

# COMMUNITY-BASED SCIENTIFIC DISCOVERY & WATER RESOURCE MANAGEMENT

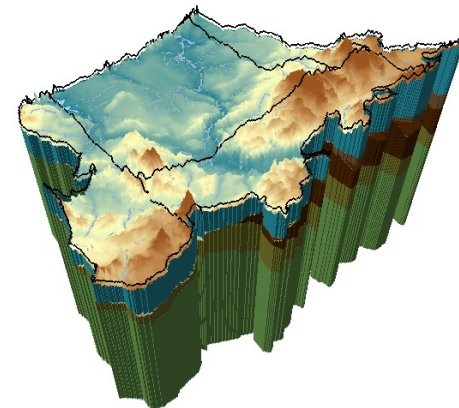
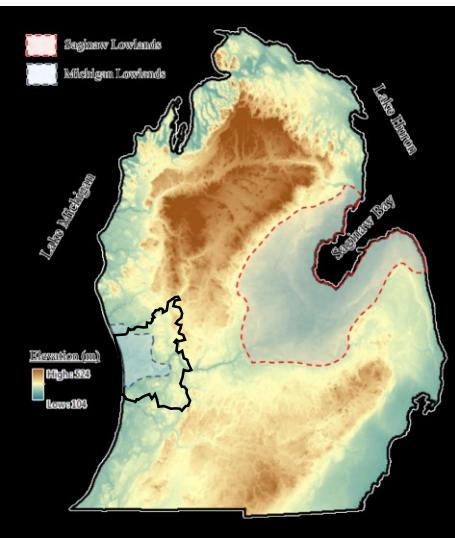
Applications in Ottawa County and New  
Opportunities for Michigan

**By Zachary Curtis  
with Paul Sachs**

Prepared for the Michigan SWCS Seminar:

“A MATTER OF BALANCE: Perceptions, Engagement and  
Partnerships for On-Farm Conservation”

**March 6, 2019**



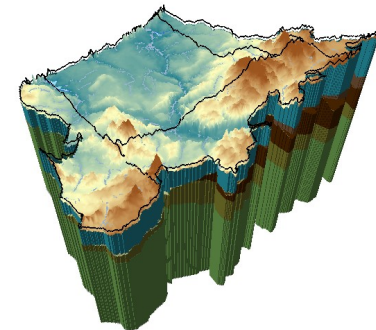
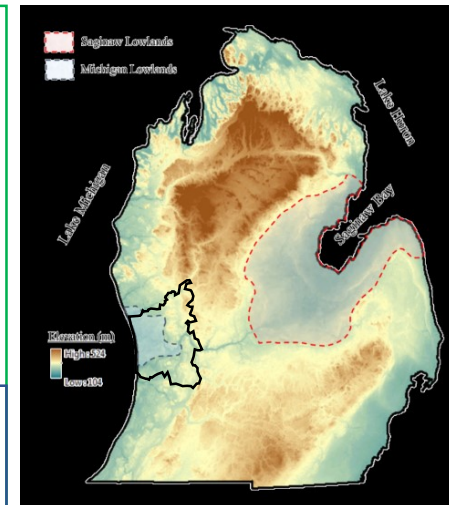
# Presentation Outline

- **Topic:** Groundwater resource study in west-central southern Michigan

- **Problem/Motivation:** Recent concerns over availability and water quality
- **Scientific Challenges:** Need for lots of data and system-based understanding
- **Technical Solutions:** Integrating data/knowledge from different stakeholders, agencies, etc.

- **Key Scientific Findings:** natural and human impacts

- **Awareness:** public education and community outreach
- **Partnerships:** linking policy, conservation, education
- **Management Strategies:** land development, water use, site design, etc.



Zach

Paul

# ACKNOWLEDGEMENTS

The research described in the presentation was funded by the Michigan Department of Agriculture and Rural Development (MDARD) and the Ottawa County Planning Commission.

The project tasks were completed through a collaborative effort from different stakeholders, researchers, planners, and outreach specialists from Ottawa County and Michigan State University.



# Groundwater Research Team

## Civil & Environmental Engineering, Michigan State University

- *Shu-Guang Li*, Ph.D, P.E., F. ASCE, F. GSA, Department of Civil & Environmental Engineering, Michigan State University
- *Zachary Curtis*, Ph.D., Department of Civil & Environmental Engineering
- *Hua-Sheng Liao*, Ph.D., Department of Civil & Environmental Engineering
- *Prasanna V. Sampath*, Ph.D., Indian Institute of Technology Tirupati

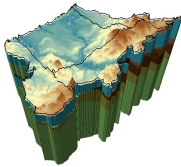
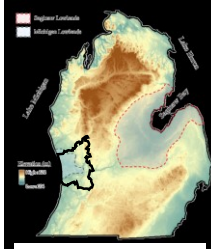
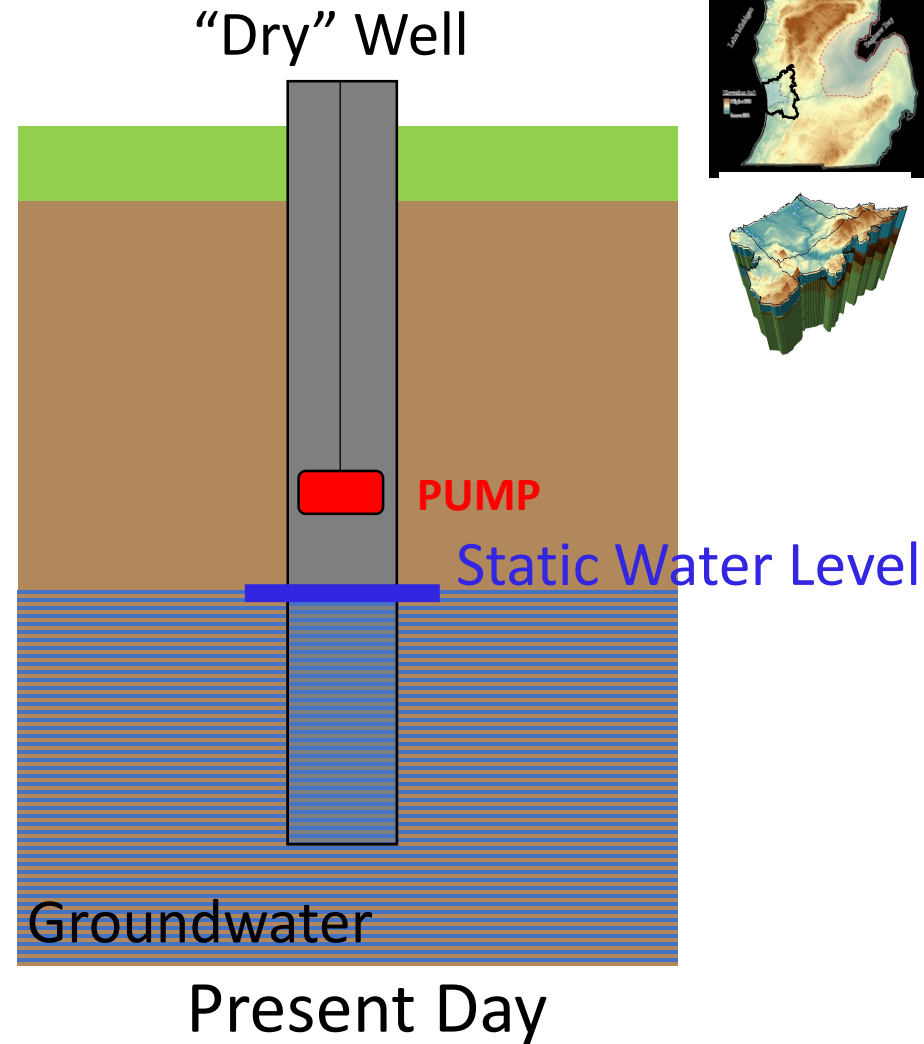
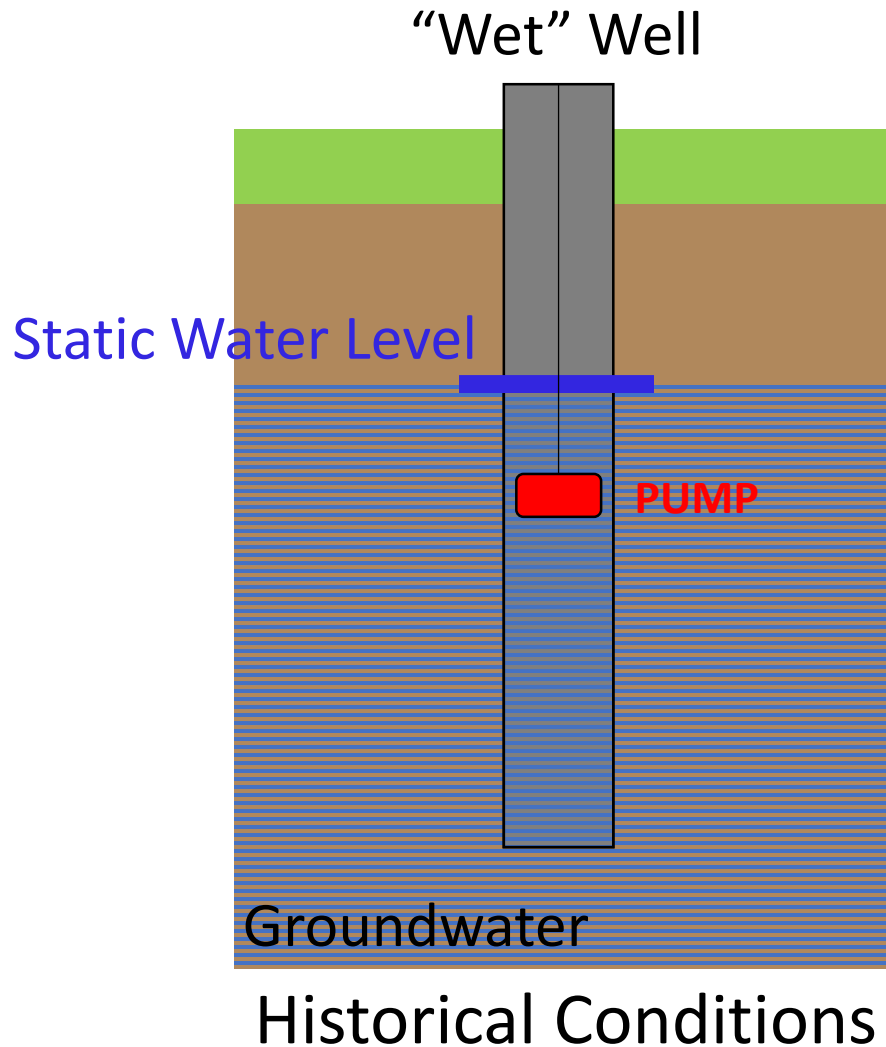


## With special assistance from:

- *David P. Lusch*, Ph.D., Department of Geography, Environment, and Spatial Sciences

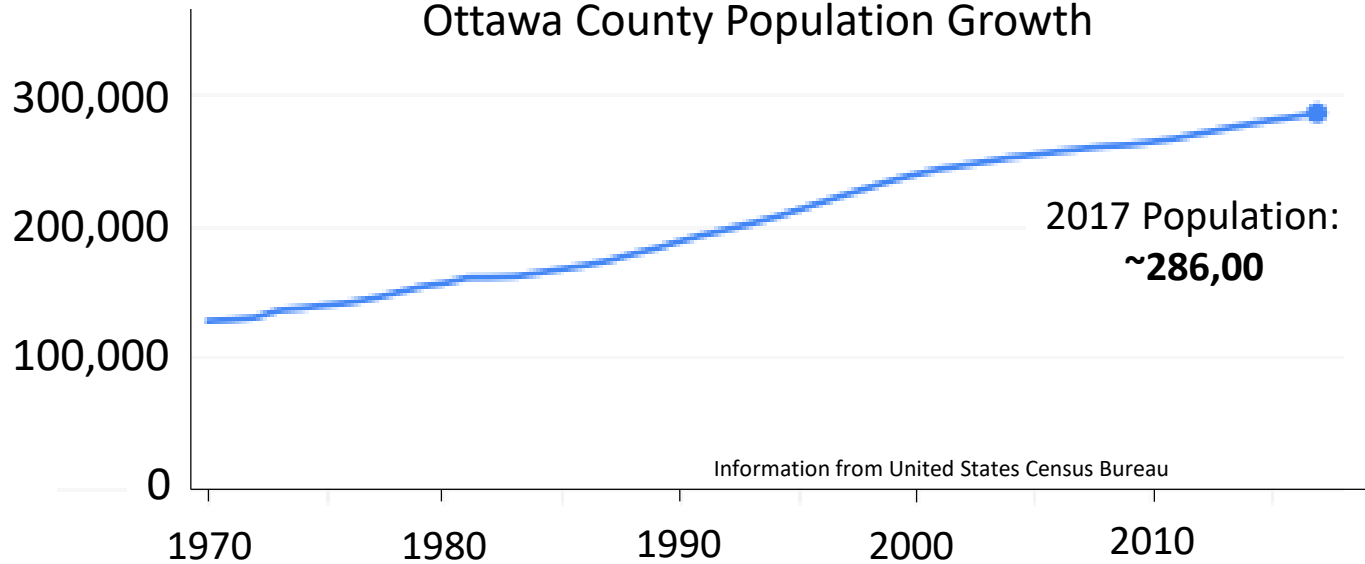


# Groundwater Quantity Issues



# Impacts of Increases Water Demand?

Ottawa County Population Growth



Information from United States Census Bureau

Fastest Growing  
County in Michigan

Expanded Agricultural /  
Horticultural Activities



# Groundwater Quality Issues

Elevated salinity levels in groundwater

...used for irrigation



Chloride concentration (mg/L)	Effect on crops	Susceptible plants
140-350	Moderately sensitive plants show injury	Potato, corn, wheat, squash, alfalfa, tomato
Above 350	Serious injury can occur	Sugarbeet, asparagus

Information in table taken from Ayers and Westcot (1985)

...and water supply

EPA Secondary Drinking Water Standard  
(Chloride): 250 mg/L

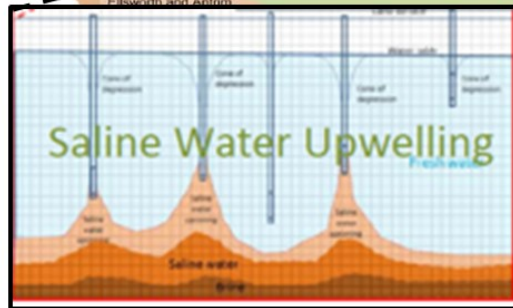
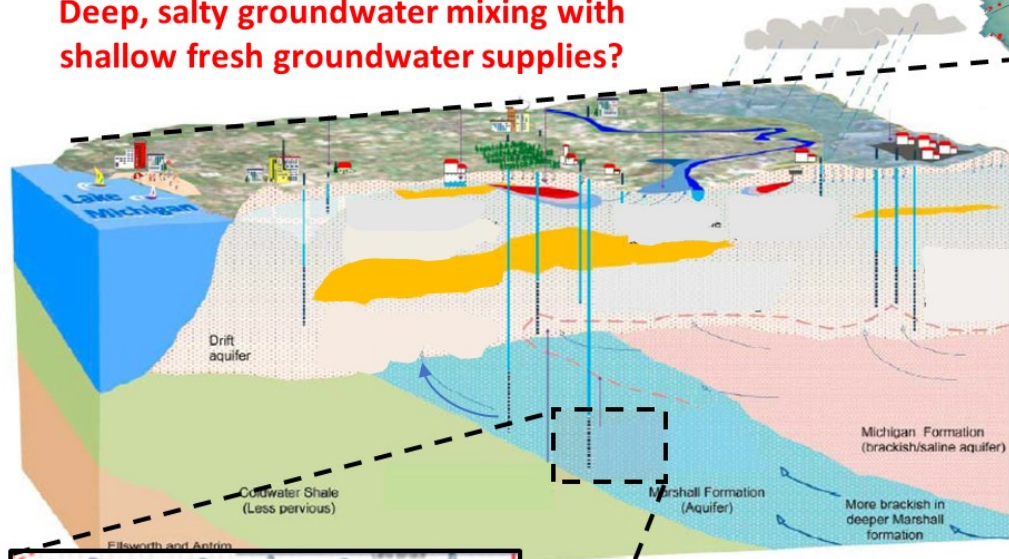
- Aesthetic quality
- Dietary concerns
- Corrosive properties



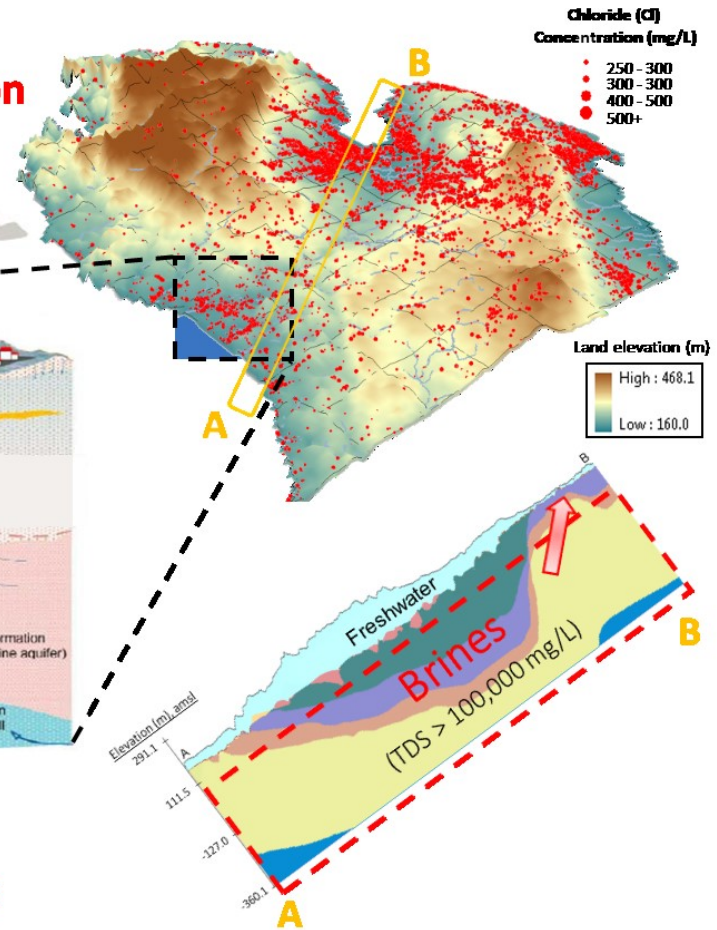
# Water Quality: A "System" Problem?

## Basin-scale Cl Contamination

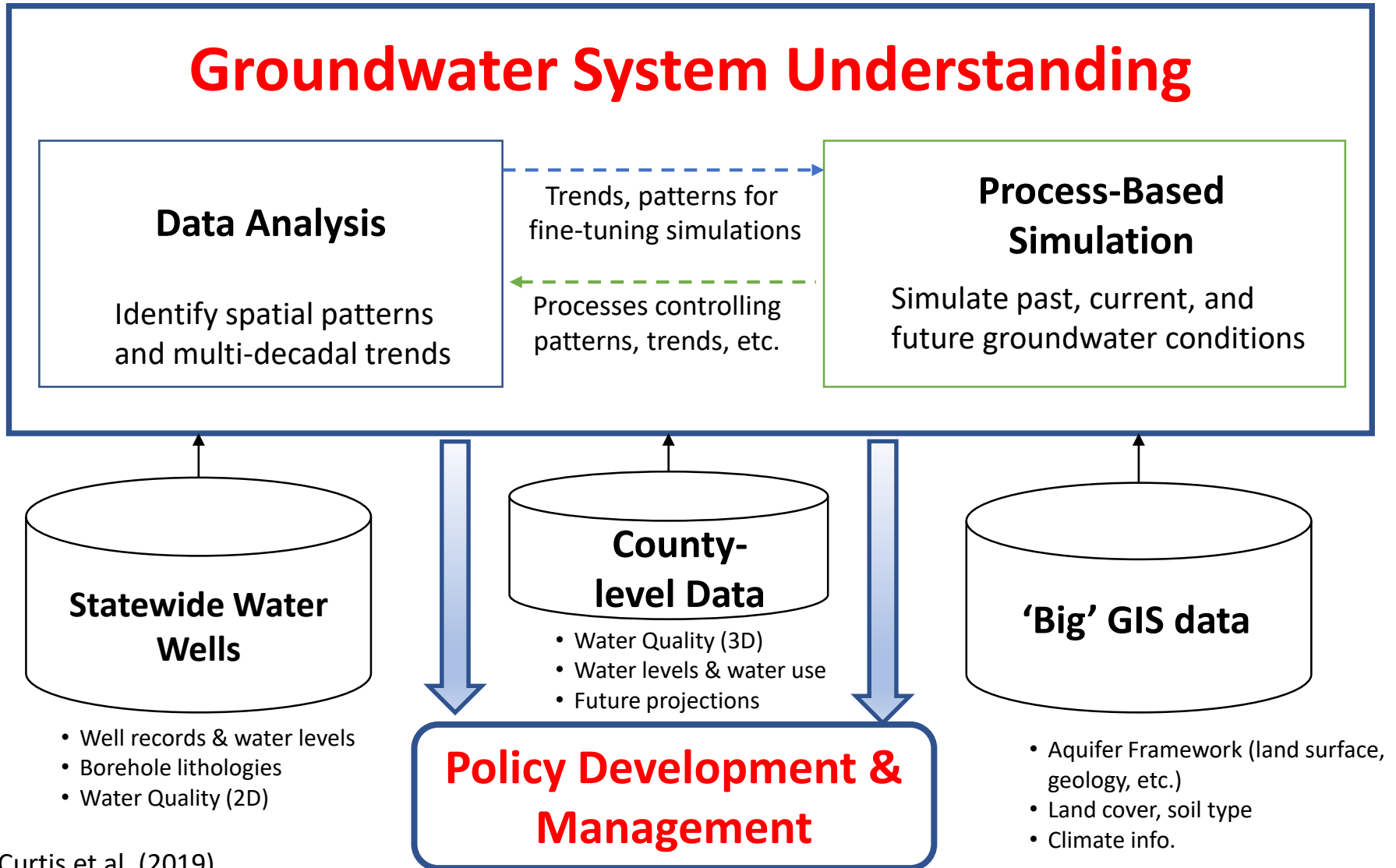
Deep, salty groundwater mixing with shallow fresh groundwater supplies?



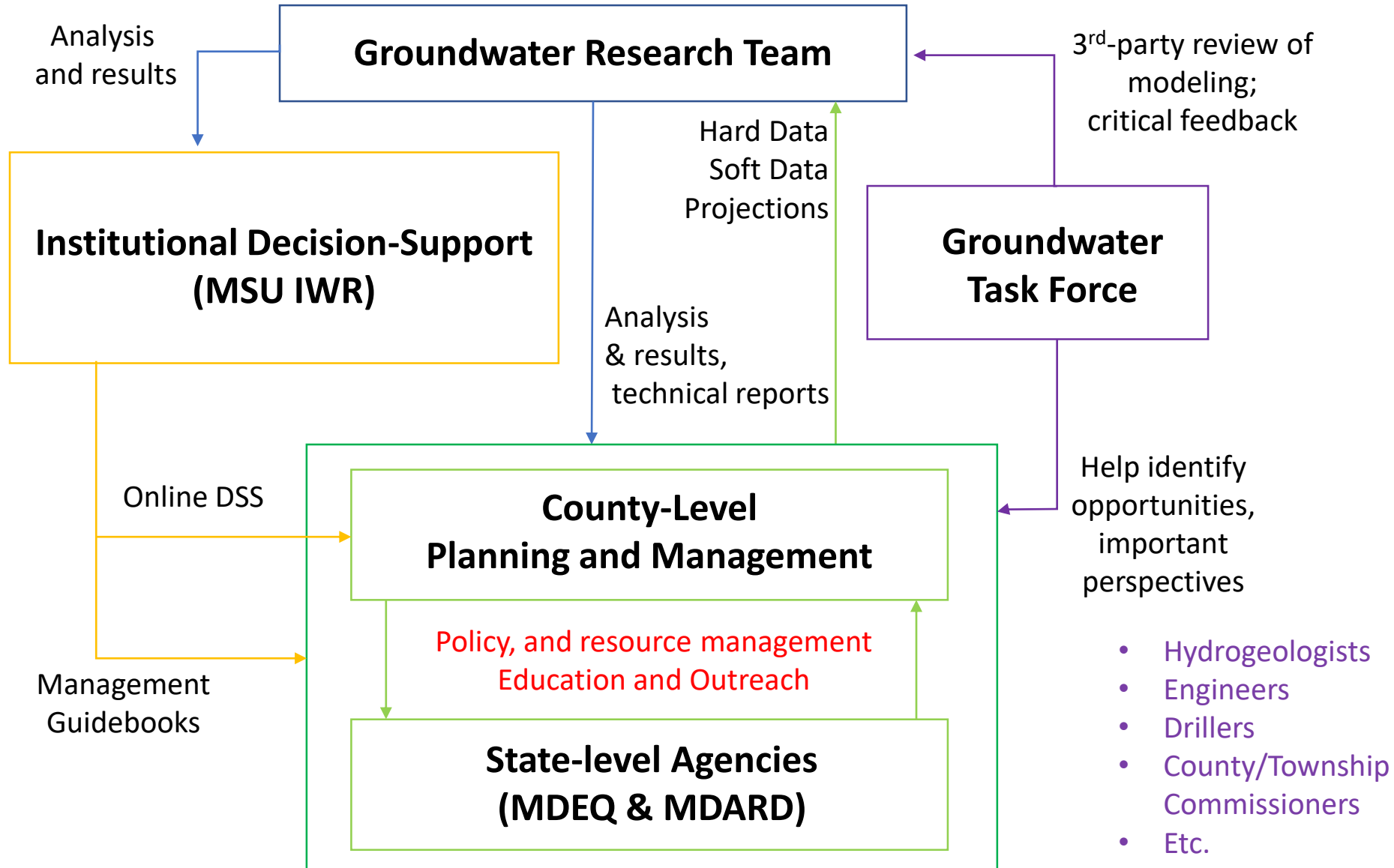
Pumping inducing more upwelling?



# Framework for Analysis



# Community Effort





# Volunteer Well Testing

Where do we have high Cl levels? (present-day)

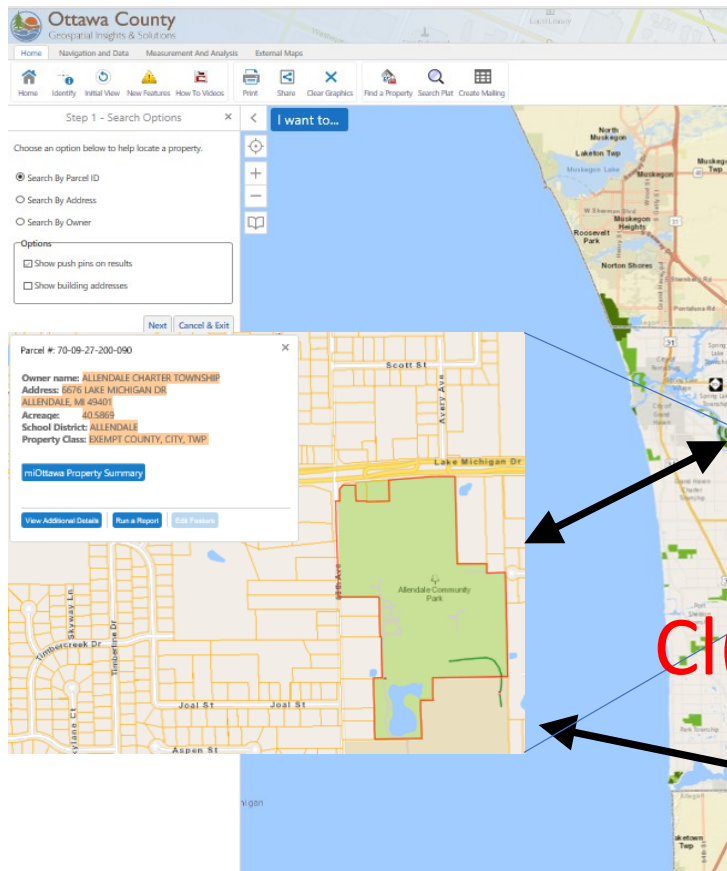
Over 540 samples  
from 468 properties



# Historical Data Mining

What were Cl levels in the past?

Partial Chemistry Test



<b>Project:</b> Parcel #70-13-11-200-009		<b>Project No:</b> 2110520					
<b>Lab Order:</b> 1411326		<b>Collection Date:</b> 11/10/2014 10:00 am					
<b>Lab ID:</b> 1411326-001A		<b>Received Date:</b> 11/11/2014 10:15 am					
<b>Client Sample ID:</b> [REDACTED]		<b>Matrix:</b> DRINKING WATER					
		<b>Sampled By:</b> [REDACTED]					
<b>Analyses</b>	<b>Result</b>	<b>Units</b>	<b>RPT Limit M.C.L.</b>	<b>Date</b>	<b>Analyst</b>	<b>Analyzed</b>	<b>Method #</b>
A2) Owner	[REDACTED]			11/10/2014			FLD
A3) Reason(Purpose)	Loan Eval						
A4) Location	Kitchen						
A5) Twp	Blendon						
Iron	0.560						
Sodium	132						
E. Coli	Absent						
Total Coliform	Absent						
Fluoride	0.52						
Nitrite, Nitrogen as N	< 0.10						
Nitrate, Nitrogen as N	< 0.10						
Total Nitrate & Nitrite	< 0.10						
Sulfate	68.1						
Hardness (As CaCO3)	140						

<b>Well ID:</b> 19000004464		<b>County:</b> Washtenaw		<b>Township:</b> Blendon		<b>City:</b> Blendon	
<b>Latitude:</b> 42.838901		<b>Longitude:</b> -84.558191		<b>Well Status:</b> WSSM		<b>Source ID/Well No:</b>	
<b>Method of Collection:</b> Interpretation Map		<b>Well Use:</b> Household		<b>Well Depth:</b> 183.00 ft		<b>Well Date:</b> 10/22/2004	
<b>Drilling Method:</b> Rotary		<b>Well Type:</b> PVT-3000		<b>Height:</b> 1.00 ft, above grade		<b>Well Date:</b> 10/22/2004	
<b>Casing Type:</b> PVC-3000		<b>Casing Joint:</b> Unknown		<b>Casing Flange:</b> None		<b>Well Date:</b> 10/22/2004	
<b>Diameter:</b> 5.00 in. to 120.00 ft. depth		<b>Well Depth:</b> 183.00 ft.		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	
<b>Borehole:</b> 9.00 in. to 120.00 ft. depth		<b>Well Depth:</b> 183.00 ft.		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	
<b>Static Water Level:</b> 31.00 ft. Below Grade		<b>Well Yield Test:</b> 4.50 in. to 120.00 ft.		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	
<b>Well Yield Test:</b> 4.50 in. to 120.00 ft.		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	
<b>Screen Installed:</b> No		<b>Intake:</b> Backhoe Well		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	
<b>Well Grouted:</b> Yes		<b>Grouting Method:</b> Unknown		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	
<b>Grouting Material:</b> 5.00		<b>Grouting Depth:</b> 0.00 ft. to 120.00 ft.		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	
<b>Wellhead Completion:</b> Filter adapter		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	
<b>Nearest Source of Possible Contamination:</b>		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	
<b>Type:</b> Septic tank		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	
<b>Distance:</b> 75 ft.		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	
<b>Direction:</b> South		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	
<b>Abandoned Well Plugged:</b> Yes		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	
<b>Casing Removed:</b> No		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	
<b>General Remarks:</b> MICHIGAN DRILLING - PREVIOUS OWNER		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	
<b>Other Remarks:</b>		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004		<b>Well Date:</b> 10/22/2004	

$Cl(x,y,z,t)$

Ottawa County Online Property Mapping tool

Well Driller report



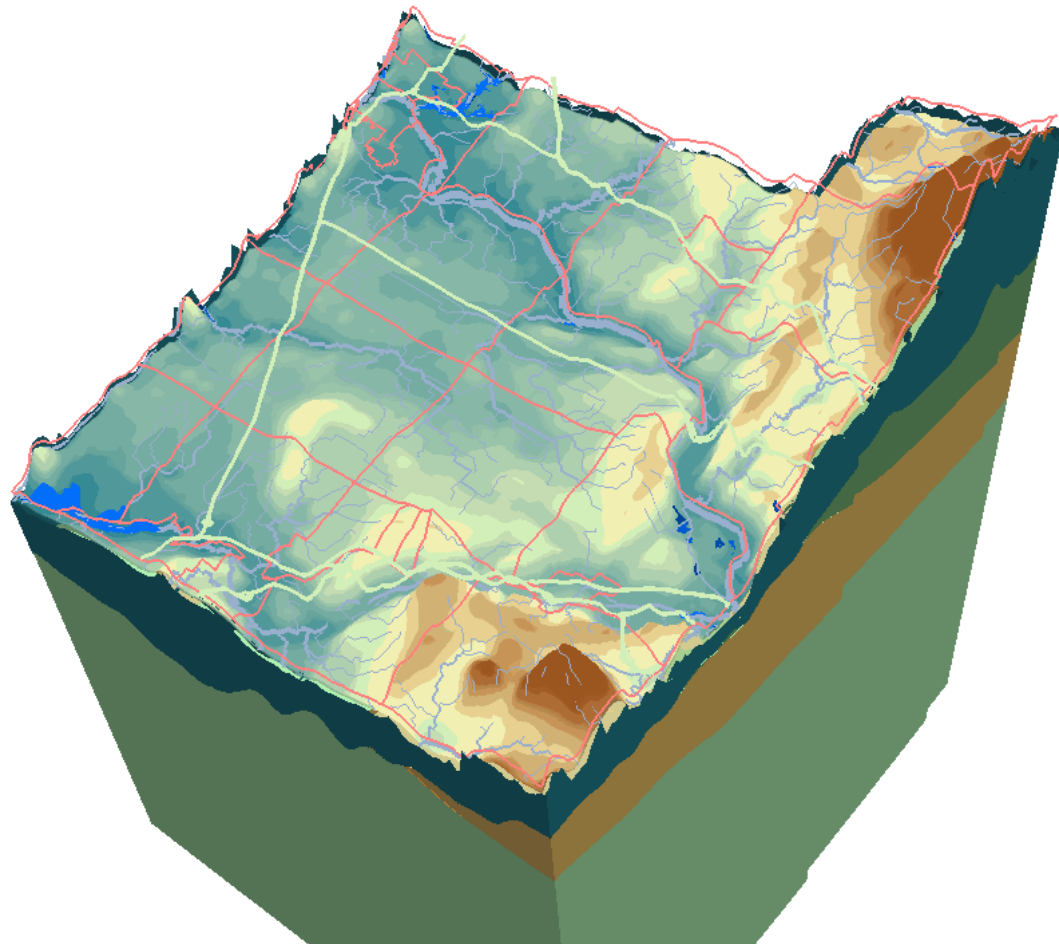
# Water Quality Results

## 3D Spatial Patterns

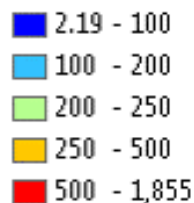
As depth ↑ , Cl ↑

Contamination primarily  
in bedrock aquifer

-> consistent with a  
deep source (brines)

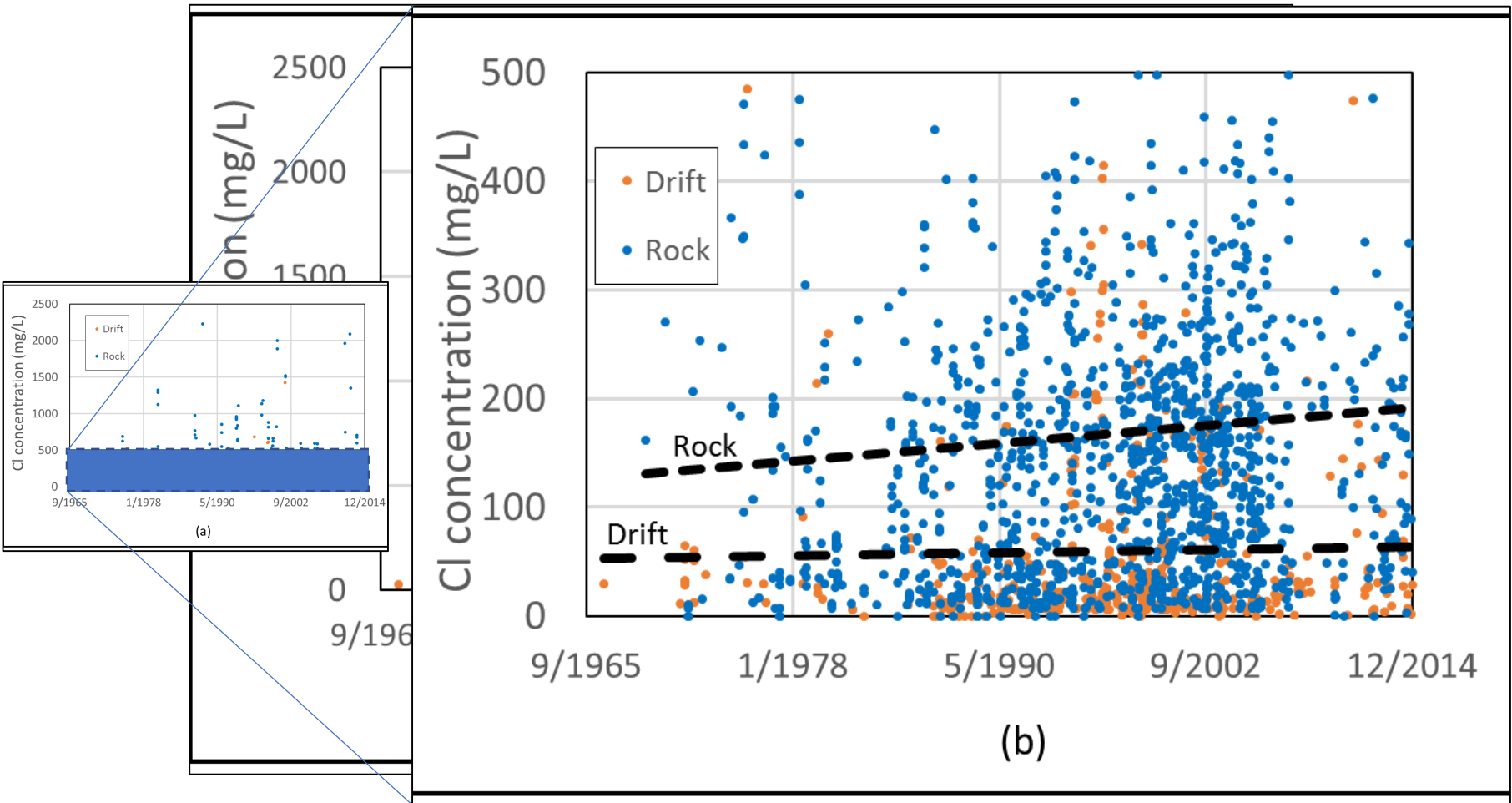


Chloride mg/L



# Water Quality Results

## Temporal Trends

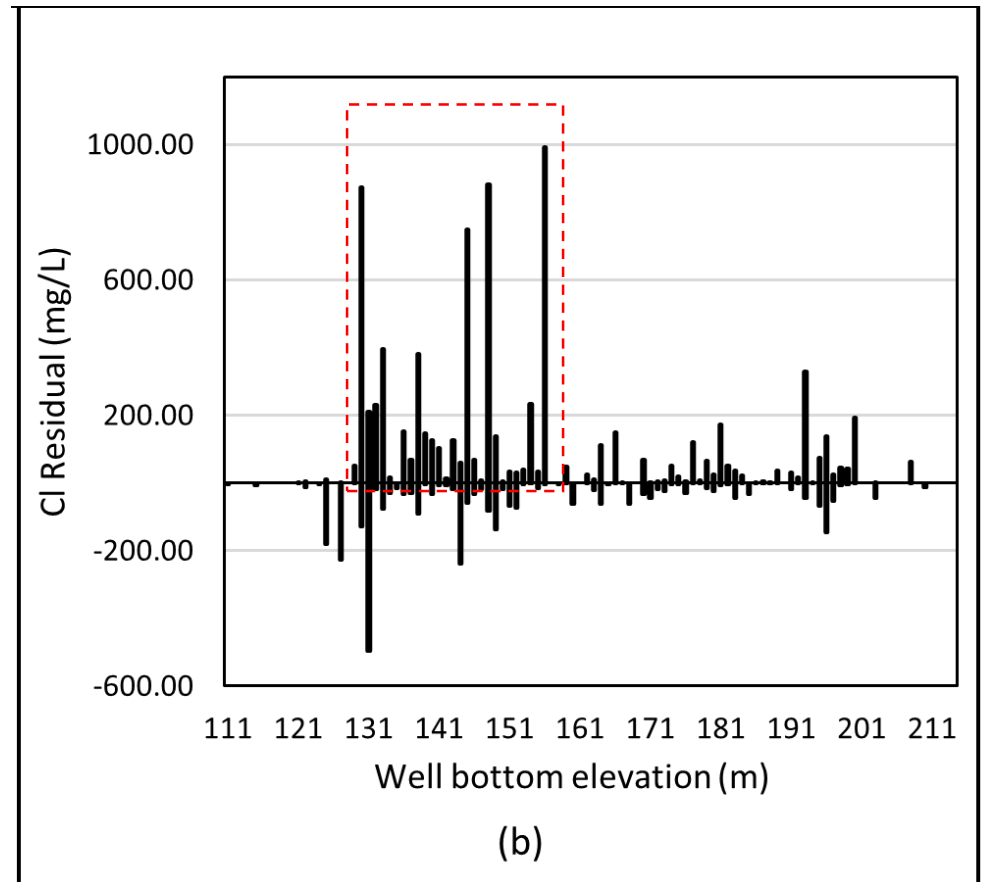
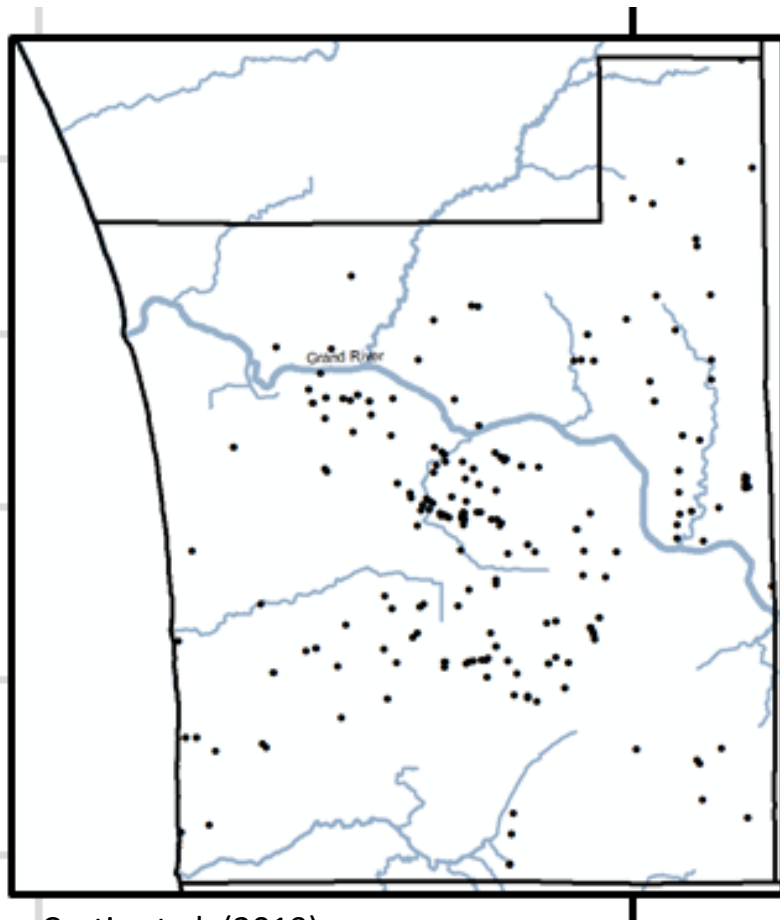


# Water Quality Results

## Temporal Trends

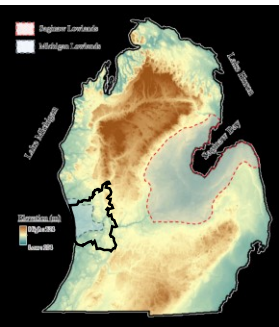
General increase in Cl levels with time

Most increases are deep, in the bedrock (where Cl is high)

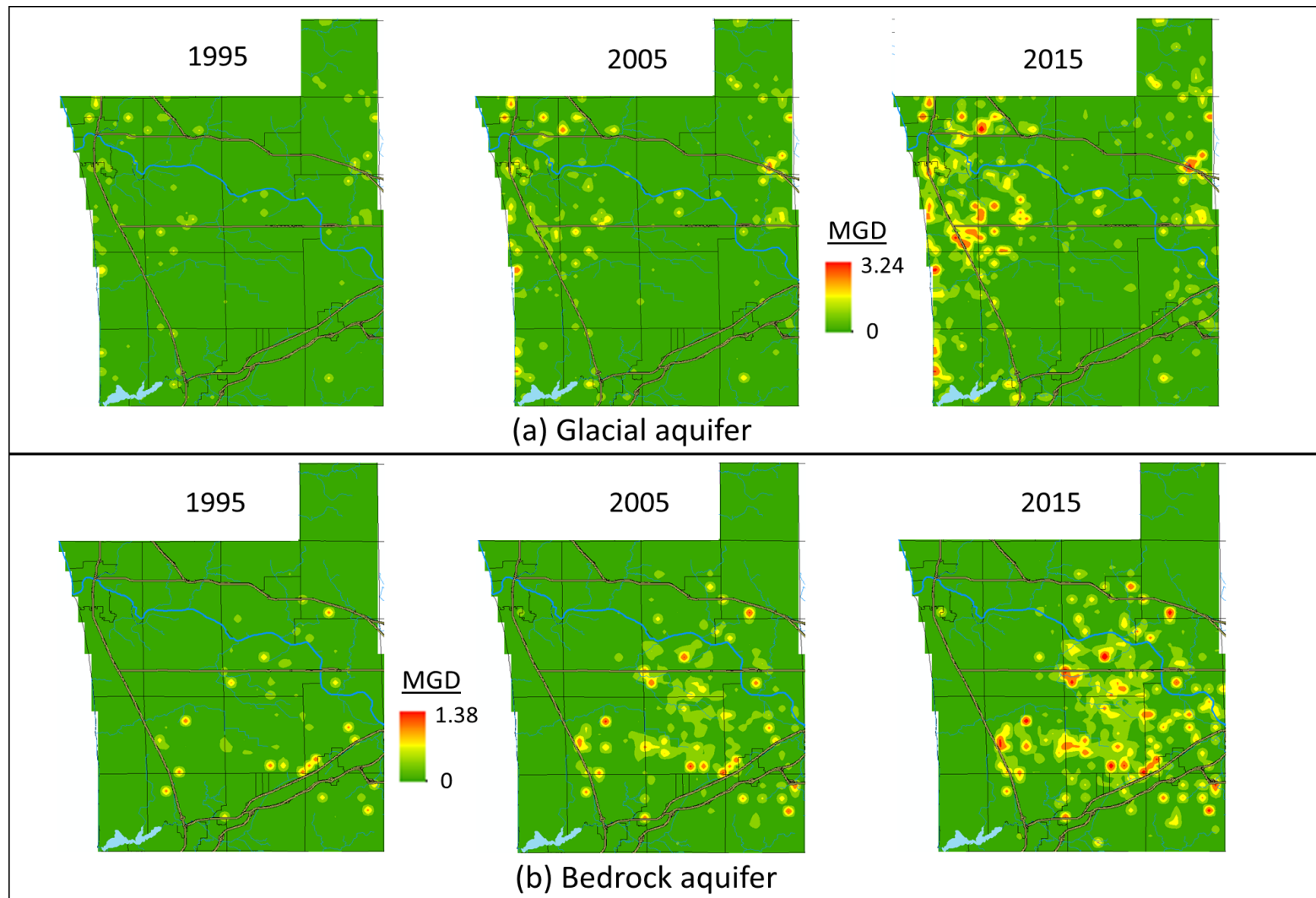


# Tracking Groundwater Use

Water use  
over time

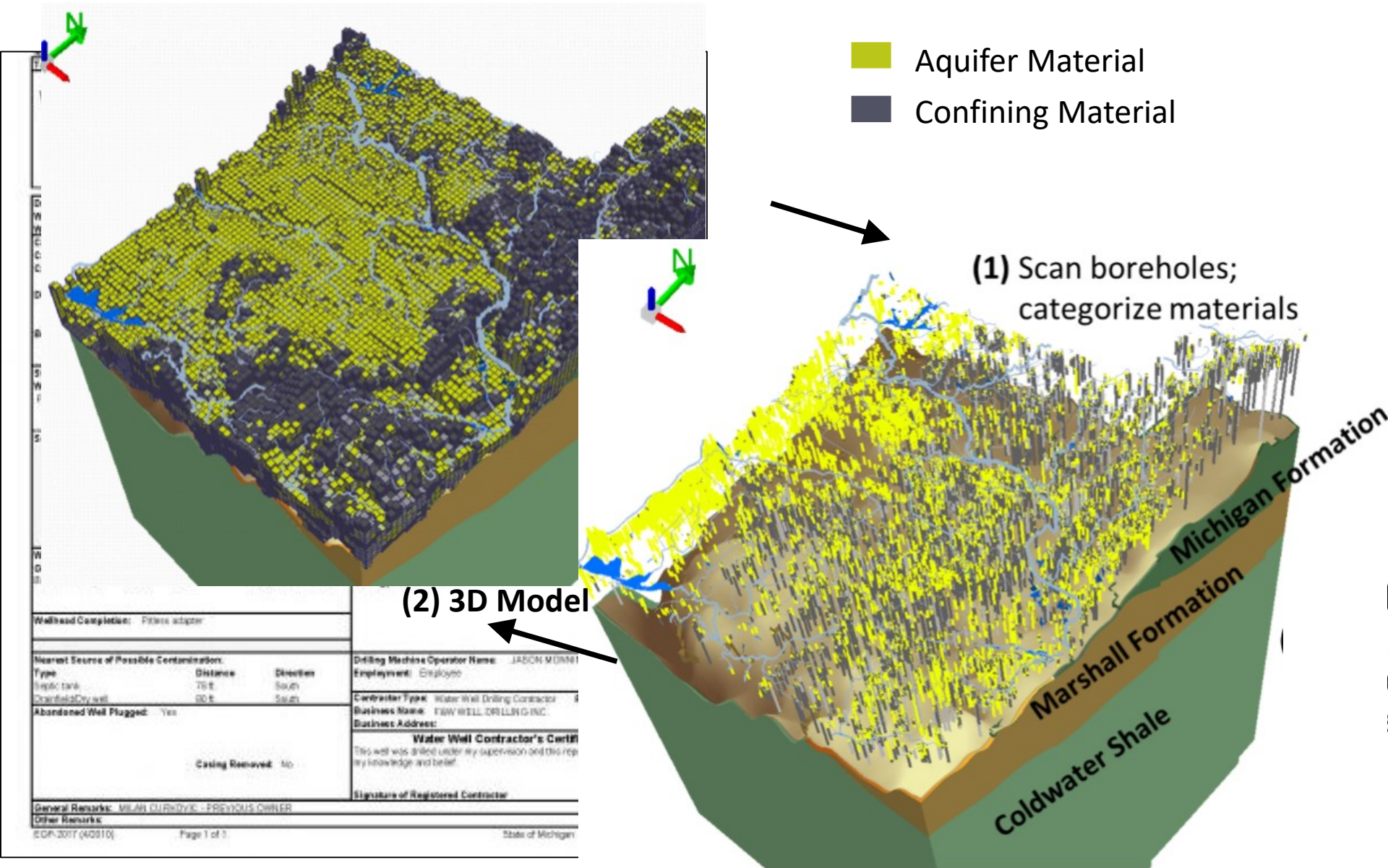


Well  
Locations  
through  
time



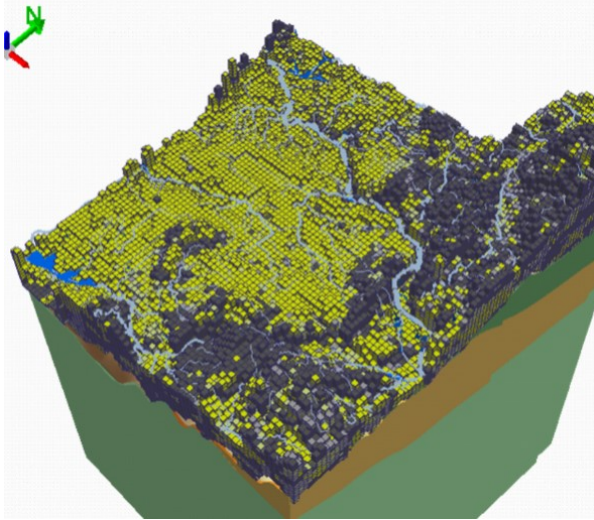


# Aquifer Material Mapping

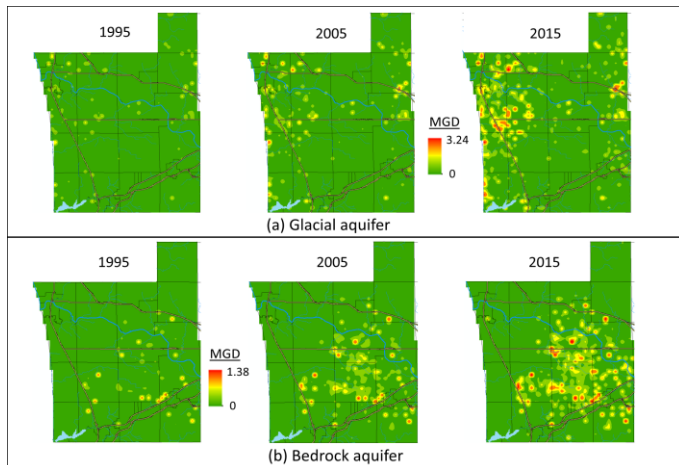


# Groundwater Flow Simulator

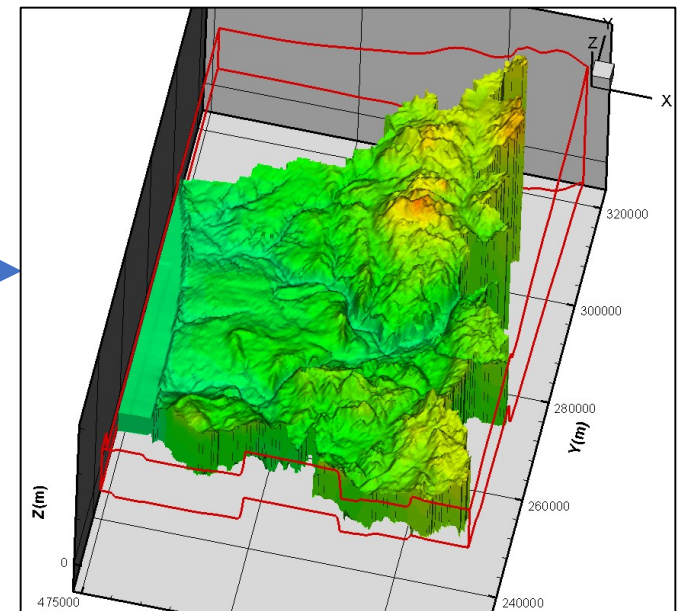
Geologic Model



Water Use Model



Recharge model



Groundwater Flow Simulator

Observed Static Water Levels  
(model comparison/calibration)

# Flow Model Results

Year 1966

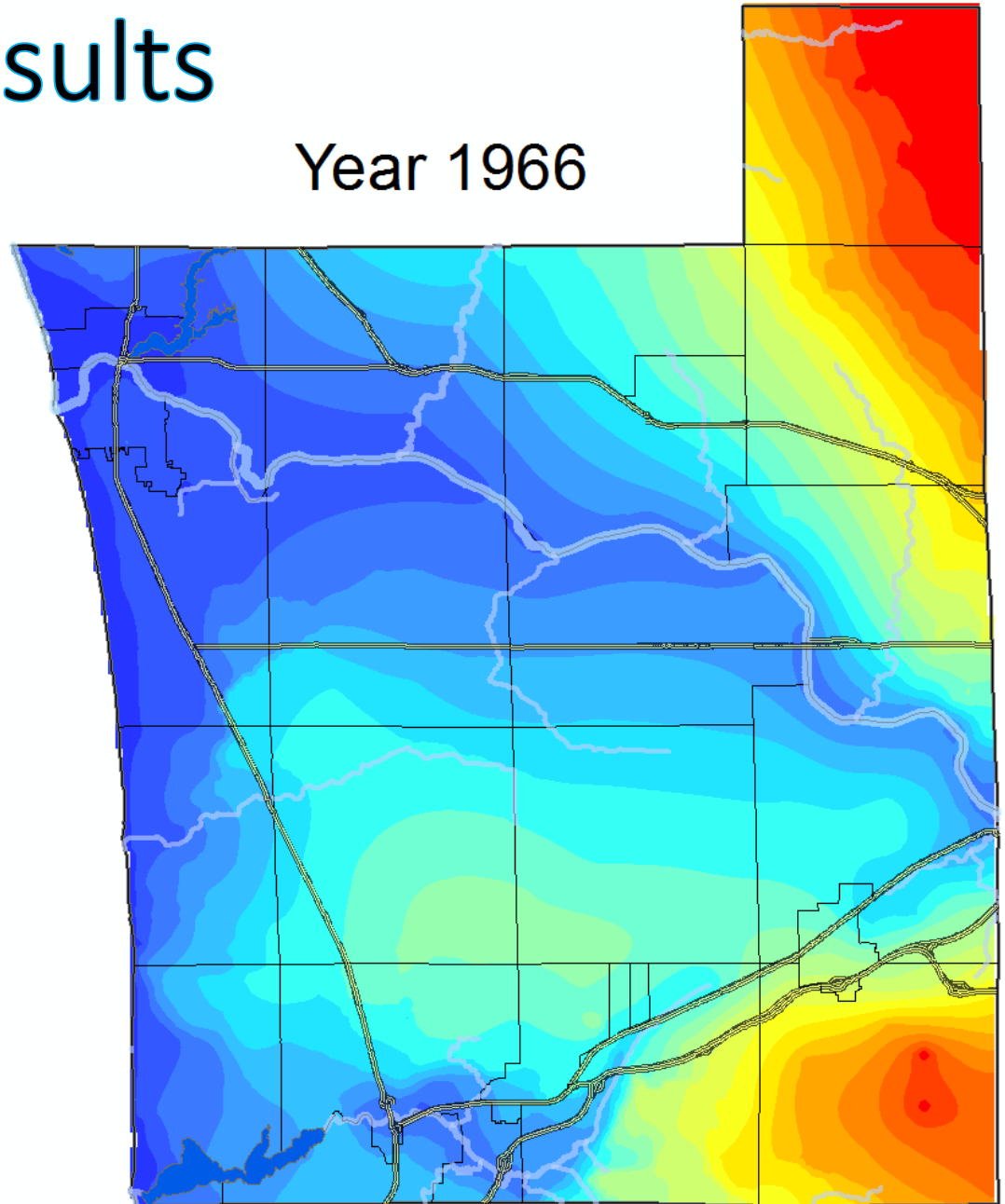
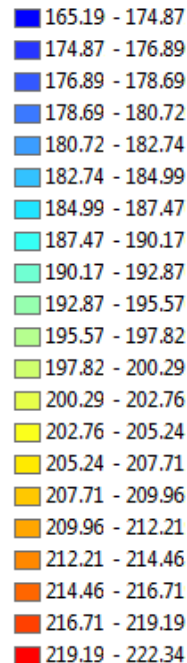
Groundwater levels  
over time, deep  
bedrock aquifer

Significant declines  
over time

Expanding, deepening  
'cone of depression'



Groundwater  
level (m)





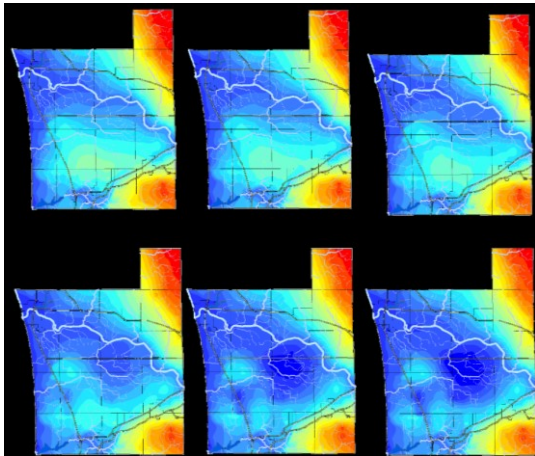
# Water Quality + Flow Results

## Spatial Comparison

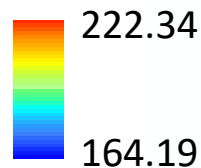
Cl  $\uparrow$  where GW levels are low

Some areas are naturally low...

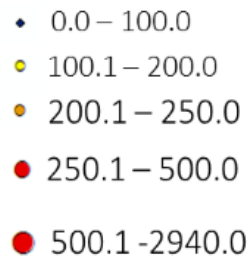
Others are 'artificially' low  
(due to pumping)



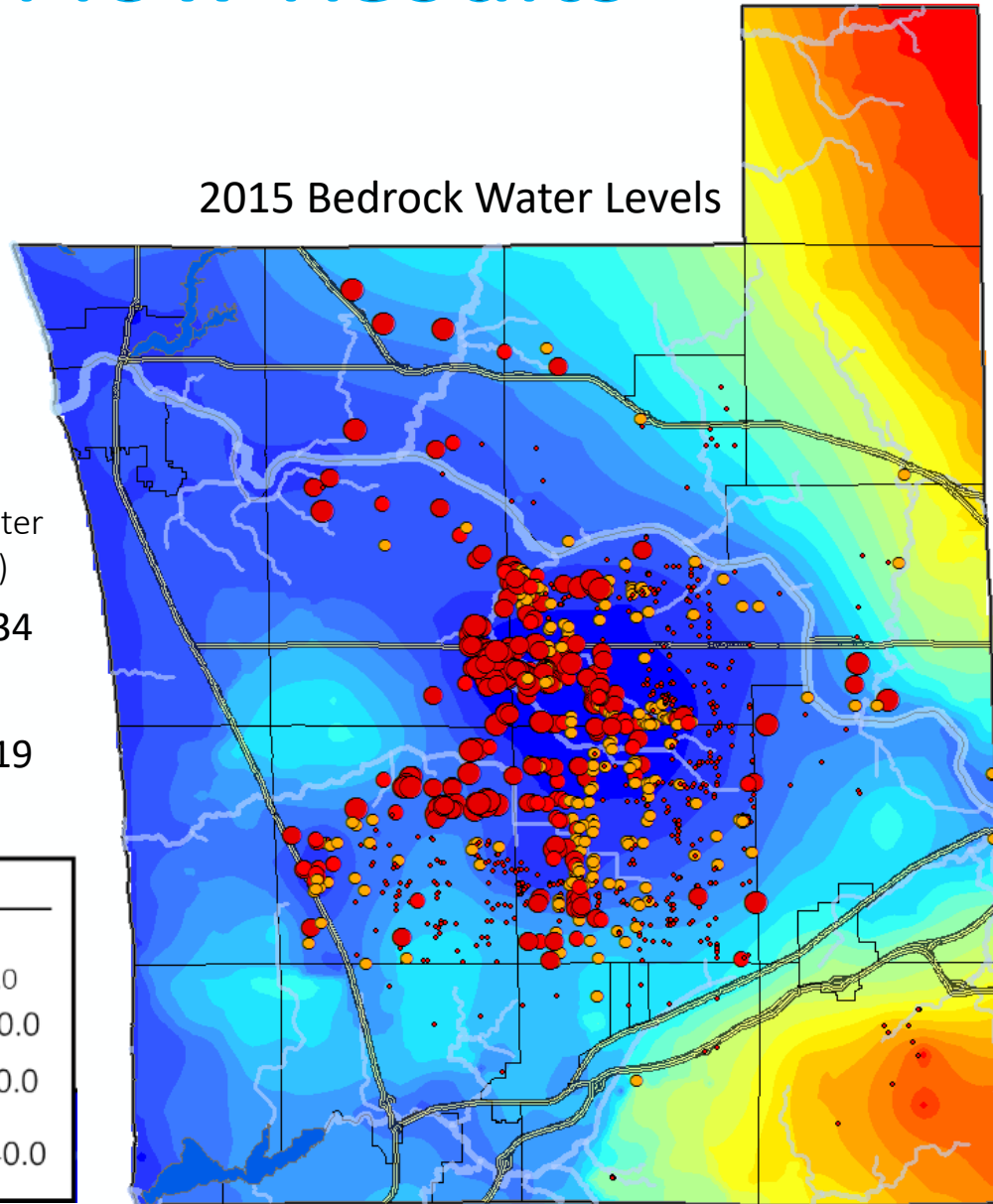
Groundwater  
level (m)



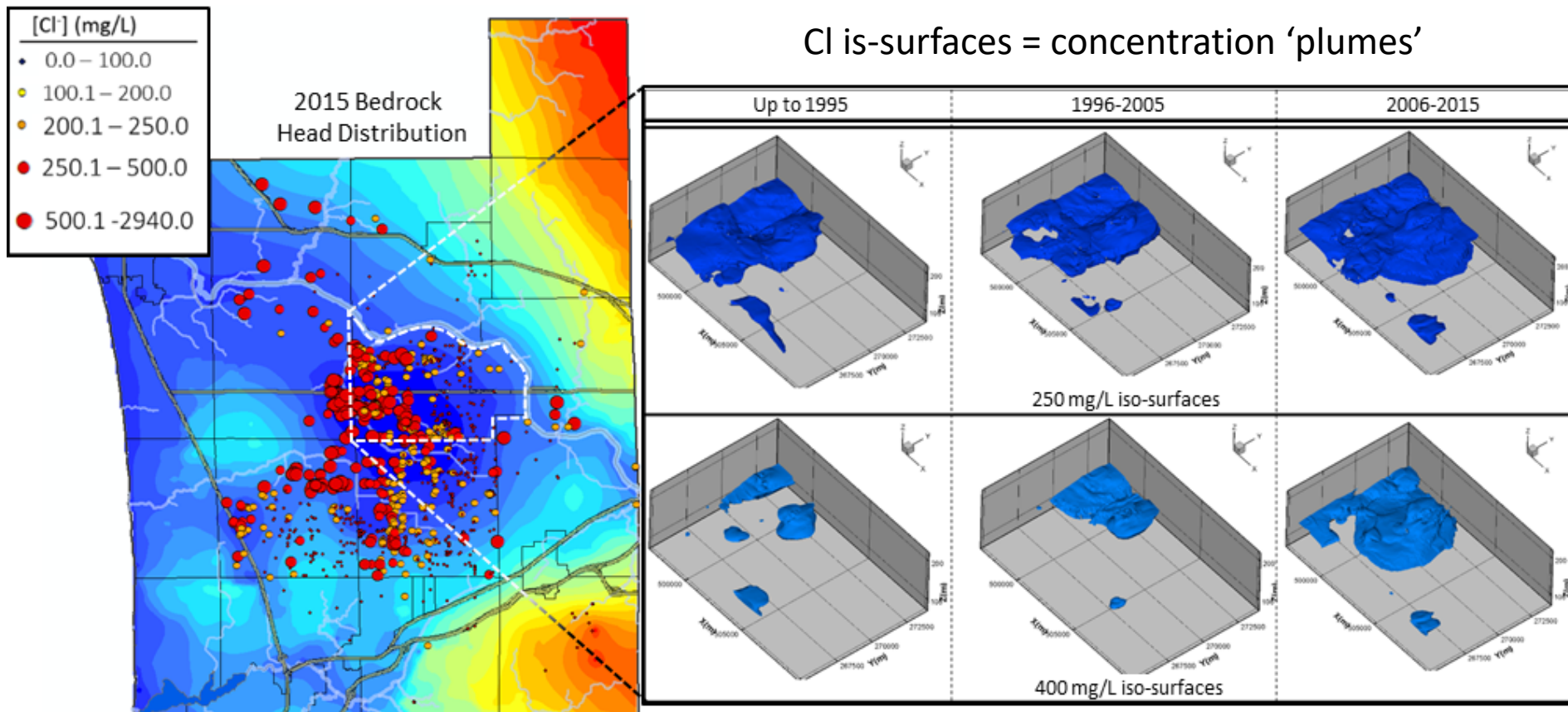
[Cl<sup>-</sup>] (mg/L)



2015 Bedrock Water Levels



# 'Plume' Expansion in an area of significant drawdown (GW↓)



# Summary of Key Findings

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Groundwater elevations have significantly declined in the last 50 years, particularly in the central portions of the bedrock aquifer underlying Ottawa County

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Gradual, distributed increases in groundwater withdrawals played a primary role in this decline

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Both natural and human processes determine where Cl is high  
(where GW levels are low)

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Chloride concentrations are increasing with time in the Ottawa County aquifer system, apparently due to cumulative increases in pumping

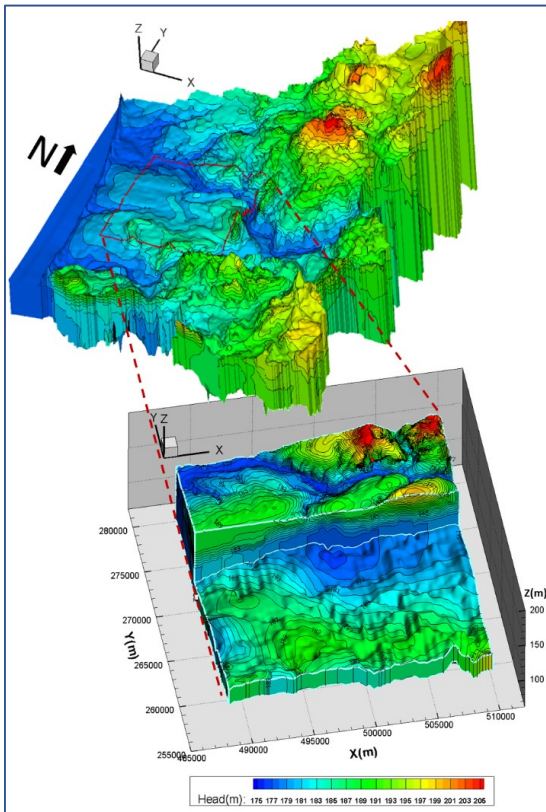
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The issues facing Ottawa County emerge from collective impacts of many processes – human and natural (resource development and geologic setting)



# Related Modeling Work

Calibrated GW Flow model

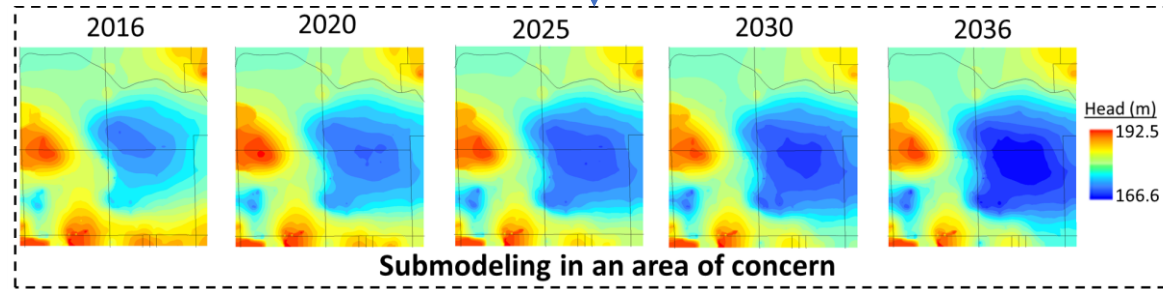


Interactions with county and township planners, stakeholders

Detailed projections:

- well build-out, groundwater use
- land use/land cover
- climate trends

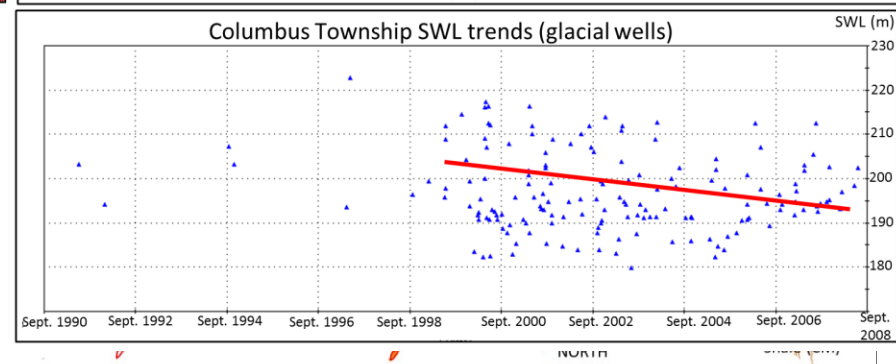
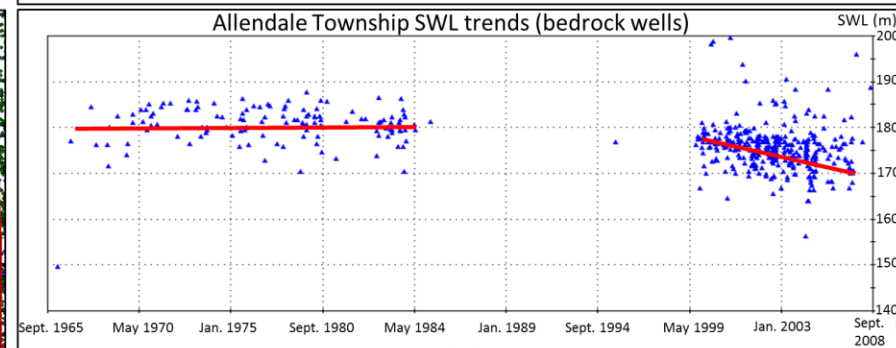
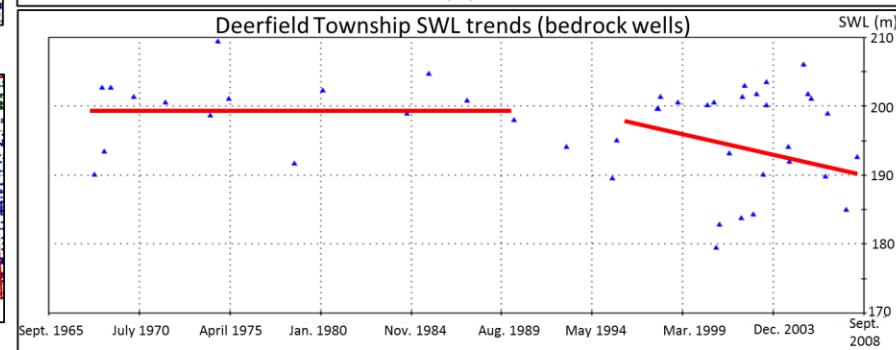
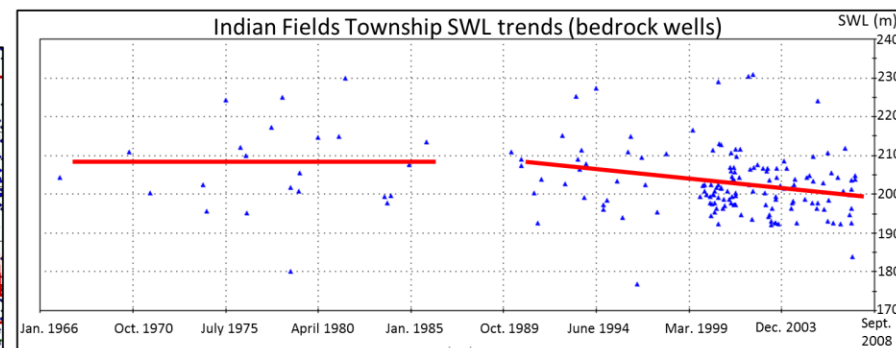
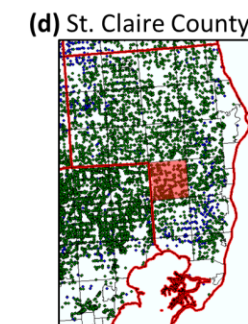
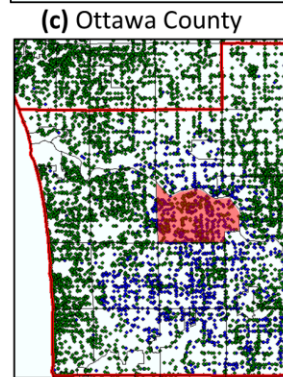
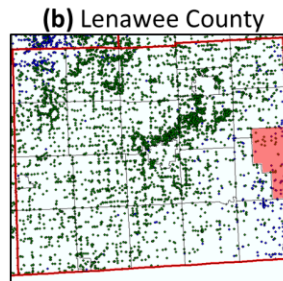
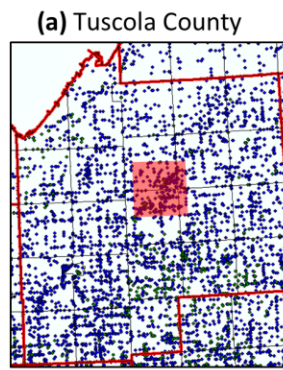
Long-term changes in GW Levels (2018-2036)



# Statewide Implications

## Screening-Level Data Analysis

Issues facing Ottawa County are symptomatic of a larger problem



# Important Take-aways (Process)

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Much data used for modeling/analysis was: pre-existing, free, and available throughout the state

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Stakeholder and community input throughout the entire scientific investigation process was crucial

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This is a complex multidimensional problem – no single party to blame – and will require complex solutions (partnerships, knowledge sharing, etc.)

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# Thank you!

- Questions?
  - Want a copy of a related report/publication?
- => Please email me:

[zach@magnet4water.com](mailto:zach@magnet4water.com)

- Cited journal publications:

Curtis, Z.K., Li, S.G., Liao, H.S. and Lusch, D., 2018. Data-Driven Approach for Analyzing Hydrogeology and Groundwater Quality Across Multiple Scales. *Groundwater*, 56(3), pp.377-398.

Curtis, Z.K., Liao, H.S., Li, S.G., Sampath, P.V. and Lusch, D.P., 2019. A multiscale assessment of shallow groundwater salinization in Michigan. *Groundwater*. <https://doi.org/10.1111/gwat.12873>

Liao, H.S., Curtis, Z.K., Sampath, P.V. and Li, S.G. Simulation of Flow in a Complex Aquifer System Subjected to Long-term Well Network Growth. *Groundwater (in review)*.