Unmanaged Aquifer Recharge:

Revisiting Sustainable Yield in Northeast Illinois

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NGWA Groundwater Summit
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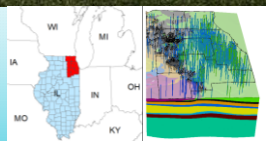
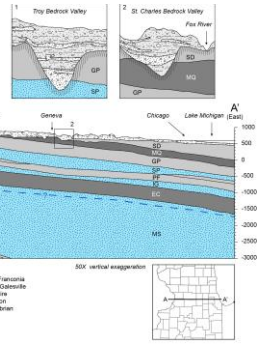
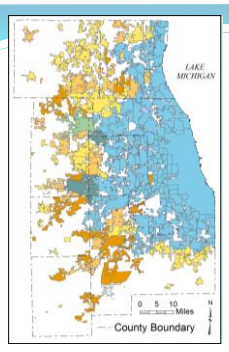


Hydrostratigraphy of Northern Illinois



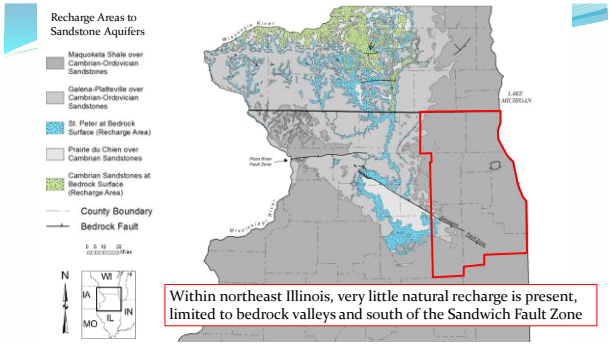


Source of Community Water Supplies

Groundwater (GW)
- Sandstone
- Sandstone (Partial)
- Shallow Bedrock/Glacial

Surface Water
- Lake Michigan
- Fox River
- Kankakee River

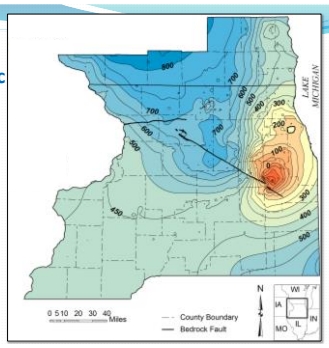
Mixed Sources
- Fox River/GW
- Lake Michigan/GW



Within northeast Illinois, very little natural recharge is present, limited to bedrock valleys and south of the Sandwich Fault Zone

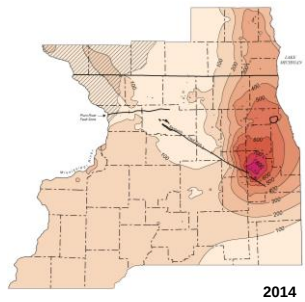
2014 Potentiometric Surface

Head (ft AMSL)
- > 800
- 700 to 800
- 600 to 700
- 500 to 600
- 400 to 500
- 300 to 400
- 200 to 300
- 100 to 200
- 0 to 100
- -100 to 0
- -200 to -100
- -300 to -200
- < -300



Drawdown Since Pre-Development
- < 100
- 100 to 200
- 200 to 300
- 300 to 400
- 400 to 500
- 500 to 600
- 600 to 700
- 700 to 800
- 800 to 900
- >900

County Boundary
Bedrock Fault
Head Change Contour
Driftless Area



2014

Previous Estimates of Aquifer Sustainability

- Estimates of sustainable yield of the sandstone aquifers range from 43 MGD (Suter et al., 1959) to 65 MGD (Walton, 1964)
  - Both methods rely on using the regional gradient assuming similar head in all aquifers
    - Synoptic measurements biased toward high-capacity production wells, often open to multiple aquifers, masking local head separation
  - Neither estimate delineates the individual contributions from various units
  - Both approaches neglect changes in storage within confining units

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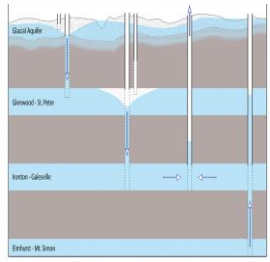
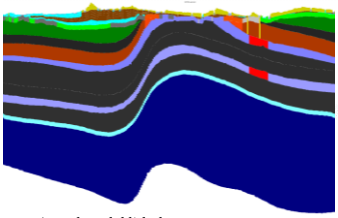
Revisiting Sustainable Yield

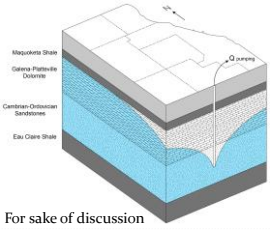
- As the system is complicated by the presence of multi-aquifer wells (MAWs), with demands increasingly focused on a single aquifer, head differences in excess of 250 feet have developed near the center of the cone of depression
- Requires a data-driven approach honoring the actual lithology and observed heads in each aquifer



Head Specified Model



Actual model lithology



For sake of discussion

Application of head-specified model

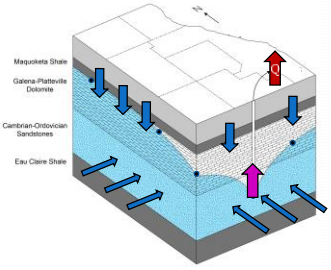
Input - Water level measurements
Output - Flow rates

Calibrate to **pumping rate** over the entire history of withdrawals in northeast Illinois

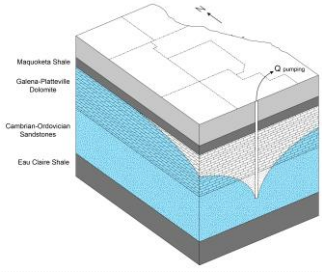
If **all sources of water** are properly conceptualized, **flow rate** will match **pumping rate**

If there are additional sources of water not being modeled, **flow rate** will show a deficit compared to **pumping**

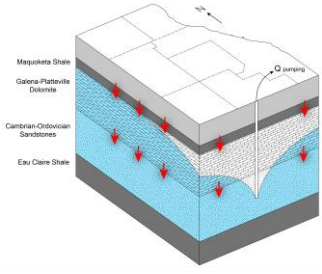
Excess **flow** compared to **pumping** indicates unallocated pumping or too much recharge over a time range



Estimated sources of water in NE Illinois



Vertical infiltration into sandstone (natural)



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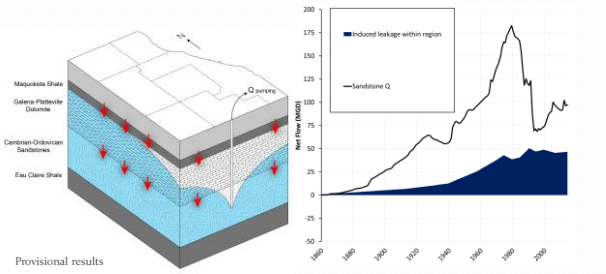
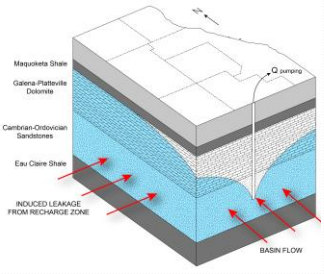
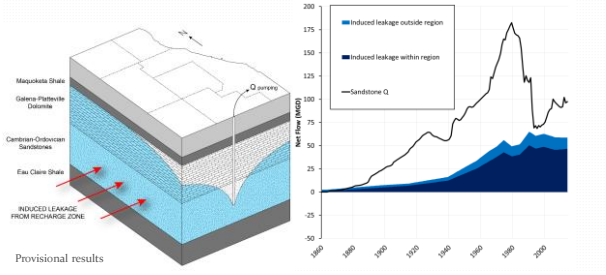


Provisional results

Flow from outside region

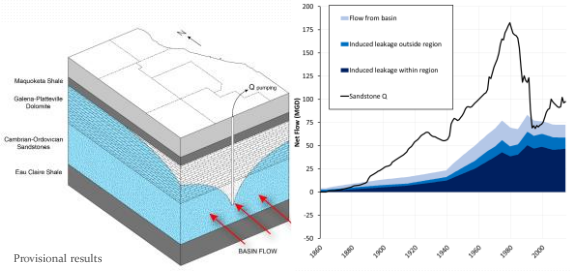


Flow from outside region (recharge)



Provisional results

Flow from outside region (basin)



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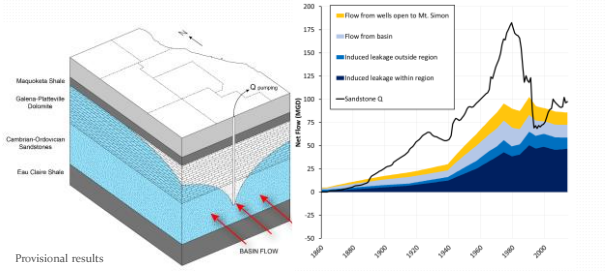
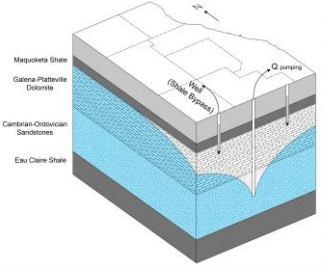


Provisional results

Vertical leakage to sandstone (anthropogenic)



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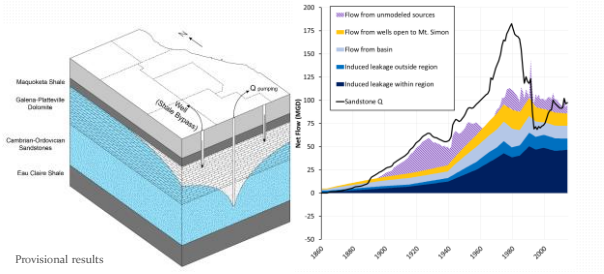
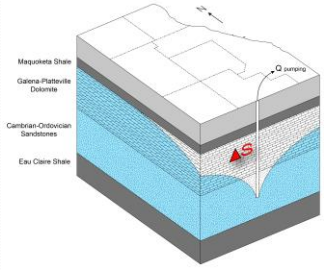


Provisional results

Removal of water from storage



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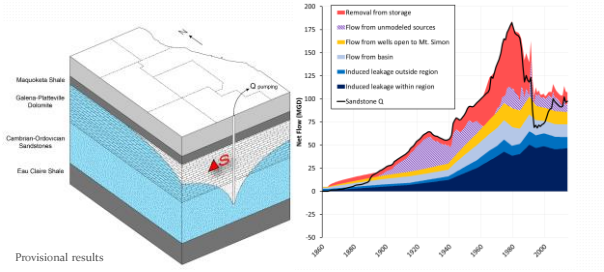

Provisional results

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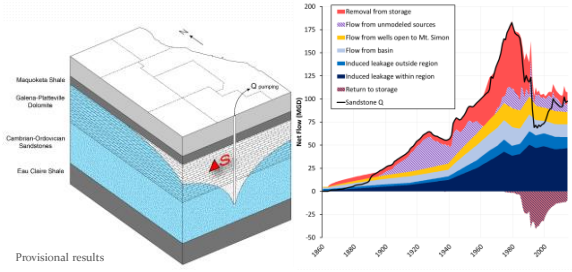
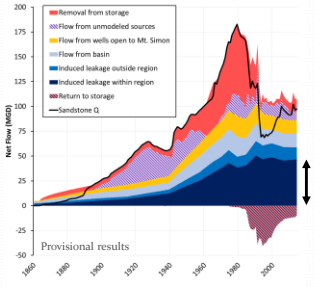


Provisional results

What is sustainable?



Provisional results

Arguably, considering only induced leakage within Northeast Illinois provides the greatest water security for the region

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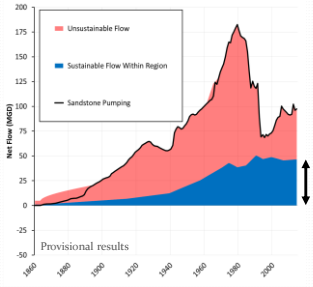

Provisional results

All other sources take water from elsewhere (putting NE Illinois at the mercy of outside development) or induce flow of poor quality water

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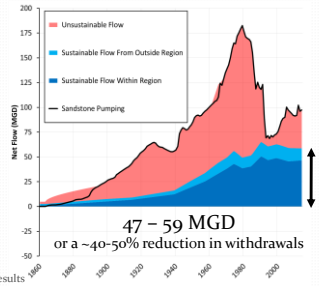
What is sustainable?



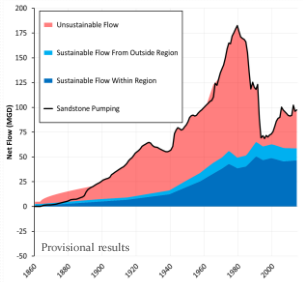
All other sources take water from elsewhere (putting NE Illinois at the mercy of outside development) or induce flow of poor quality water

Arguably, considering only induced leakage within Northeast Illinois provides the greatest water security for the region

However, traditional estimates of sustainable yield have included flow from recharge outside NE Illinois

Provisional results

Other considerations

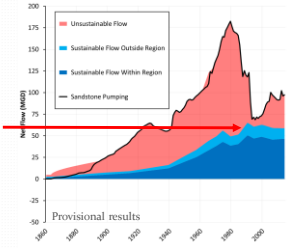


This approach does not consider reductions in natural groundwater discharge (yet), which would limit the amount of water available in recharge areas

Likely not a significant amount outside of northeast Illinois, but may be locally important in some streams and rivers

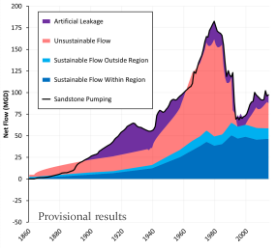
The circuitous process of defining sustainability

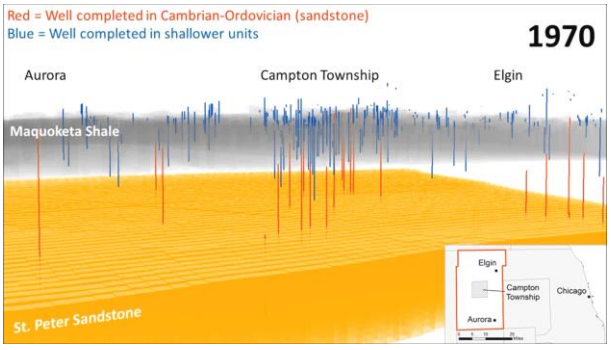
- With increasing demands comes an increase in gradient, and thus increasing leakage… normally
- Heads have fallen below confining units in most areas of northeast Illinois, meaning a maximum **natural** leakage rate has been achieved



Artificial leakage

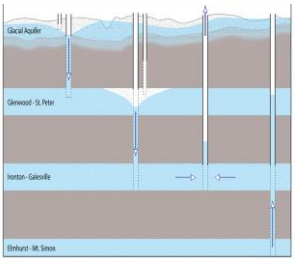
- However, a considerable portion of flow to sandstone aquifers within northeast Illinois is water draining from shallower units via wells with long open intervals
- This is not expected to be a source of water long term, as much of this water is likely water draining from storage





Artificial leakage

- Despite nearly 50% of modern demands coming from wells completed in only the Ironton-Galesville, model results suggest nearly 70% of sandstone flow comes from the St. Peter Sandstone
- Ironton-Galesville increasingly dependent upon artificial leakage from wells



Provisional results

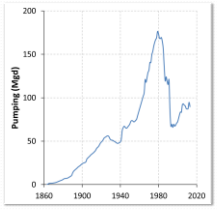
Conclusions

- Demands continue to exceed sustainable yield in northeast Illinois
  - Model simulations suggest as little as 6 MGD of additional demands in the center of the cone of depression could begin dewatering the Ironton-Galesville sandstone
- Sustainable yield estimate of 49-57 MGD assumes that both the St. Peter and Ironton-Galesville are being utilized
  - With the Ironton-Galesville receiving no direct recharge in Illinois, its sustainable yield is largely dependent upon artificial leakage

Conclusions

- Northeast Illinois can be viewed as one long (unintentional) aquifer recharge project
  - Model results suggest 16% of the total sandstone flow for the entire history of withdrawals may have been water draining from shallower units via wells with long open intervals
- Without the contribution of artificial leakage, the system would likely have been depleted several decades ago

Questions?



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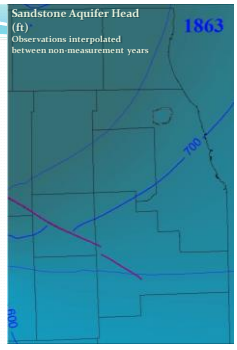

References

- Abrams, D.B., D.R. Hadley, D.H. Mannix, G.S. Roadcap, S.C. Meyer, K.J. Hlinka, K.L. Rennels, K.R. Bradbury, P.M. Chase, and J.J. Krause. 2015. *Changing Groundwater Levels in the Sandstone Aquifers of Northern Illinois and Southern Wisconsin: Impacts on Available Water Supply.* Illinois State Water Survey Contract Report 2015-02, Champaign, IL.
- Abrams, D.B., G.S. Roadcap, and D. Mannix. 2017. Developing Potentiometric Surfaces and Flow Fields with a Head-Specified MODFLOW Model. Groundwater.
- Mannix, D.H., D.B. Abrams, and G.S. Roadcap, (In preparation). Unmanaged Aquifer Recharge: Conceptualizing and Simulating Artificial Leakage from Long Open Interval Wells.