: https://www.pca.state.mn.us/water/road-salt-and-water-quality
Water chemistry – distinguishing source

- Chemistry of groundwater vs. surface water
- Use this to answer:
  - Is a well drawing water from a lake?
  - Is a stream fed by groundwater?
- Alkalinity, electrical conductivity typically higher in groundwater

<table>
<thead>
<tr>
<th></th>
<th>Groundwater</th>
<th>Surface water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical conductivity, µs/cm</td>
<td>161-249</td>
<td>31-63</td>
</tr>
<tr>
<td>Alkalinity, as mg/L CaCO₃</td>
<td>83-132</td>
<td>8-28</td>
</tr>
</tbody>
</table>

*Mean values from each unit for samples interpreted as groundwater-dominated or surface-water dominated.
4. Groundwater flow model

- Simulate regional flow system using GFLOW
  - 6 total models (1-2 per unit)
- Water table map
  - GFLOW vs. point interpolation
Groundwater flow model: Simulated baseflow
Groundwater flow model as a tool

• Simulate changes in baseflow or water levels (e.g. from new well)
• Identify areas contributing groundwater to a stream or wetland
• Ideal for extracting inset model -- use regional results as boundary conditions for smaller model
Summary

• Products of this study create a framework for future work in northern WI.

• Geodatabase, maps, and models will be made publicly available. Reports in peer review.

• Continuing work...
  • Use report to guide data collection – water table, streamflow measurements, geology, etc.
  • Local studies in areas of interest
Thank you!
Questions?