

groundwater/surface-water interactions

Evan Christianson, PG

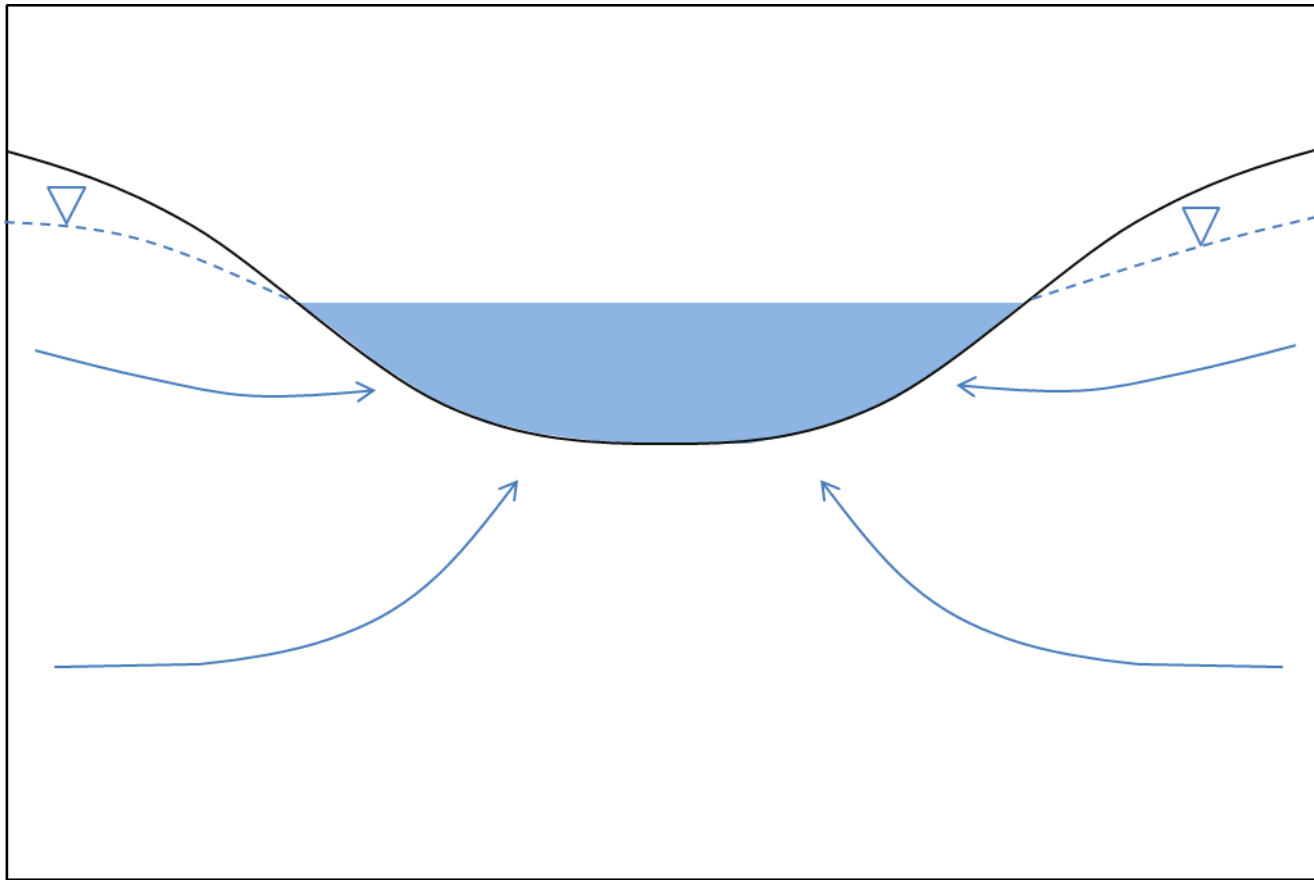
Barr Engineering Company

Discussion of....

- Groundwater/Surface-Water Interactions
- Groundwater Recharge
- Impacts from Pumping
 - Potential effect on water appropriations permitting

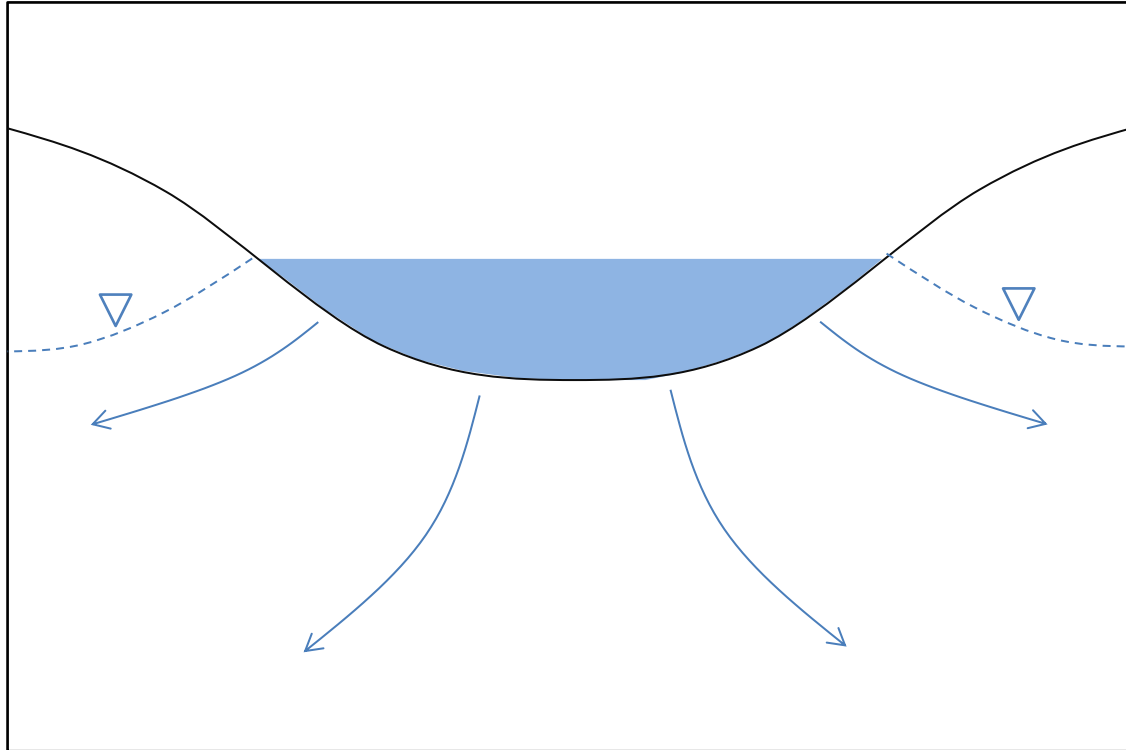
Groundwater/Surface-Water Interactions

discharge lake/wetland gaining stream



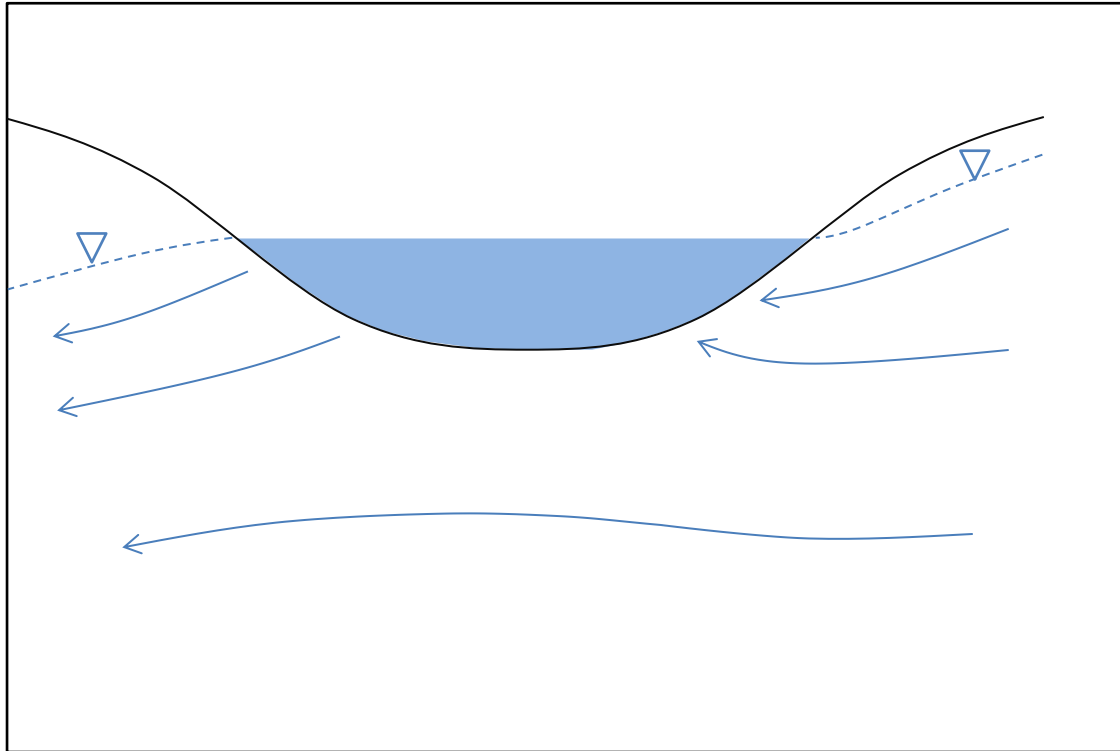
Mostly receives groundwater inflow

recharge lake/wetland losing stream



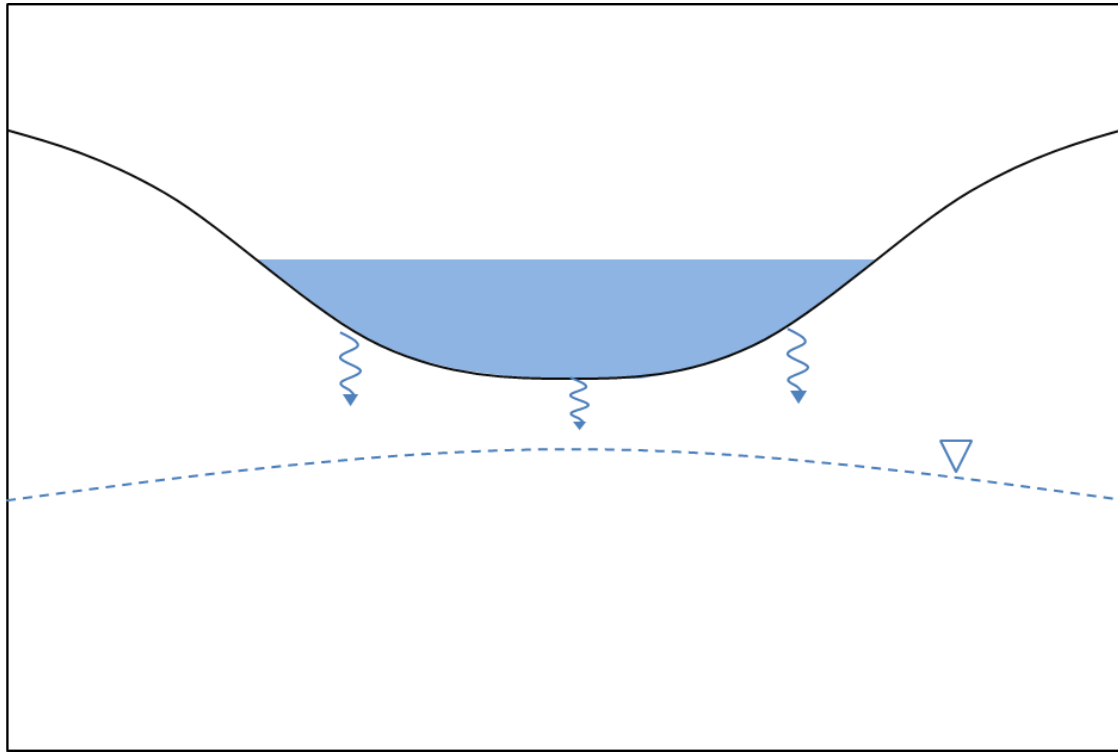
- **Mostly loses water as seepage to groundwater**
- **Rate of loss dependent on:**
 - difference between aquifer hydraulic head and water stage
 - lake/stream bed characteristics
 - aquifer characteristics

flow-through lake/wetland



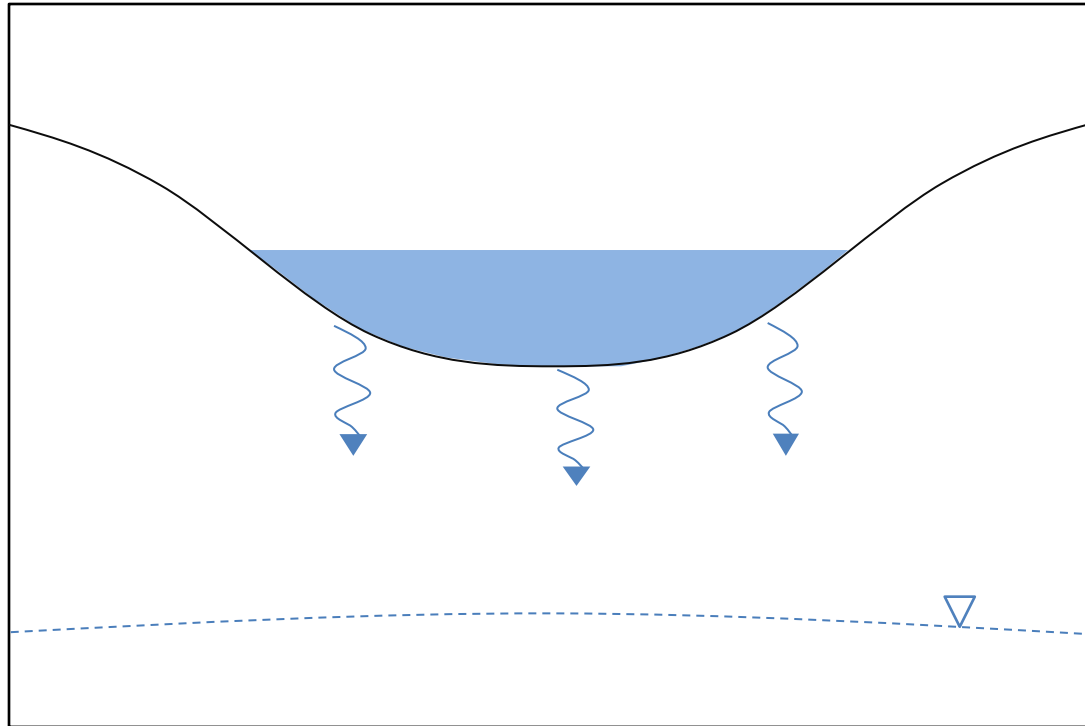
- **Groundwater flow both into and out of lake/wetland**
- **Rate of loss dependent on:**
 - difference between aquifer hydraulic head and water stage
 - lake/stream bed characteristics
 - aquifer characteristics

disconnected lake/wetland/stream shallow water table



**Water table slightly below lake/wetland/stream bottom
Fluctuations in water table affect flow dynamics**

disconnected lake/wetland/stream deep water table

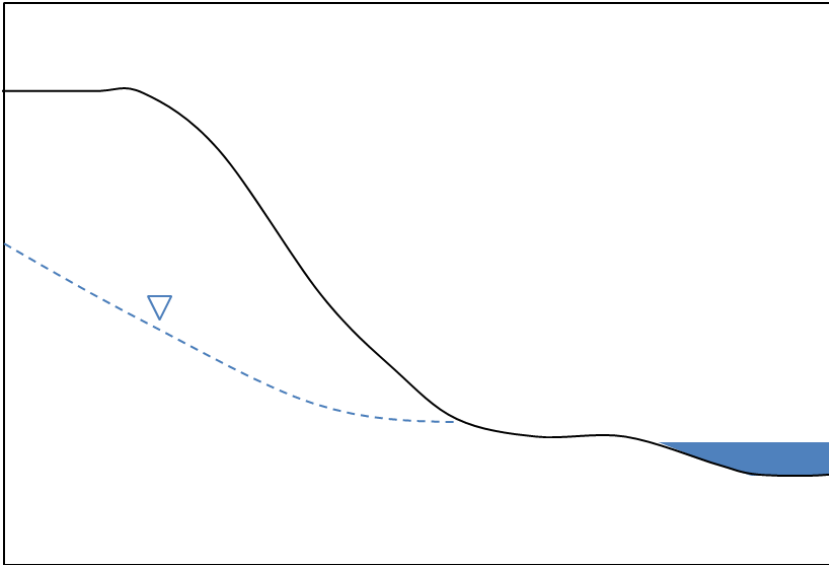


Water table far below lake/wetland/stream bottom

Loss of water to the unsaturated zone

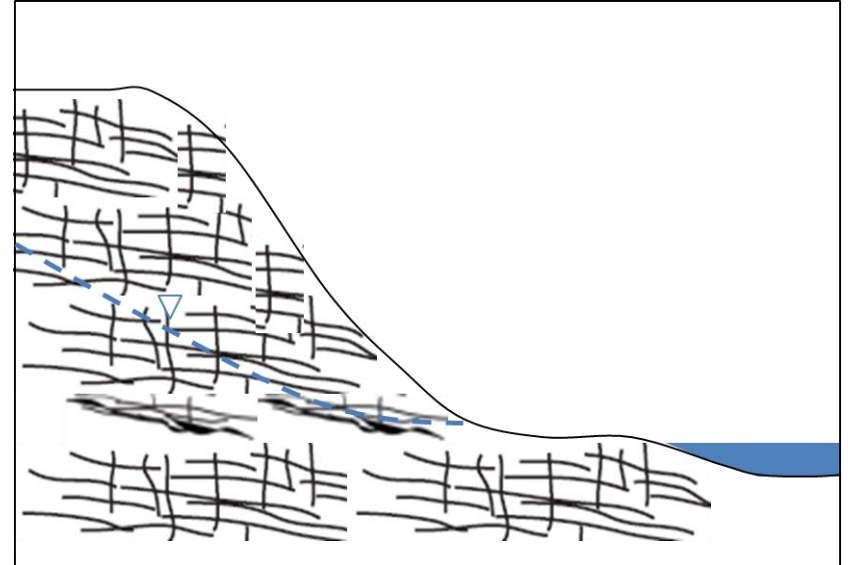
Change in water table has no effect on lake/wetland/stream

non-karst spring



Flow from spring controlled by porous media flow

karst spring

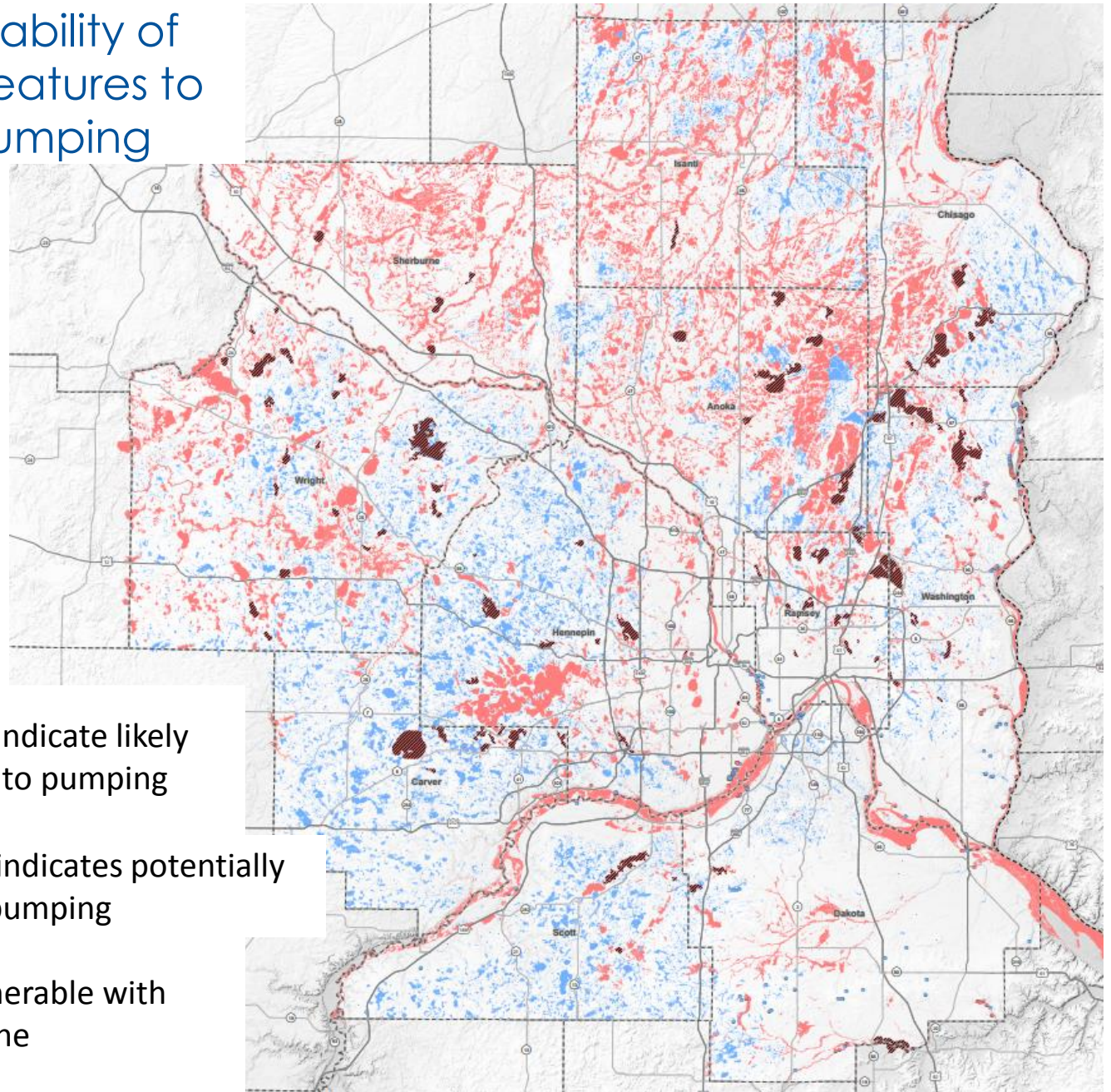





Flow from spring controlled by karst flow and/or low-permeability layers

Vulnerability to Changes in Groundwater System

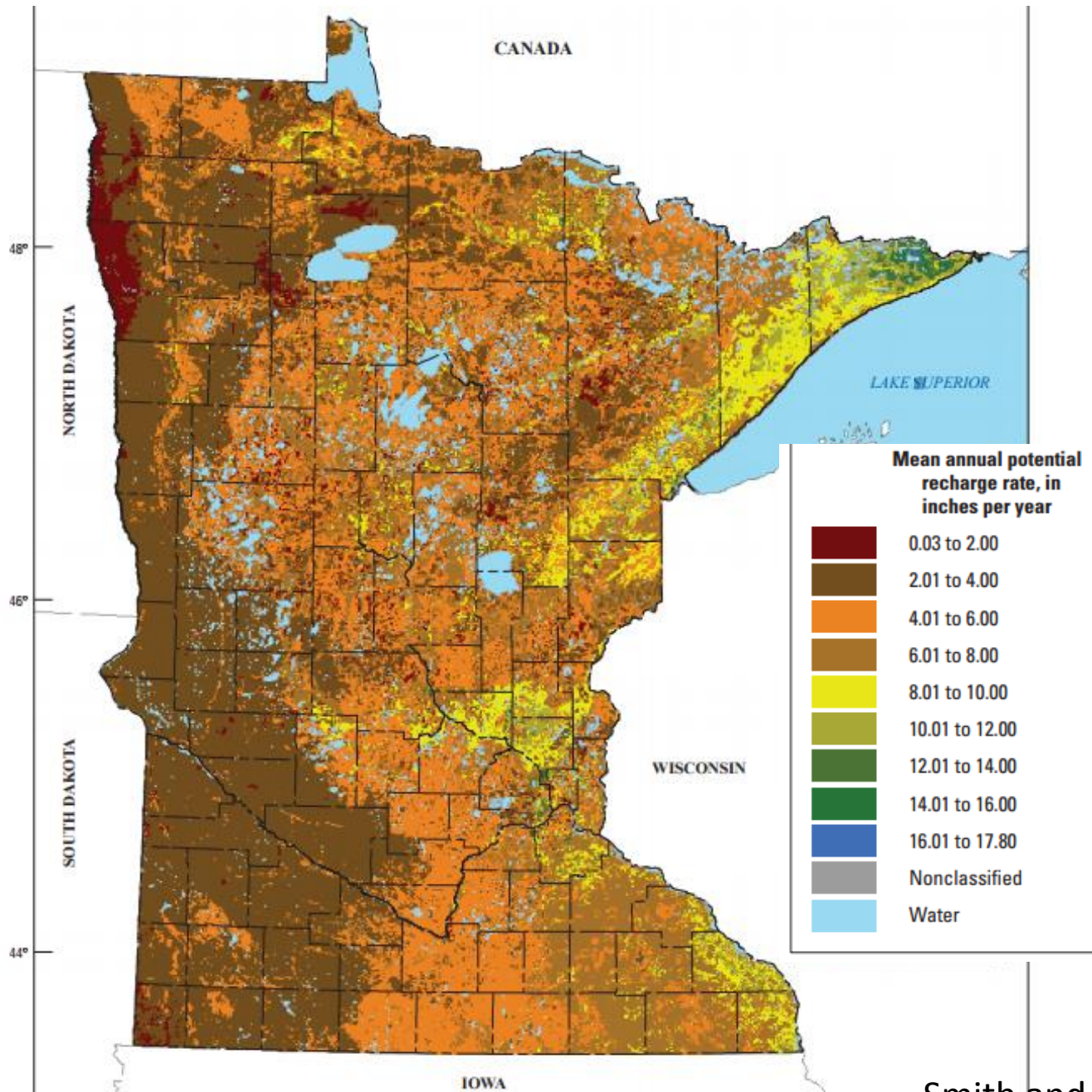
- Connected or Disconnected (perched)
- Connection type (flow-through, discharge etc.)
- Geology
 - Glacial Sediments
 - Bedrock
 - Soils
- Surface-water characteristics
 - Depth, Geometry, etc.
- Sensitivity of Biota

potential vulnerability of surface-water features to groundwater pumping

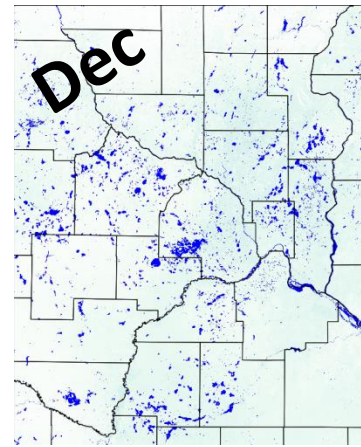
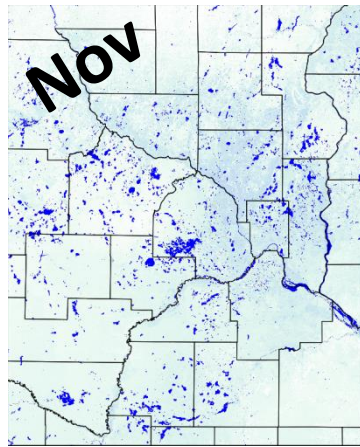
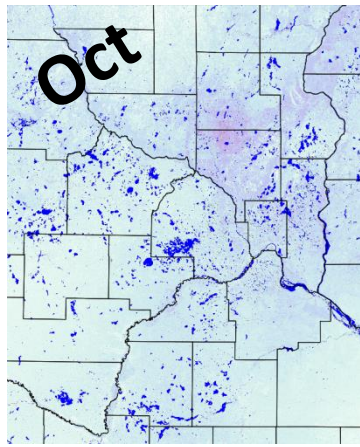
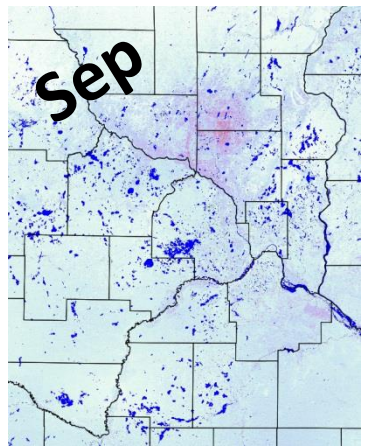
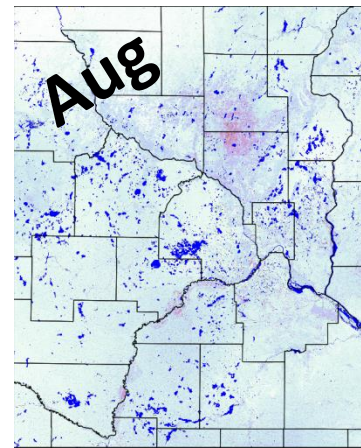
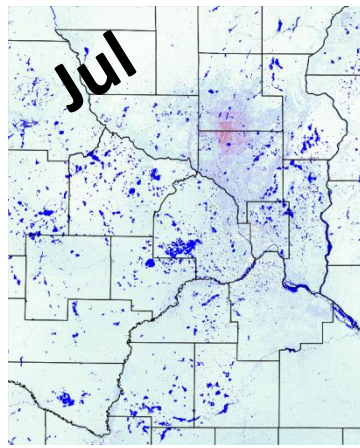
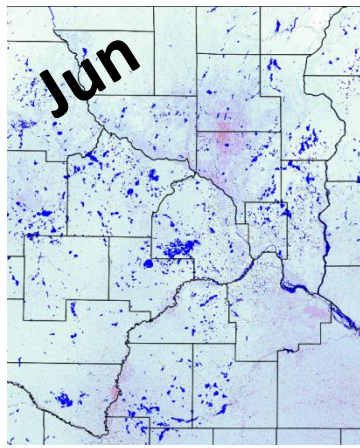
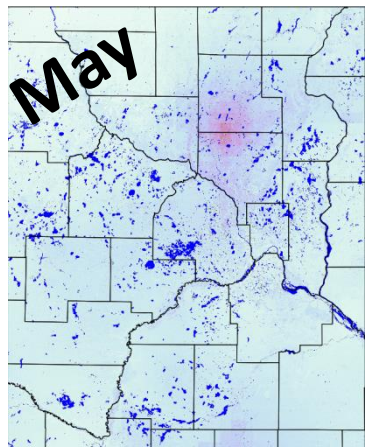
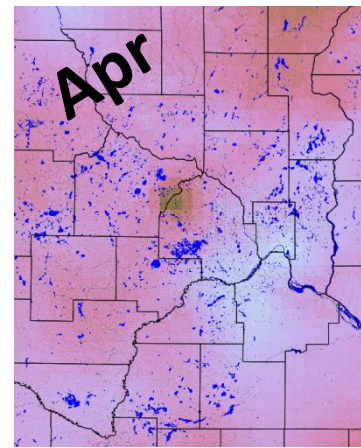
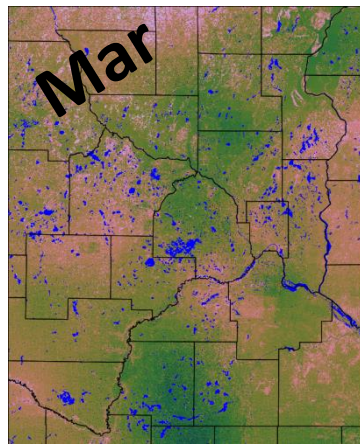
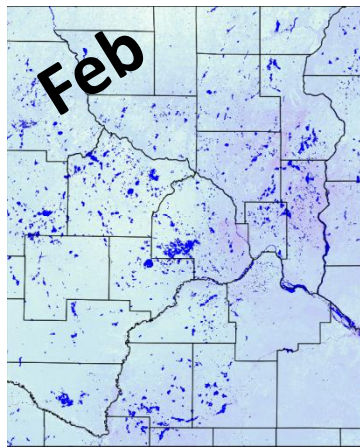
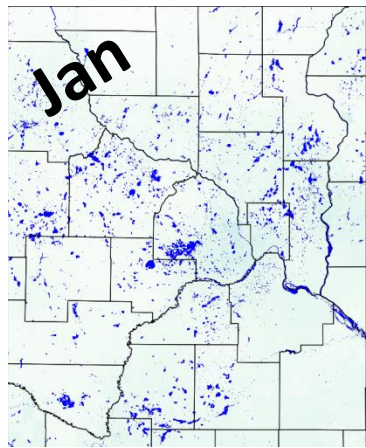


-  Available data indicate likely not vulnerable to pumping
-  Available data indicates potentially vulnerable to pumping
-  Potentially vulnerable with wide littoral zone

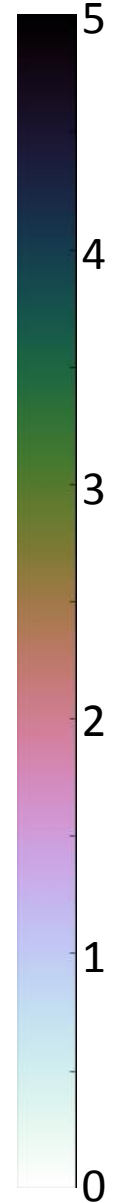
Groundwater Recharge



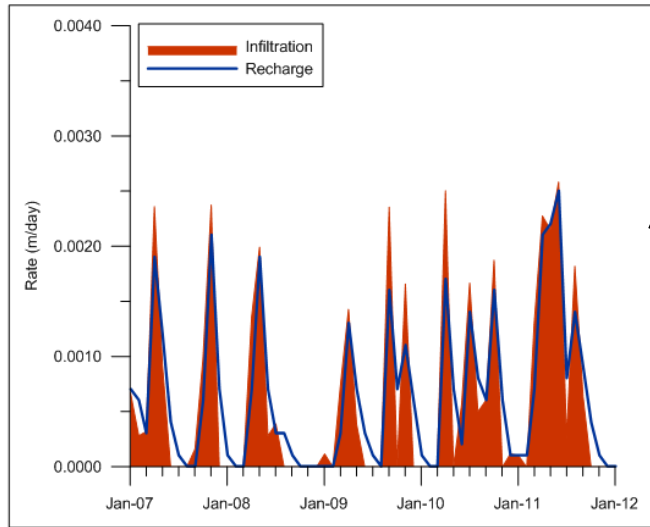
Smith and Westenbroek, 2015



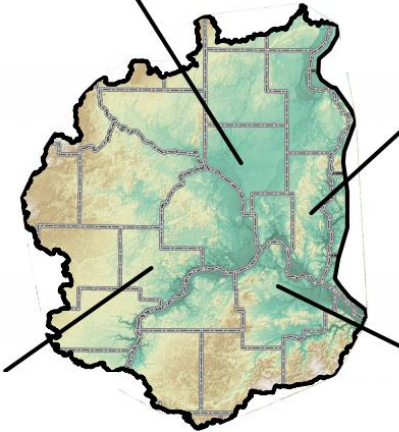
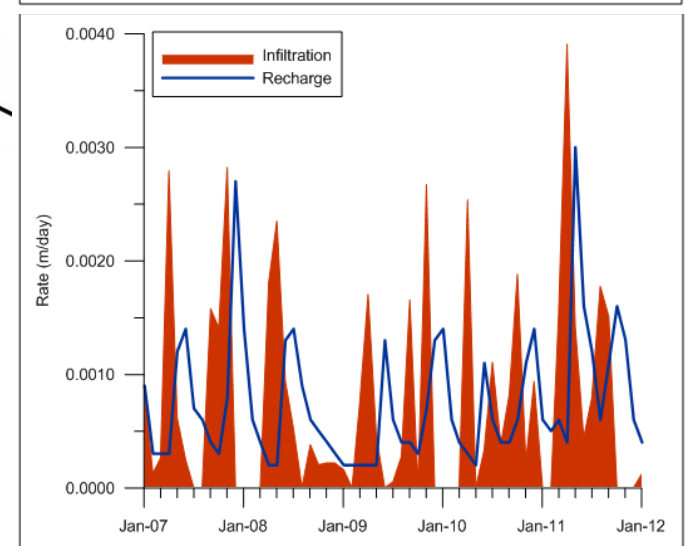
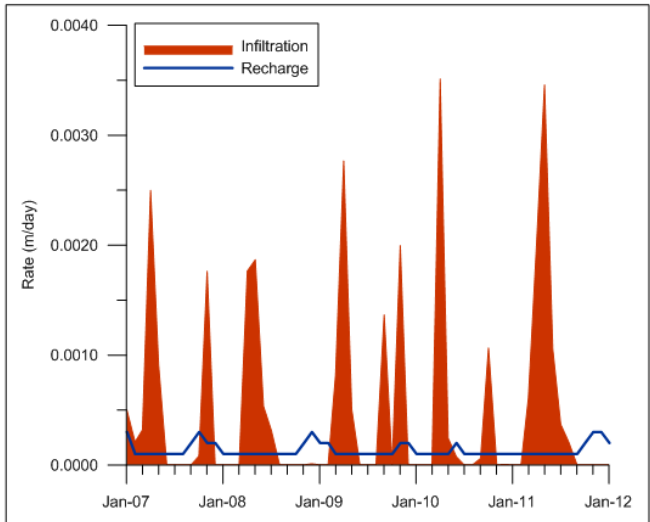
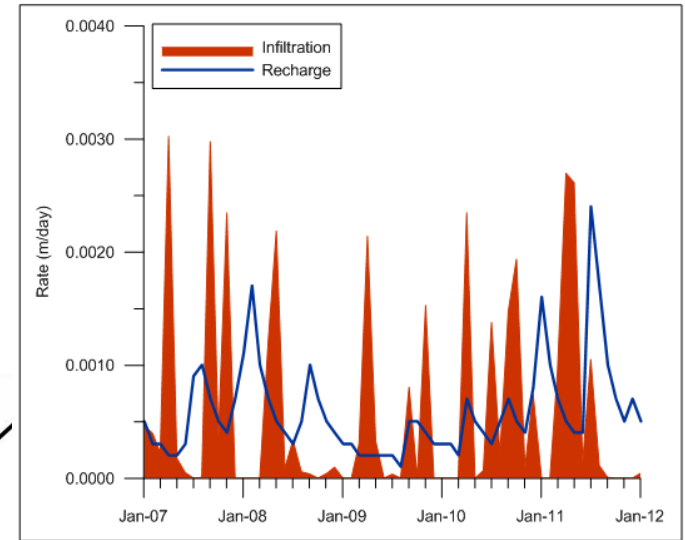
Avg.
Infiltration
(in/month)



Time lag between infiltration and recharge

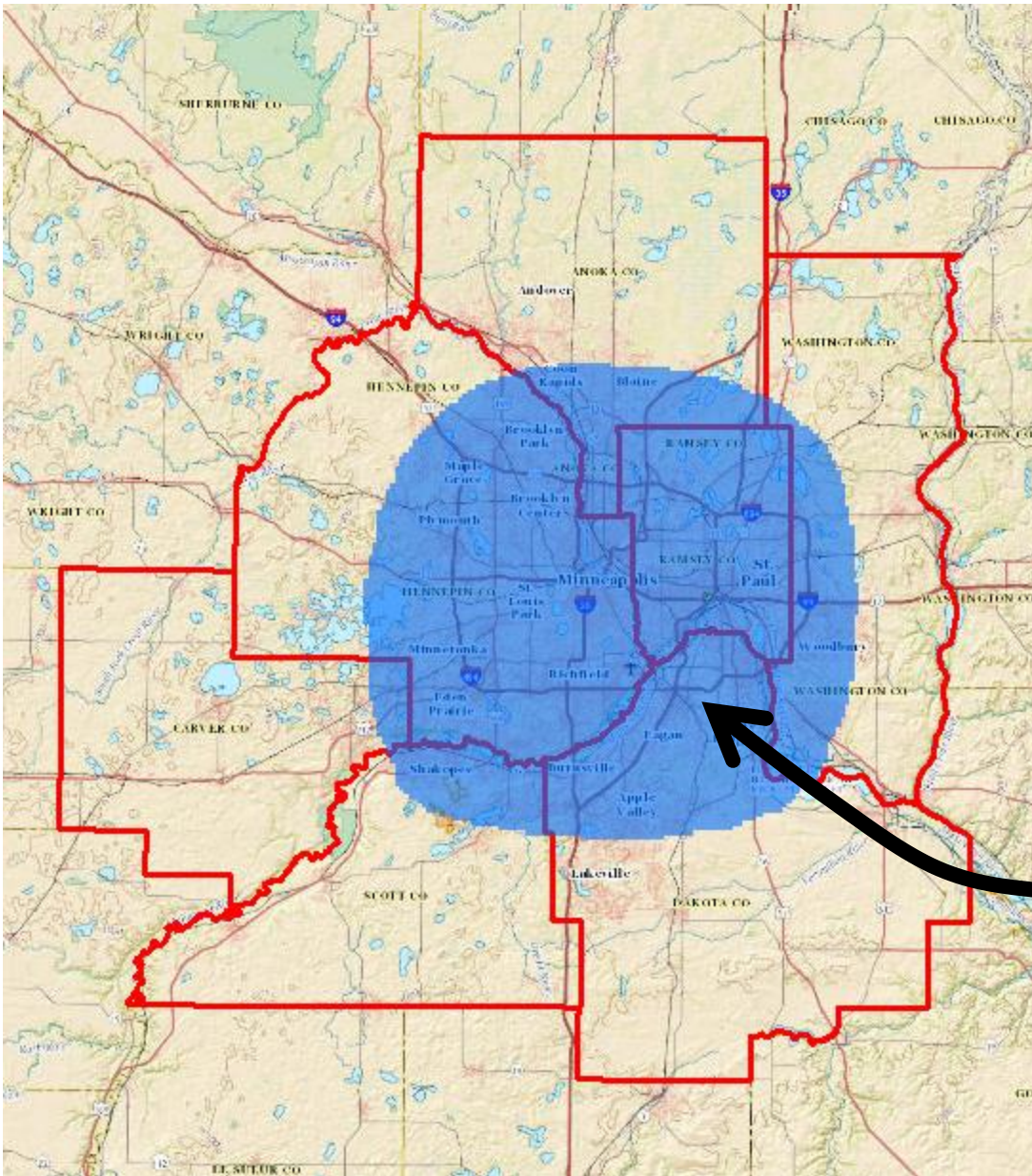


Infiltration
Recharge

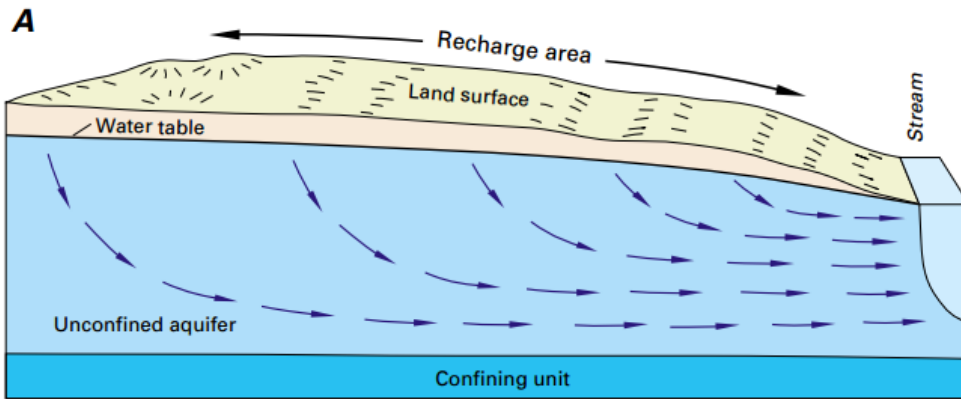


Impacts of Groundwater Pumping

Groundwater Pumping 7-County Metro Area

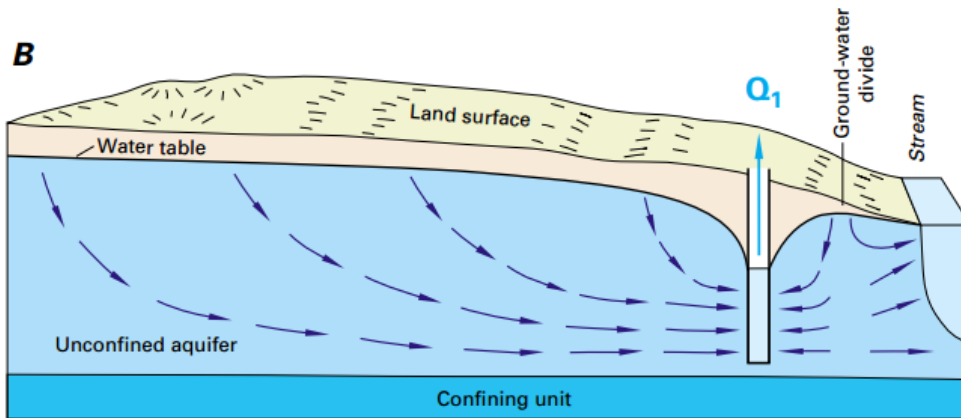


- 316 Million Gallons Per Day
 - > 200,000 gpm
- Equivalent to 2.2 inches per year across the metro
 - Approximately 27% of average recharge
- Or 100% recharge in this area



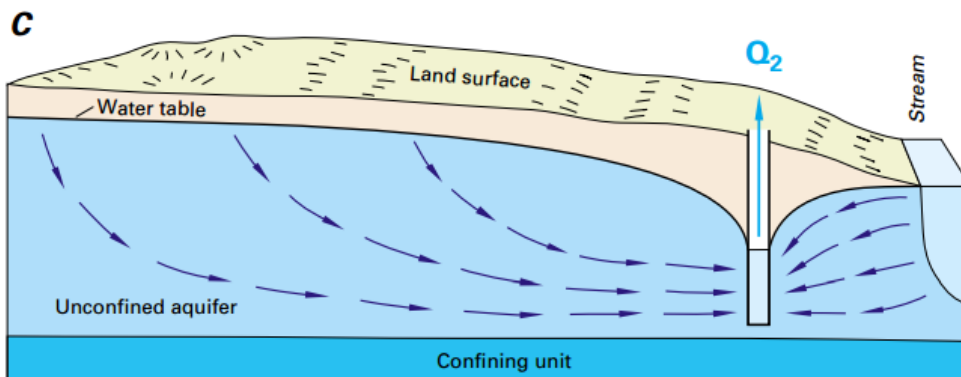
natural conditions

- recharge = ground water discharge



well pumping at rate, Q_1

- well “captures” water that would have discharged to stream
- groundwater divide forms between stream and well



well pumping at higher rate, Q_2

- well “captures” water that would have discharged to stream and pulls water directly from the stream
- groundwater divide forms between stream and well

Any pumping will reduce groundwater flow to lakes and streams

- Conservation of mass

The aquifer that water is withdrawn from only affects:

- 1) the location/areal extent of the reduction
- 2) time lag

MN 103G.272 Subdivision 2

Groundwater appropriations that will have ~~potential impacts~~ **negative** impacts to surface waters are subject to applicable provisions in section 103G.285

Original language from 2010 modified in 2014

103G.285 = Surface water appropriations;
process and limits

What is a negative impact?

MN DNR Thresholds

Report to the Minnesota State Legislature: Definitions and Thresholds for Negative Impacts to Surface Waters, January 2016

Streams

- Diversion limit of no more than 10% of the August median base flow

Lakes

- *with constant stream outflow* = apply stream threshold
- *without constant stream outflow* = protection elevation
- Goal is to maintain characteristic hydrology, ecology, and riparian uses of the lake most of the time

Wetlands

- Currently proposing establishing target hydrographs for various wetland types
- Currently very limited wetland-related hydrologic data

Effect on permitting process



- 1.) Establish negative impact thresholds for surface water bodies
- 2.) Establish sustainable diversion limits that will maintain protected flows and protection elevations for those water bodies
- 3.) Conduct groundwater modeling to determine the effects of groundwater withdrawals on the surface water bodies
- 4.) Assess to what degree individual groundwater withdrawals may need to be adjusted.

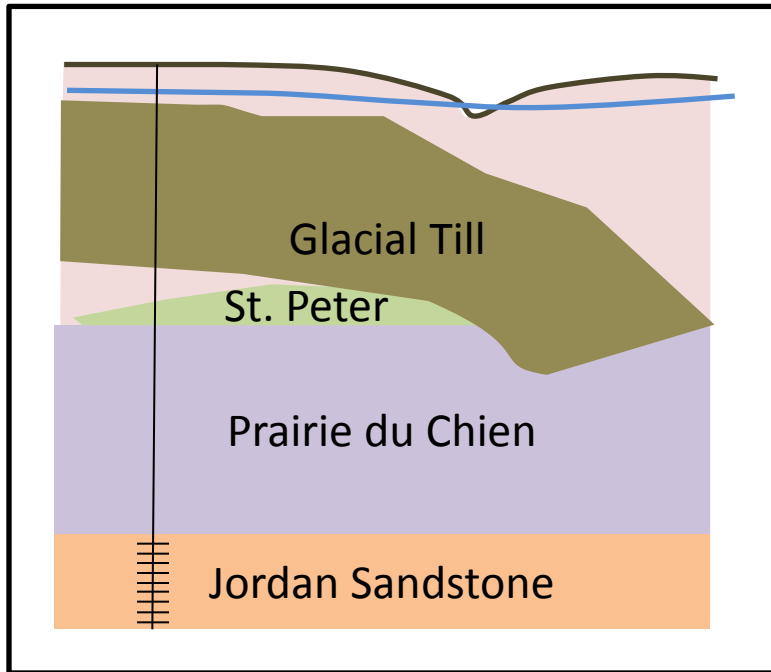
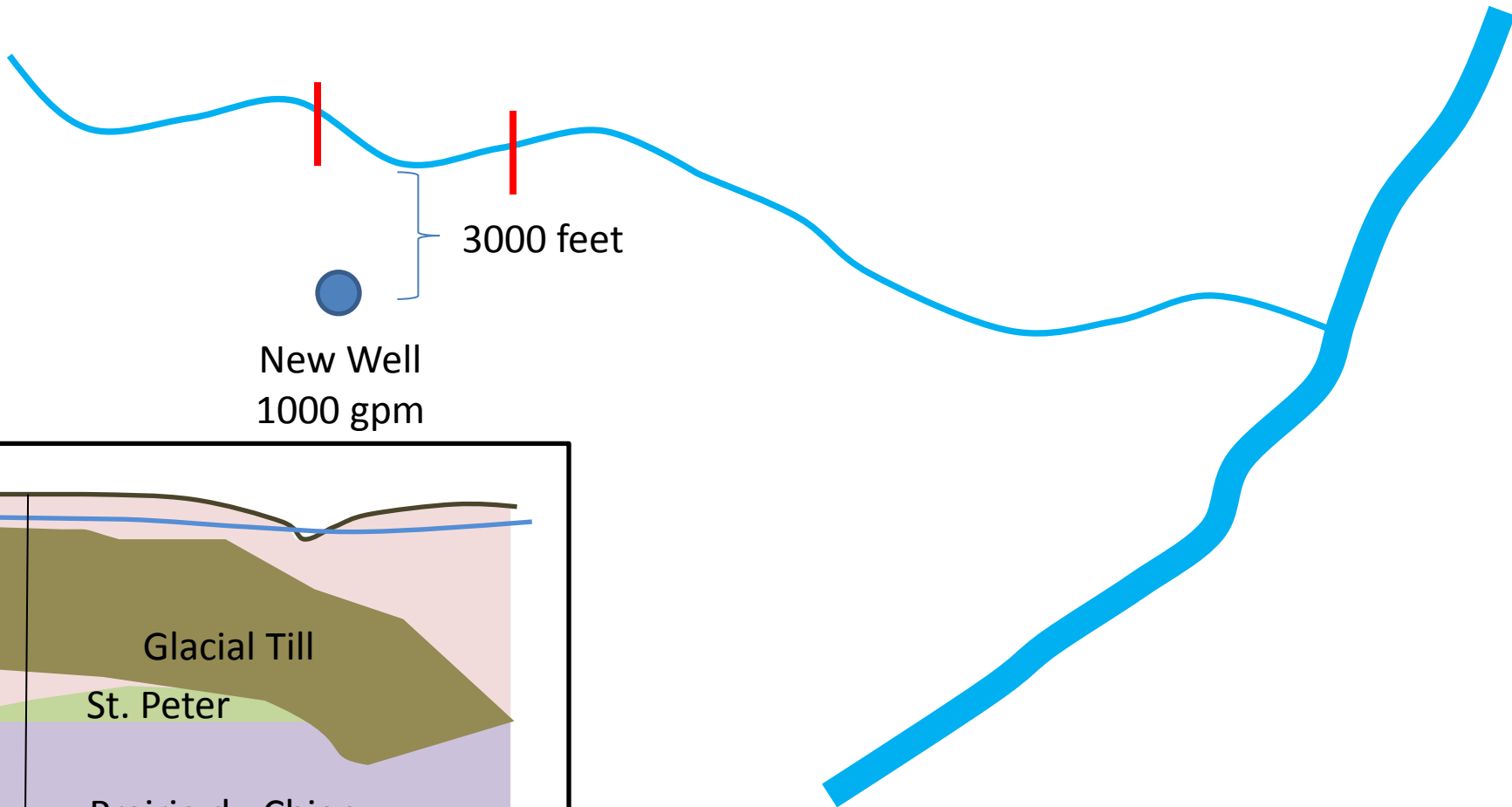
Minnesota Water Priority Classes

- Riparian water law system
- New permit applicants have same priority as existing permit holders, assuming water is for the same purpose
- If a conflict exists, water users have the opportunity to develop a plan for proportionate distribution of limited water available among all users in the same **priority class**.

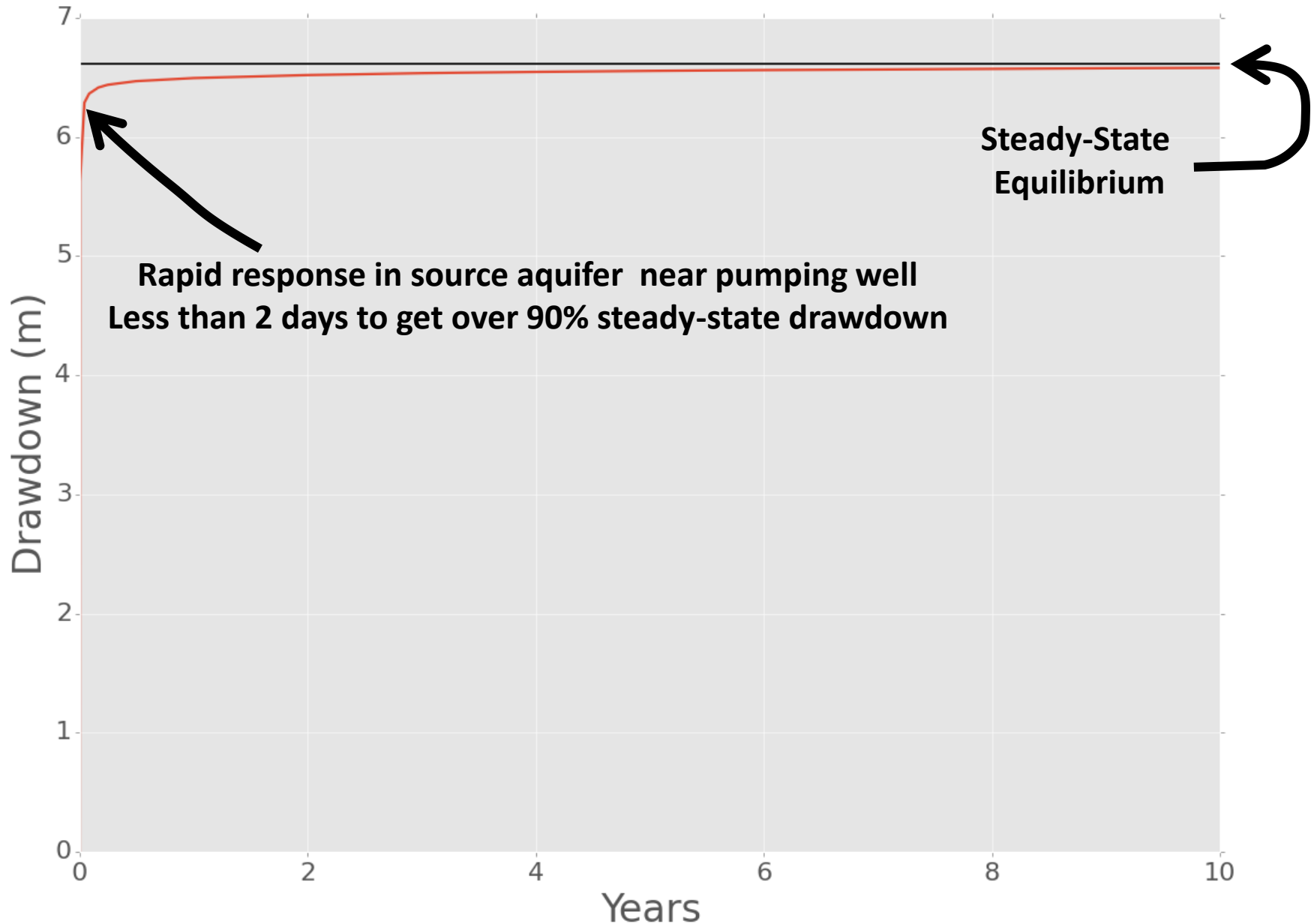
Minnesota Water Use Priority Classes

- 1.) Municipal water supply and power production with contingency plan
- 2.) < 10,000 gallons per day
- 3.) Agriculture irrigation and agriculture processing
- 4.) Power production in excess of contingency plan
- 5.) Other > 10,000 gal/day
- 6.) nonessential uses

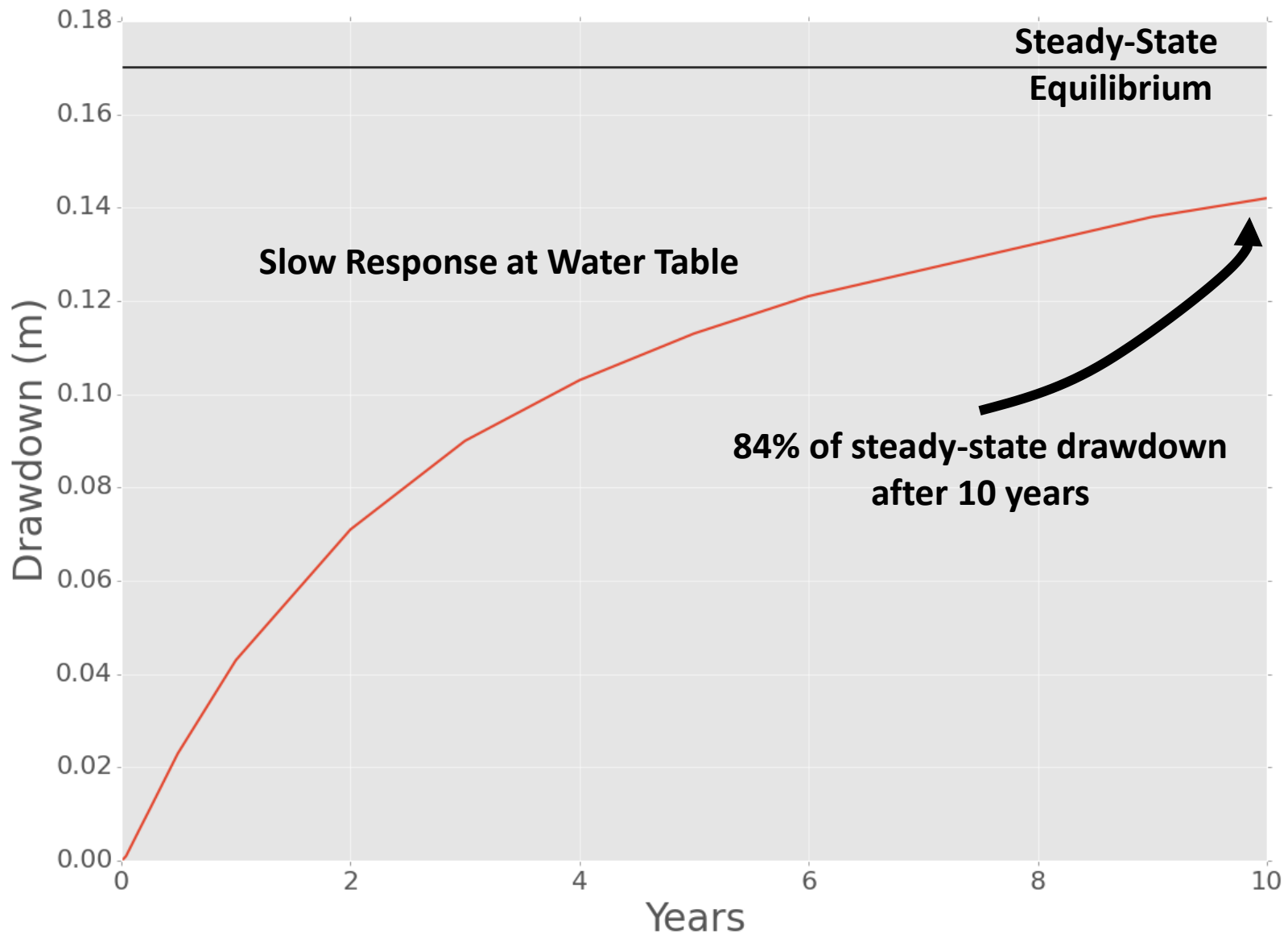
Local Thought Experiment



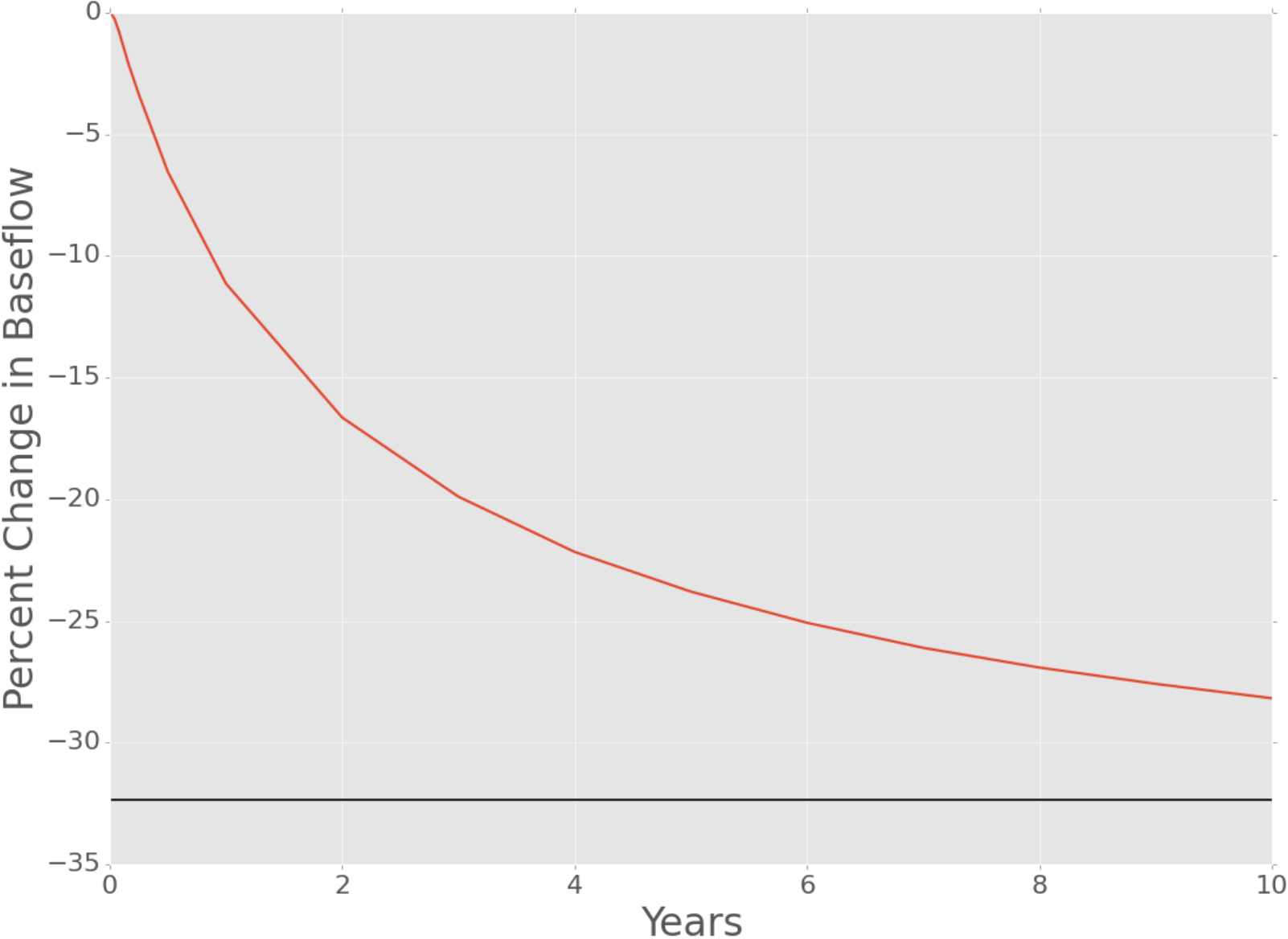
Drawdown in Jordan Aquifer Near Pumping Well



At Water Table Near Pumping Well

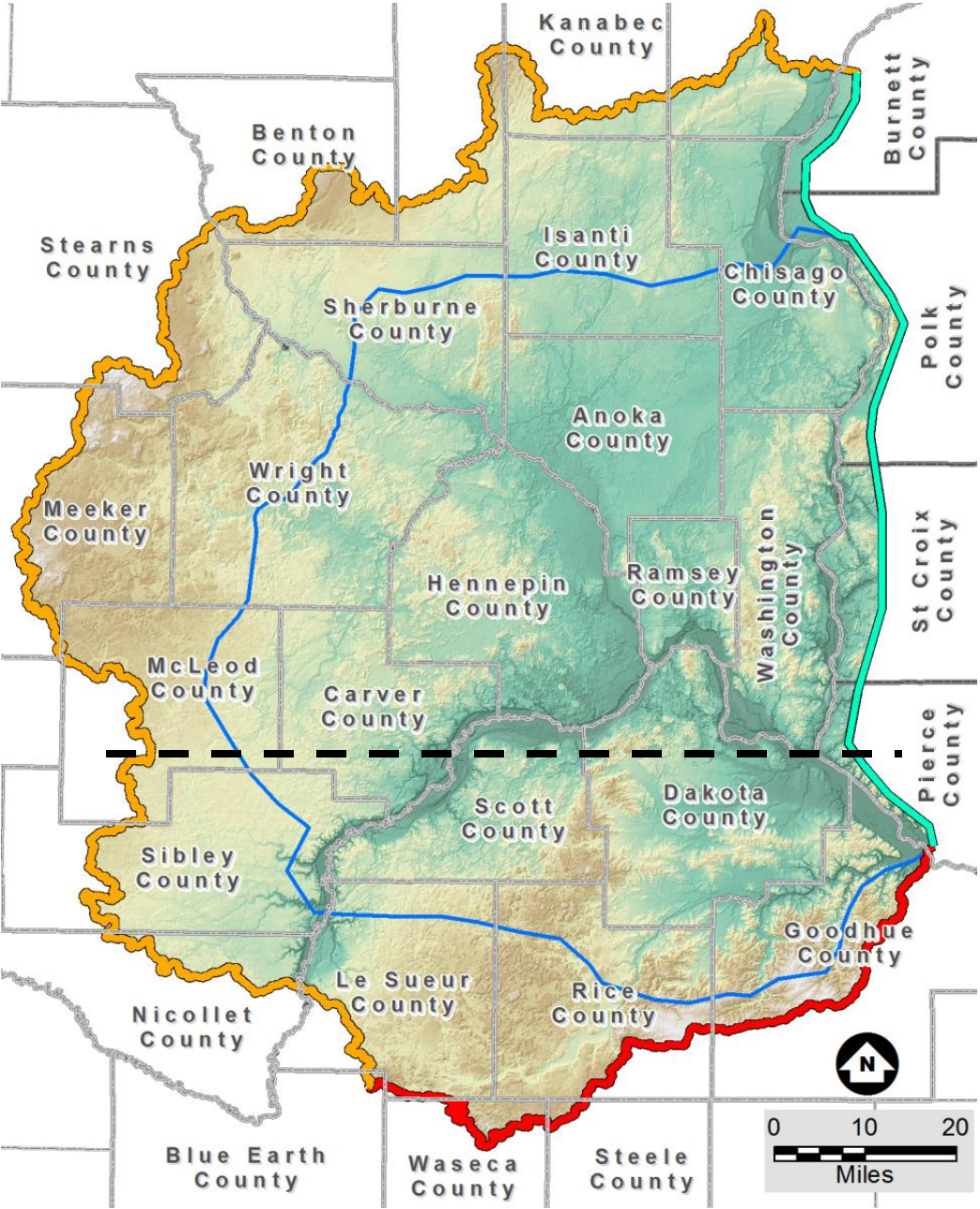






Change in Baseflow for Small Reach Near Well



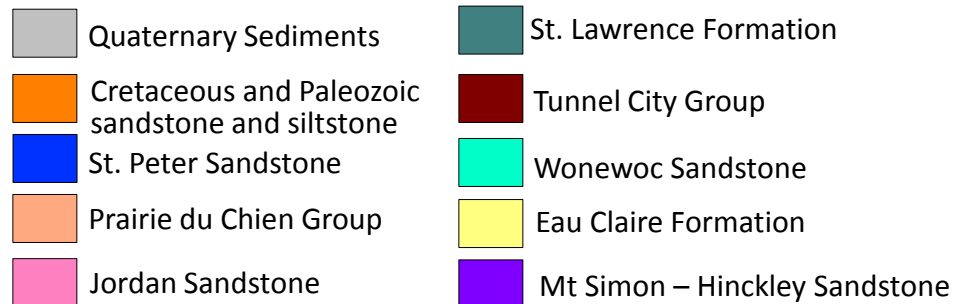
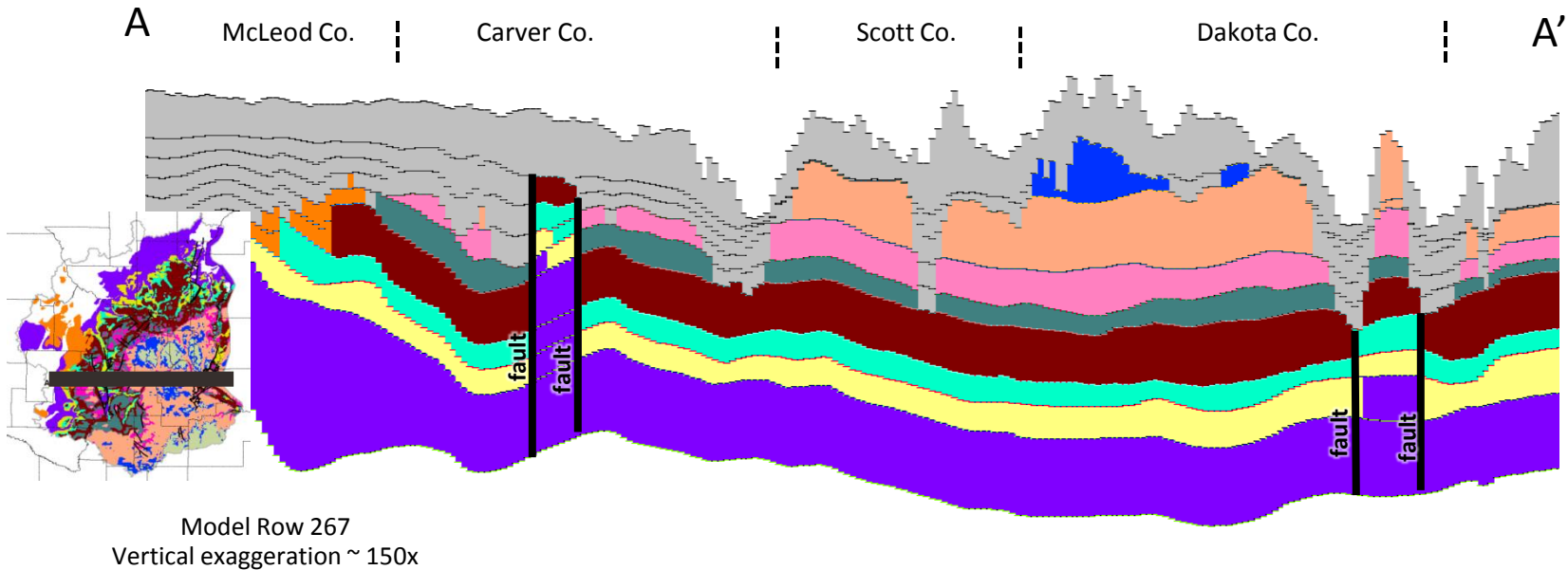
Metro Model 3

covers 11-county metro



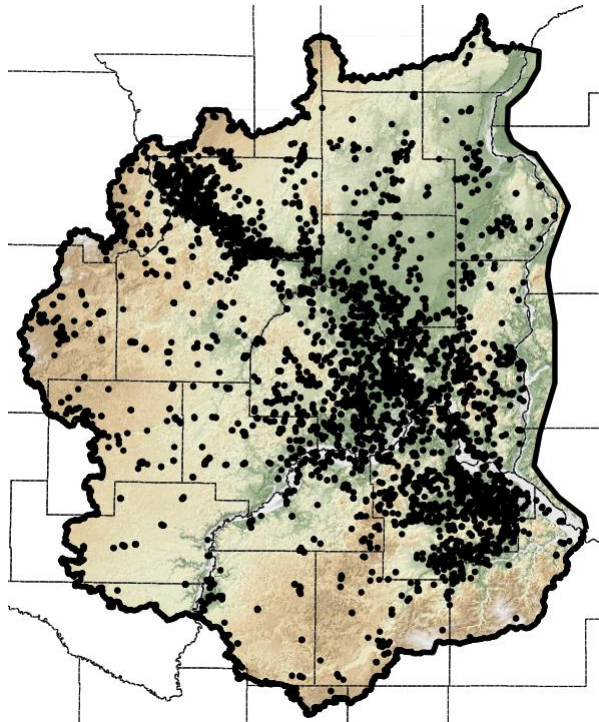
-  Constant Head
-  General Head
-  No Flow
-  Metro Model 2 Boundary

All Major Aquifers and Aquitards

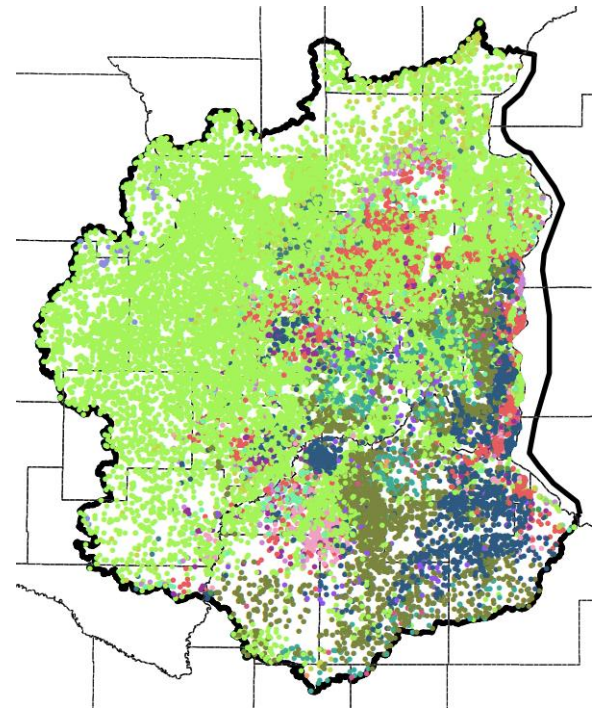


Metro Model 3

- Pumping from all high capacity wells
- Recharge from SWB model
- Incorporation all detailed bedrock and glacial geology
- Steady-state and transient
- Extensive calibration process



Pumping Wells



Head Targets

Jordan Aquifer

1995

