Allegan County Groundwater Study

Phase 1: Understanding the Big Picture

February 4, 2021

A Presentation by:

Hydrosimulatics INC.

Phase 1 Deliverables

- This graphical summary of the Phase 1 Study – key conclusions, followed by supporting evidence presented as a Groundwater "Story"
- A summary report of the "Story of Allegan County's Groundwater"
- A Final Technical Report – a detailed, annotated graphical report including all deliverables (map and data layer products, visualizations) of the Phase 1 study.

Phase 1 Key Findings

- There does not appear to be a groundwater resource crisis like we uncovered in neighboring Ottawa County

- However, we identified similar issues that led to their crisis:
  - Significantly elevated nitrate concentrations impacting shallow groundwater
  - Significantly elevated chloride concentrations impacting groundwater discharge areas
  - A large number of potential or known sites of contamination
  - Hints of systematic decline in groundwater levels because of cumulative water use trends (well network growth)

- We have provided a “one-stop” collection of existing data related to Allegan County’s groundwater system. This provides lots of valuable information to support decision-making and management.

- We feel strongly that the best use of this collection of data and modeling results is with an interactive Decision-Support System that can be used to address the current and future set of groundwater uses in Allegan County

A Story of Allegan County's Groundwater

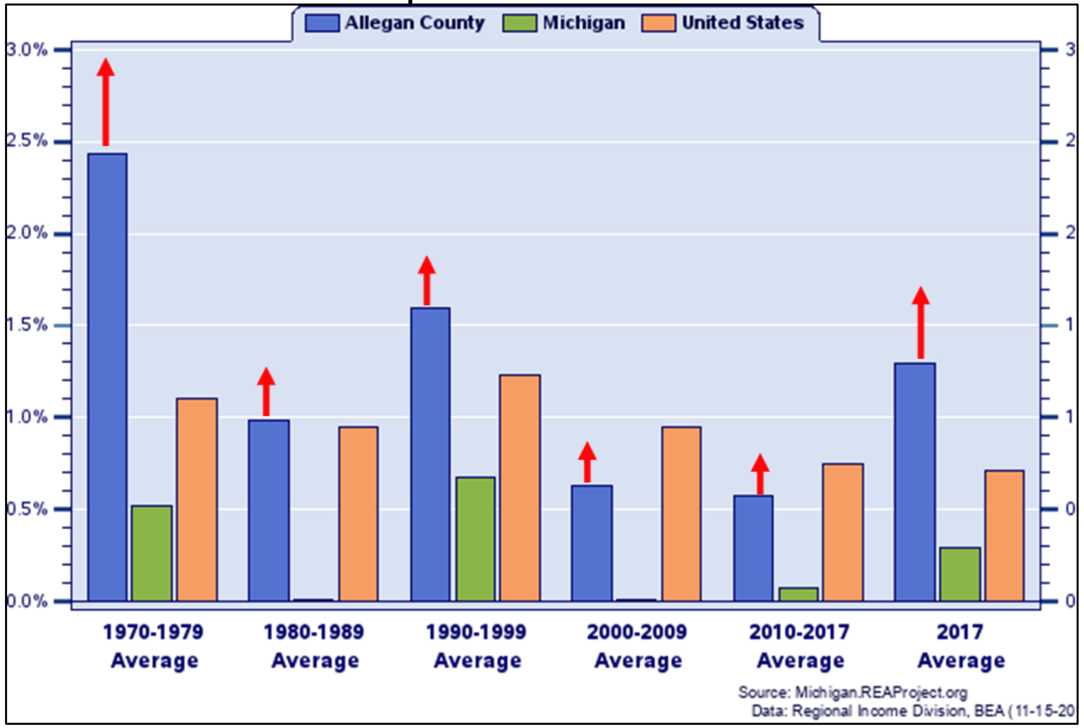
With a Focus on Management Implications

Part 1: Water Quantity & Aquifer Analysis

- Growth and Development
- Source of Water – Groundwater
- Aquifer Framework
- Countywide Flow Patterns
- Discharge and Recharge Areas
- Depth-to-Water Table
- Detailed 3D Heterogeneity
- 3D Geologic Model
- Hydraulic Conductivity and Aquifer Yield
- Long-term Sustainability
    - Long-term Recharge
    - Increased Groundwater Use
    - Temporal Water Level Trends

Development, Population Growth, and Increased Water Use

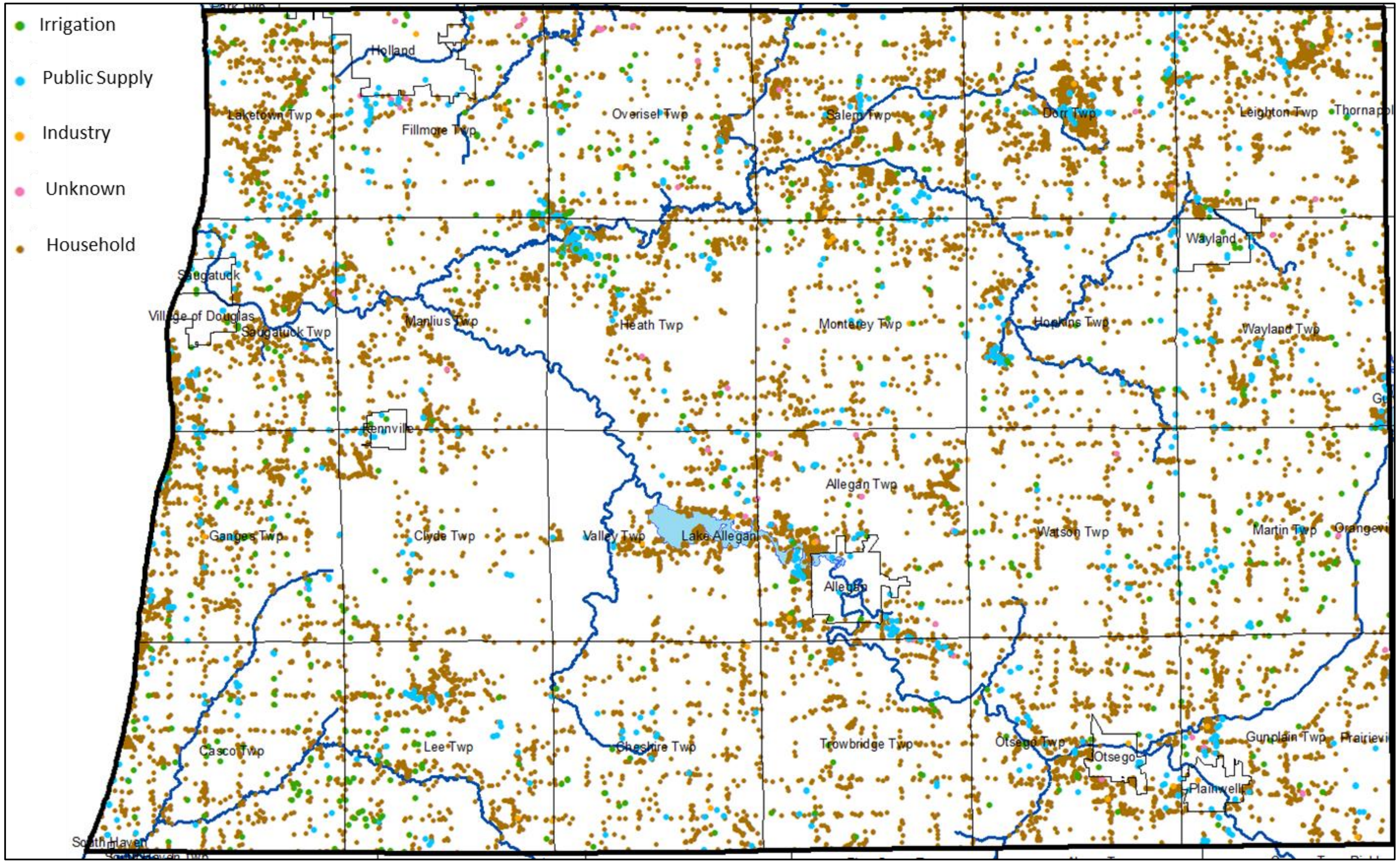
Population Growth



Agricultural Activities

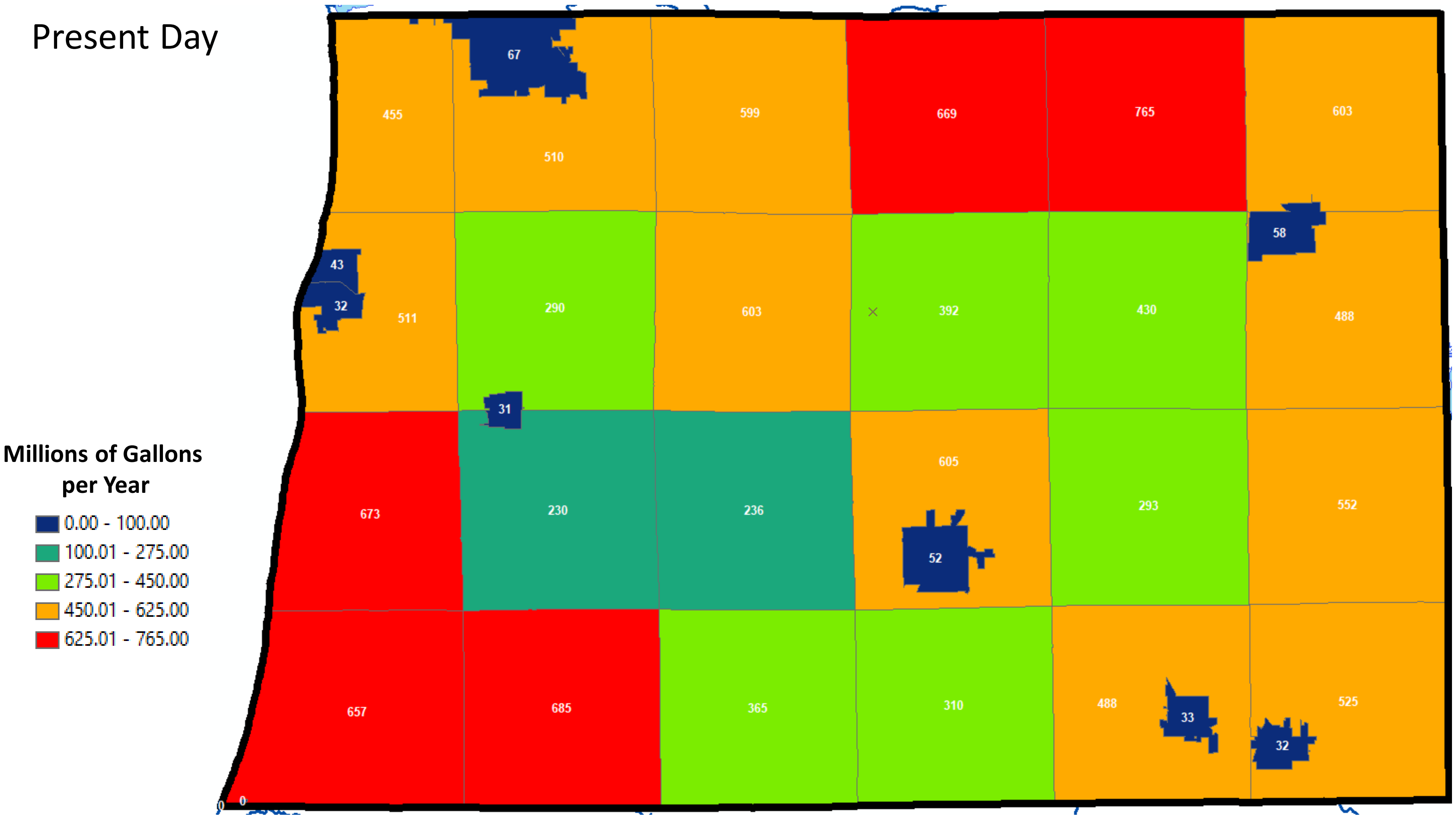
- Period of growth that started decades ago and sustained in recent years => Systematic increases in water use
- Effective long-term management requires holistic understanding of the county's water system

Source of Water: Groundwater



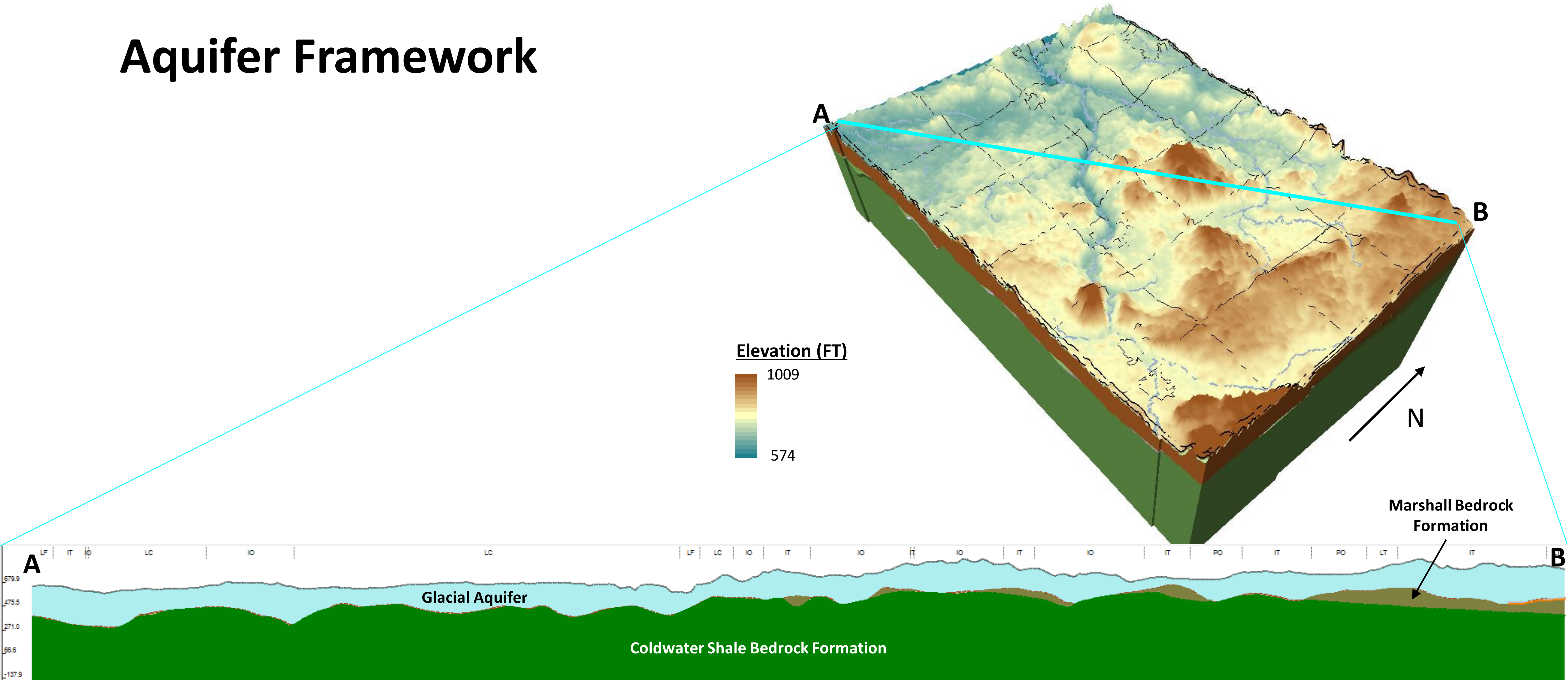
- Presently (and historically), essentially all water supply is from groundwater
- Used for: household water; public water supply (year-long and transient); irrigation, and industry

Screening-level Estimate of Groundwater Use



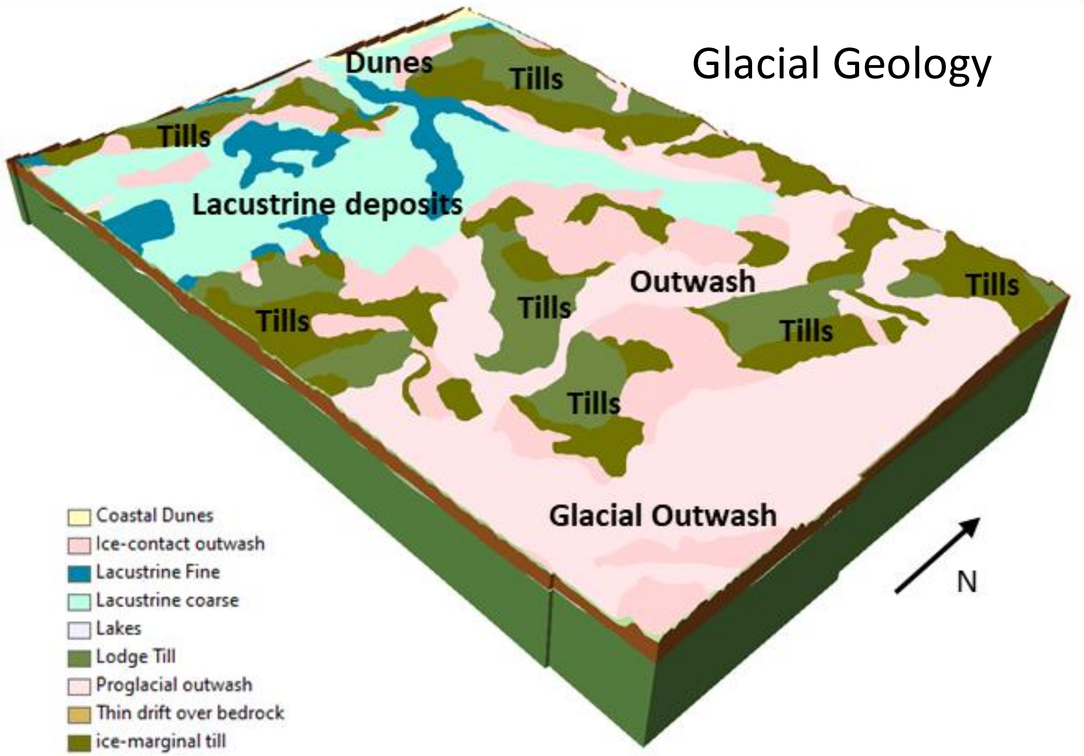
- Cumulative groundwater use is significant throughout virtually all parts of the County
- And because the subsurface is 'invisible' and actions / events impacting groundwater are delayed … System-based management is especially critical!!

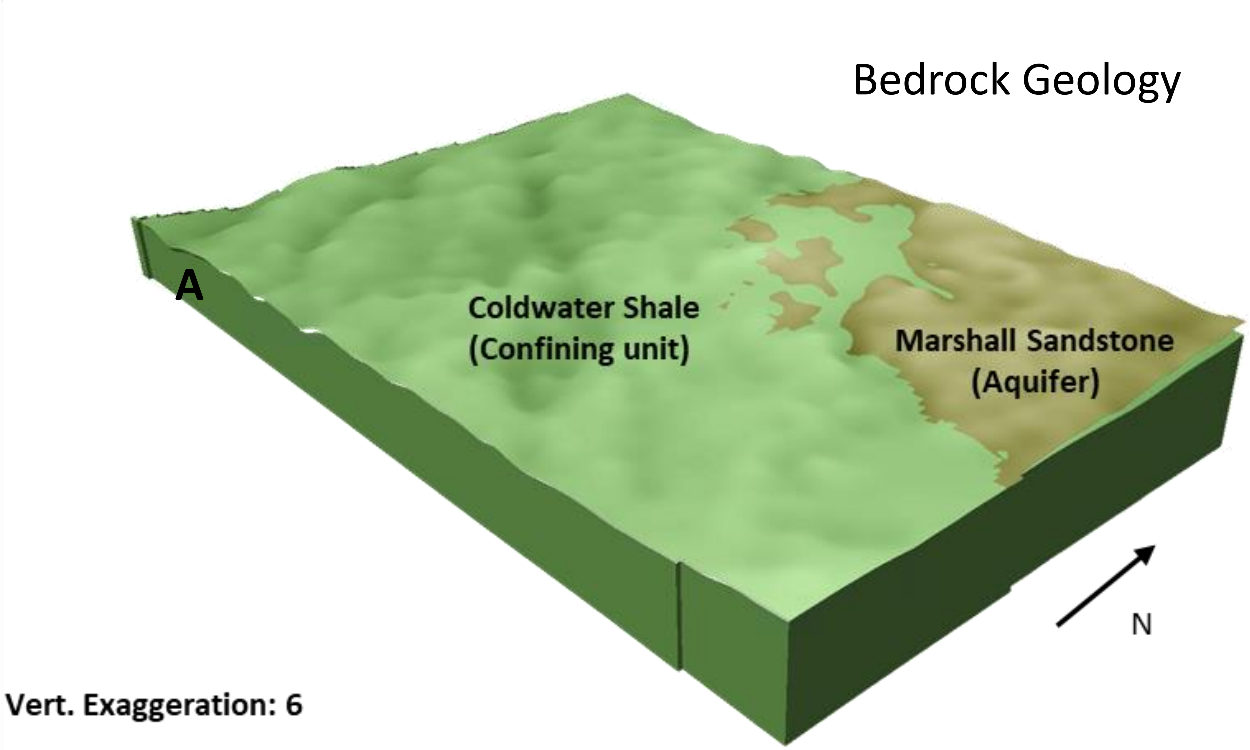
Aquifer Framework



- Two aquifer “layers”: shallow “glacial” aquifer and a deep “bedrock” aquifer
- Glacial aquifer covers all portions of the county
- …Mostly underlain by Coldwater Shale bedrock formation (low permeability), except in northwest -> Marshall Sandstone

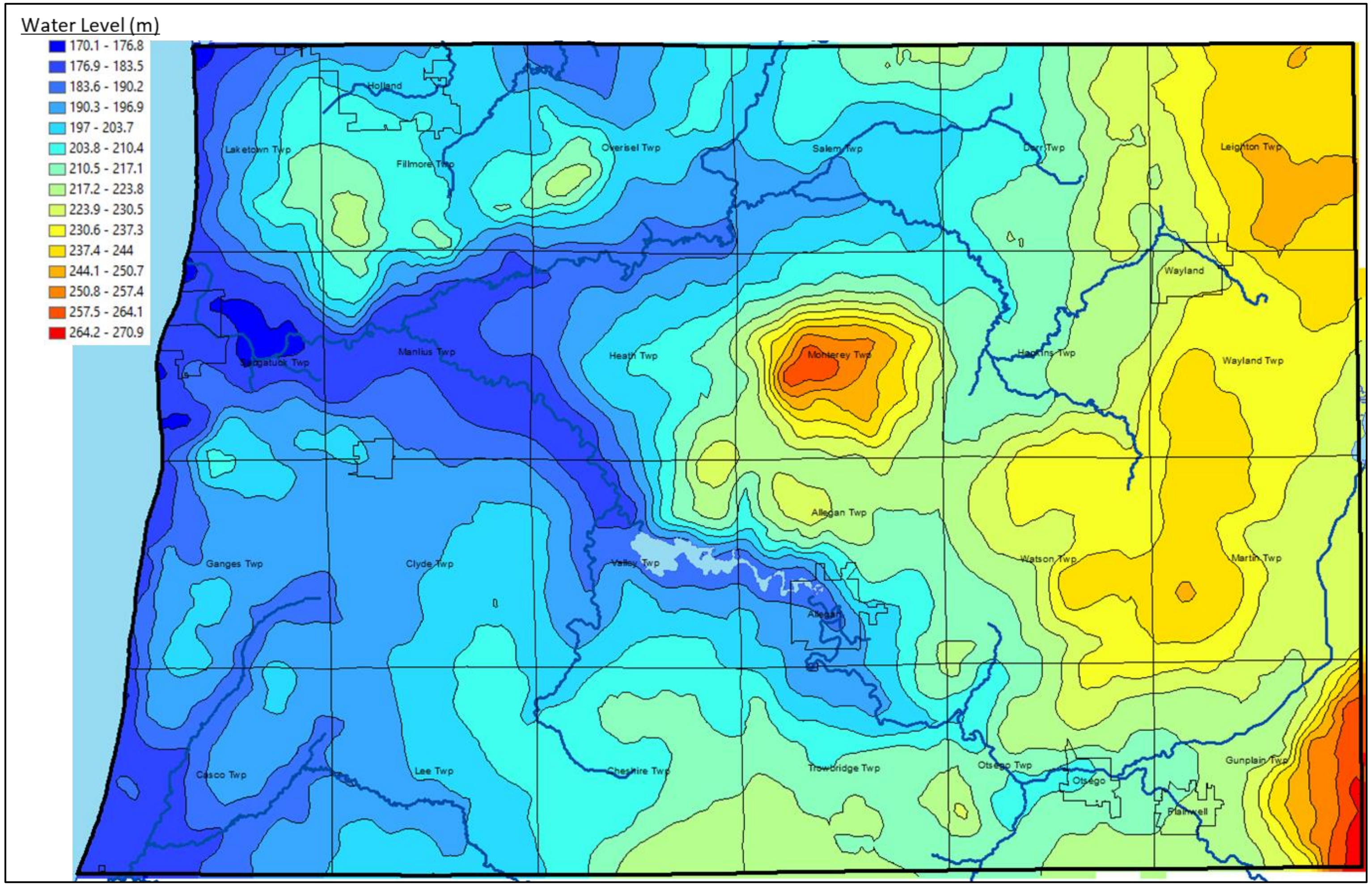
Aquifer Framework





- Glacial aquifer – unconsolidated sediments from glacial advances and retreats; wide range of physical characteristics
- Bedrock aquifer – fractured portions of the Marshall Sandstone; pinching out along Western subcrop extent

Flow Patterns – Glacial Aquifer

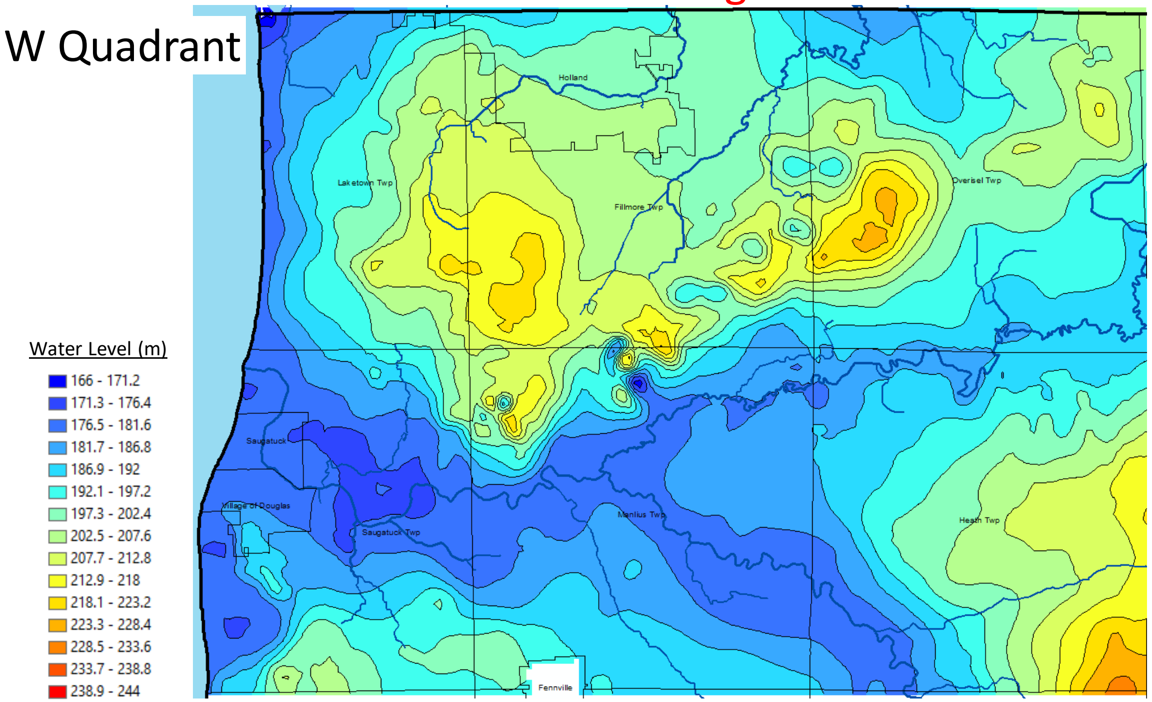


- Water table pattern plays a critical role in groundwater management:
  - Dictates groundwater flow direction
  - Controls groundwater speed

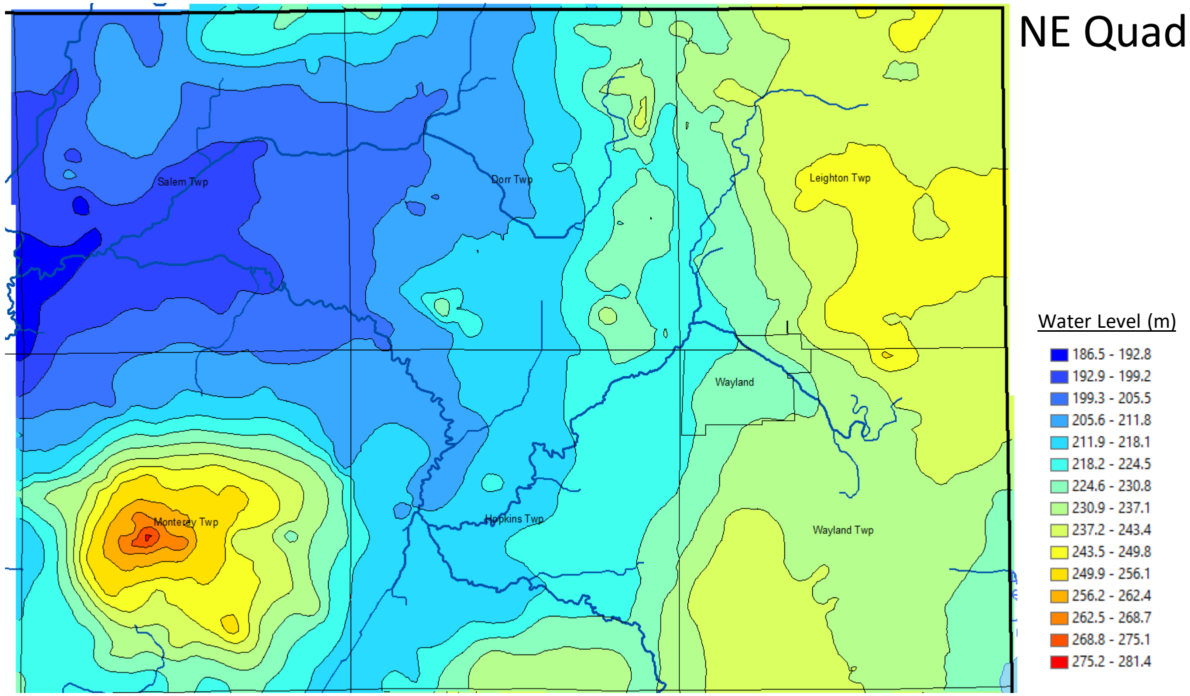
→ Contamination control; groundwater source protection

Subregional Water Table Mapping (more spatial details)

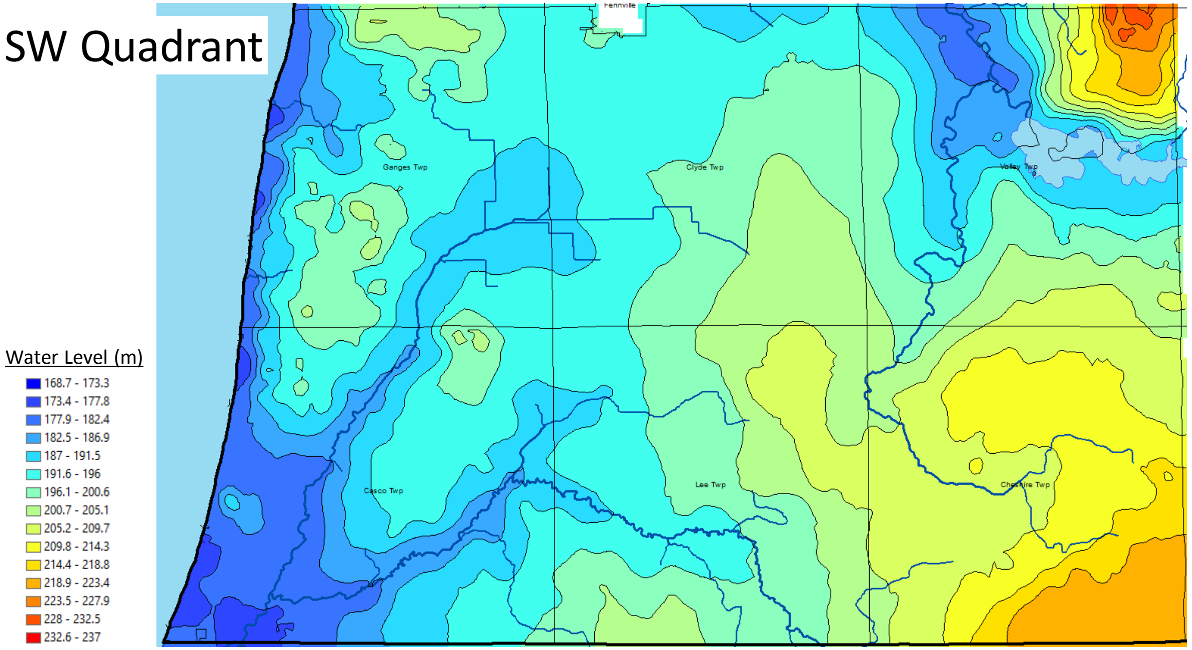
NW Quadrant



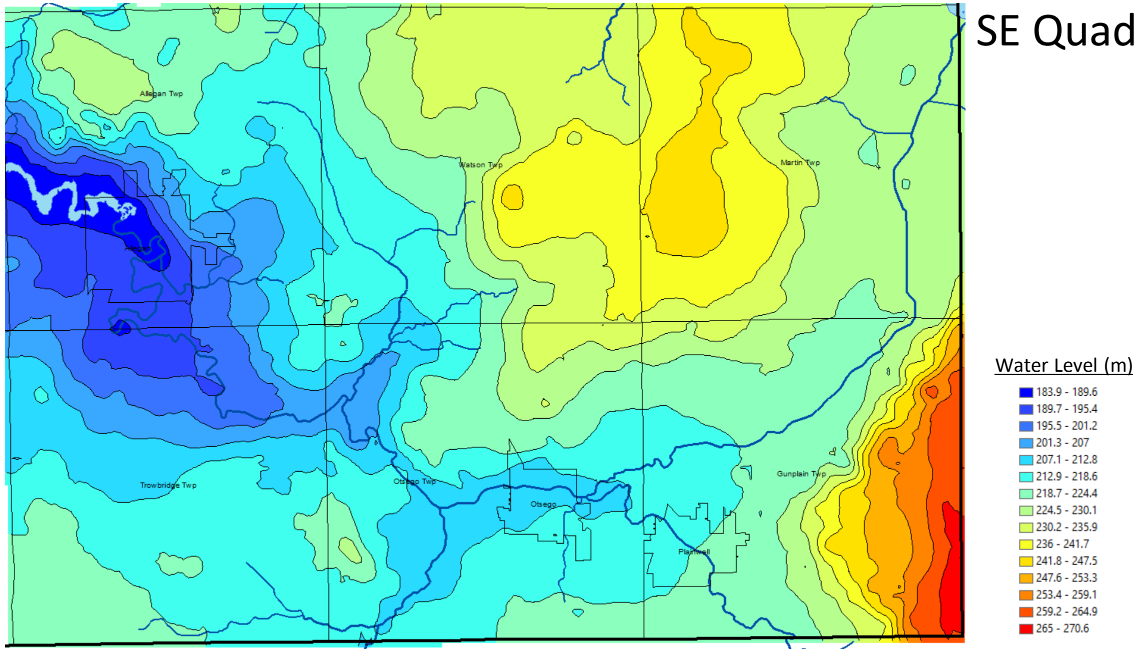
NE Quadrant



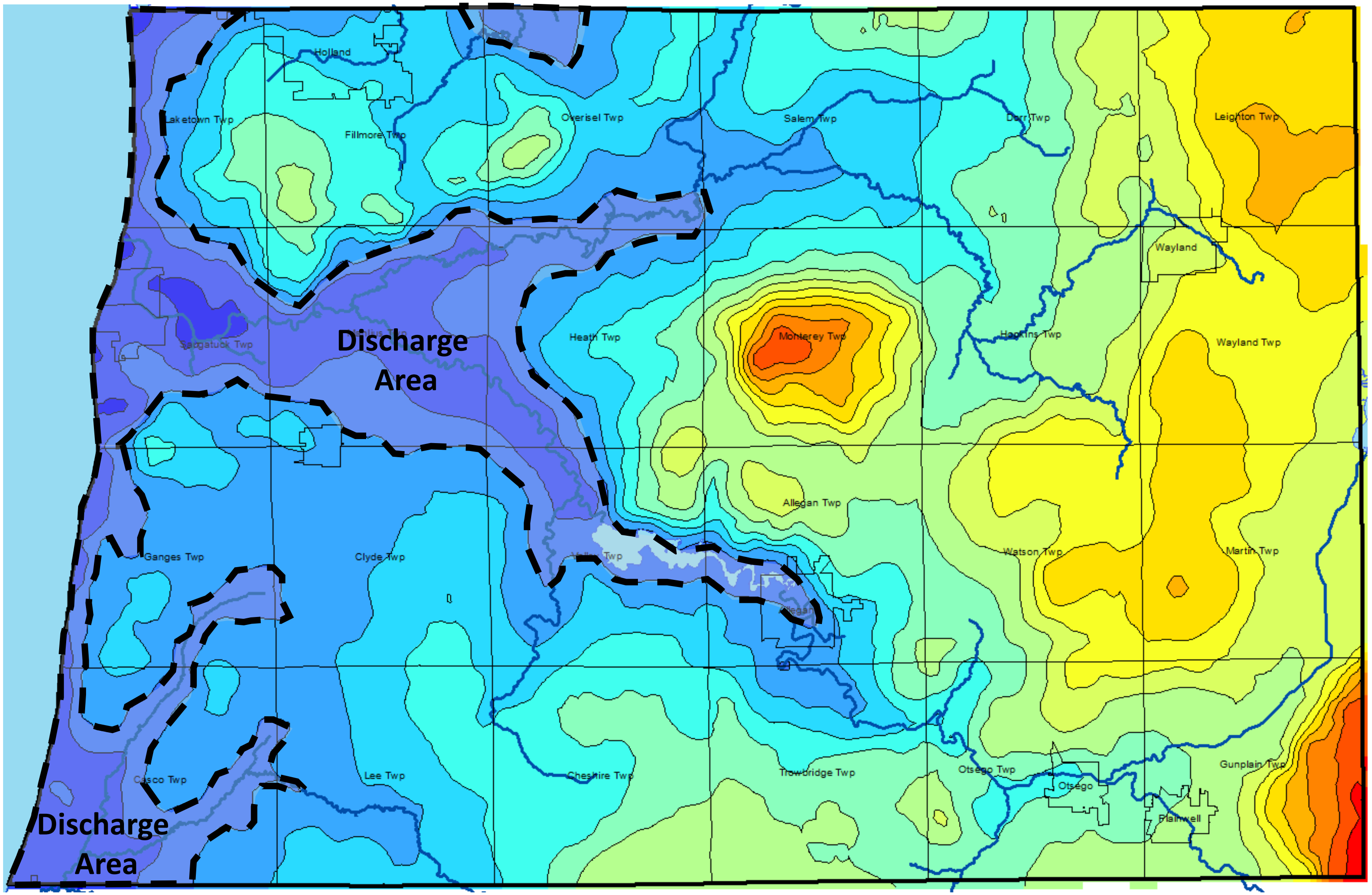
SW Quadrant

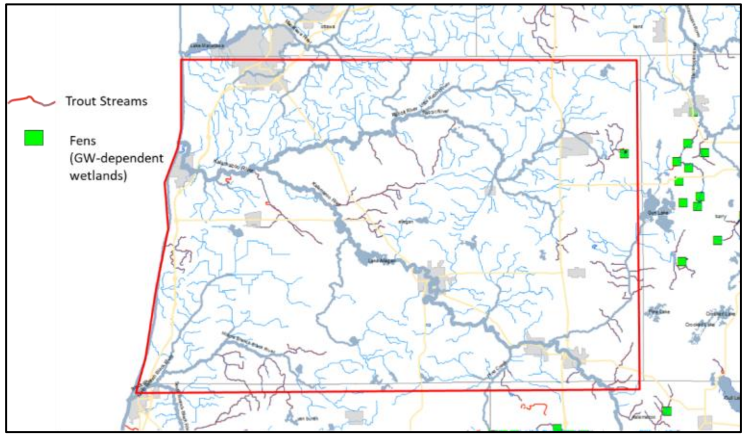


SE Quadrant



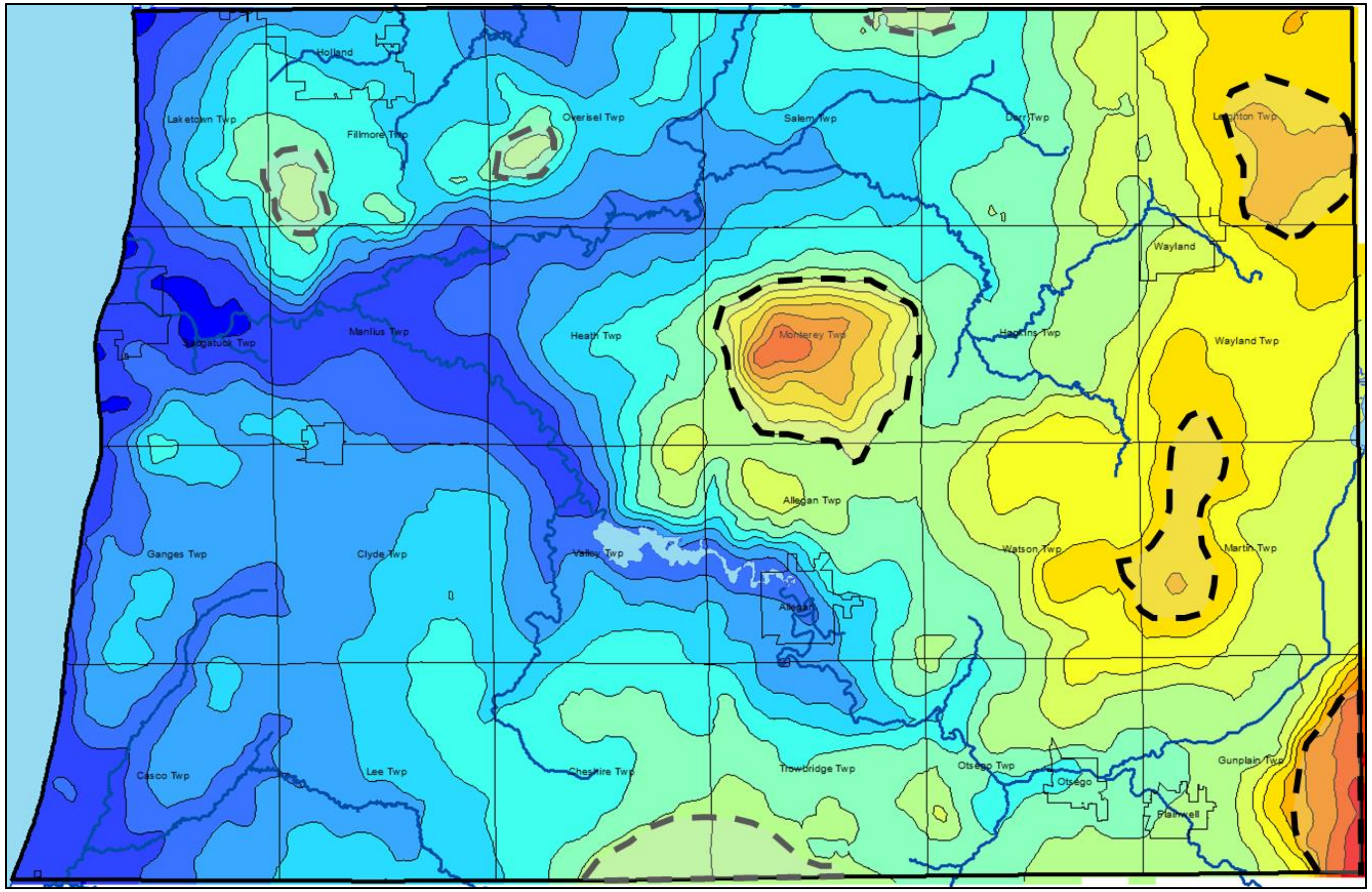
Discharge Areas – Glacial Aquifer





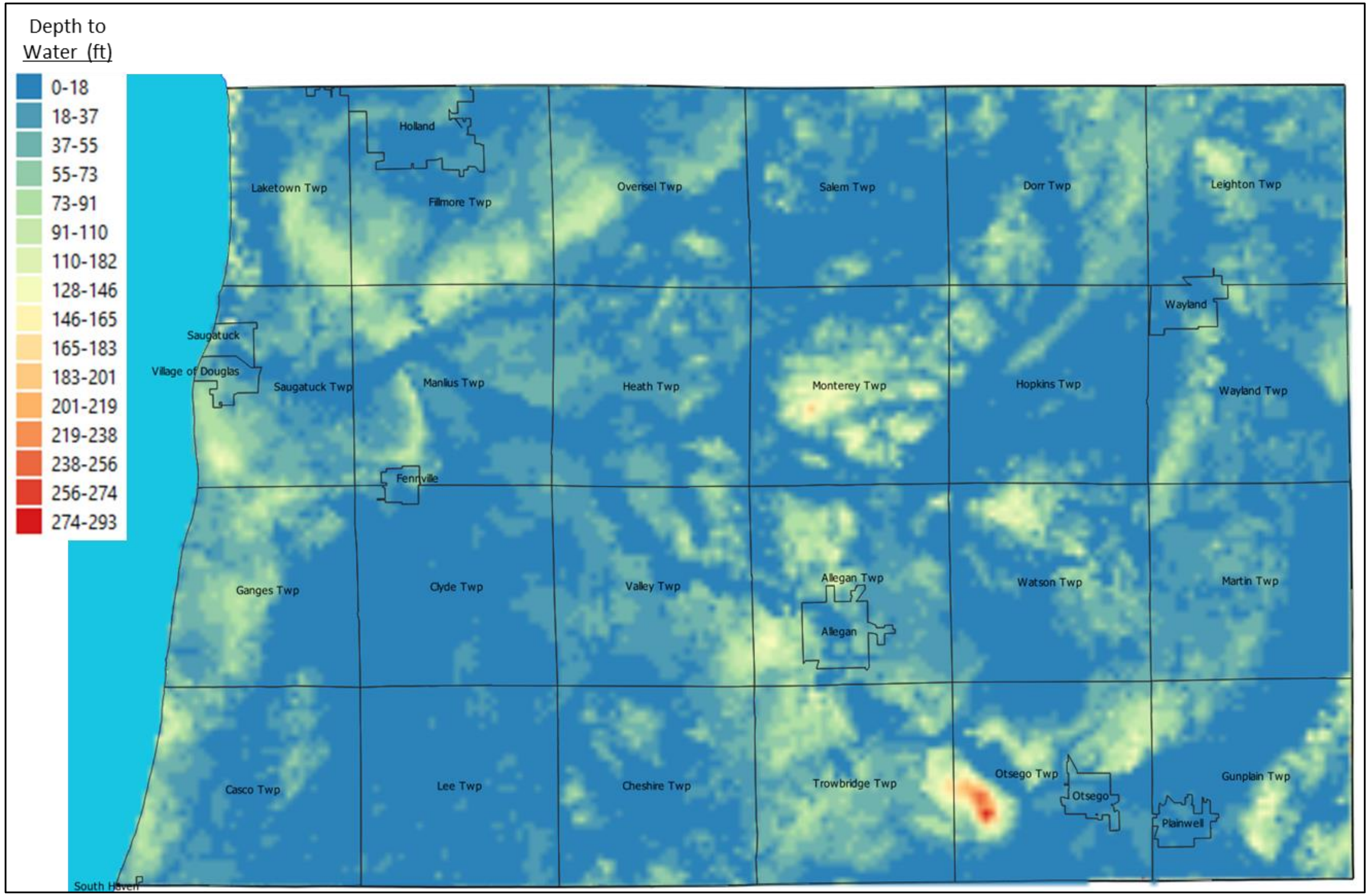
- Discharge primarily to the major surface water bodies and along their corridors
- Streams, lakes, and wetlands in discharge areas:
  - Have significant groundwater components
  - ….and are habitats for groundwater-dependent ecosystems.

Recharge Areas – Glacial Aquifer



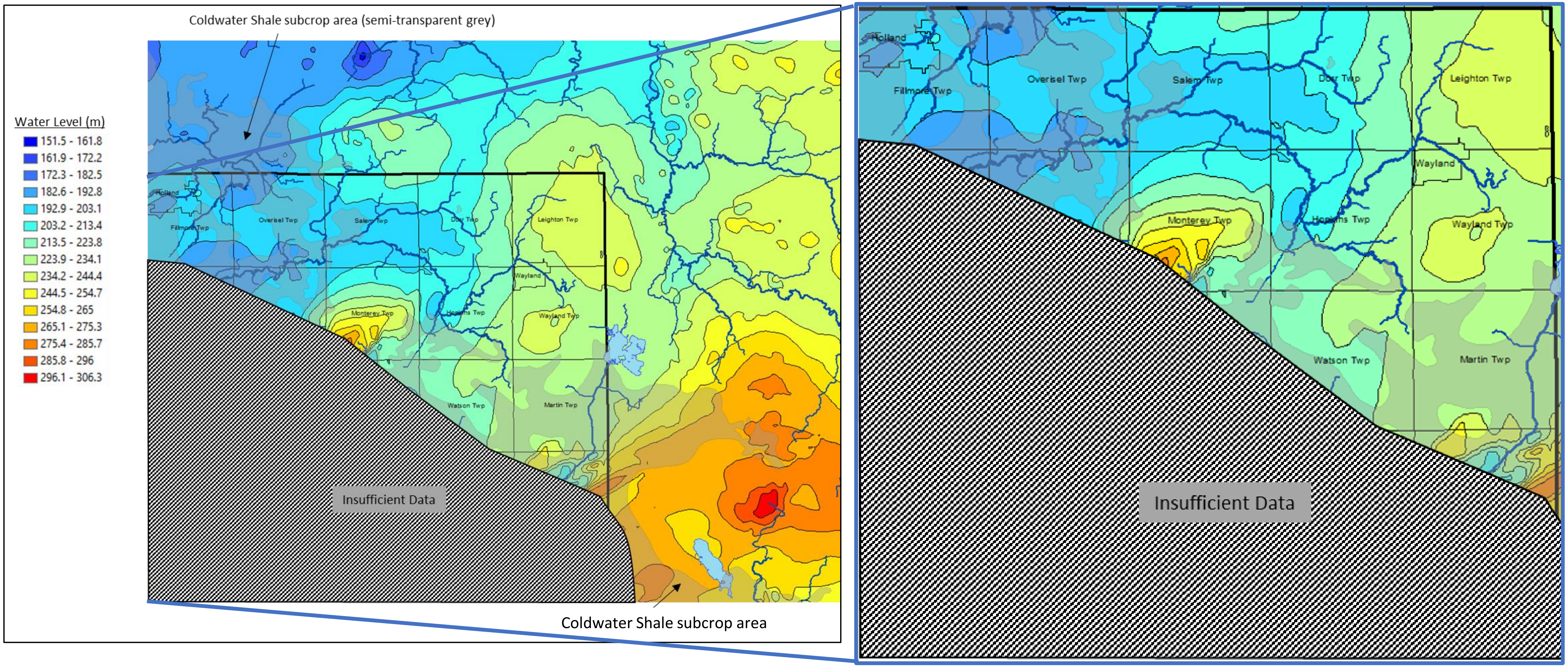
- Recharging water moves deep and travels regionally, feeding the entire aquifer
- Location of recharge area has important management implications:
  - Land use planning (development disproportionately impacts aquifer sustainability)
  - Waste disposal activities (spills have significantly more impact)

Depth-to-Water



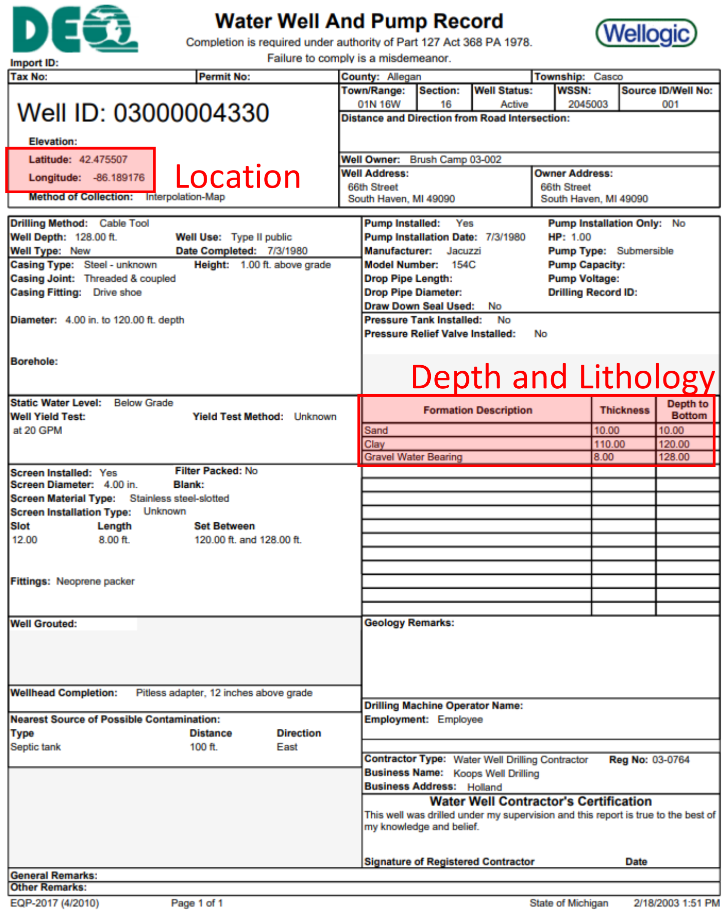
- Depth-to-water plays an important role in groundwater management, e.g.:
  - Designing a water well
  - Evaluating the risk of basement flooding
  - Assessing aquifer vulnerability

Flow Patterns – Bedrock Aquifer



- Bedrock aquifer is recharged “locally” or directly from above … little flux coming from the regional recharge mound
- Groundwater discharges toward the surface (through the glacial aquifer) primarily along the Rabbit River and its tributaries

Detailed 3D Heterogeneity of the Subsurface



Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No: | Permit No: | County: Allegan | Township: Casco

Town/Range: 01N 16W | Section: 16 | Well Status: Active | WSSN: 2045003 | Source ID/Well No: 001

Well ID: 03000004330

Elevation:
Latitude: 42.475507
Longitude: -86.189176
Method of Collection: Interpolation-Map

Location

Distance and Direction from Road Intersection:

Well Owner: Brush Camp 03-002

Well Address: 66th Street, South Haven, MI 49090

Owner Address: 66th Street, South Haven, MI 49090

Drilling Method: Cable Tool
Well Depth: 128.00 ft. Well Use: Type II public
Well Type: New Date Completed: 7/3/1980
Casing Type: Steel - unknown Height: 1.00 ft. above grade
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 4.00 in. to 120.00 ft. depth

Borehole:

Pump Installed: Yes Pump Installation Only: No
Pump Installation Date: 7/3/1980 HP: 1.00
Manufacturer: Jacuzzi Pump Type: Submersible
Model Number: 154C Pump Capacity:
Drop Pipe Length: Pump Voltage:
Drop Pipe Diameter: Drilling Record ID:
Draw Down Seal Used: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Depth and Lithology

Formation Description	Thickness	Depth to Bottom
Sand	10.00	10.00
Clay	110.00	120.00
Gravel Water Bearing	8.00	128.00

Static Water Level: Below Grade
Well Yield Test: Yield Test Method: Unknown
at 20 GPM

Screen Installed: Yes Filter Packed: No
Screen Diameter: 4.00 in. Blank:
Screen Material Type: Stainless steel-slotted
Screen Installation Type: Unknown

Slot	Length	Set Between
12.00	8.00 ft.	120.00 ft. and 128.00 ft.

Fittings: Neoprene packer

Well Grouted:

Geology Remarks:

Wellhead Completion: Pitless adapter, 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	100 ft.	East

Drilling Machine Operator Name:
Employment: Employee

Contractor Type: Water Well Drilling Contractor Reg No: 03-0764
Business Name: Koops Well Drilling
Business Address: Holland

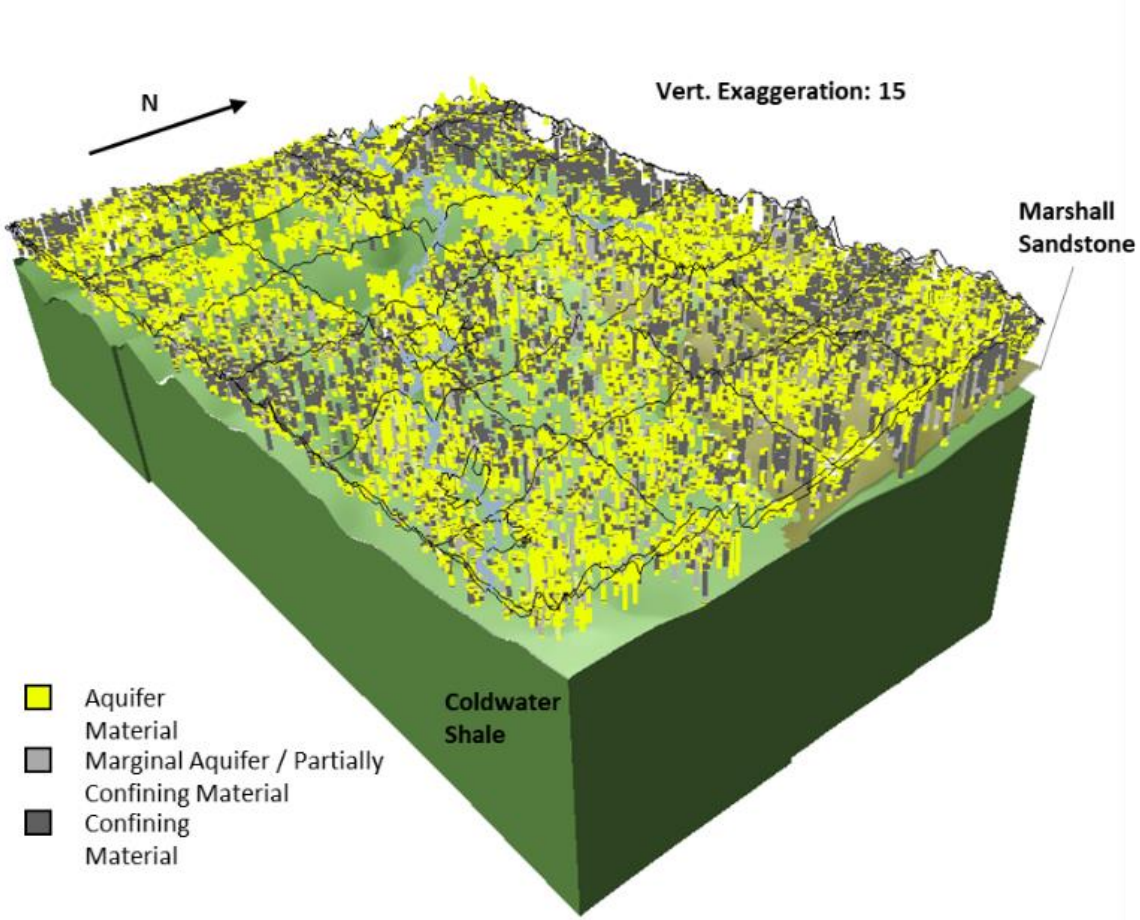
Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor Date

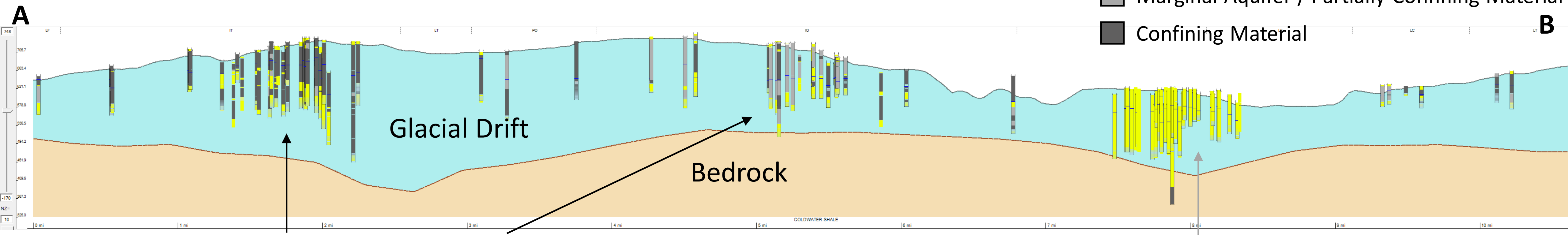
General Remarks:
Other Remarks:

EQP-2017 (4/2010) Page 1 of 1 State of Michigan 2/18/2003 1:51 PM



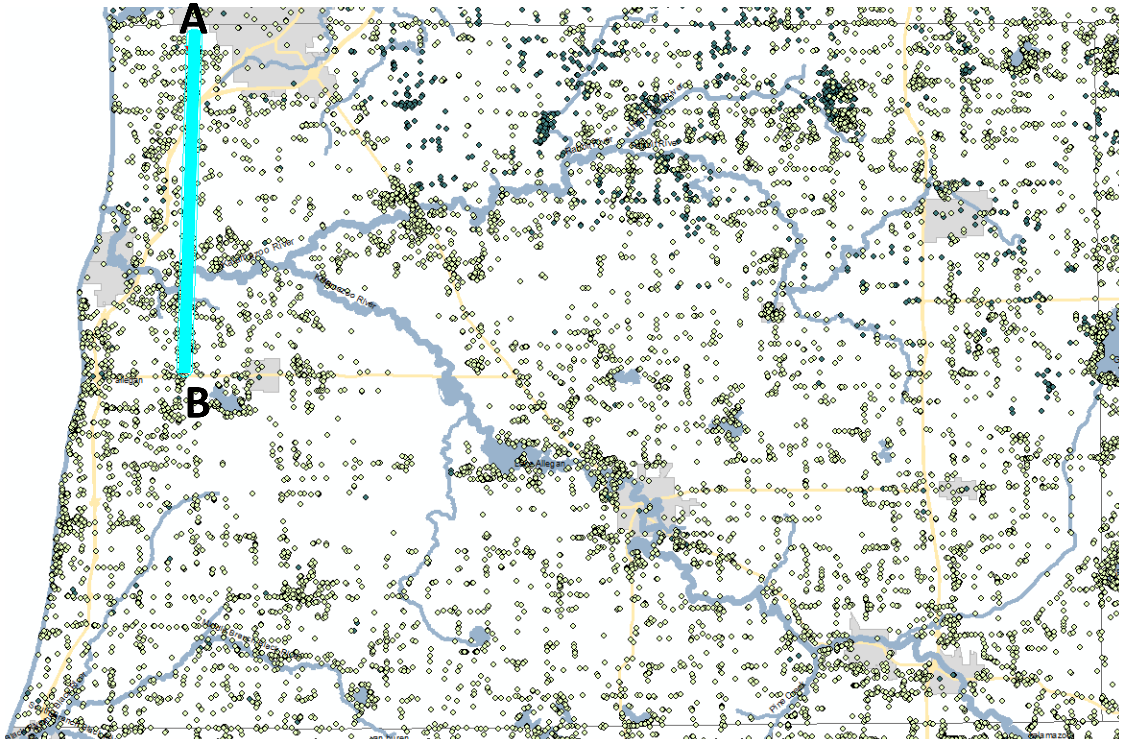
- Glacial aquifer extremely heterogeneous (mixed), both horizontally and vertically
- …Some parts are very permeable, while others are less permeable (some areas may yield very little groundwater)

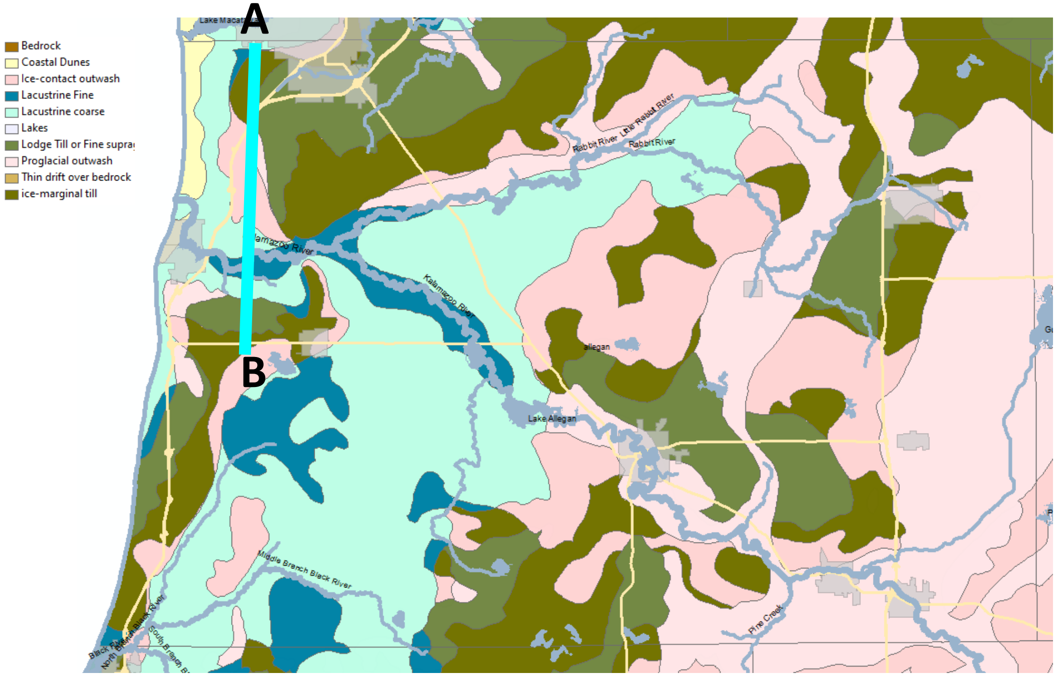
3D Heterogeneity of the Subsurface



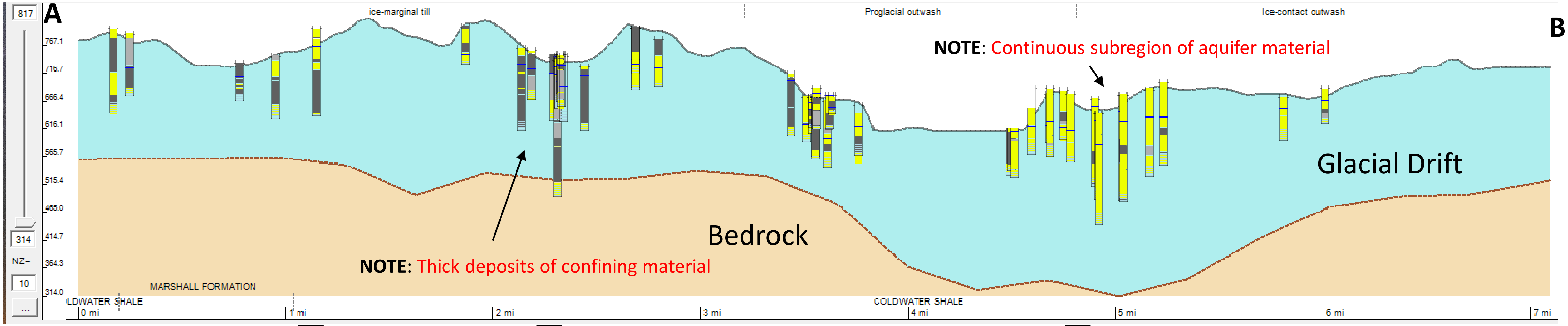
NOTE: Confining material underlain by aquifer materials

NOTE: Continuous subregion of aquifer material

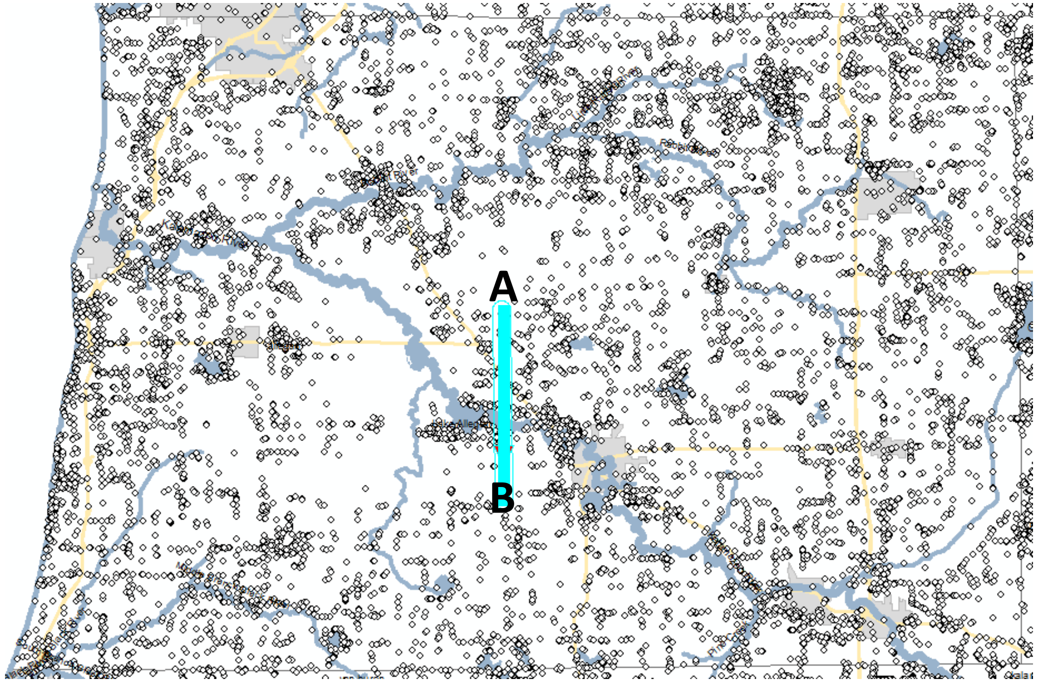


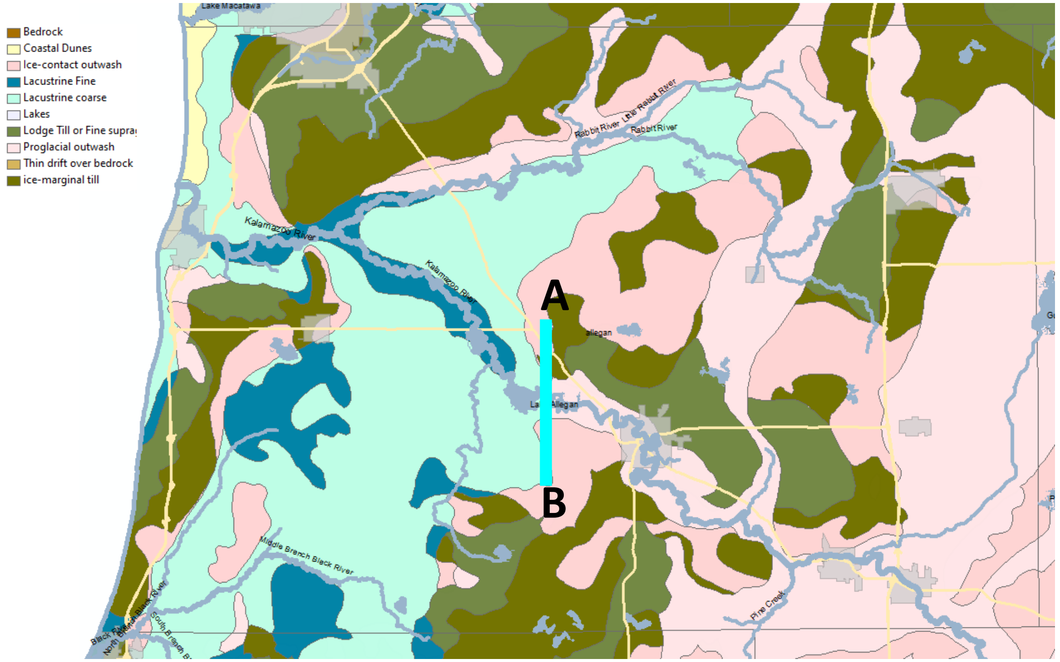


3D Heterogeneity of the Subsurface



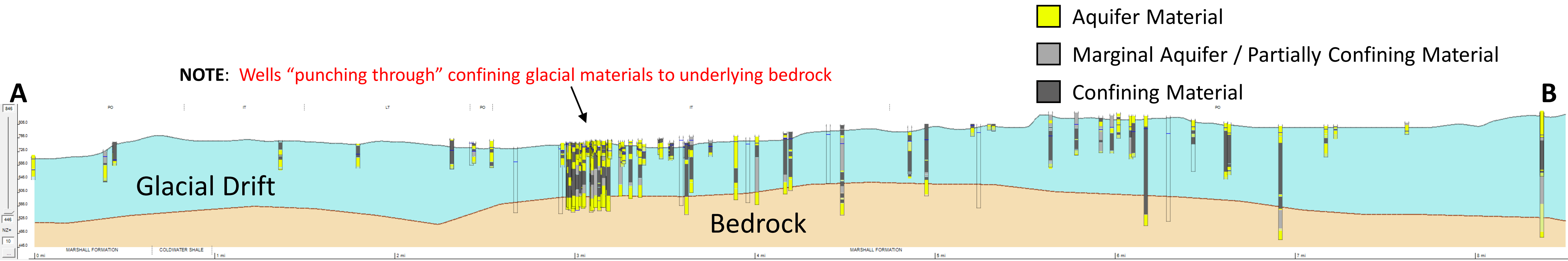
Aquifer Material | Marginal Aquifer / Partially Confining Material | Confining Material

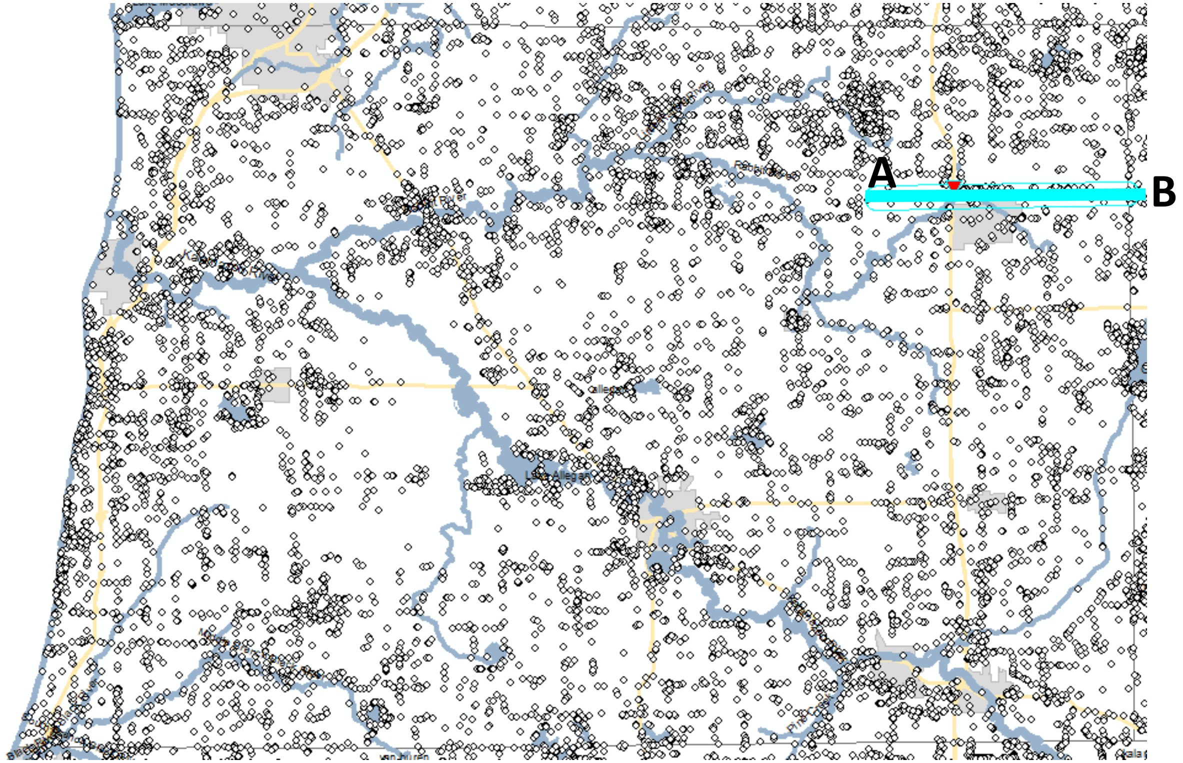


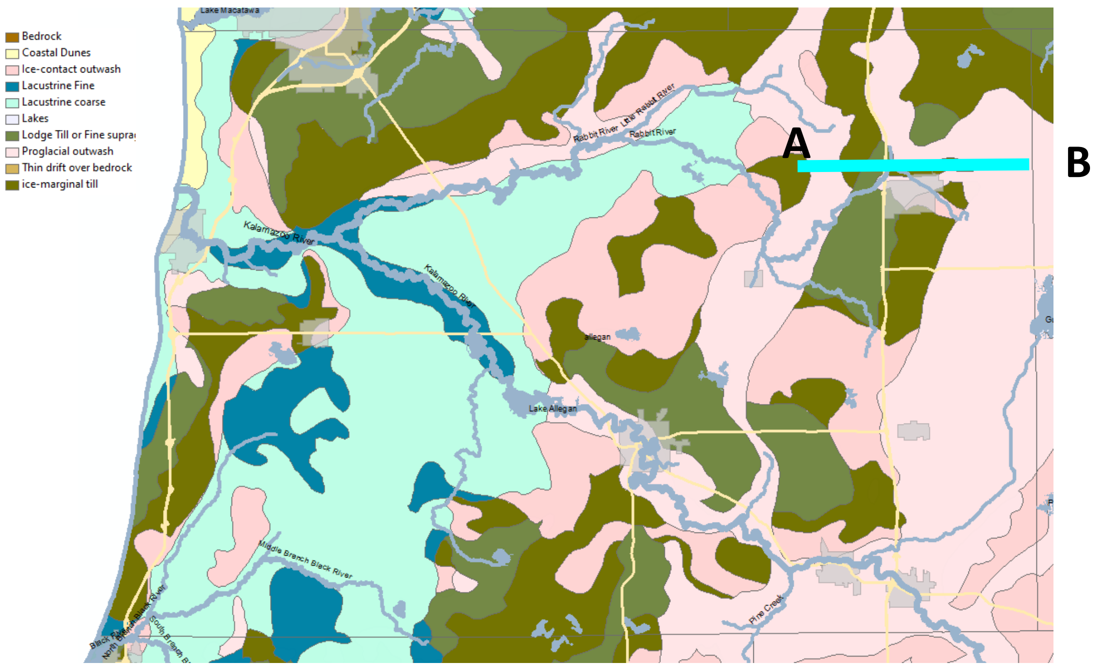


3D Heterogeneity of the Subsurface

NOTE: Wells "punching through" confining glacial materials to underlying bedrock







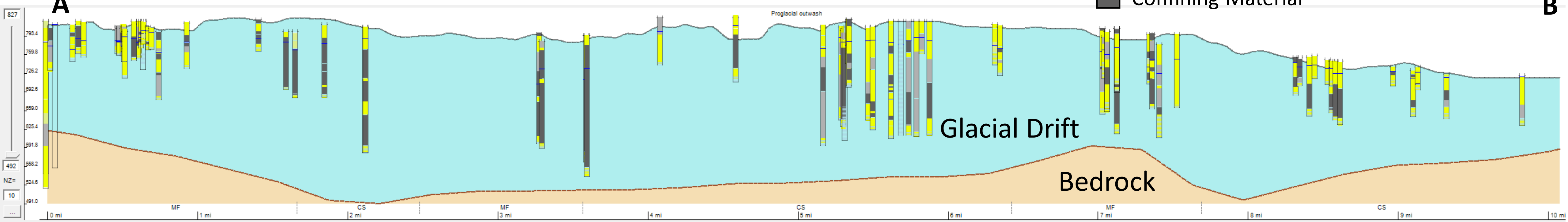
3D Heterogeneity of the Subsurface

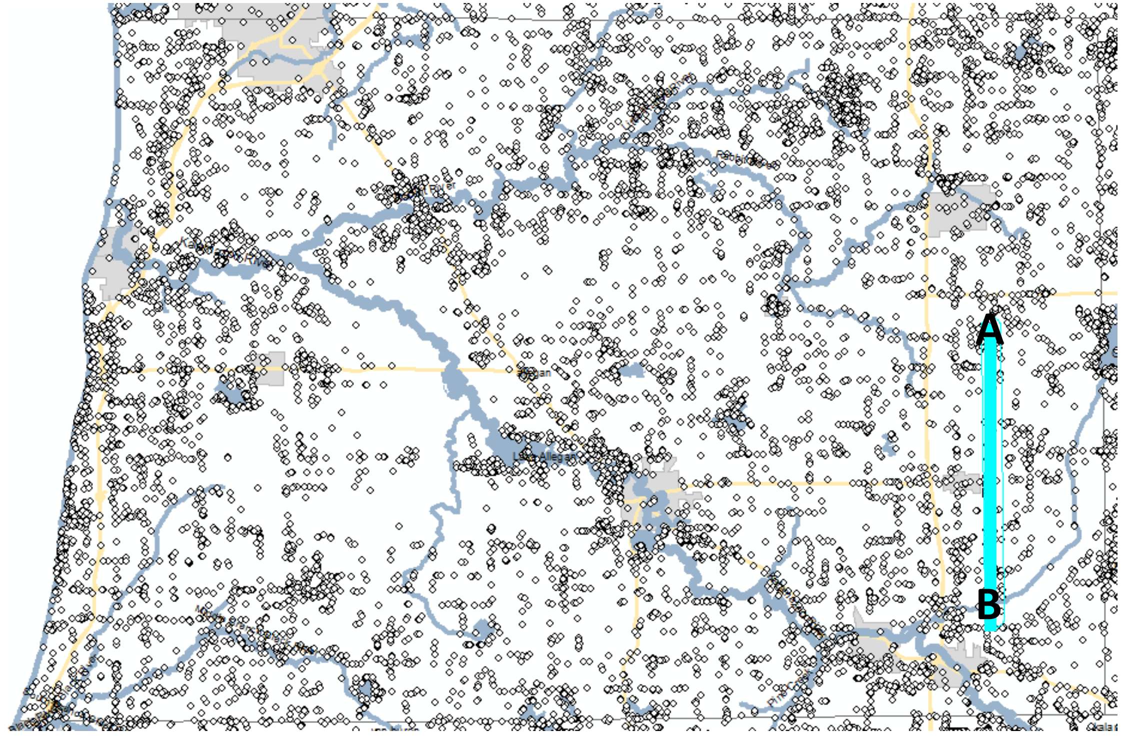
Aquifer Material

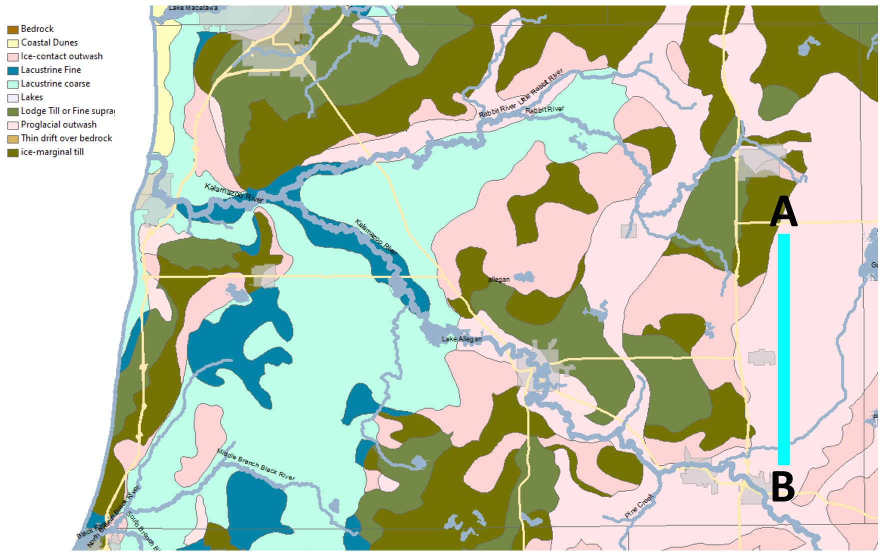
Marginal Aquifer / Partially Confining Material

Confining Material

NOTE: Thick glacial deposits with large degree of vertical and horizontal variability

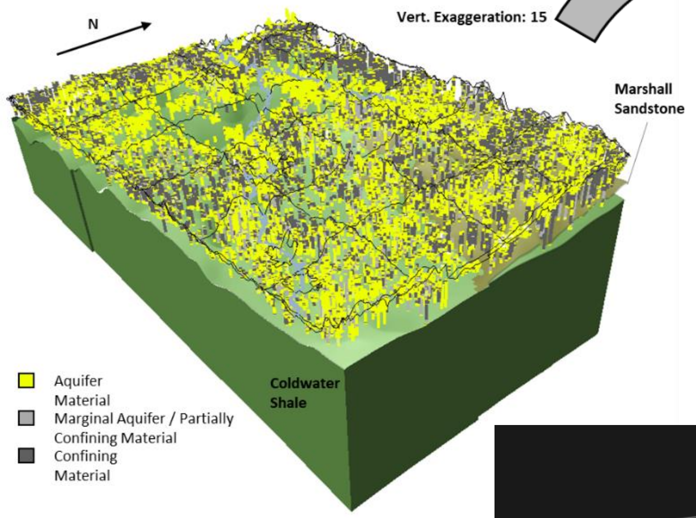






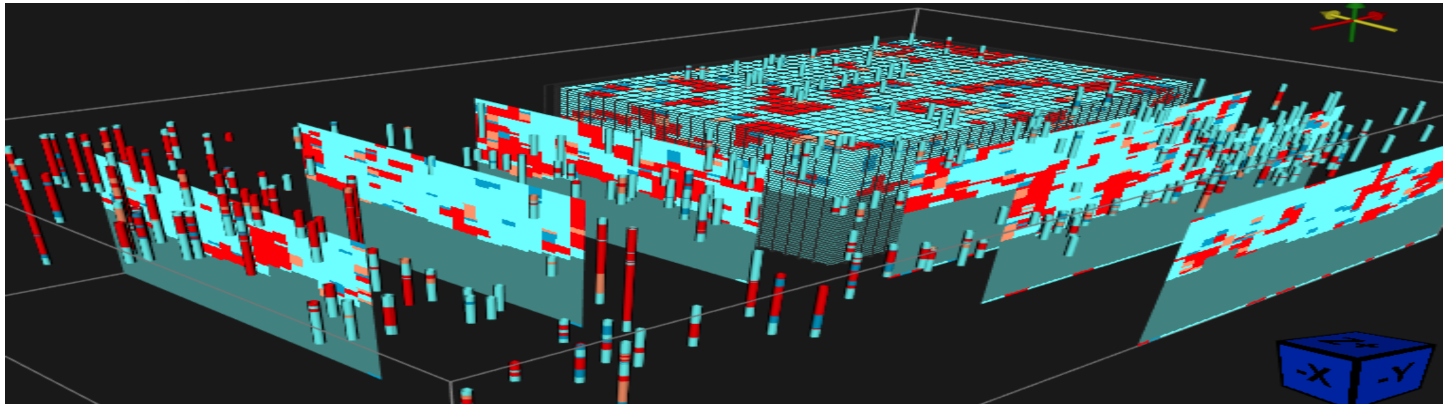
3D Geological Model of the Glacial Aquifer

3D Lithology

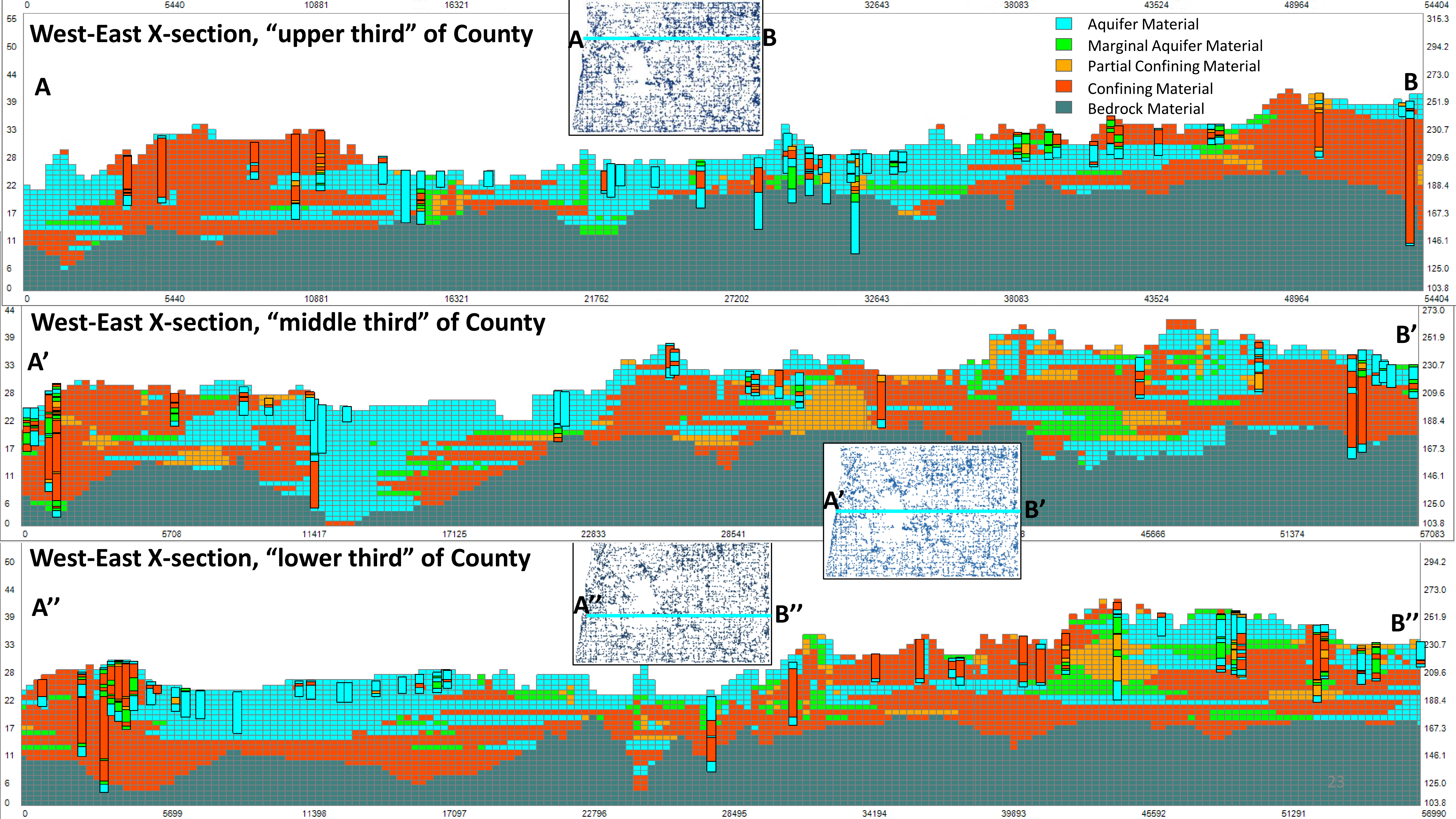


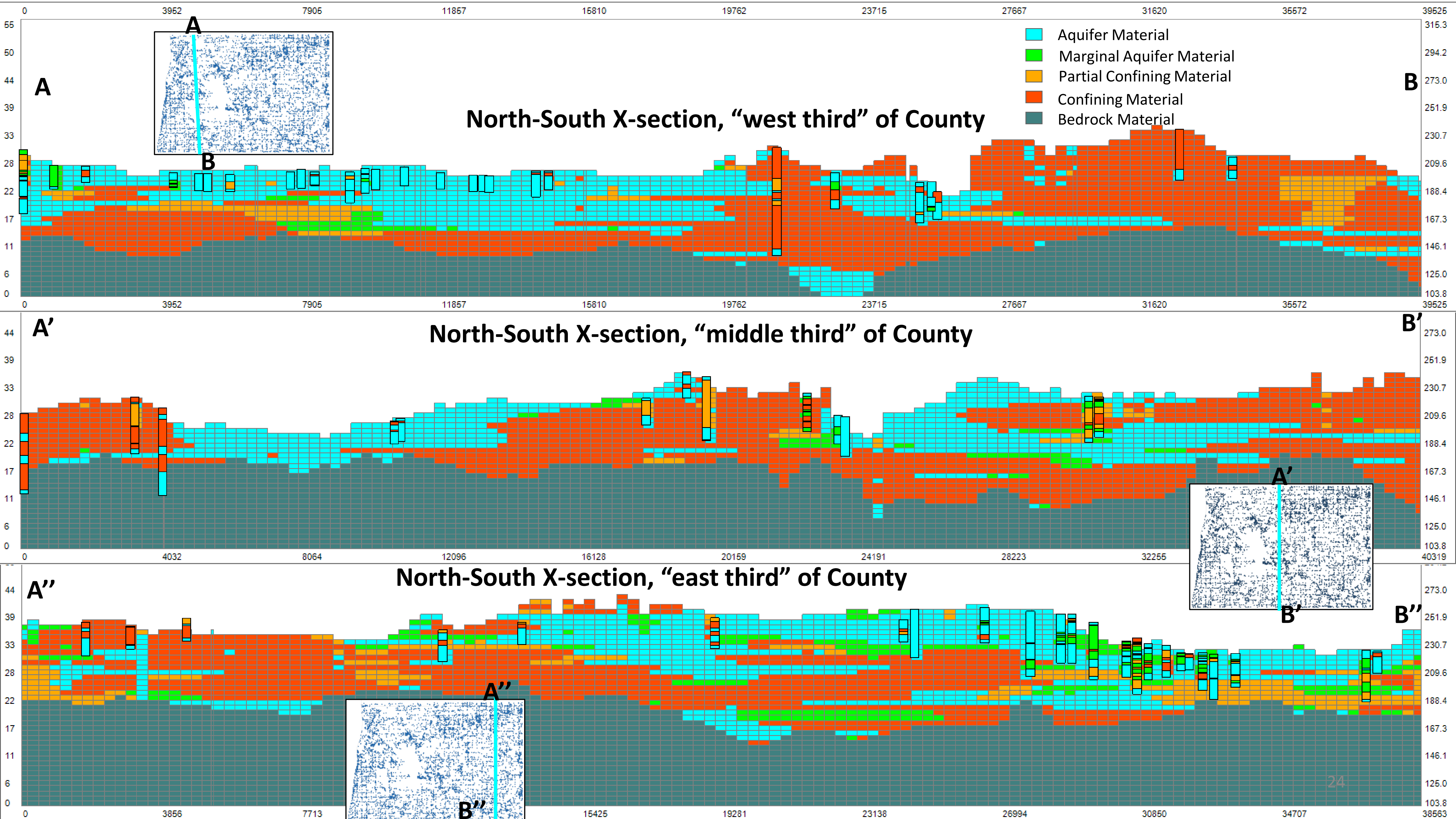
Transition Probability (TP) Geostatistical Simulation

3D Geologic Model

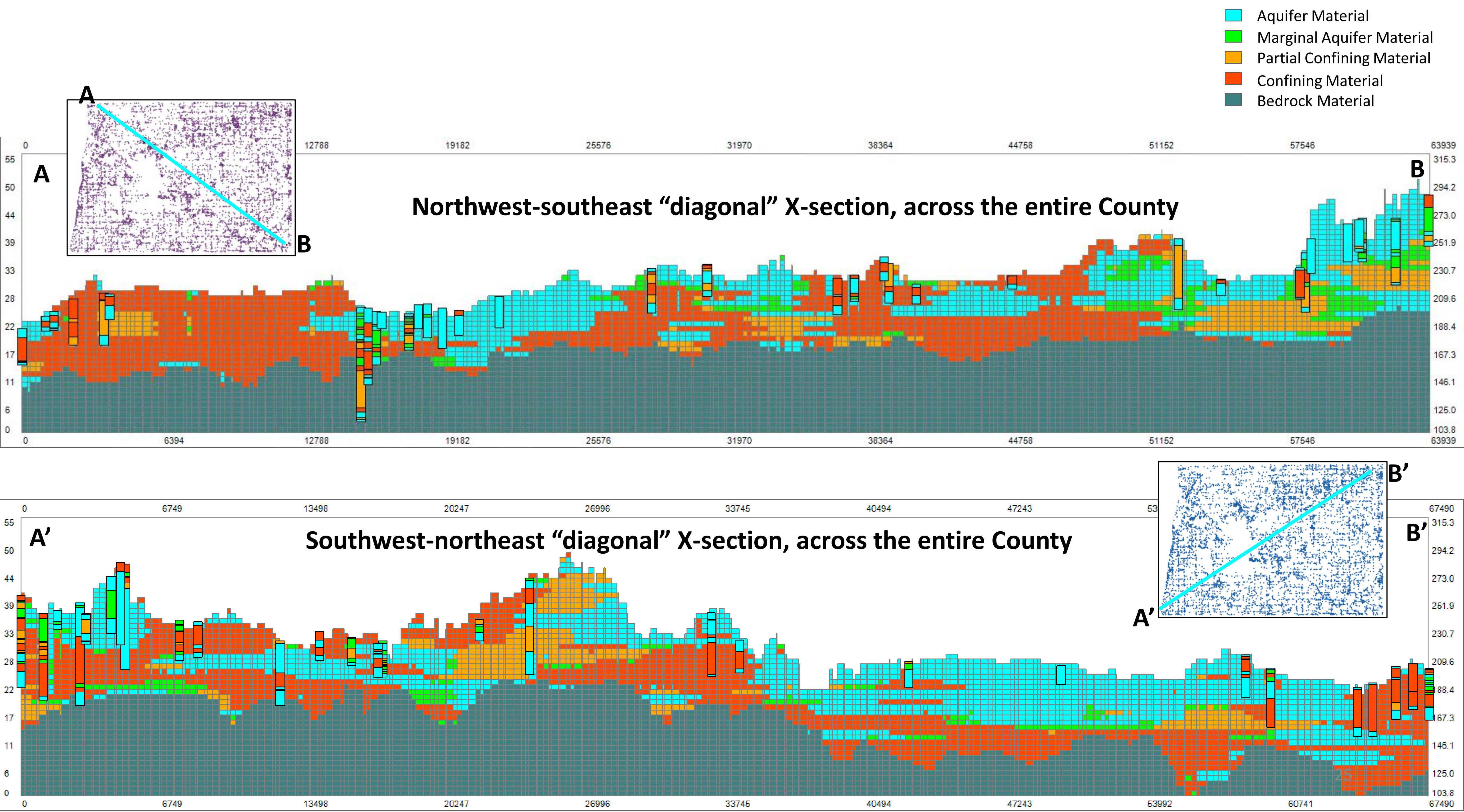


- Resulting 3D model is extremely useful:
  - water resources development and well siting (where to drill and at what depth)
  - protection of strongly connected streams and groundwater-dependent ecosystems
  - prediction of contaminant transport needed for pollution control.


West-East X-section, “upper third” of County
A
B
Aquifer Material
Marginal Aquifer Material
Partial Confining Material
Confining Material
Bedrock Material
0
5440
10881
16321
21762
27202
32643
38083
43524
48964
54404
55
50
44
39
33
28
22
17
11
6
0
315.3
294.2
273.0
251.9
230.7
209.6
188.4
167.3
146.1
125.0
103.8
West-East X-section, “middle third” of County
A’
B’
0
5708
11417
17125
22833
28541
45666
51374
57083
West-East X-section, “lower third” of County
A’’
B’’
0
5699
11398
17097
22796
28495
34194
39893
45592
51291
56990

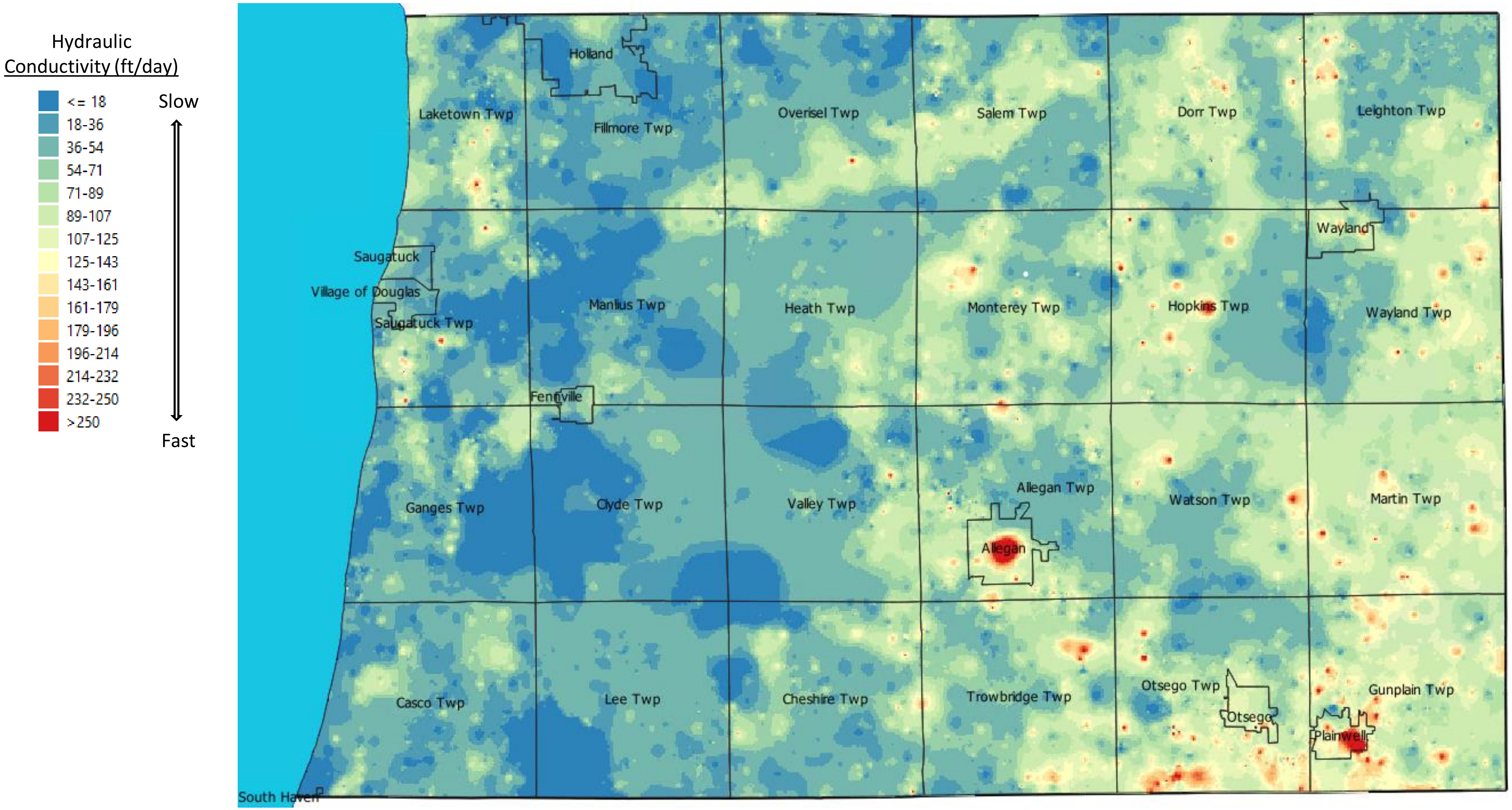


North-South X-section, “west third” of County
A
B
Aquifer Material
Marginal Aquifer Material
Partial Confining Material
Confining Material
Bedrock Material
0
3952
7905
11857
15810
19762
23715
27667
31620
35572
39525
55
50
44
39
33
28
22
17
11
6
0
315.3
294.2
273.0
251.9
230.7
209.6
188.4
167.3
146.1
125.0
103.8
North-South X-section, “middle third” of County
A’
B’
0
4032
8064
12096
16128
20159
24191
28223
32255
40319
North-South X-section, “east third” of County
A’’
B’’
0
3856
7713
15425
19281
23138
26994
30850
34707
38563



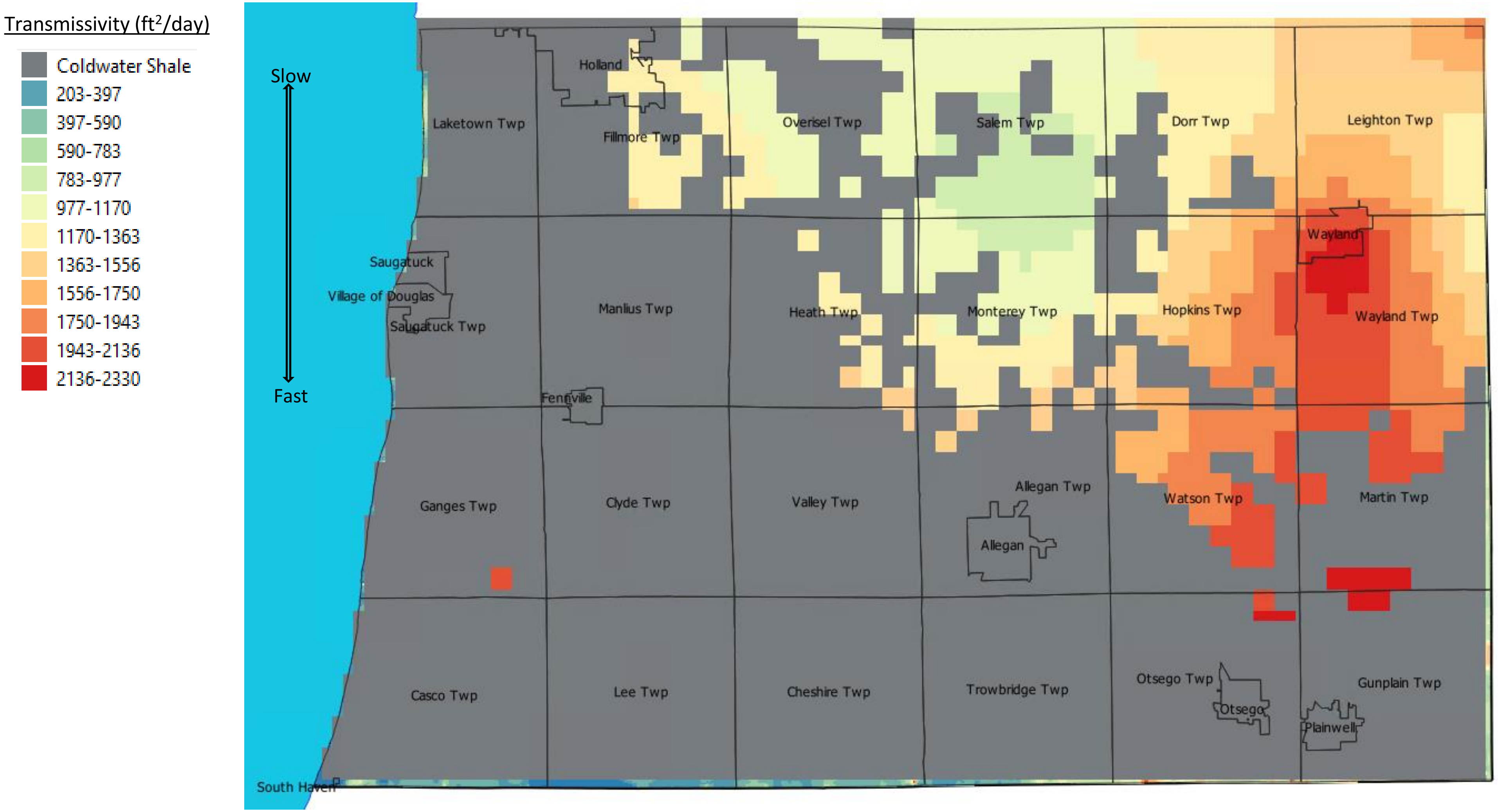
Aquifer Material
Marginal Aquifer Material
Partial Confining Material
Confining Material
Bedrock Material
A
B
Northwest-southeast "diagonal" X-section, across the entire County
A'
B'
Southwest-northeast "diagonal" X-section, across the entire County

Hydraulic Conductivity



- Hydraulic Conductivity (K) – a fundamental property of geologic materials => how fast groundwater moves
- *Vertically-averaged conductivity of the glacial aquifer shown here … vertical variability of K can range orders of magnitude

Transmissivity – Bedrock Aquifer



- Transmissivity (T) – product of conductivity and aquifer thickness (T=K*B) … controlling aquifer productivity
- Statewide perspective: T in Allegan County is low to very low … meaning impacts (e.g., drawdown) are more localized

Aquifer Yield

Hydraulic Conductivity ✓

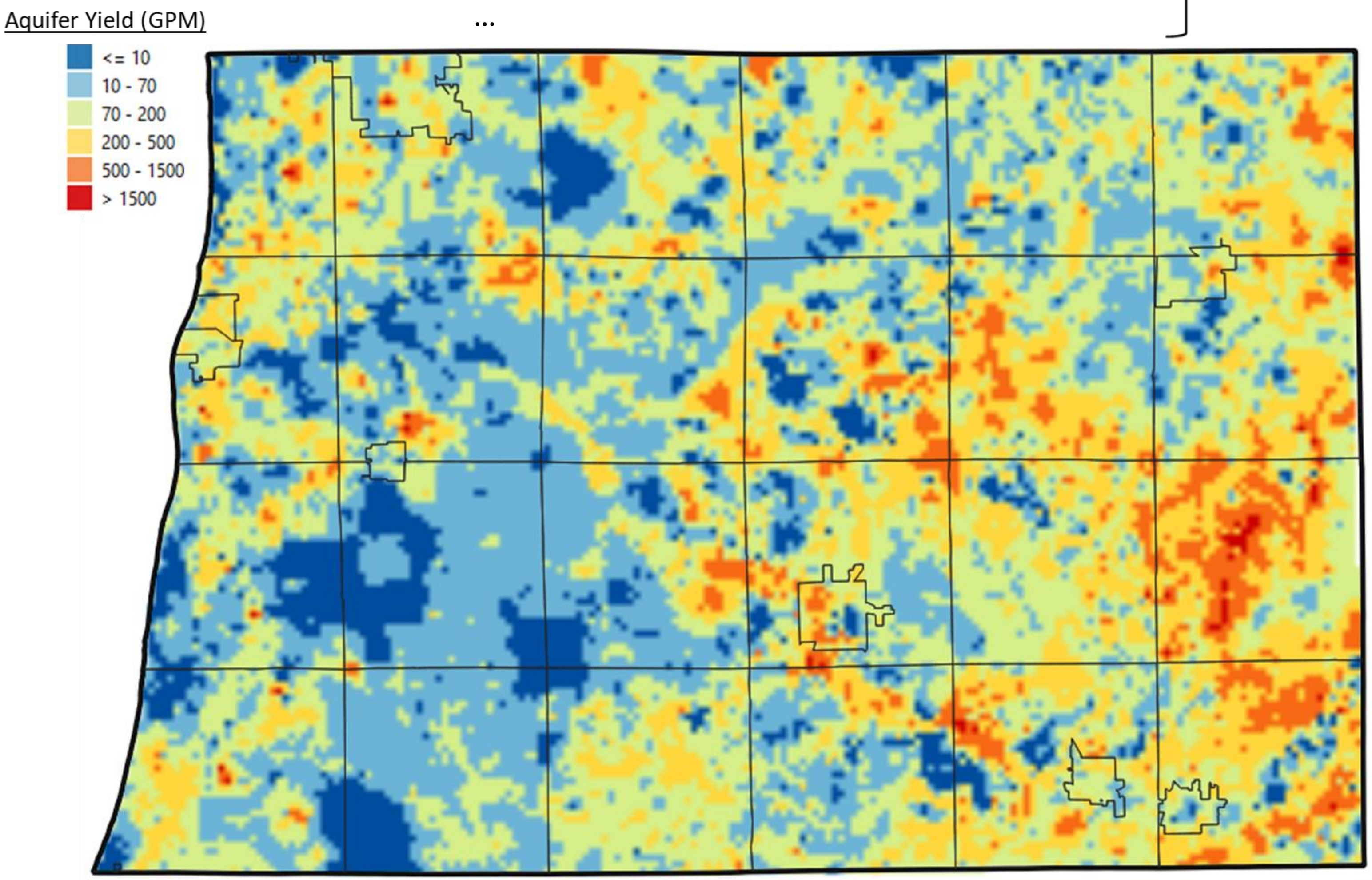
Saturated Thickness ✓ (SWL, Well Screen Depth)

Allowable Drawdown (50% of water available)

Assumed Well Efficiency (70% efficient)

…

→ Pumping Rate (AQ Yield)



- This map is useful for assessing the aquifer's ability to produce groundwater; note the significant spatial variability
- *Analysis assumes 2D flow to wells, but in reality … significant vertical flow with head loss => actual yield likely to be less

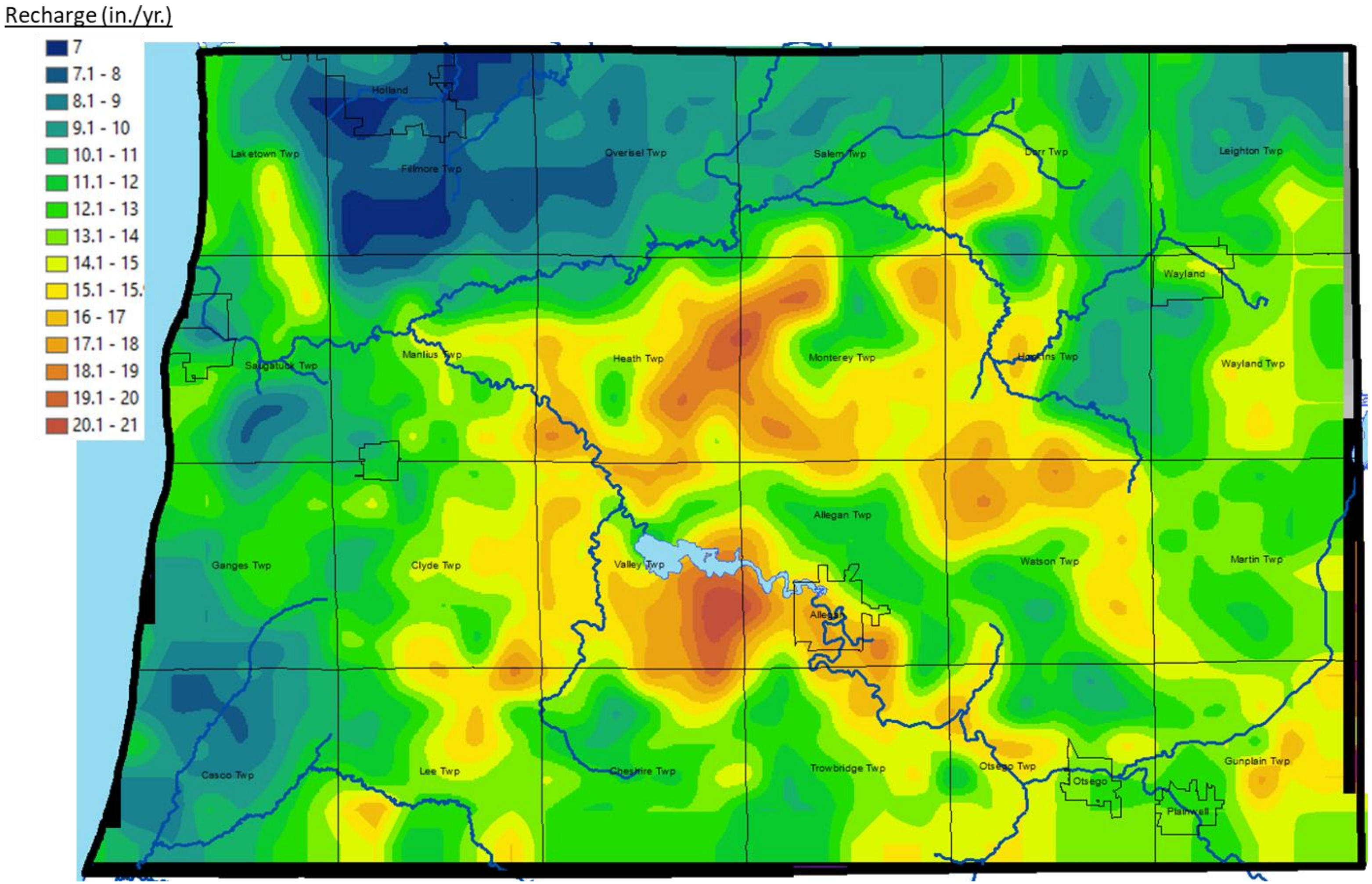
Long-term Sustainability of Groundwater Use

Depends on:

- Ability of aquifer to produce water (aquifer yield)

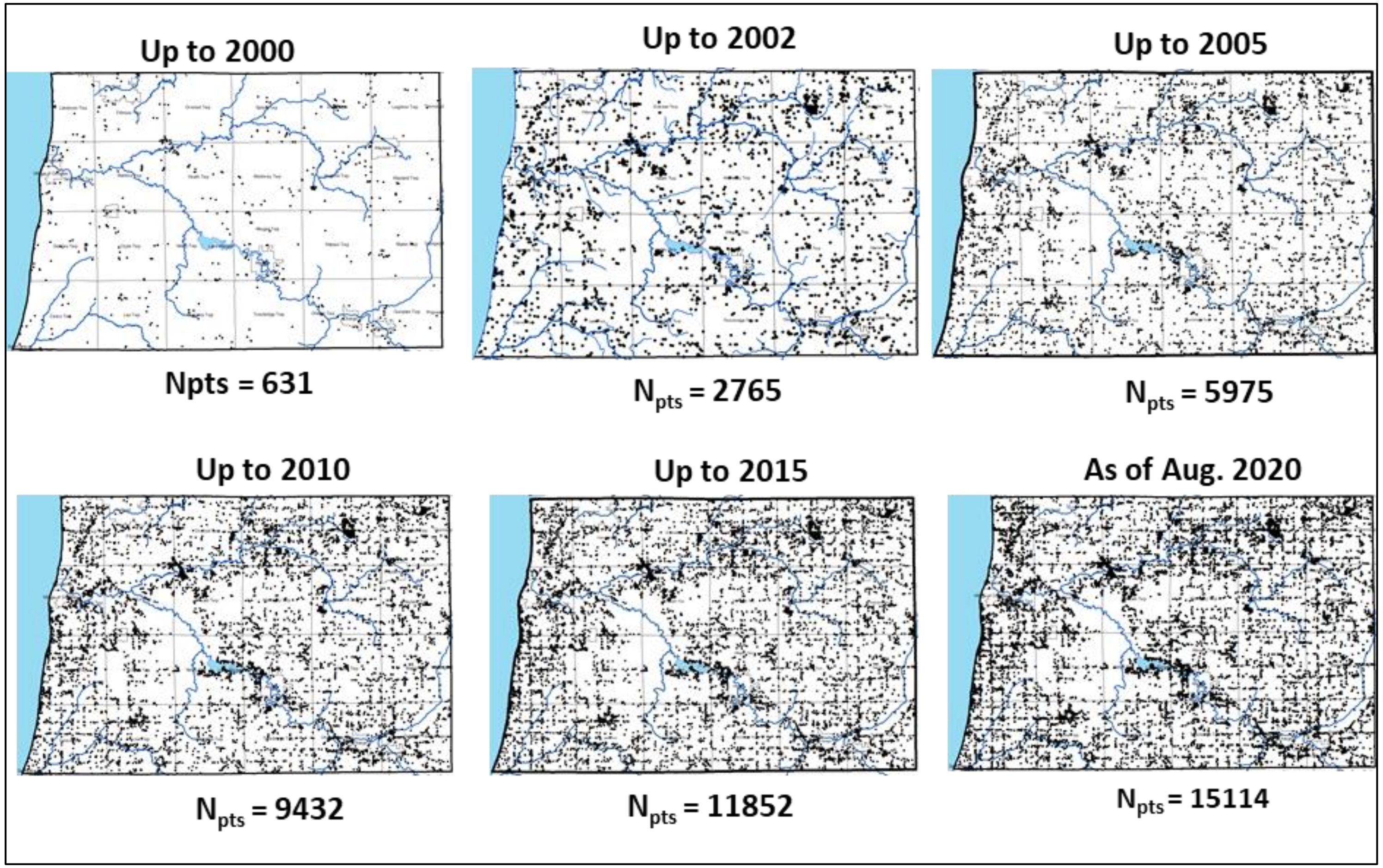
- **Aquifer Recharge distribution**
- **Cumulative Water Use Trends**

Long-term Mean Recharge Distribution



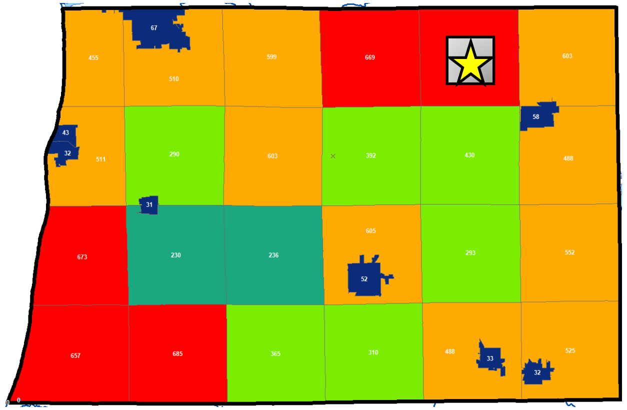
- Recharge = net infiltration of land surface water to water table; depends on climate, watershed characteristics, land use
- Important implications for management, e.g., assessing aquifer vulnerability to surface contamination

Increased Groundwater Use

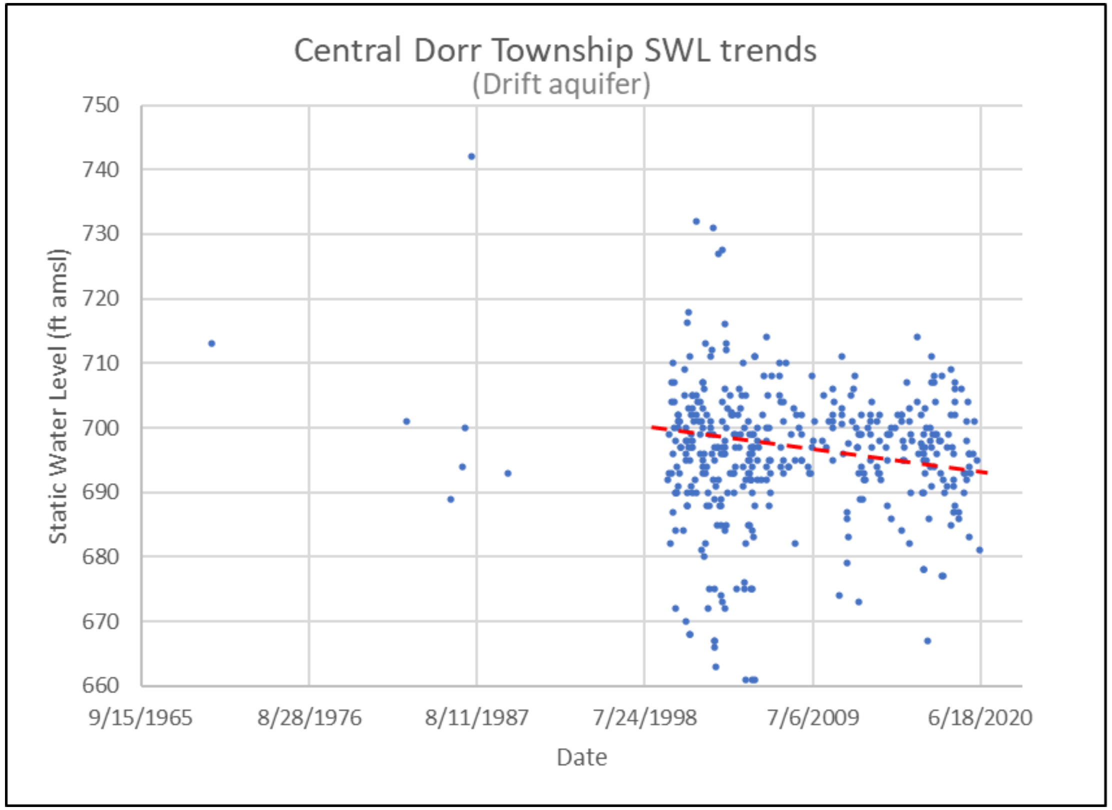


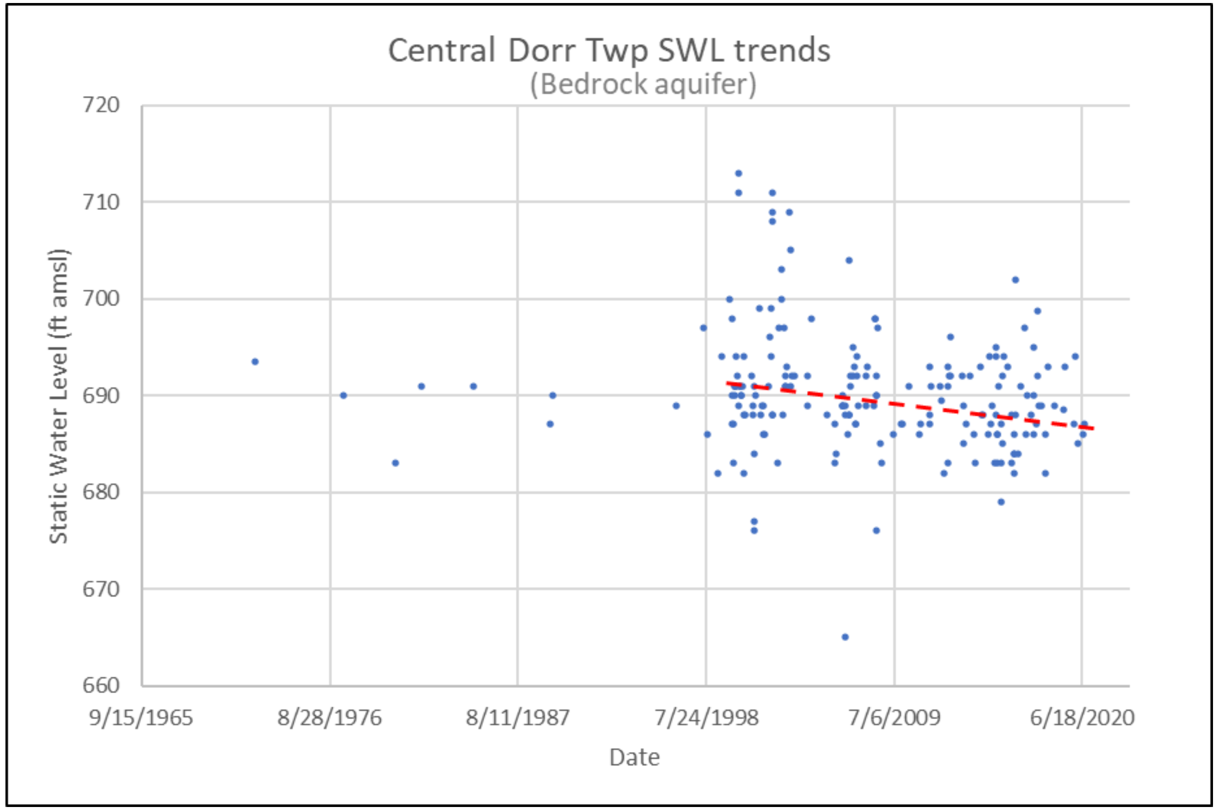
- Analysis of Wellogic records => significant increase in the number of wells, especially since 2000, in all parts of the county
- *Actual number of wells exceeds the estimates provided here … but spatiotemporal patterns are consistent with reality and very insightful for identifying areas of growth

Temporal Water Level Trends



Indication of long-term decline? (areas of increased groundwater use)





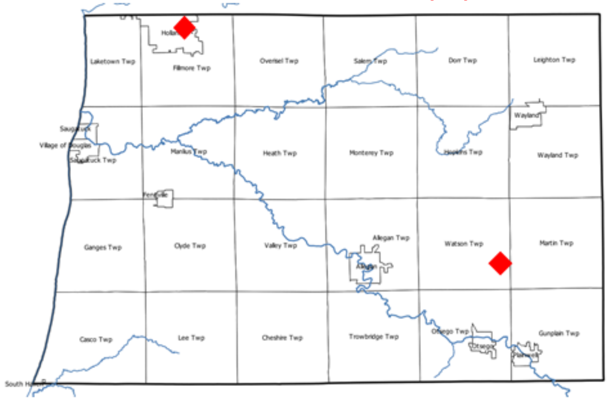
- Lack of long-term monitoring well data => analyze SWL data collected over sufficiently large area (w/ representative dates)
- If temporal decline is larger than SWL spatial variability and measurement "noise" … trend can be identified
- Systematic (e.g., township-wide) declines are not clearly observed … but hints of declines in some areas (must confirm)

Part 2: Water Quality

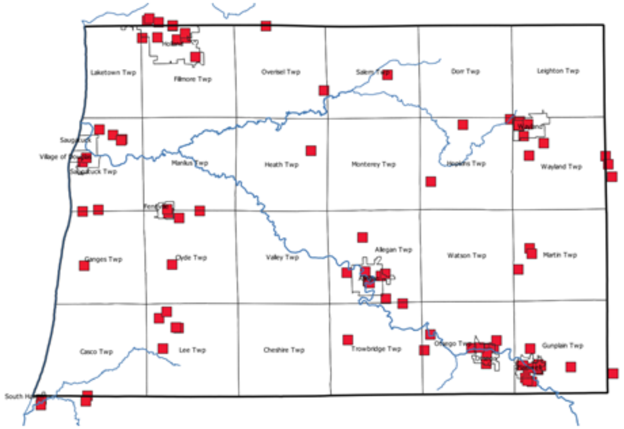
- Known and Potential Sites of Contamination
  - PFAS
  - Leaky Underground Storage Tanks
  - Landfills and Waste Handlers
  - Oil and Gas Wells
- Nonpoint Source Pollution
  - Nitrate
  - Chloride
  - Iron, Manganese, Sodium, Arsenic, and lead

Known & Potential Sites of Contamination

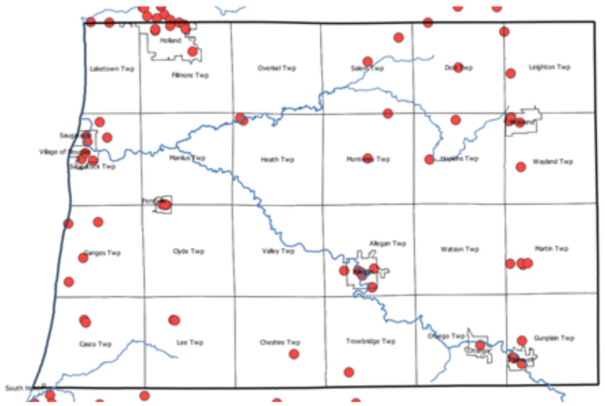
PFAS Sites (2)



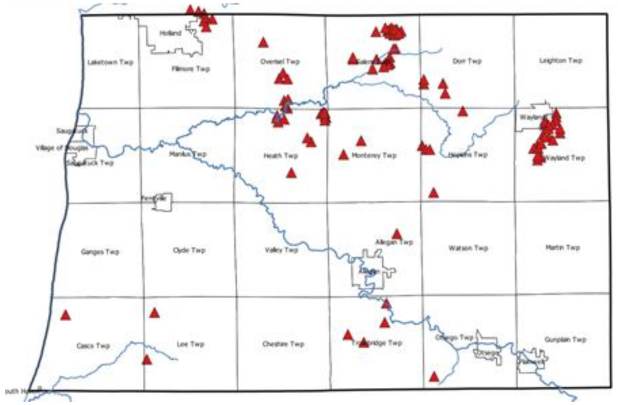
Sites of Environmental Concern (78)



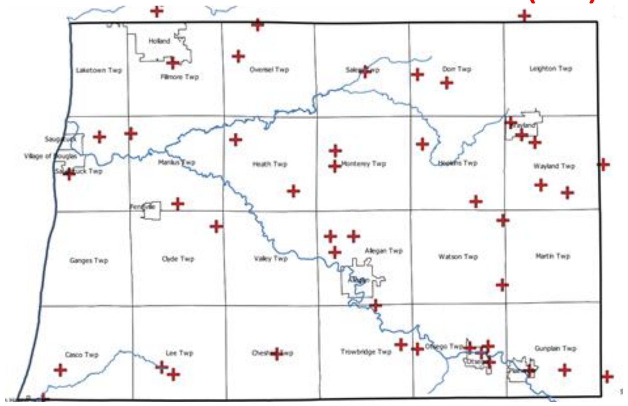
Leaky Underground Storage Tanks (168)



Oil and Gas Wells (94)

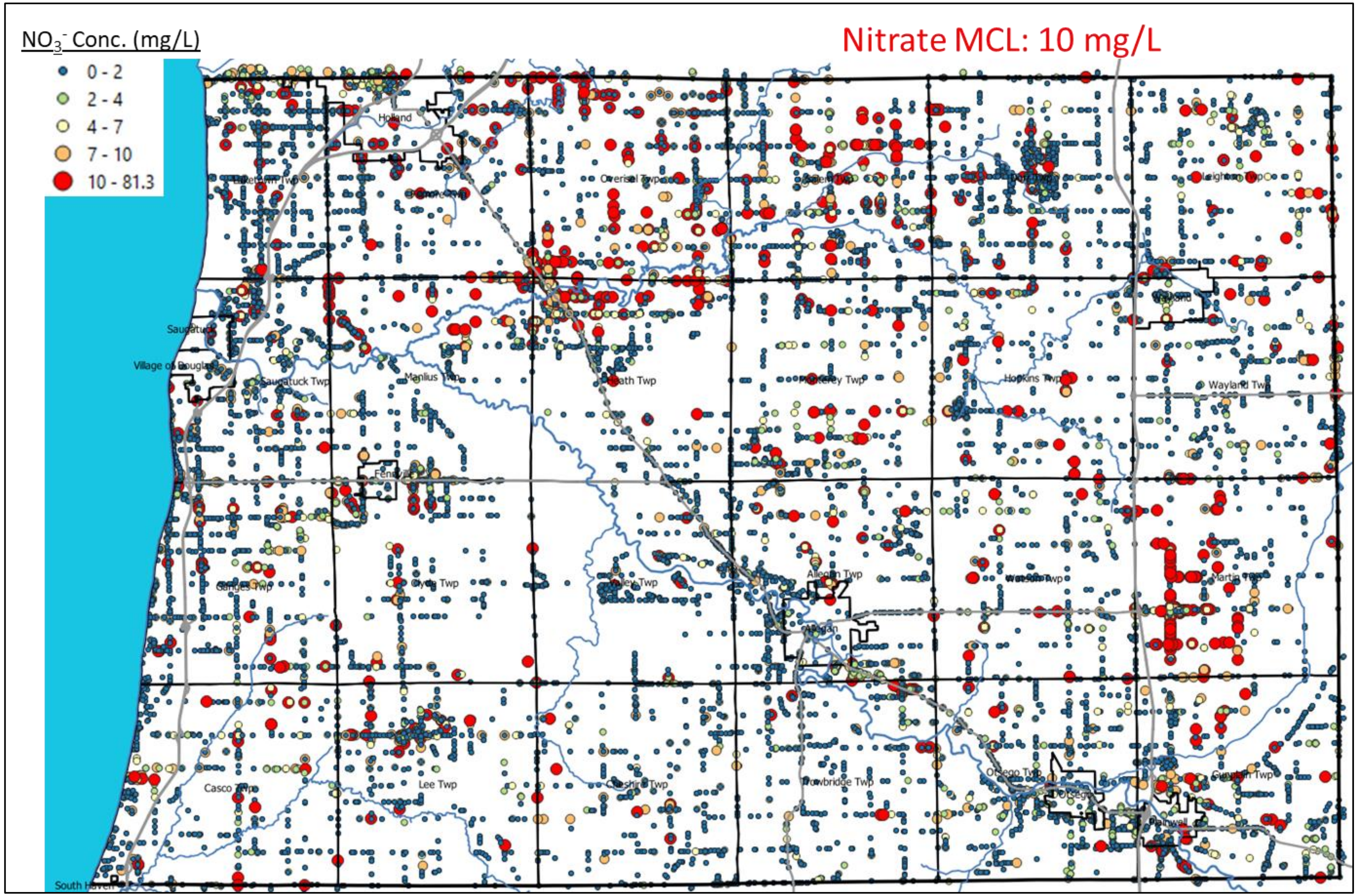


Landfills and Waste Handlers (41)



- Large number of sites means monitoring becomes very expensive => <u>prioritization is crucial</u>
- <u>Need to understand</u>: Where does a spill go? or, Where is the contamination coming from?

Nonpoint Source Pollution: Nitrate

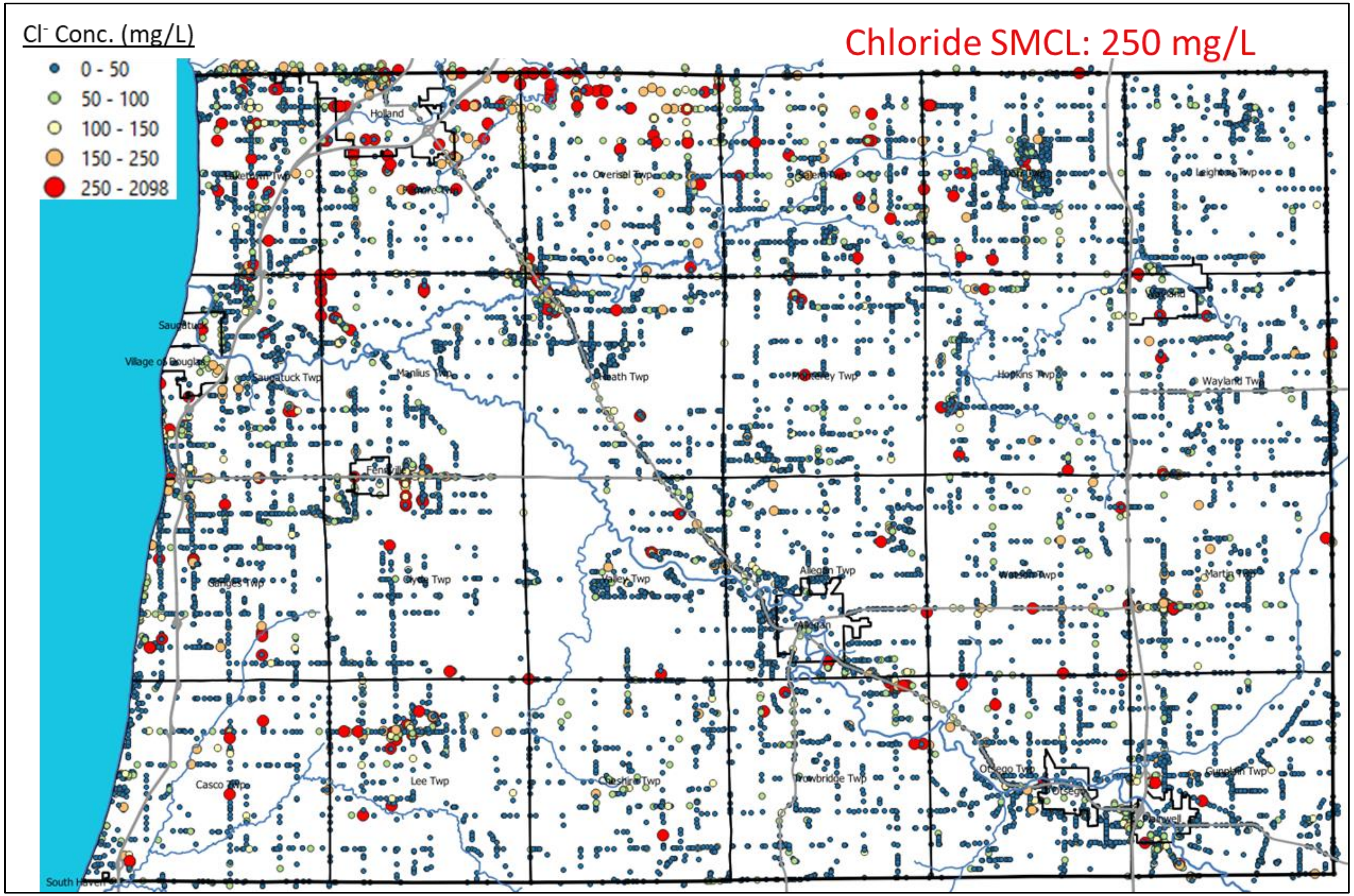


4% of samples above MCL of 10 mg/L; almost 10% are above 5 mg/L

“natural” concentrations: 2 mg/L or less)

- Nitrate concentrations are significantly elevated in the shallow aquifer (runoff from fertilizers, septic tanks / sewage)
- Nitrate concentrations above MCL are known to have adverse impacts on human health (e.g., methemoglobinemia)

Nonpoint Source Pollution: Chloride

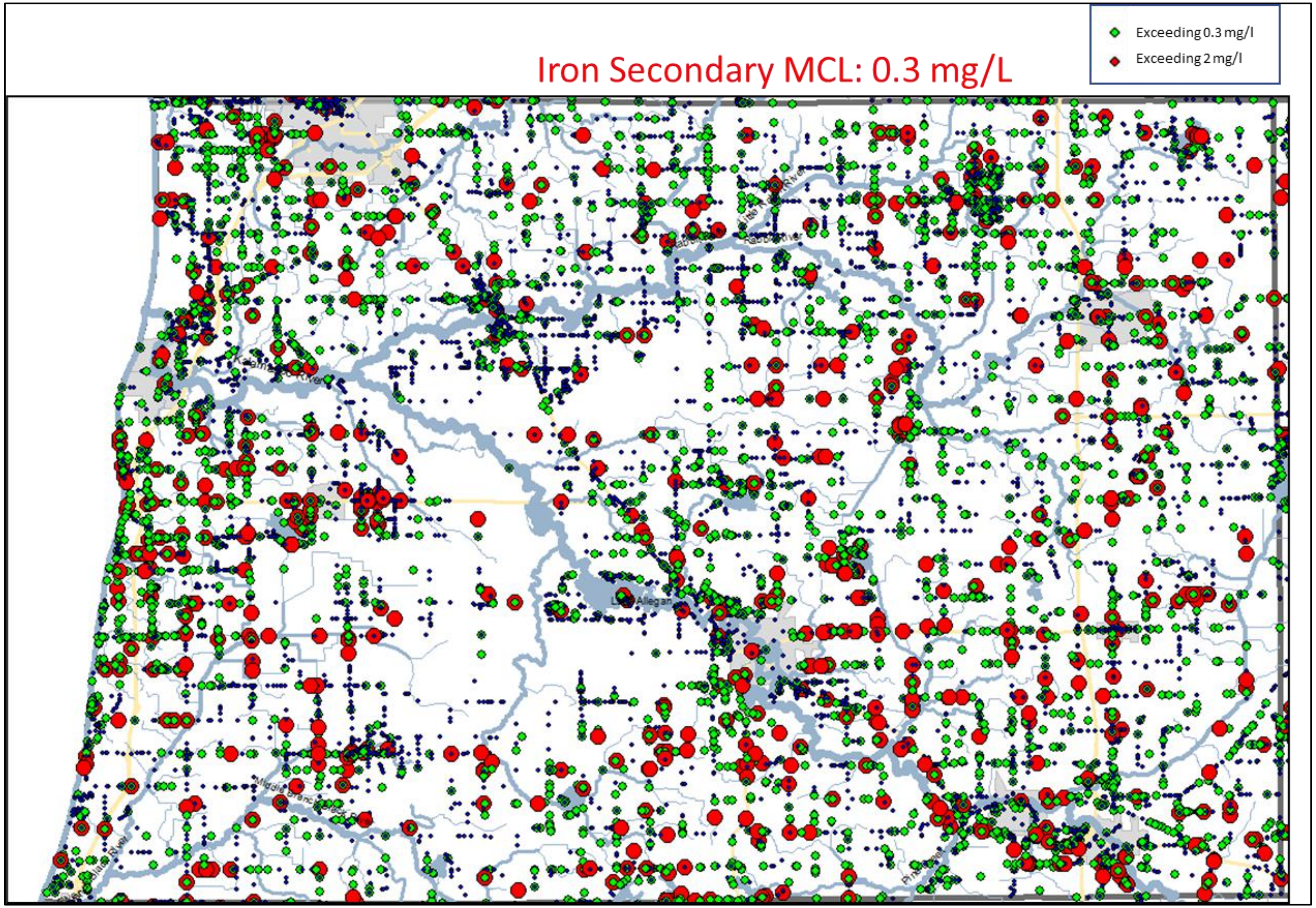


8% of samples are clearly elevated (>100 mg/L);

"natural" concentrations expected to be 15 mg/L or less

- Suspected impact to Allegan County, particularly in groundwater discharge areas => risk to agriculture;
- Road salts, septic tank effluent, fertilizers may have an impact…
- But we suspect mixing of deep brine with shallow groundwater is the main culprit … documented in other major discharge areas across Michigan, including the neighboring Ottawa County

Nonpoint Source Pollution: Iron, Manganese, Sodium, Arsenic and Lead



- Iron and manganese concentrations commonly exceeding Secondary MCL related to color and/or staining and metallic taste
- Lead and arsenic concentrations above legally enforceable standards are found in a few isolated placed across the county

Part 3 – Recommendations for Future Work

- Interactive Decision Support System
- Examples:
  - Contaminant Impact Area Evaluation
  - Wellhead Protection Area (WHPA) Delineation

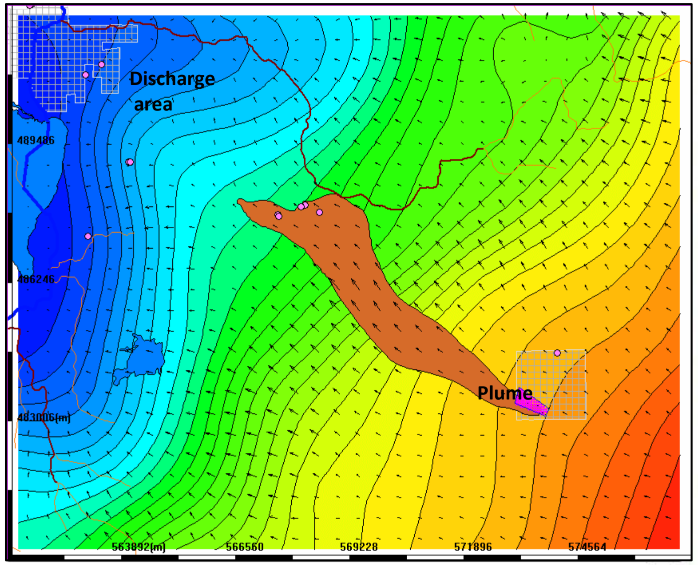
Interactive Decision Support System

<u>Zoom into any location in the county to:</u>

- **Visualize the complex 3D geology of the subsurface**, including the borehole lithologies and the results from the 3D transition probability geology model.
- **Map groundwater level distributions, flow directions and patterns** in both the shallow glacial aquifer and, where applicable, the deeper bedrock aquifer;
- **Assess vulnerability of a proposed development** to insufficient water supply by mapping / analyzing sustainable yield;
- **Map contributing source water areas / capture zones / "groundwater-sheds"** for pumping wells and groundwater-fed streams and wetlands, which is critical for holistic management of aquifer protection, wellhead protection and ecosystem protection;
- **Map contamination sites, nonpoint source contamination, environmental receptors and potential impact areas** of emerging contaminants (e.g., PFAS);
- **Map aquifer recharge areas and discharge areas to assess aquifer vulnerability** (or sensitivity) to surface contamination or saline upwelling, respectively;
- **Design monitoring well networks** for sampling water quantity (levels, fluxes) and water quality; and
- **Create 2D and 3D integrated overlays** of raw, derived, and simulated data layers.

Contaminant Impact Area Evaluation

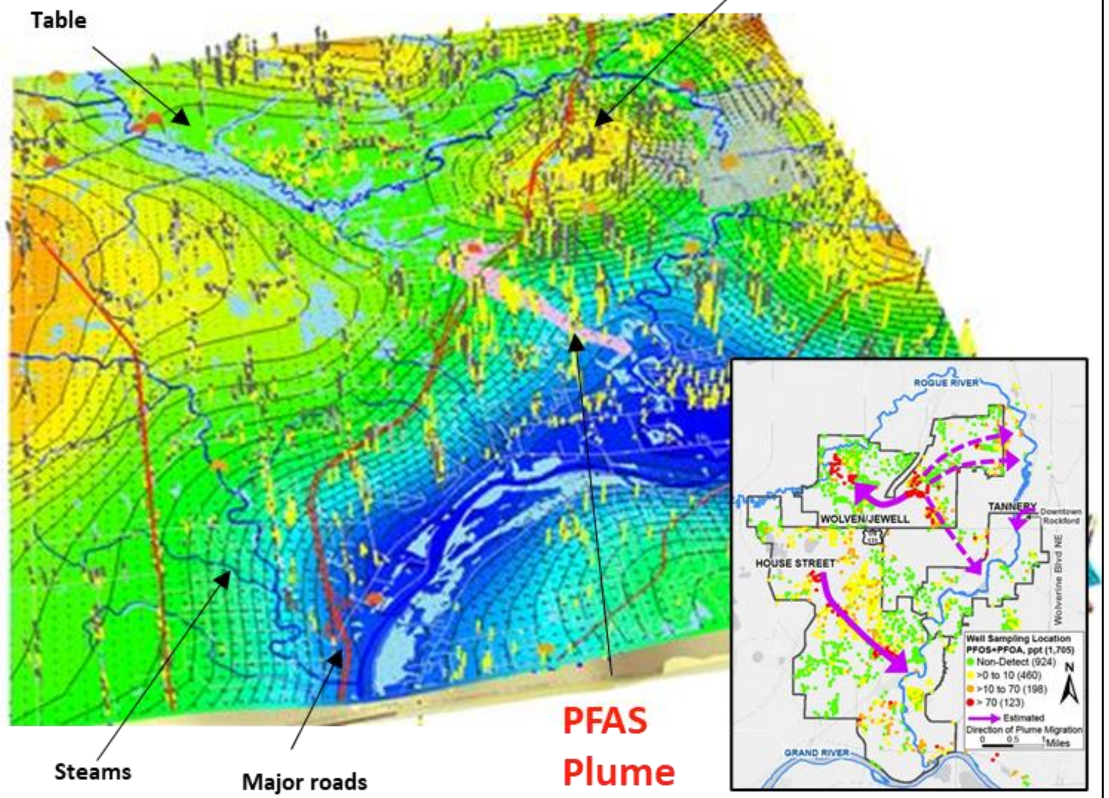
TCE plume, Mancelona MI



TCE plume delineation by the new approach matches closely with the traditional approach (hydrogeological site investigation).

Pink: Impact area for new approach, using existing data
Dark red: Impact area for traditional approach (hydrogeological site investigation)

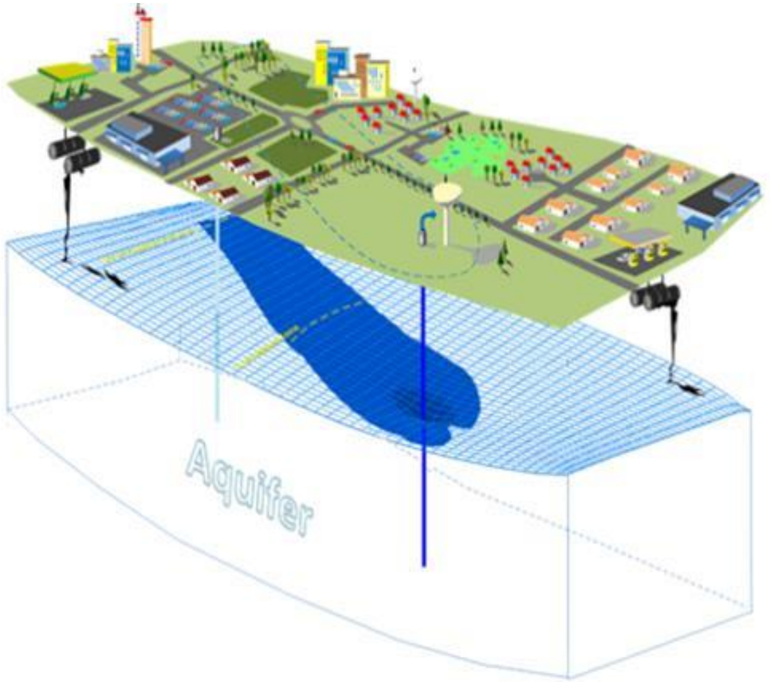
House St. PFAS Plume

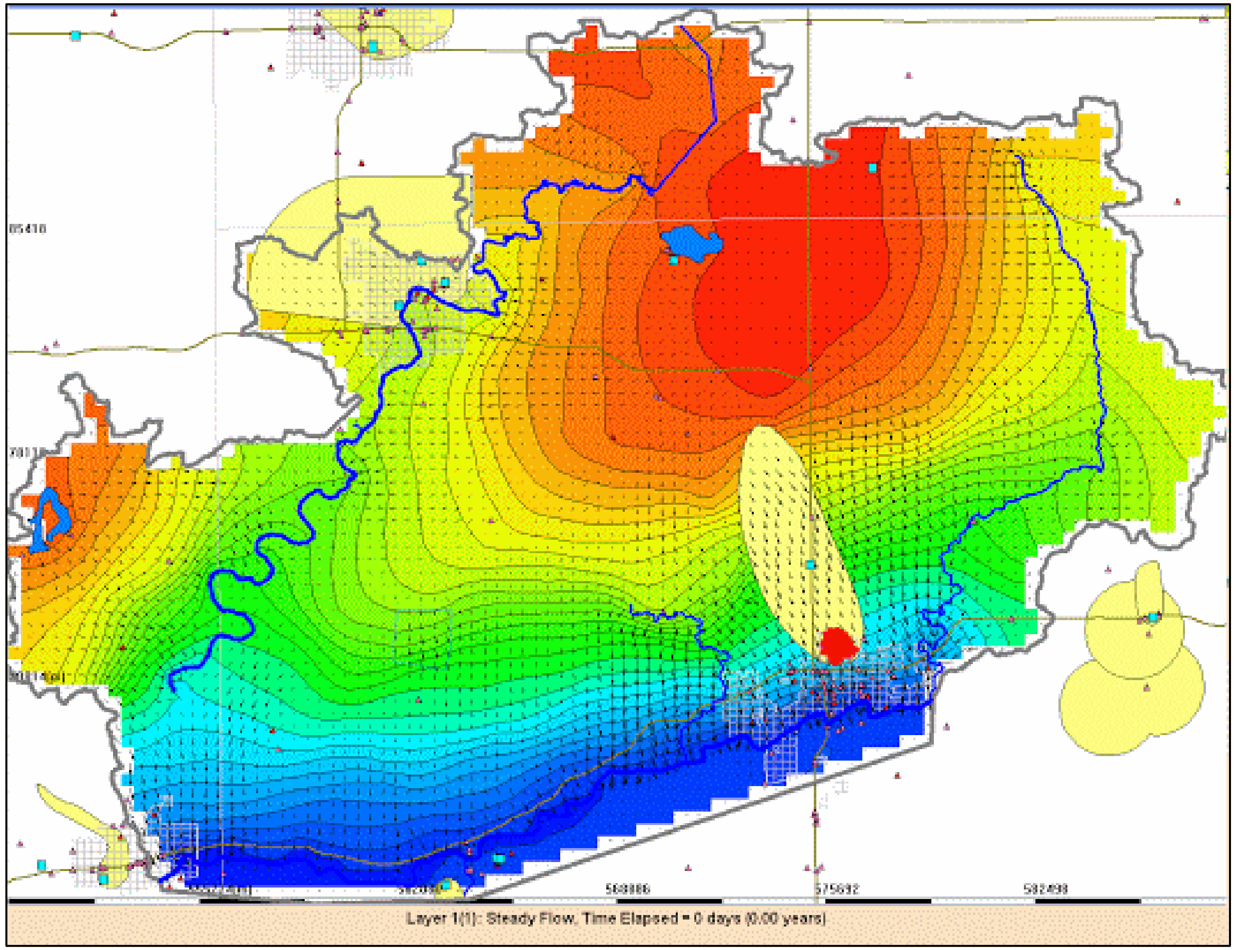


PFAS plume delineated by EGLE; direction / migration consistent with flow patterns derived from existing water well data

- Examples of forward contaminant particle tracking .... If a spill occurs, where does it go, and how long will it take?
- Interactive decision-support system can make use of existing layers to get flow direction and speed (water table patter, K)

Wellhead Protection Area (WHPA) Delineation





- Examples of backward particle tracking …. If a contaminant is found, where did it come from, and how long ago was it released?
- But also for source water protection (wellhead protection area – WHPA – and ecosystem protection)

Questions and Discussion