Michigan Has Plenty of Groundwater -Or Does It?

(The Myths of Groundwater Abundance in Michigan)

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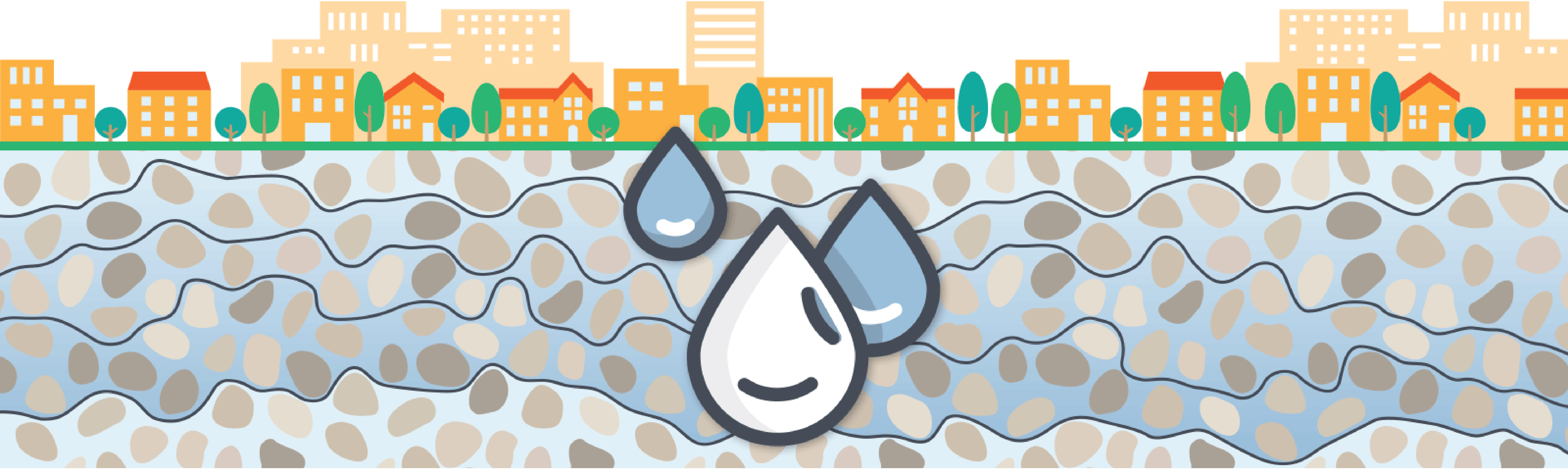


Grand Valley State University
Robert B. Annis Water Resources Institute

Image: Punarbharan Foundation

Outline

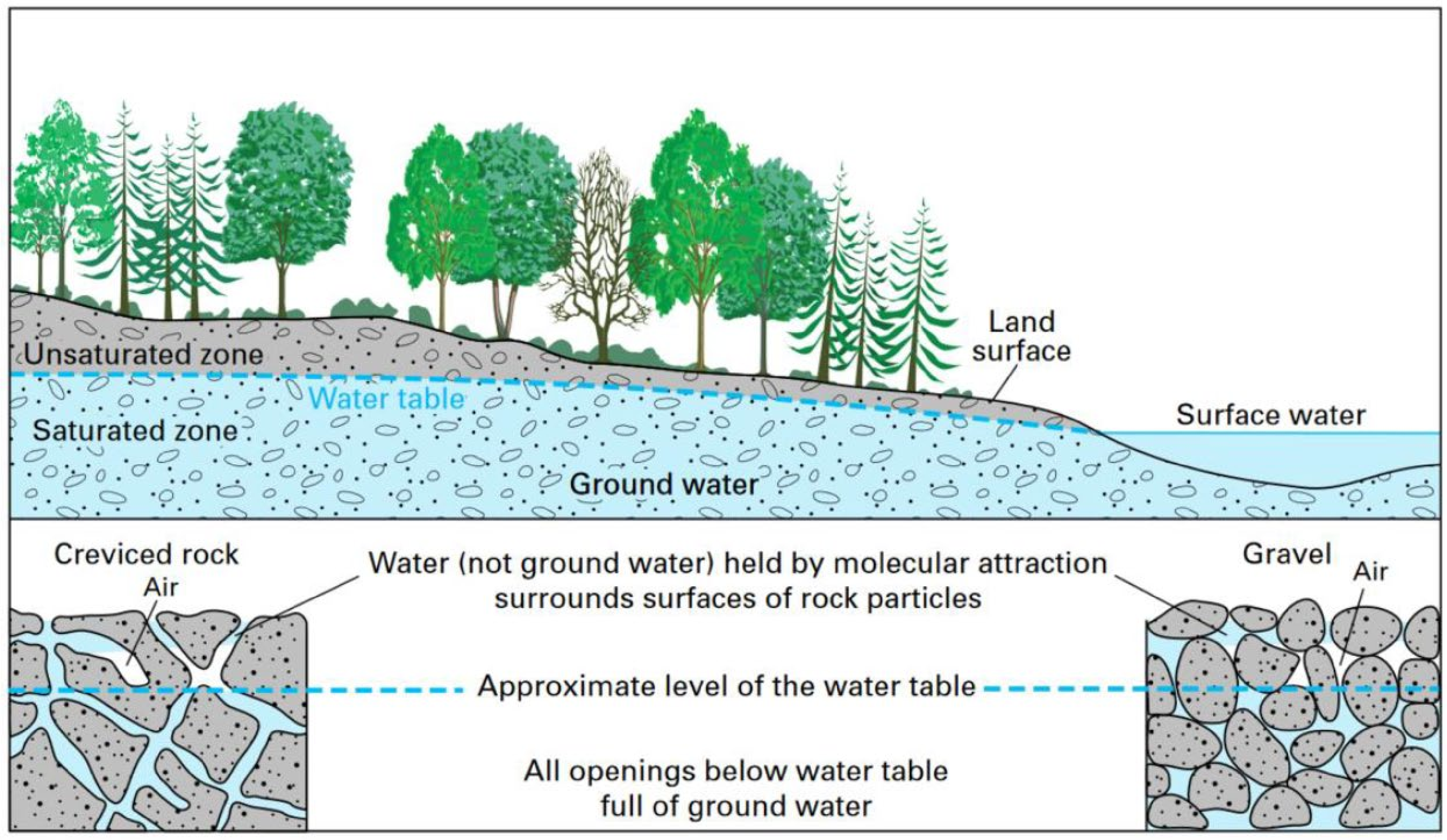
- Groundwater 101
- Groundwater in Michigan
- Groundwater Concerns
- Recommendations

Groundwater Statistics: US

- ~ % of US freshwater supply is groundwater
- Groundwater accounts for 20% of total US water use; > 80 billion gallons of groundwater are withdrawn daily in the US
- % of Americans drink groundwater
- Groundwater provides more than 50 billion GPD in support of the nation’s agricultural production

Aquifers

Underground geologic formation through which water can percolate, sometimes very slowly



Source:
USGS Water Science School

Aquifers

Geological Formations:

- <u>consolidated</u>: tightly bound geologic formation composed of sandstone, limestone, granite, or other rock; very low water-yielding formations due to almost impervious nature of rock

- <u>unconsolidated</u>: loosely bound geologic formation composed of sands and gravels

Tight or Loose?

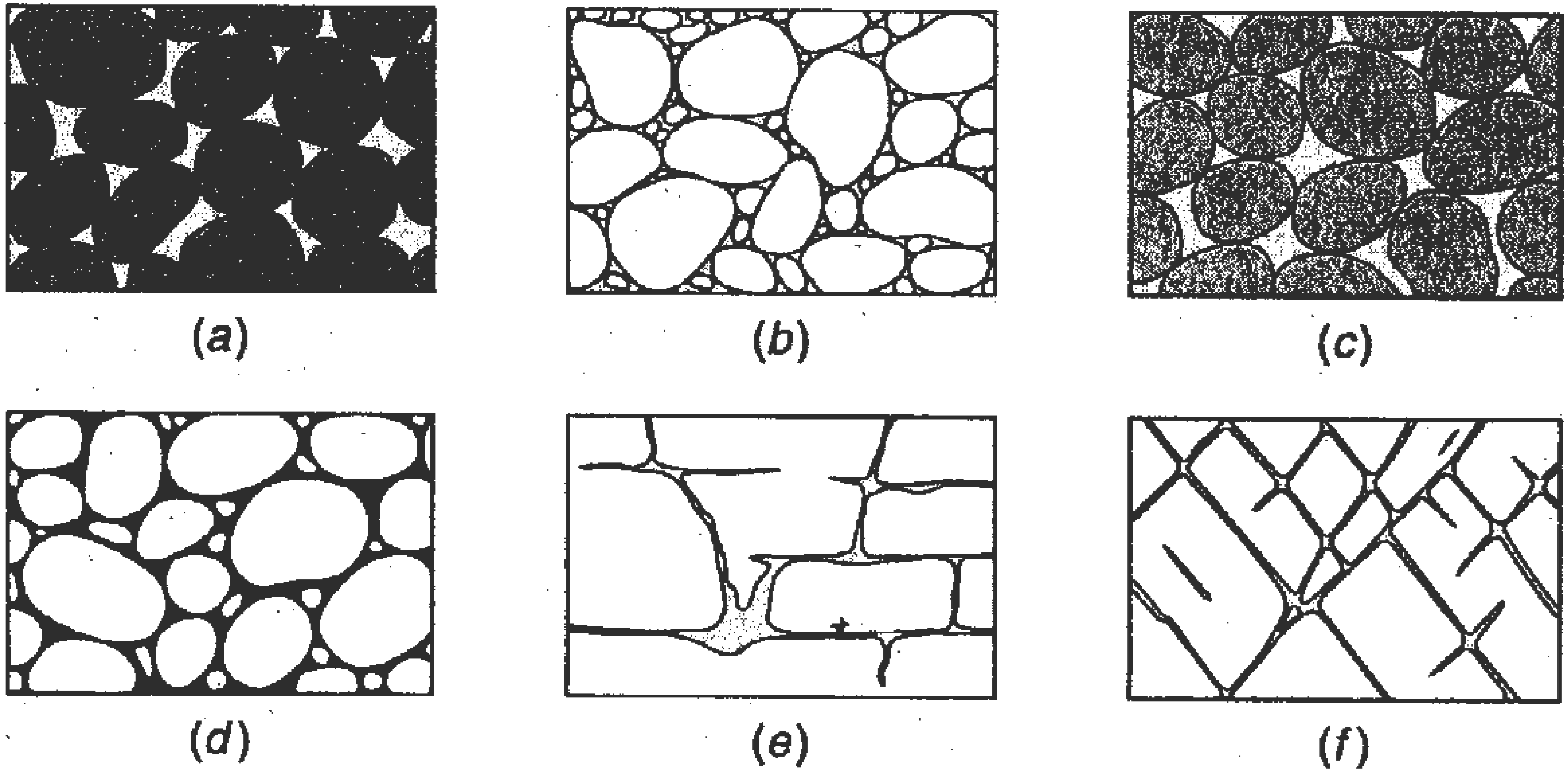
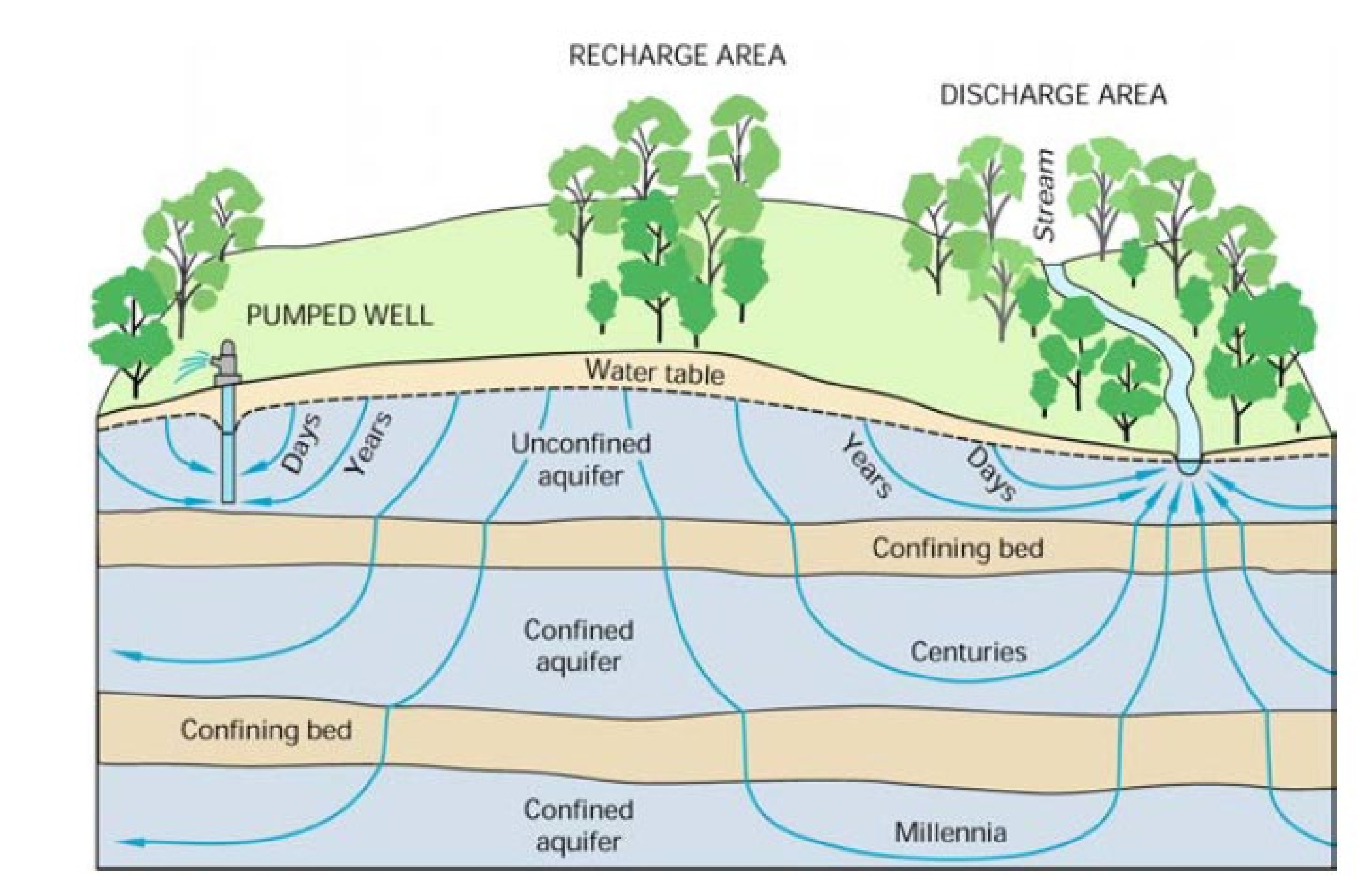


Figure 4.II

Groundwater Movement

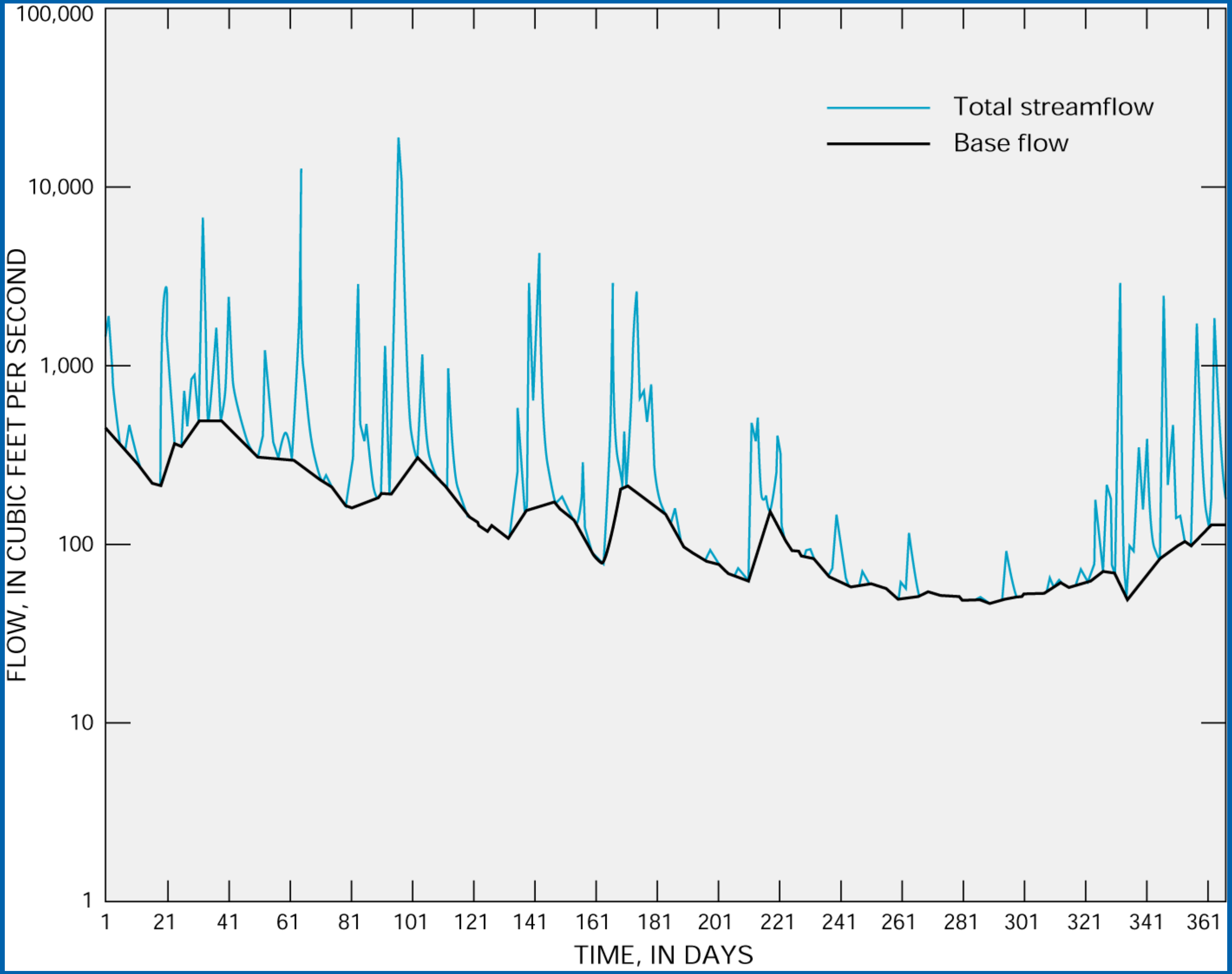
- Hydraulic Conductivity: measurement of the rate of flow of a fluid through porous material

- Measured as a rate of movement
  - inject dye into monitoring well and measure time for dye to move to next monitoring well



Source: USGS Circular 1139

Groundwater-Surface Water



Groundwater always part of the flow in most rivers; many times it is the only flow

Source: USGS Water Science Center, Lansing, MI

Water Replenishment

- Groundwater recharge:
  - downward movement of water from the land surface, into and through, upper soil layers

- Rates depend on:
  - geology (slow if material tightly packed)
  - terrain (low in areas with impervious surfaces)
  - climate
  - vegetative ground cover

Global Groundwater

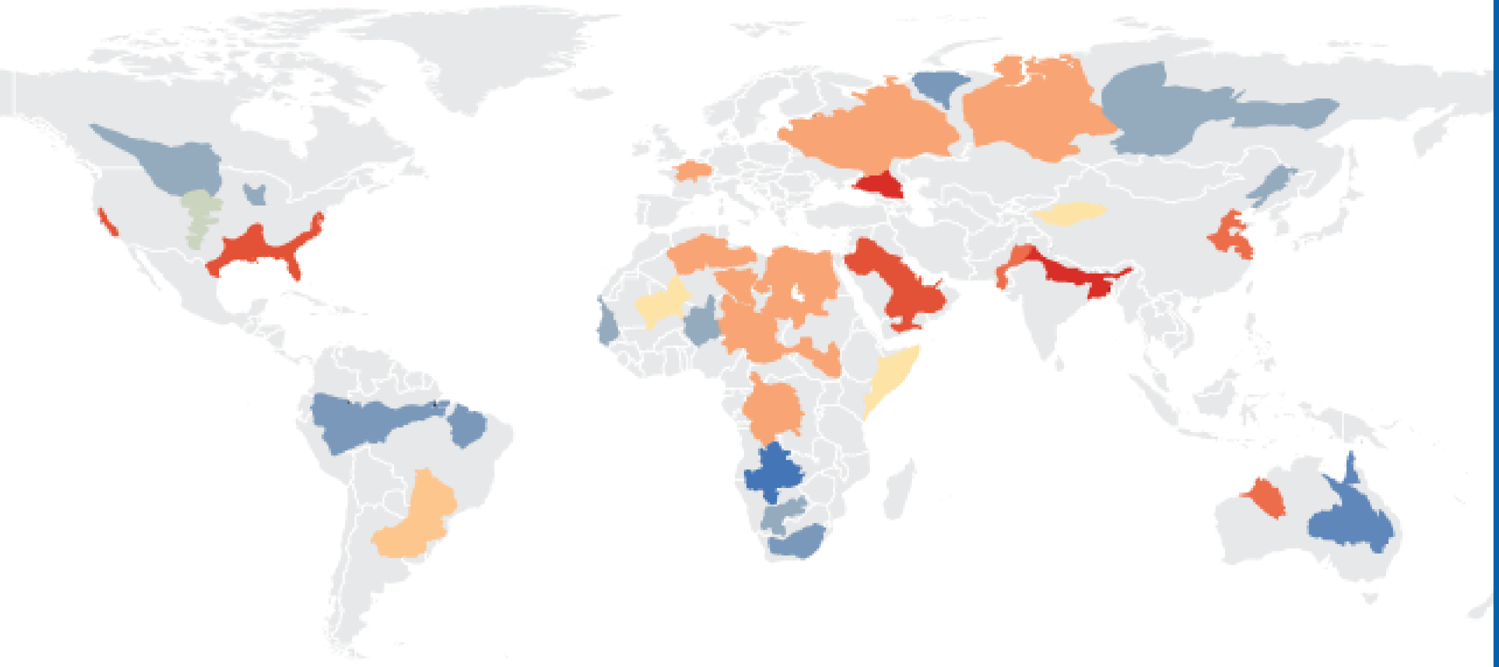
Gravity **R**ecovery **a**nd **C**limate **E**xperiment

NASA’s GRACE mission measures groundwater changes from space.

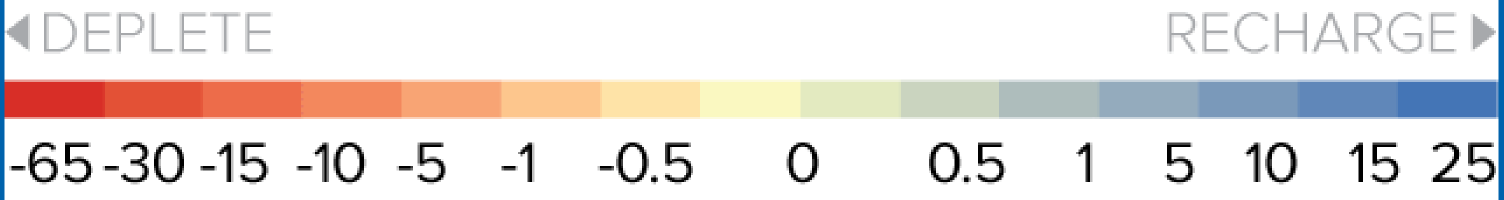
Estimates changes in the amount of water stored in a region by observing changes in the Earth’s gravity field due to changes in mass of earth.

NASA SATELLITE FINDS STRESSED AQUIFERS

The GRACE satellite system found that a majority of the world's groundwater aquifers are being depleted faster than they can recharge.



YEARLY TREND IN AQUIFER WATER LEVELS (in mm)



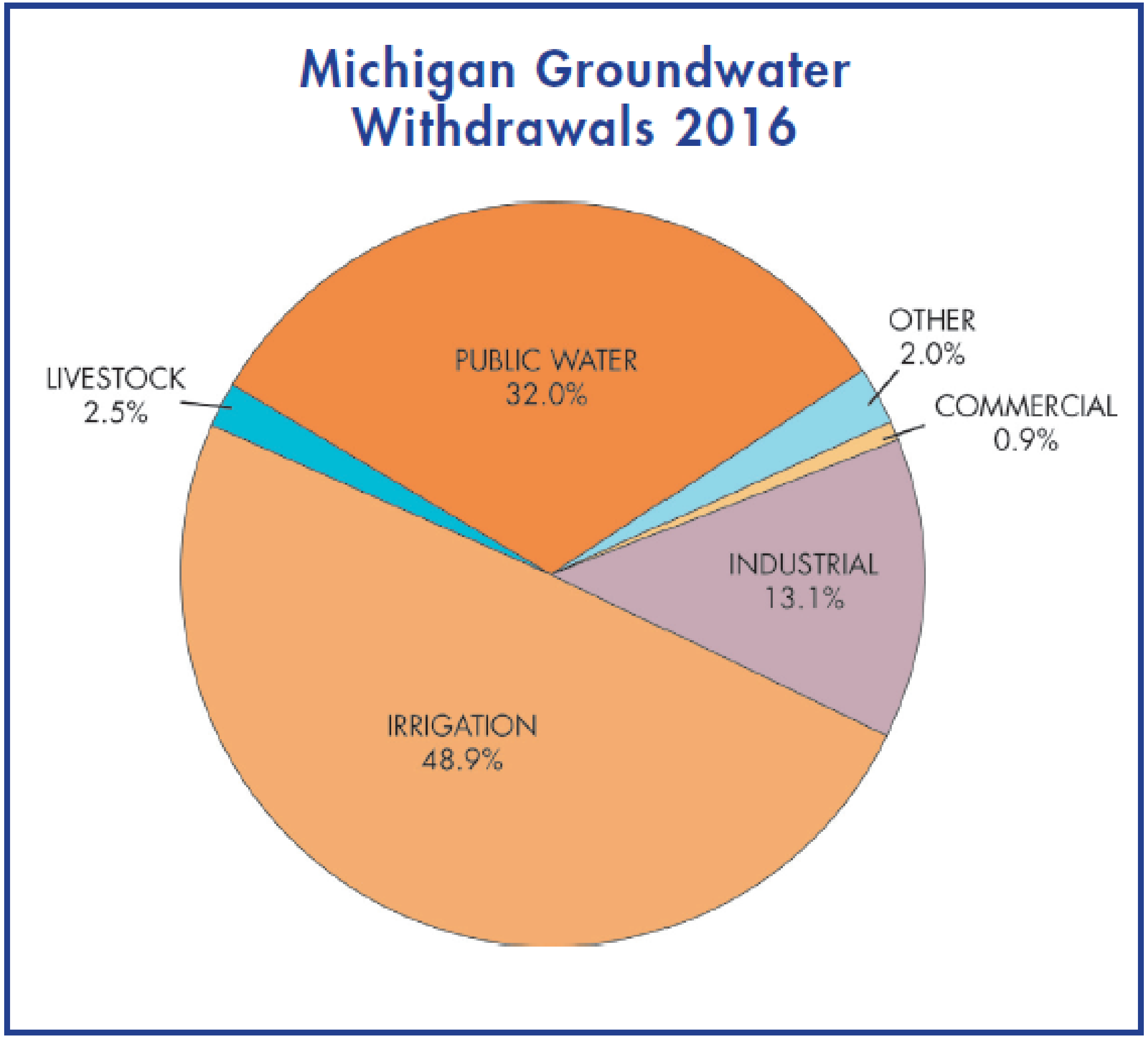
Groundwater in Michigan

Groundwater is one of MI's most important natural resources

- Public Water Supply:
  - 45% of Michiganders use groundwater as a drinking water source
  - 1.25 million private wells serve 2.6 million citizens
  - 12,038 public (community and noncommunity) wells serve 1.7 million citizens
- Groundwater: significant water source for Industry & Ag
- Groundwater is a major contributor to streams, inland lakes and wetlands, and Great Lakes coastal wetlands

What sector is the biggest user of groundwater in MI?

1. Public Water
2. Agriculture
3. Industry
4. Other



Source: MSU Extension
(http://msue.anr.msu.edu/resources/water_withdrawals_and_water_use_in_michigan_wq62)

Groundwater Threats in Michigan

- There are an estimated **26,000 groundwater contamination sites** that need state funding for cleanup; it will take decades to address at current funding.

- ~1.25 million private water wells supply drinking water to > 2 million Michiganders, but there is **no regular safety testing** of that water.

- **High-risk toxic chemicals**, including TCE, which has contaminated groundwater in >300 known Michigan locations, are still in widespread use.

- Michigan is the only state within the USA that does not currently have a statewide septic code.

- Only ... ted local
regulat ... ections.
- Abou ... anks that
were c ... out
Michig ... e,
househ ... d other
polluta ... e water).

MI **House Bills 5732 and 5733** would require MI’s 83 county governments to fund, develop, implement, and administer a program designed to help ensure that "on-site wastewater treatment systems" are properly located, built, tested, and inspected on a regular basis.

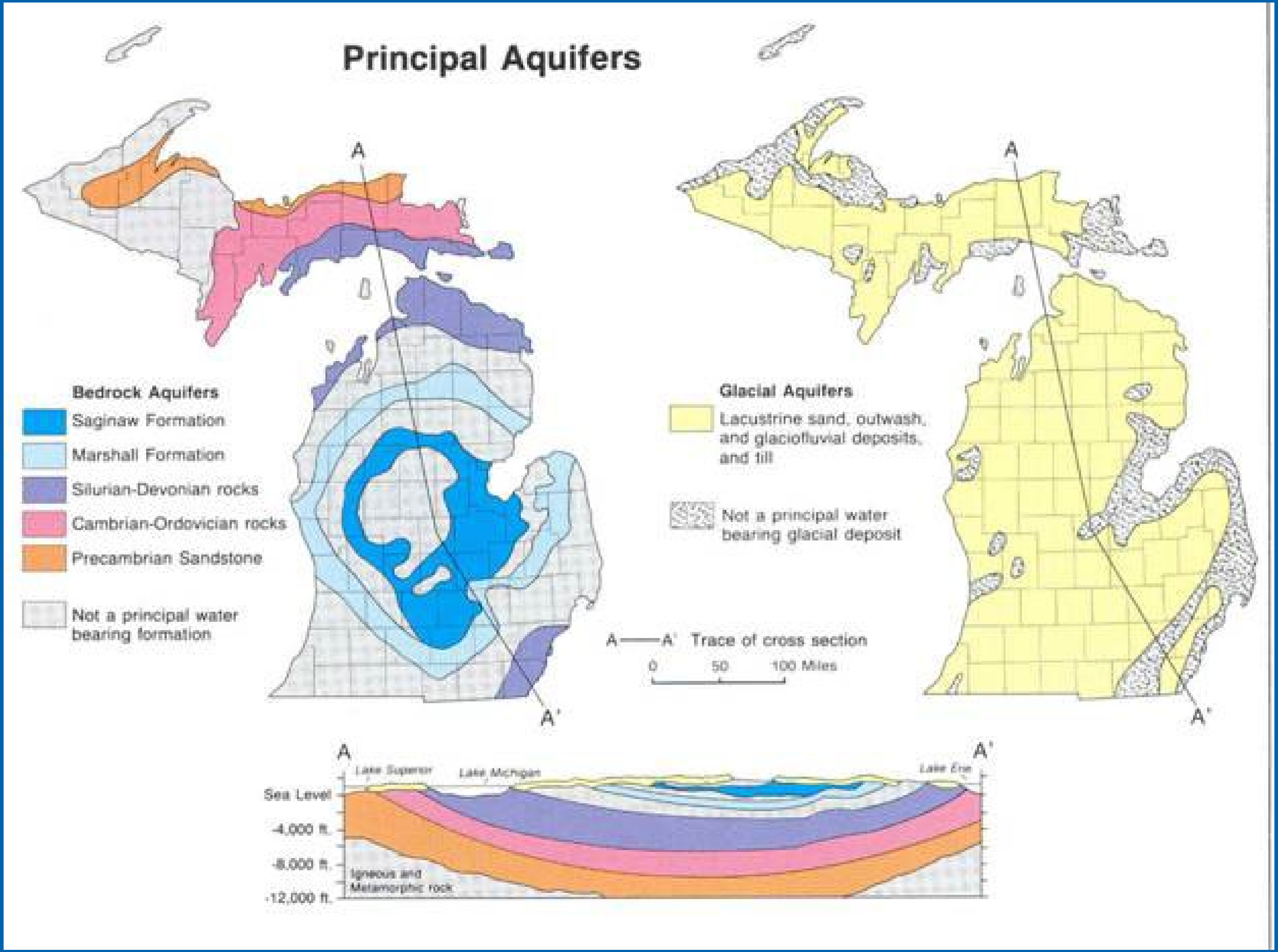
EGLE and Michigan Saves just launched the Septic Replacement Loan Program (SRLP)

Provides MI homeowners with low-interest financing options to replace their failing or near-failing septic systems: https://lnkd.in/gpjpYyWD

Groundwater Supply in Michigan

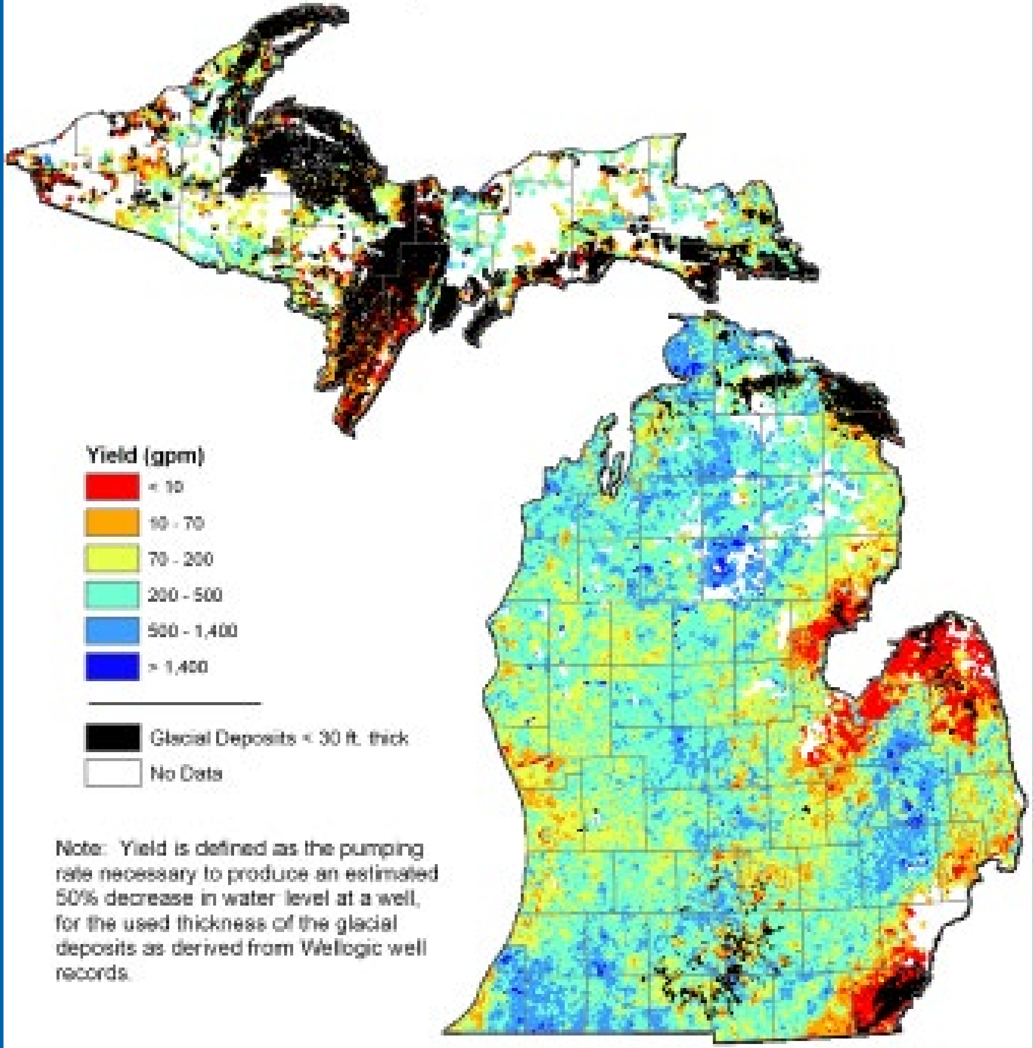
- MI has 9% of the public groundwater-based drinking water supply systems in the US (more than any other state)
- Total state groundwater daily use measures ~766 MGD.
- This is ~2.6% of the estimated 27 BGD of natural recharge to Michigan's groundwater systems.
- From a statewide perspective, the groundwater resource appears plentiful. However, this varies on a site-specific basis.

Regional abundance does not mean a lack of local shortages or competing uses



Principal Aquifers
A
A'
Bedrock Aquifers
Saginaw Formation
Marshall Formation
Silurian-Devonian rocks
Cambrian-Ordovician rocks
Precambrian Sandstone
Not a principal water bearing formation
Glacial Aquifers
Lacustrine sand, outwash, and glaciofluvial deposits, and till
Not a principal water bearing glacial deposit
A——A' Trace of cross section
0 50 100 Miles
Lake Superior
Lake Michigan
Lake Erie
Sea Level
-4,000 ft.
-8,000 ft.
-12,000 ft.
Igneous and Metamorphic rock

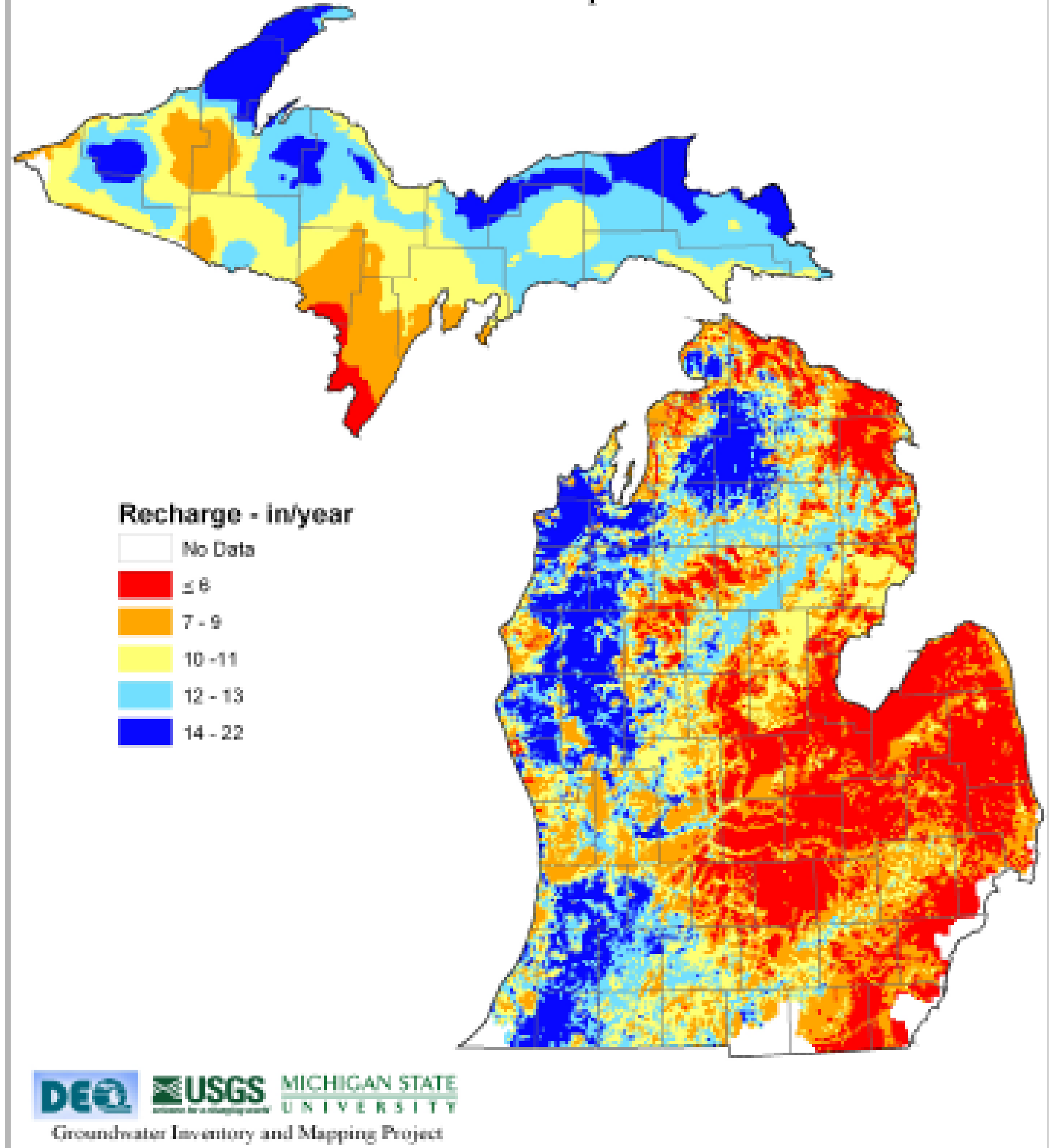
Figure 1
Glacial Deposits - Estimated Yield

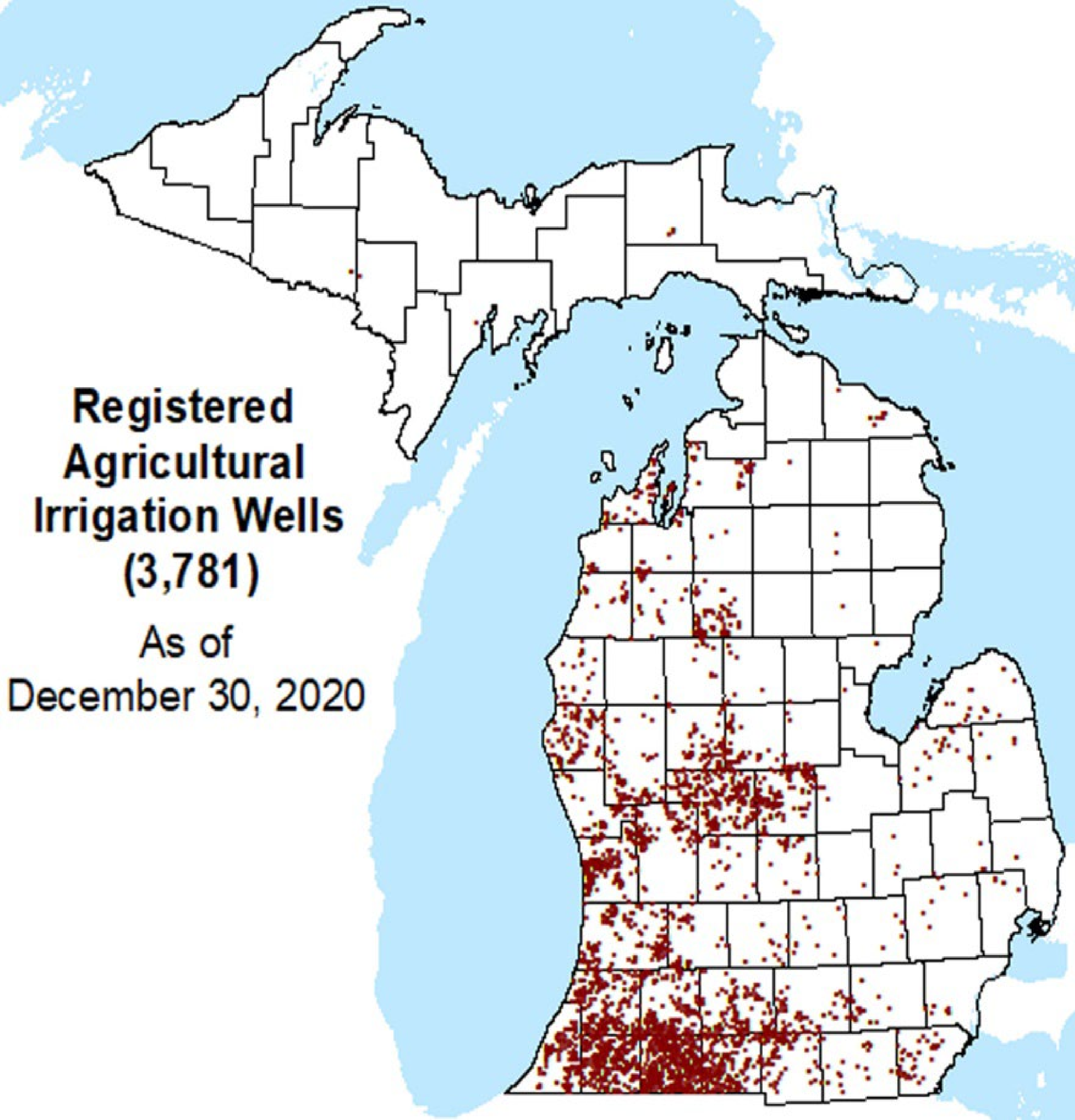


Note: Yield is defined as the pumping rate necessary to produce an estimated 50% decrease in water level at a well, for the used thickness of the glacial deposits as derived from Wellogic well records.

DEQ USGS MICHIGAN STATE UNIVERSITY
Groundwater Inventory and Mapping Project

Figure 6
Estimated Recharge to Glacial Deposits

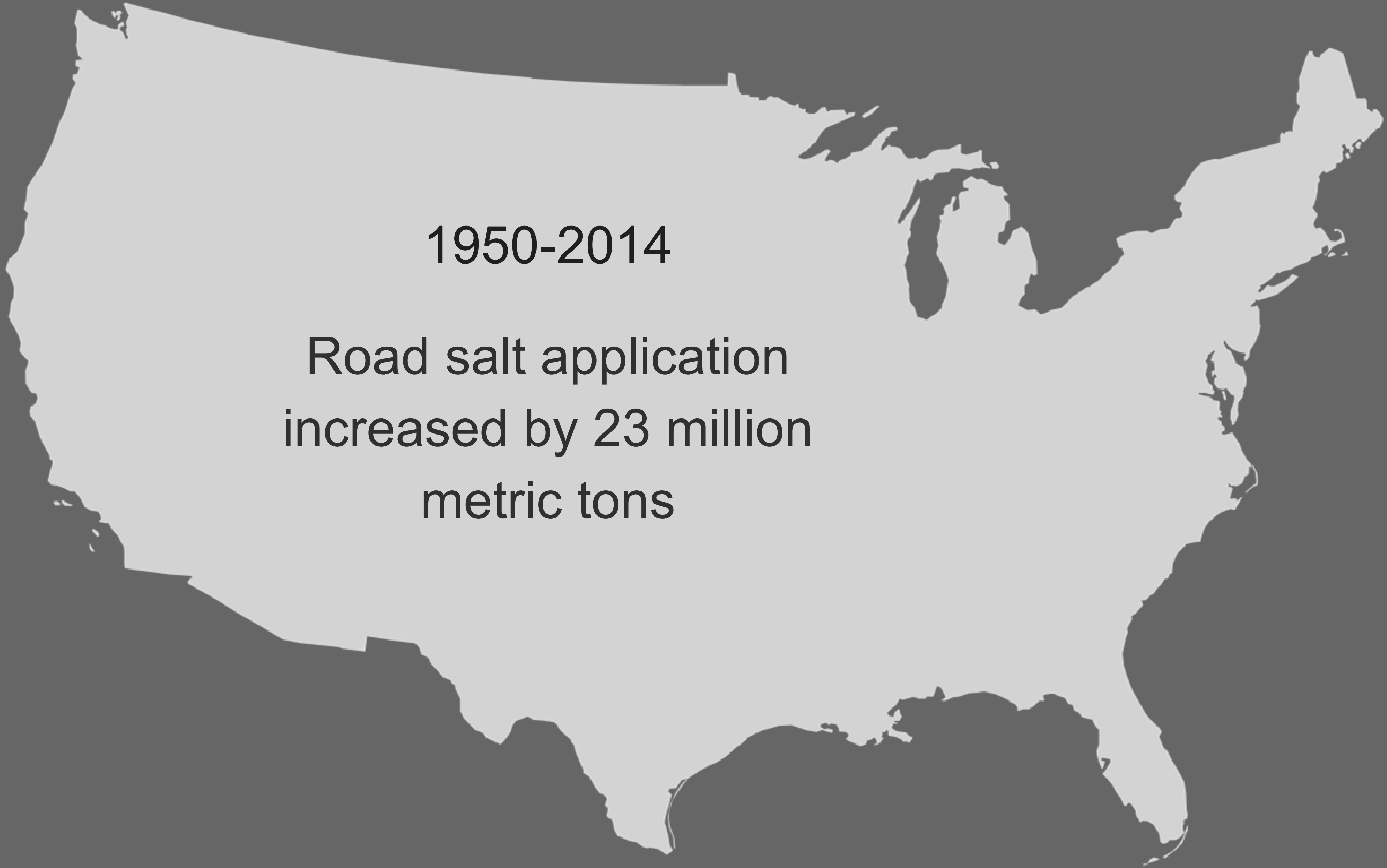




What effect(s) will climate change have on water withdrawal?

Groundwater Concerns

- Excess Chloride (salt)
- PFAS
- Climate warming (thermal pollution)

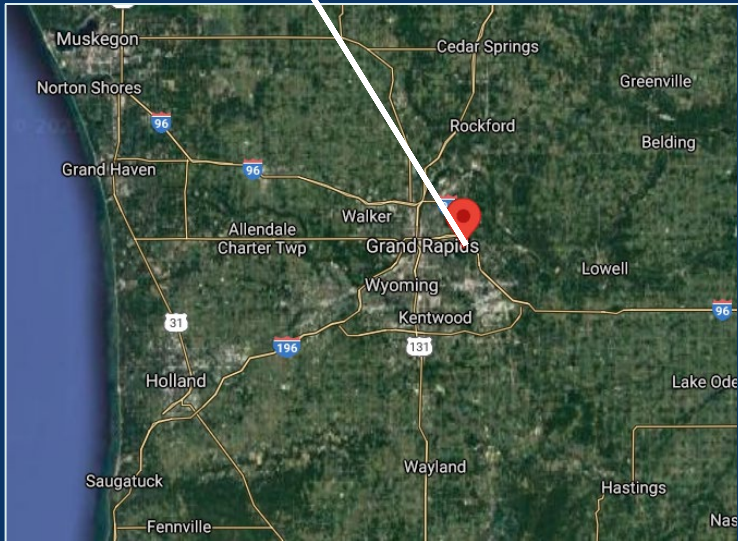

1950-2014
Road salt application
increased by 23 million
metric tons

Road Salt (Chloride) Impacts in Freshwater Ecosystems

- Detrimental impacts at all trophic levels
  - Decreased reproduction
  - Increased mortality
  - Decline in biodiversity
- Effects seen below EPA threshold of 230 mg/L and Michigan threshold of 150 mg/L

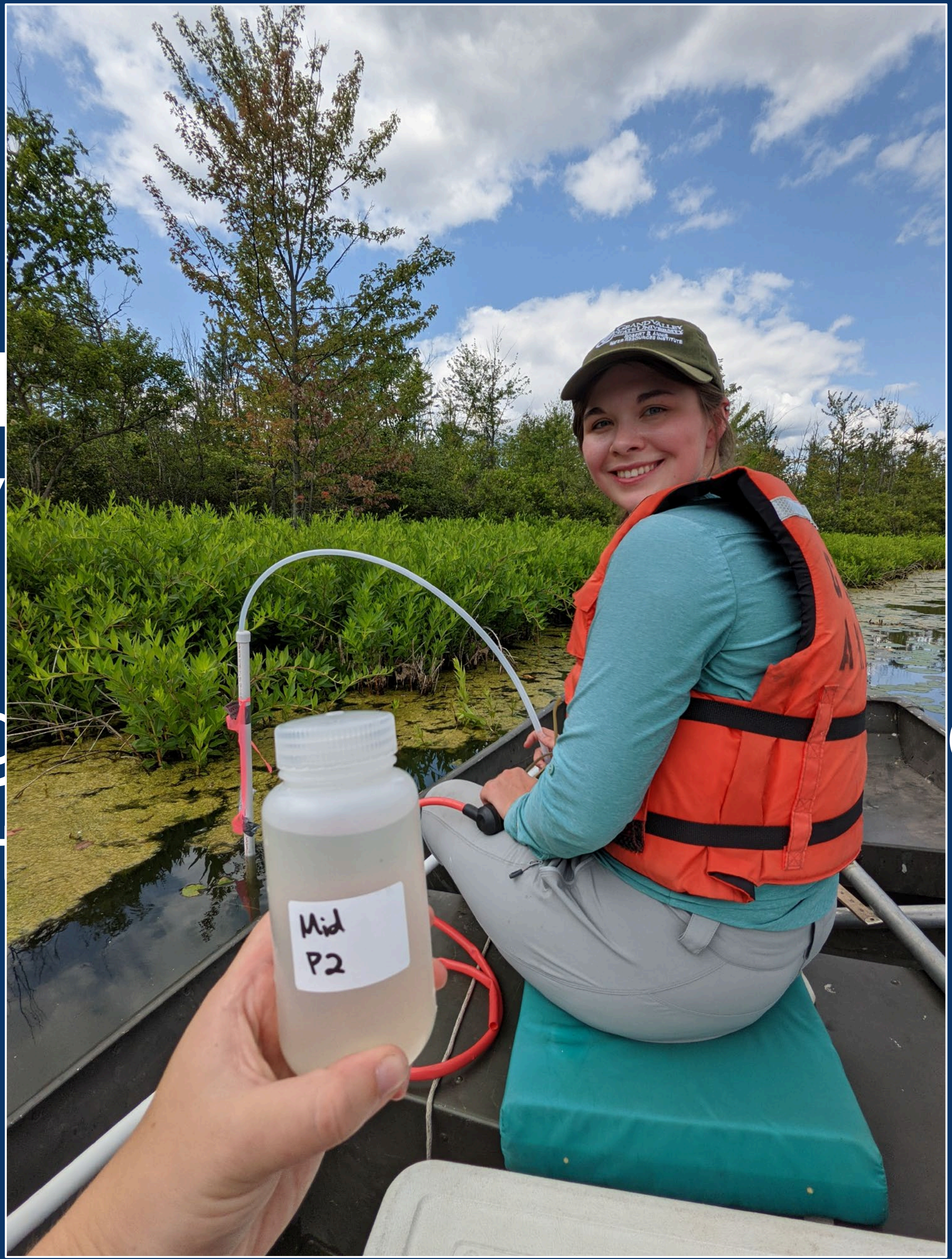
Background on Church Lake

- Located on east side of Grand Rapids, MI
- Severe road salt pollution preventing seasonal lake turnover (Foley & Steinman, 2023)
- Source of road salt: East Beltline Hwy into tributary (circled in white)
- Chloride concentrations often > 250 mg/L, exceeding EPA and MI thresholds



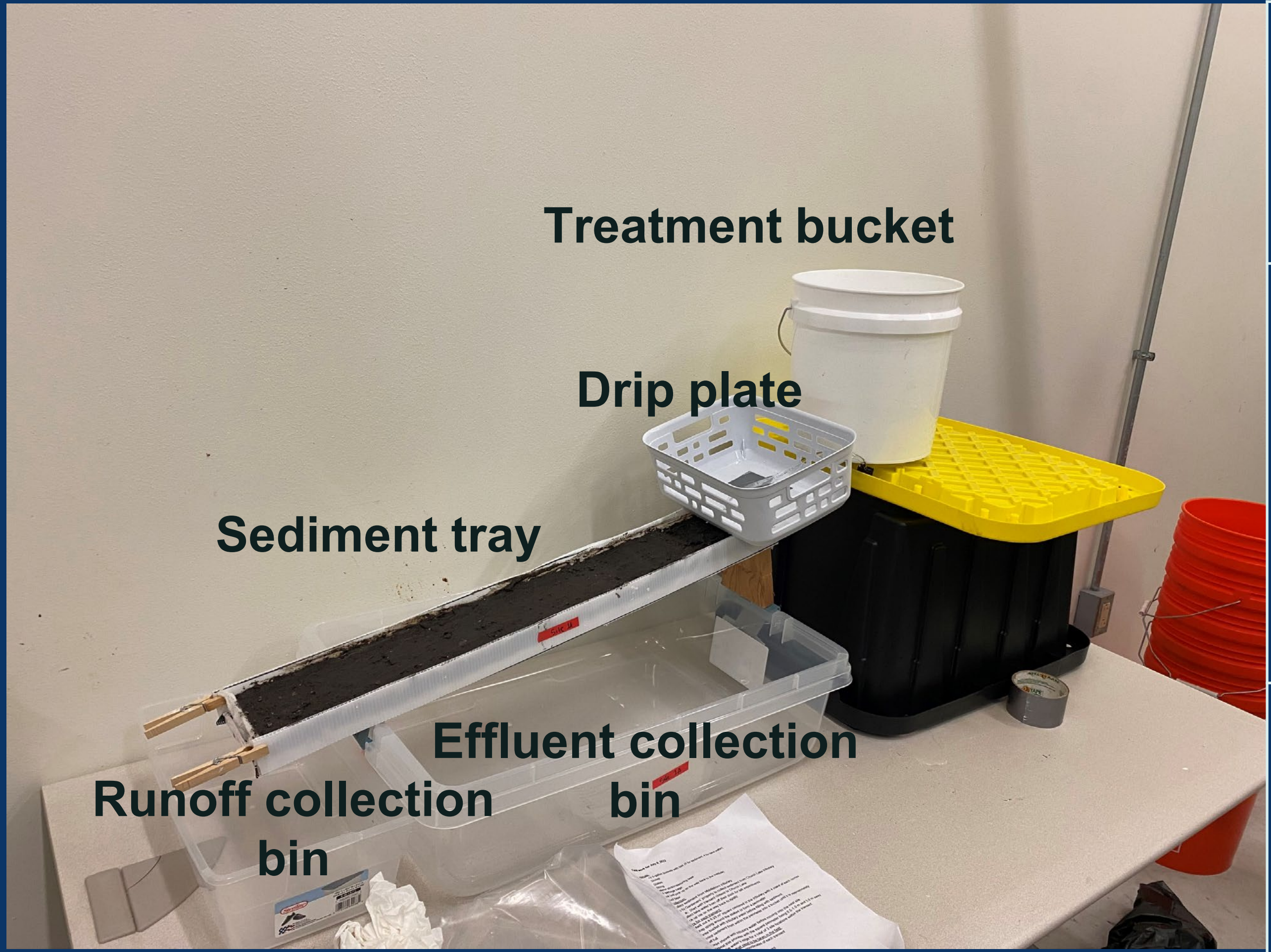
- Does tl runoff
  retain/

- Is the g d by
  the salt



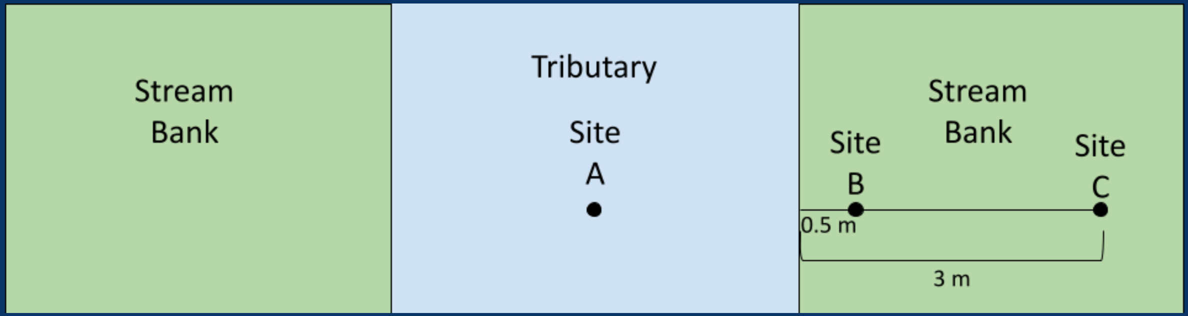
Jacquie Molloseau

Overland Flow Experiment – Summer 2022



	Phase 1: Ambient Rinse	Phase 2: Chloride Rinse	Phase 3: Recovery Rinse
Treatment	Surface lake water (Cl^- = 150 mg/L)	Deep lake water with (Cl^- = 550 mg/L)	Shallow lake water (Cl^- = 150 mg/L)
Purpose	Standardize conditions	Test for Cl^- retention	Test for Cl^- release

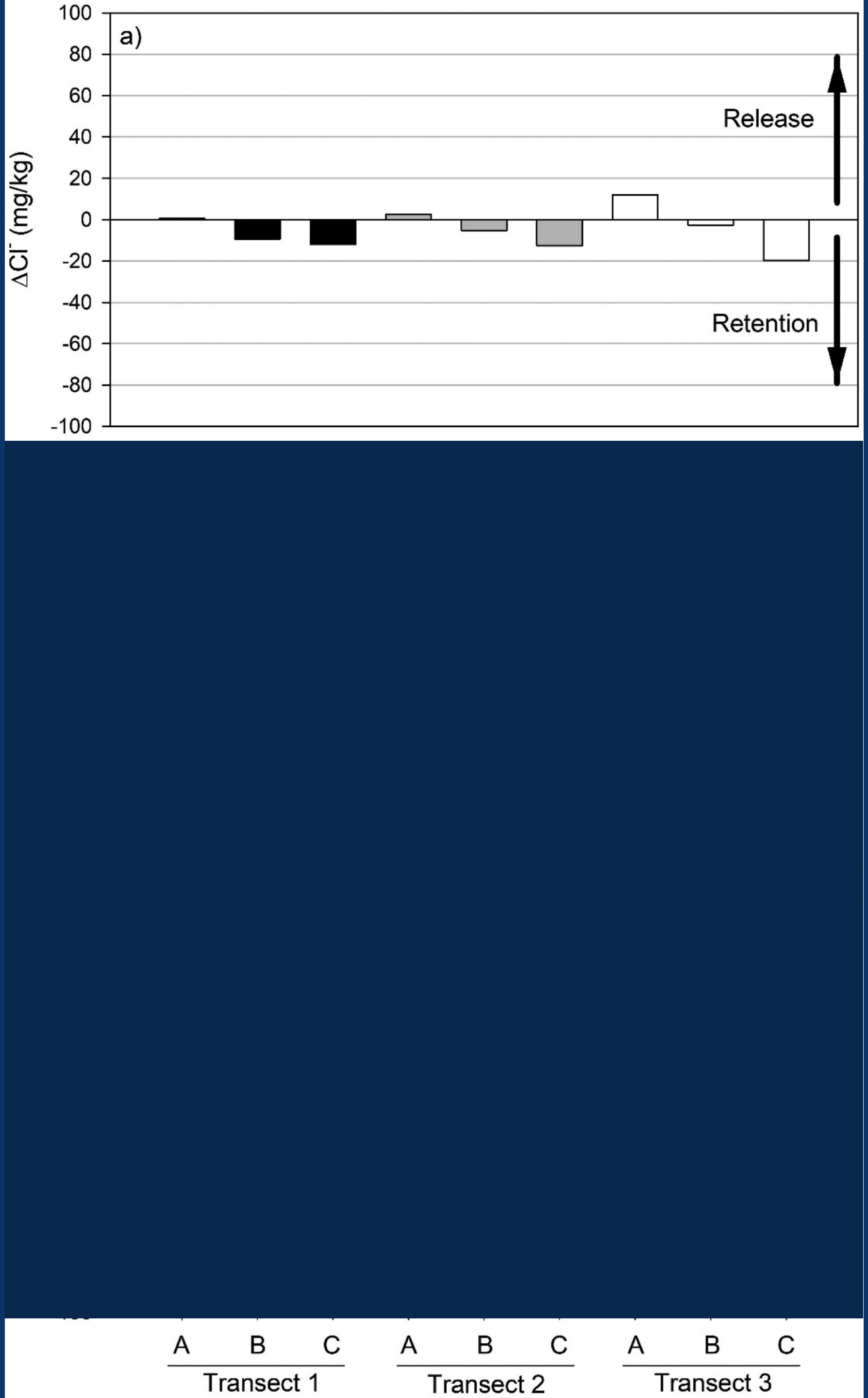
Results



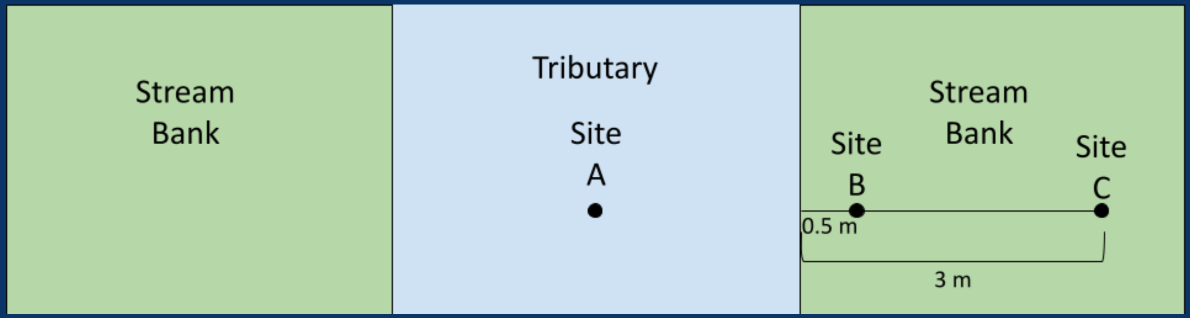
Experiment 1 (Ambient conditions)

Experiment 2 (Salt application)

Experiment 3 (Recovery rinse)



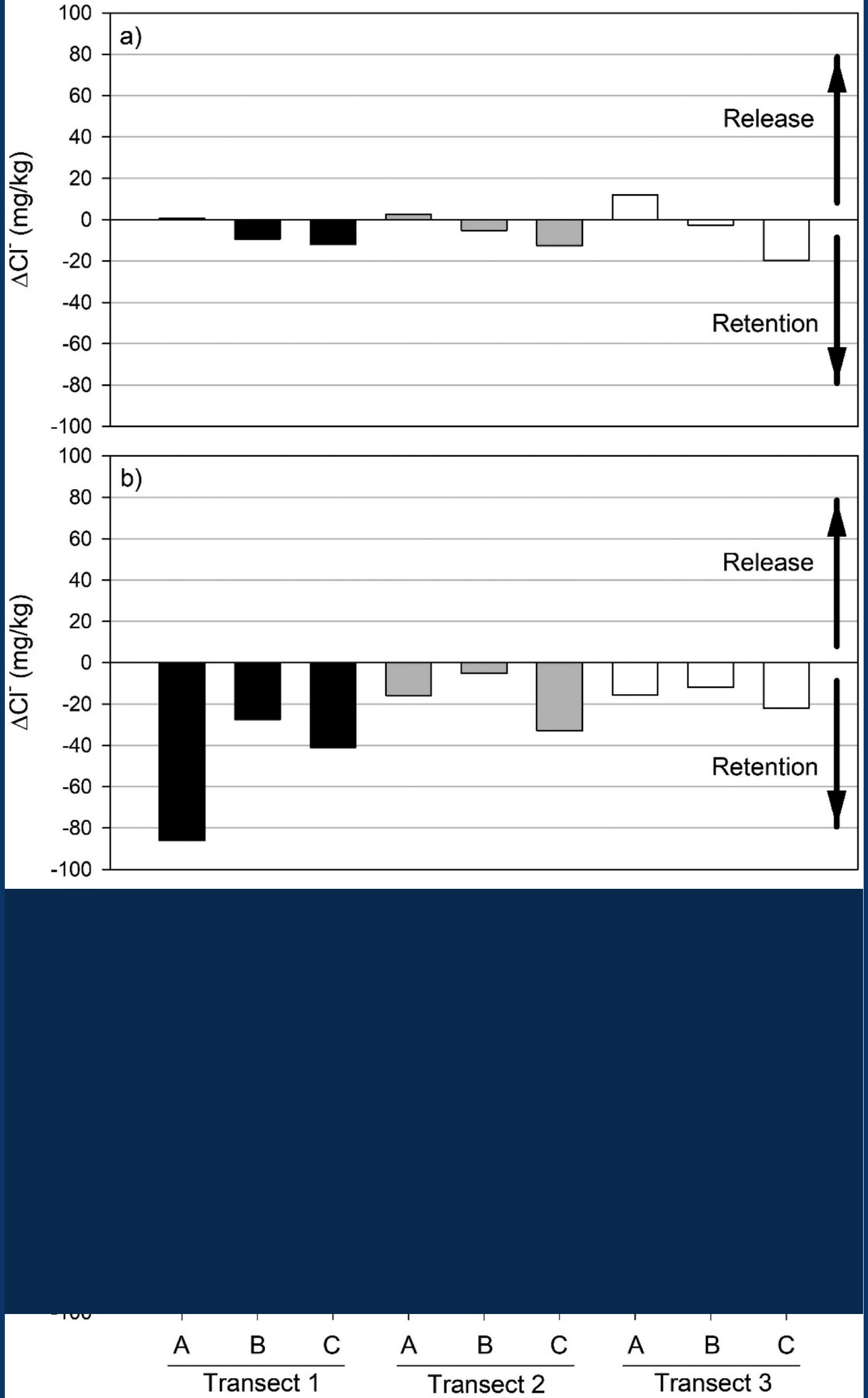
Results



Experiment 1 (Ambient conditions)

Experiment 2 (Salt application)

Experiment 3 (Recovery rinse)



Resulting publication:

Research Article

Chloride and phosphorus retention and release in soils surrounding a salt-contaminated lake in West Michigan

Jacquelyn Molloseau & Alan D. Steinman

Article: 2241478 | Received 19 Jun 2023, Accepted 23 Jul 2023, Published online: 30 Jul 2023

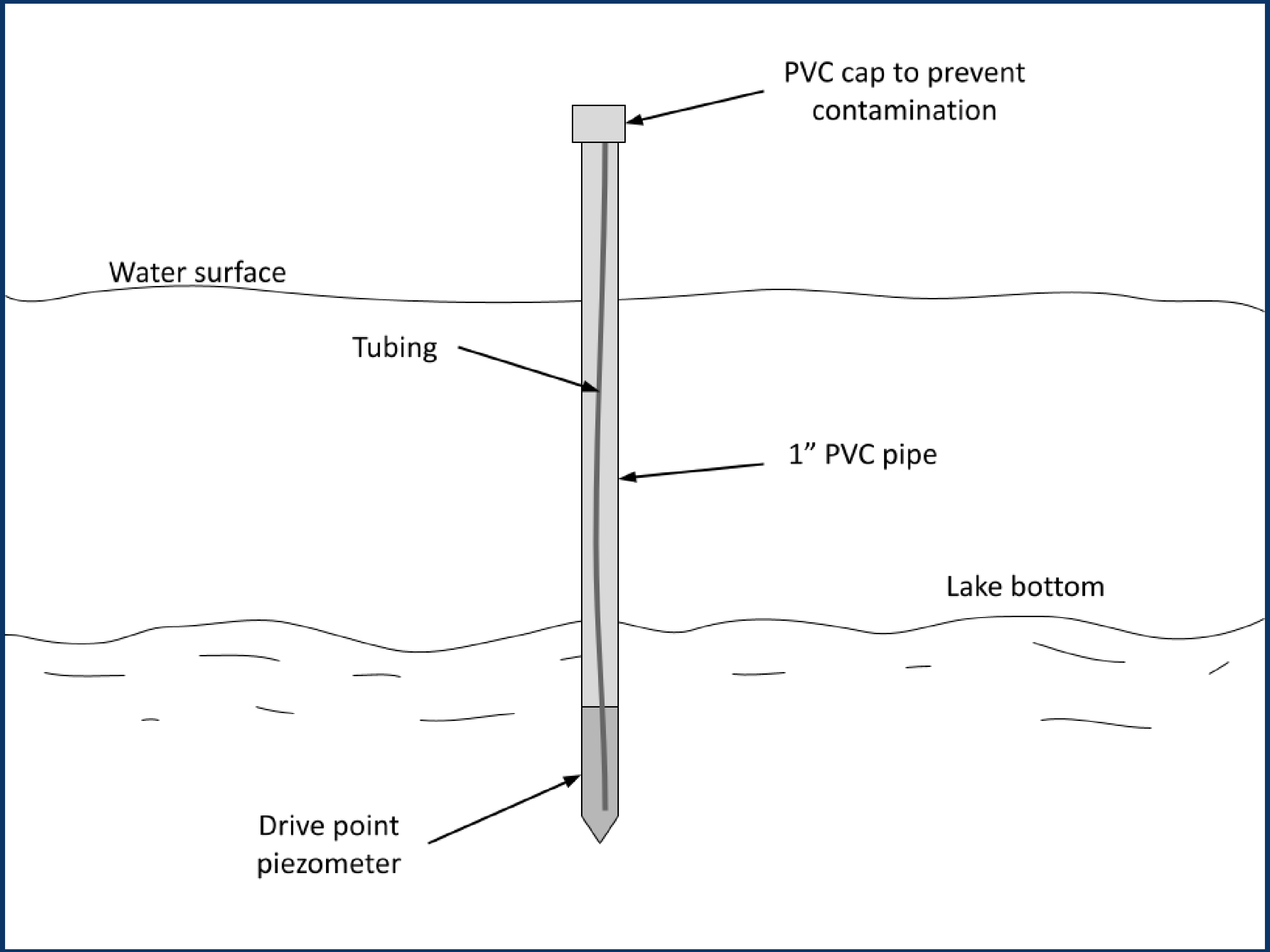
Cite this article https://doi.org/10.1080/02705060.2023.2241478 Check for updates

Conclusions:

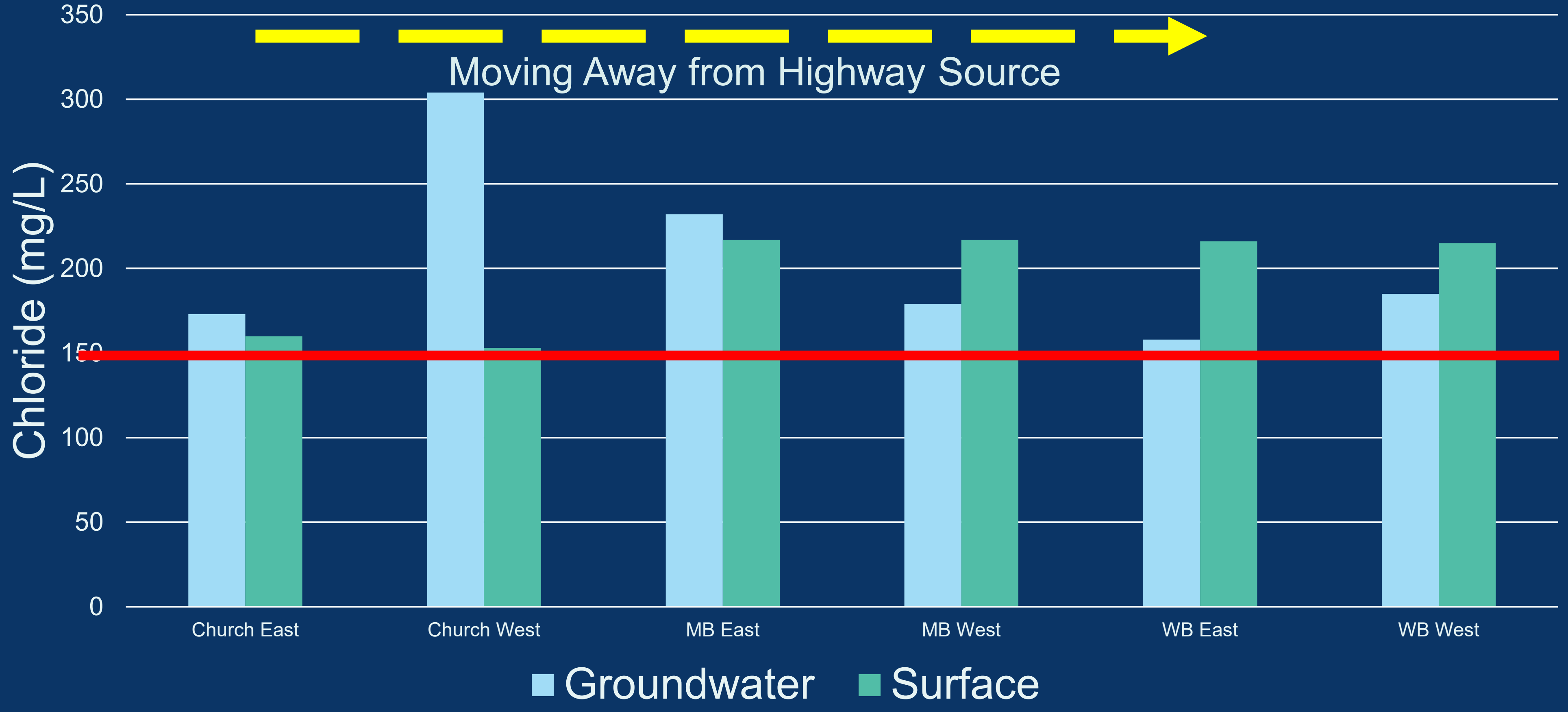
- Soils can retain salt but can quickly release it once they are wetted
- Releases suggest that groundwater may be contaminated with salt and be the source of salinity to downstream lakes

Groundwater Testing – Summer 2023

Piezometers used to extract groundwater at inflow and outflow of all 3 lakes



Conclusion: Area is saturated with chloride and groundwater is likely acting as pollution pathway

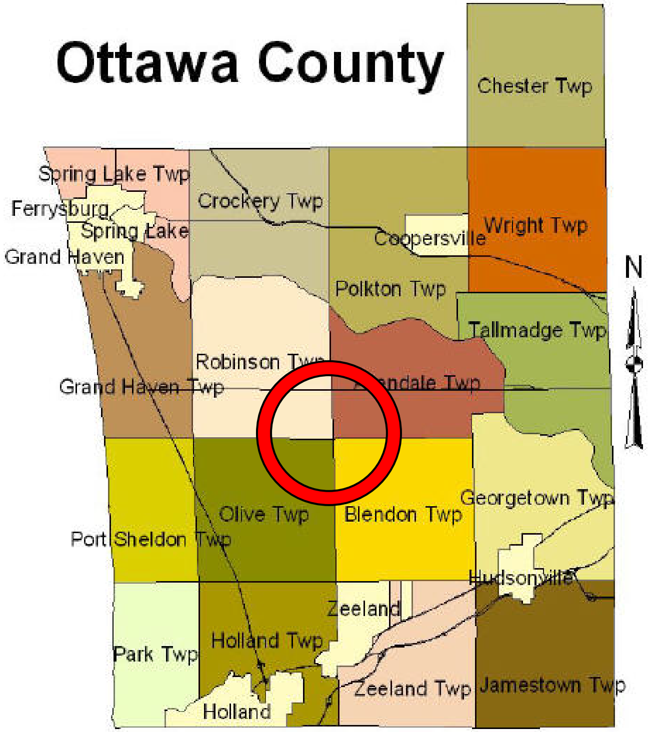


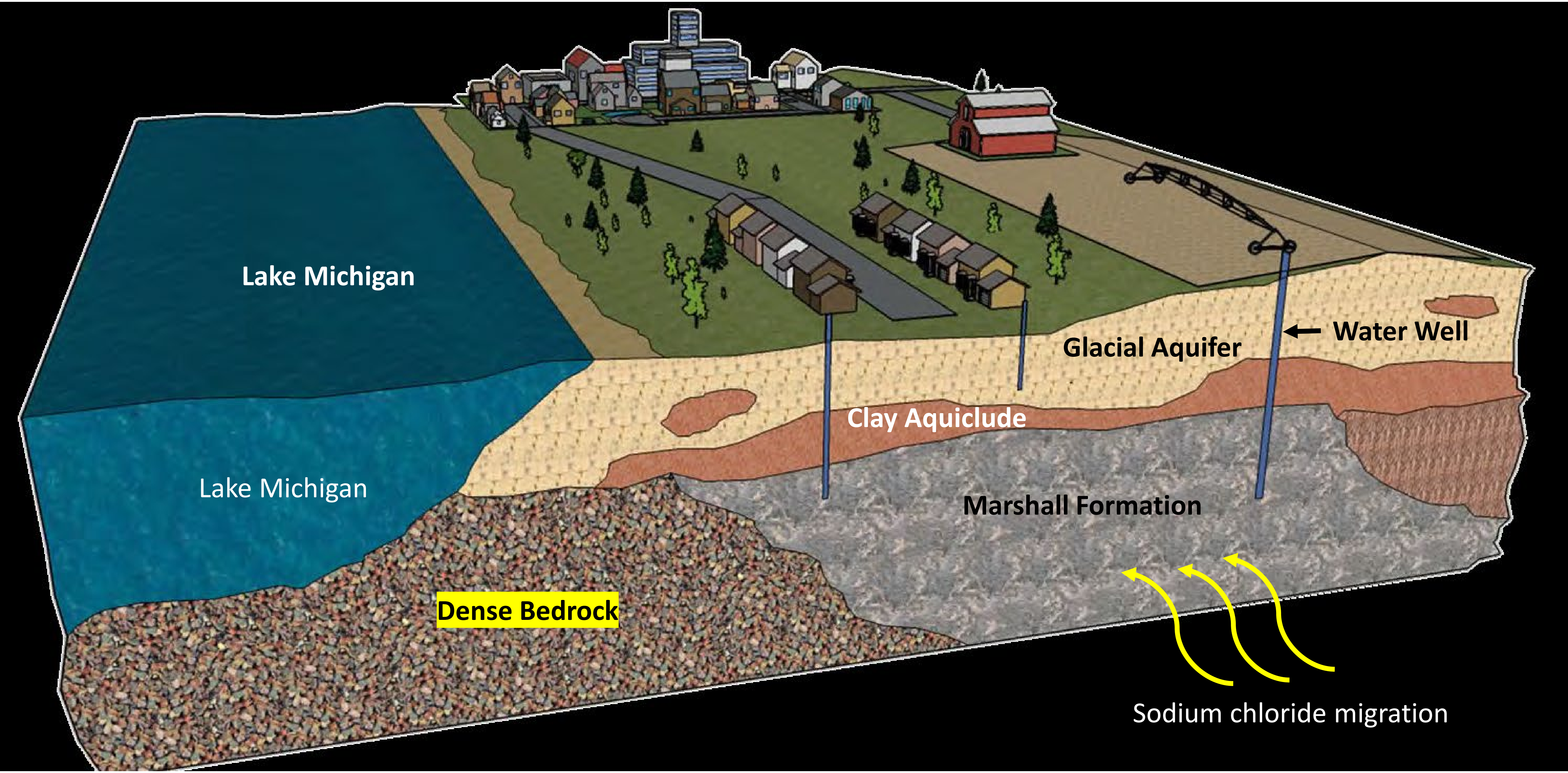
Red line: Michigan chronic Cl^- limit (150 mg/L)

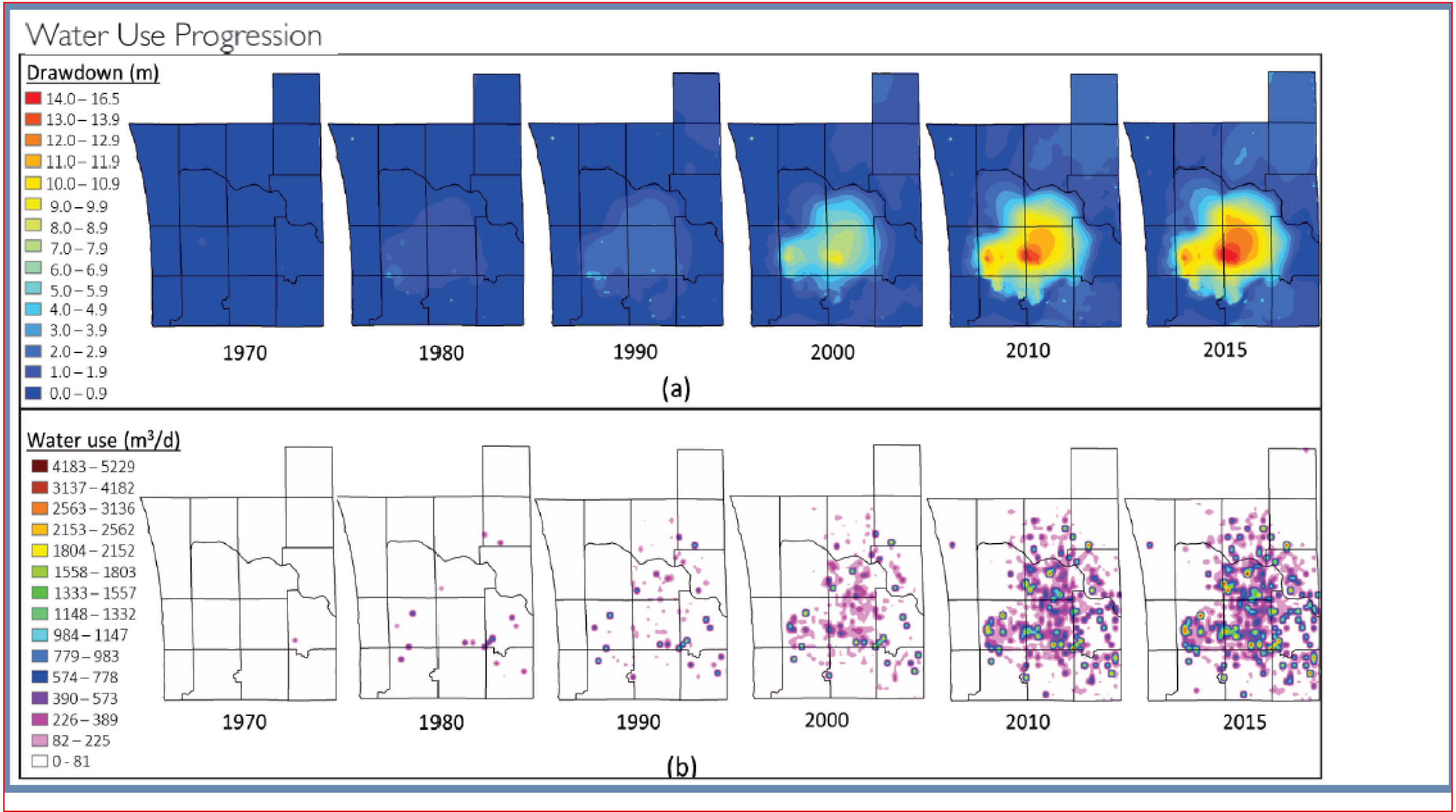
Overall Conclusions

- Sediments have capability to retain and release chloride
- Retention/release pattern → constant stress on system
- Shallow groundwater is a possible, if not likely, source of elevated Cl^- concentration in this tri-lake system
- Because de-icing salts are widely applied, chloride contamination of both surface water and groundwater may be a common phenomenon

Ottawa County is facing a groundwater crisis (naturally occurring chloride)

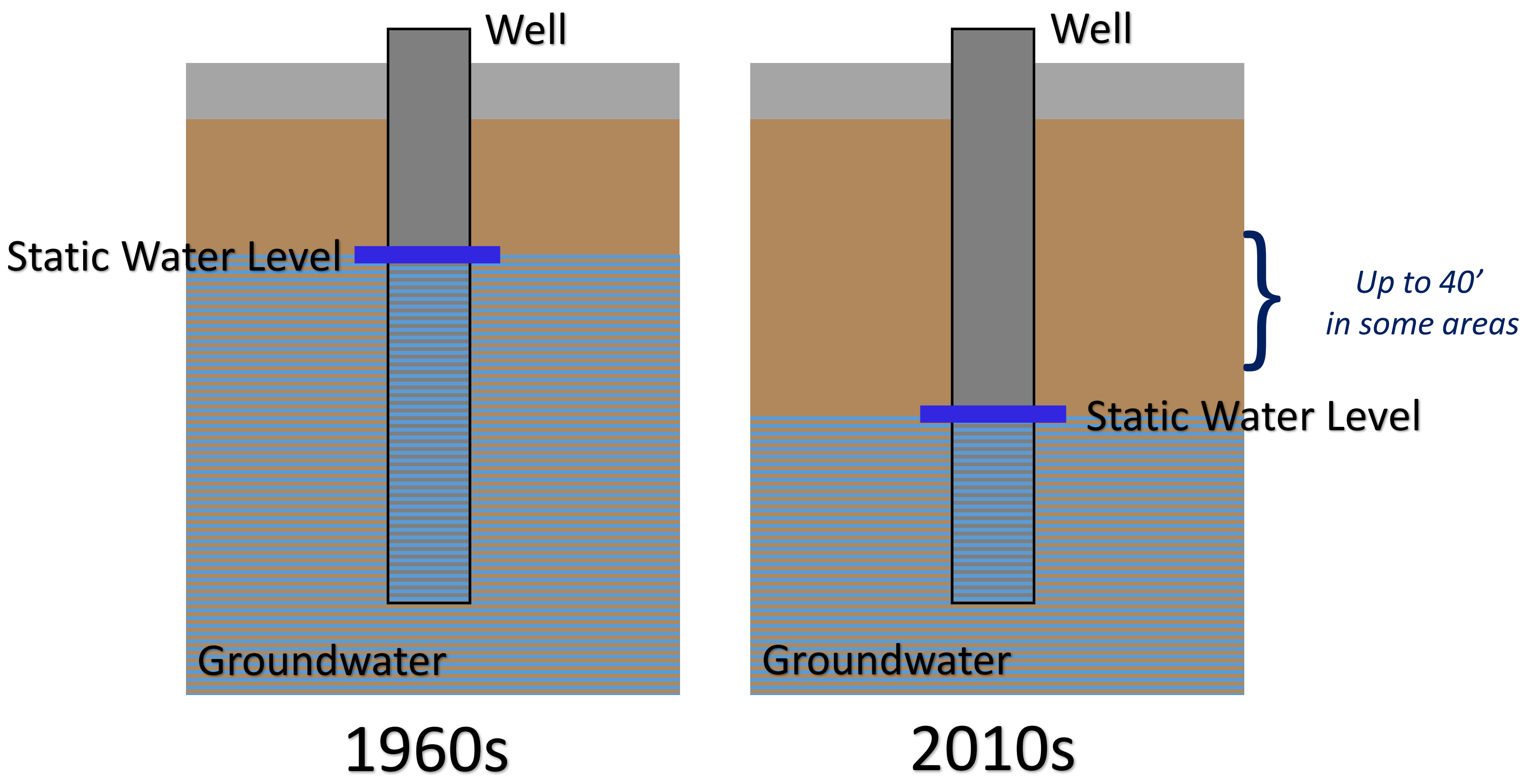



Lake Michigan
Lake Michigan
Glacial Aquifer
Water Well
Clay Aquiclude
Marshall Formation
Dense Bedrock
Sodium chloride migration



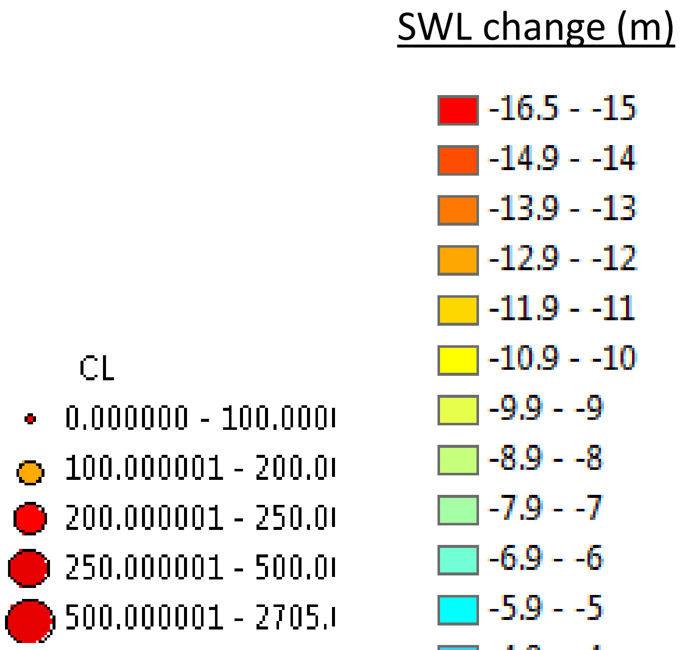
Data: MSU; Slide courtesy of Ottawa Co. Department of Planning and Performance Improvement

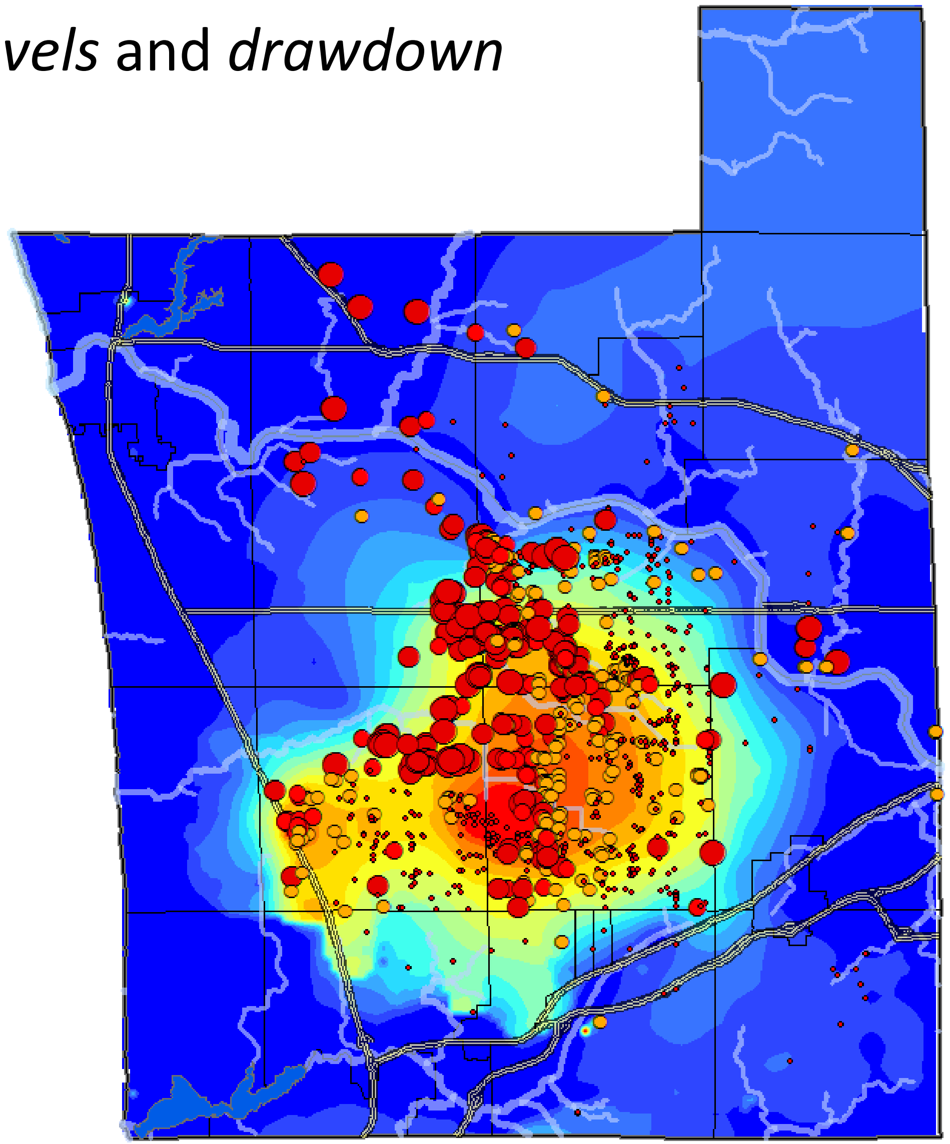
- Declining *static water levels* in the bedrock



Slide courtesy of Ottawa Co. Department of Planning and Performance Improvement

Correlation between *chloride levels* and *drawdown*





Source: Curtis et al. (2018) https://www.miottawa.org/GroundWater/pdf/phase2_report.pdf

www.miottawa.org/groundwater/

Primary Goal

Reduce dependency on deep bedrock aquifer system

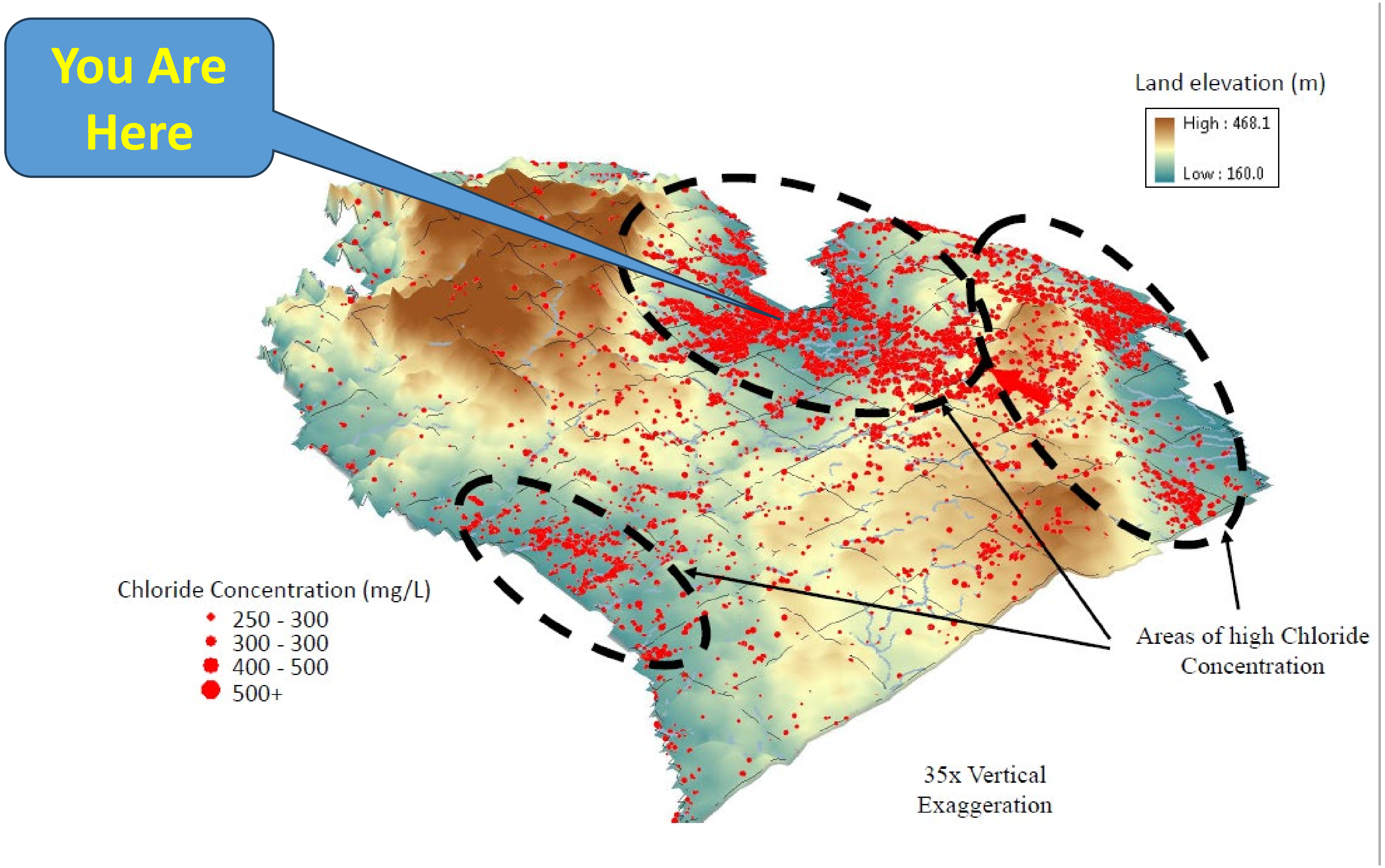
Objectives

a) Implement creative solutions to offset new withdrawals from bedrock aquifer
b) Protect and enhance recharge of bedrock aquifer
c) Embrace water conservation and reuse

Plan Components

- Consistent Education and Public Outreach
- Integrating Behavioral Change
- Implementing Mitigation Techniques
- Coordinating with All Sectors

Not just Ottawa County



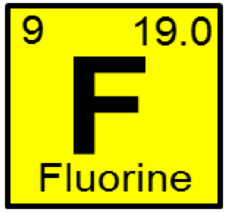
Source: Curtis et al. (2018) https://www.miottawa.org/GroundWater/pdf/phase2_report.pdf

Introduction to PFAS

PFAS: Per- and Polyfluoroalkyl Substances

- *4000+* synthetic organic compounds used since 1940s that contain multiple Fluorine (F) atoms

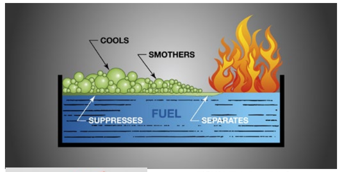
- 2 most studied PFAS are **Perfluorooctanoic Acid (PFOA)** and **Perfluorooctane Sulfonate (PFOS)**



Wide range of industrial applications:

- Polymers and coatings (Scotchgard®, Teflon®, Gore-Tex®, Stainmaster®)
- Fire-fighting foams (AFFF - Aqueous Film Forming Foam)
- Metal plating, cosmetics, food packaging, electronic and semiconductor applications, oil/mining production

For Leather



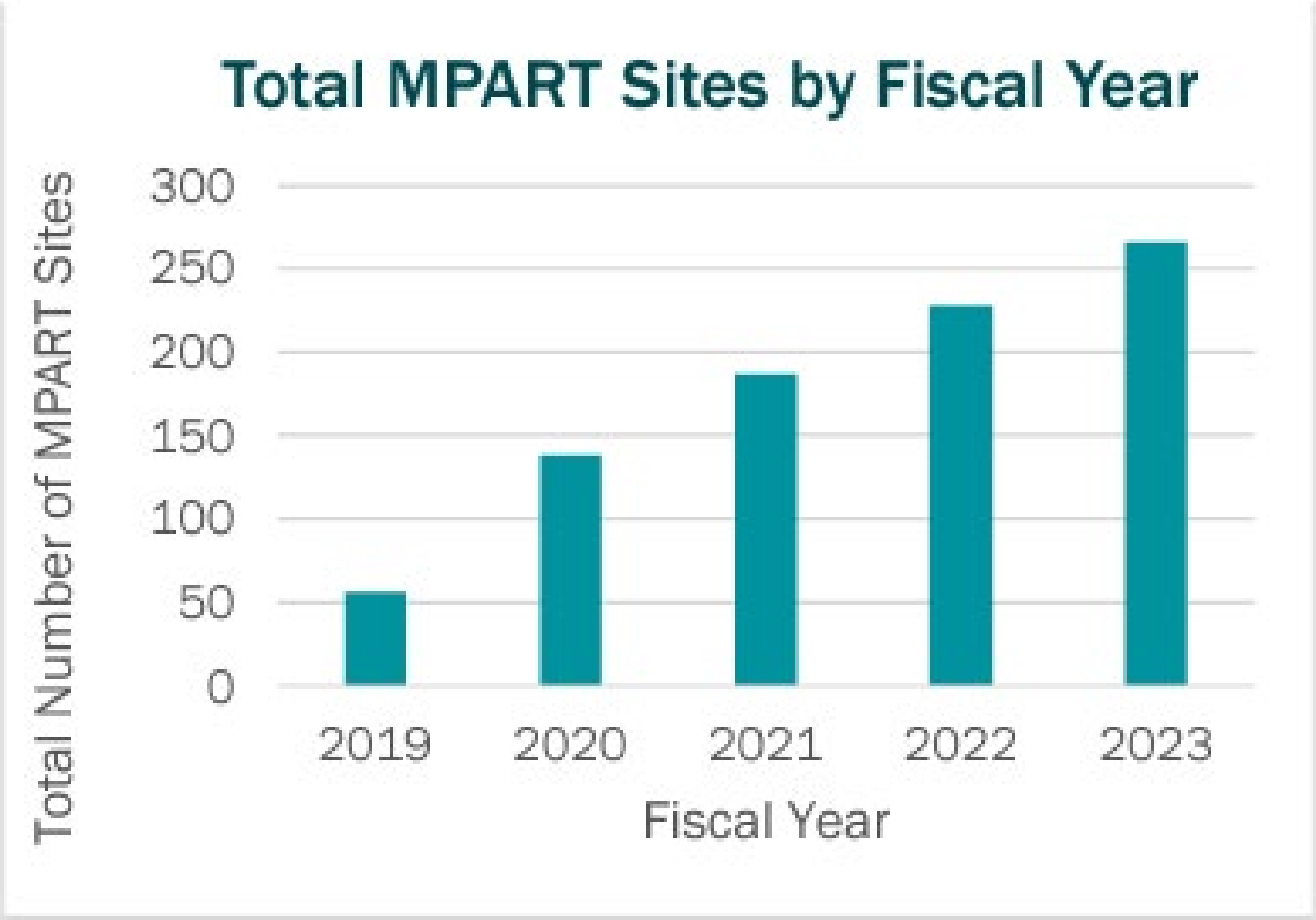
Found globally, even in remote places – transport in air and biota

PFAS Challenges

Chemical Properties for Environmental and Health Impacts:

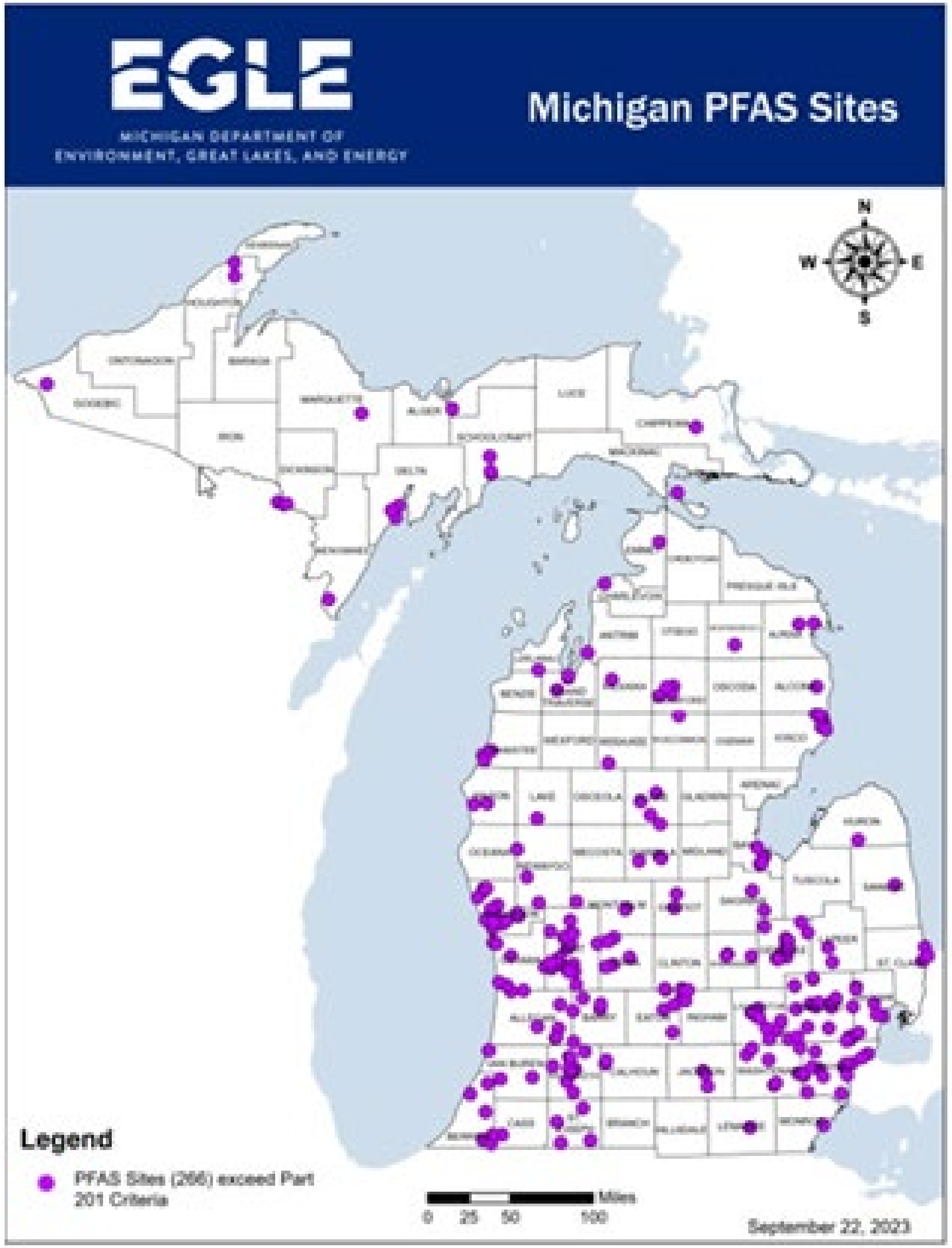
- Water Soluble
- Binds to proteins and DNA
- Circulates in blood bound to albumen
- Bioaccumulates in plants and animals
- Not biodegradable
- Reabsorbed by the kidney; resulting in long half-lives (4-9 yrs)
- We are dealing with historical releases involving decades of human exposure over multiple generations and life stages

Michigan PFAS Action Response Team (MPART)



As of the end of FY 2023, MPART had identified 266 MPART PFAS Sites.

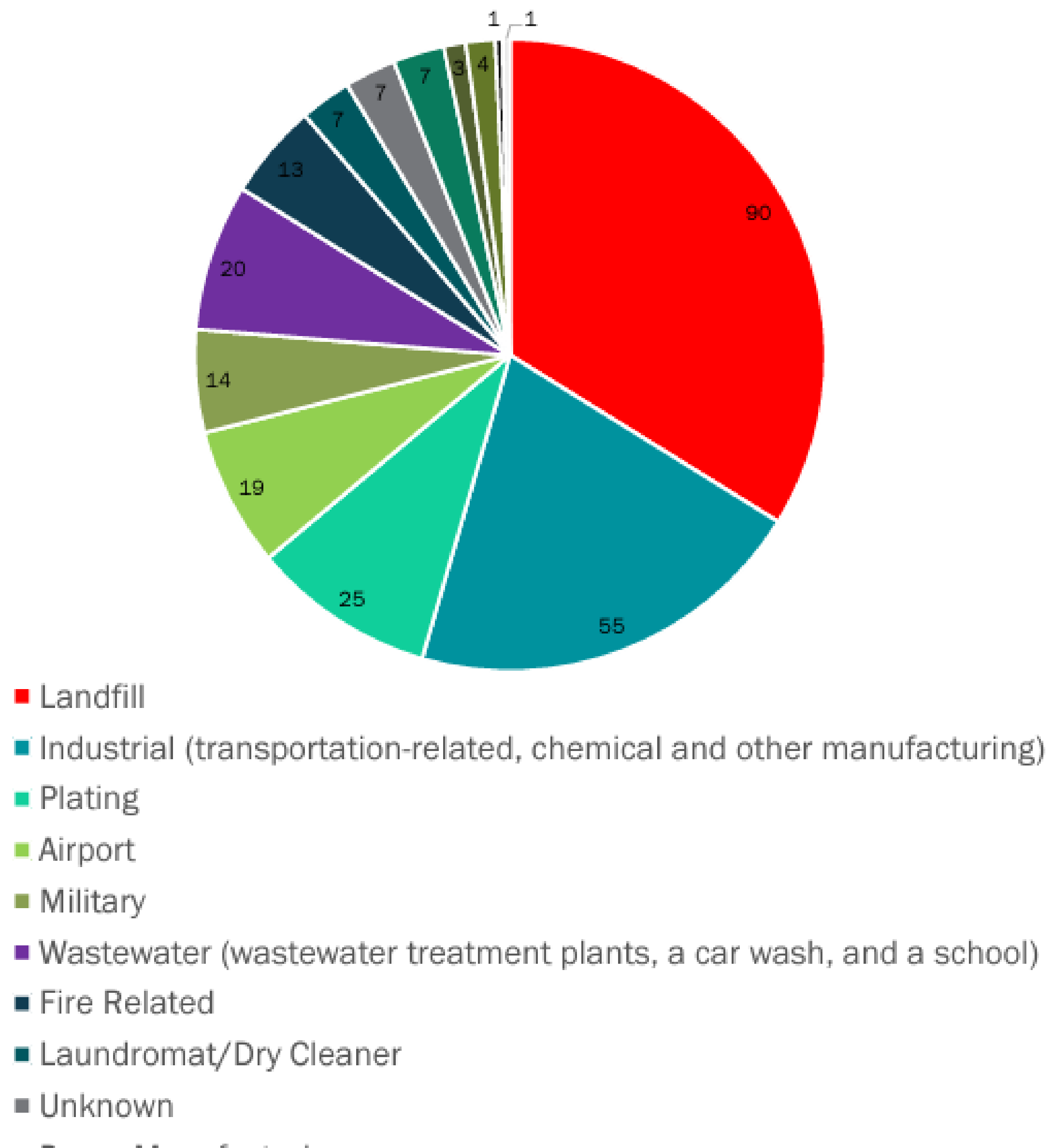
A PFAS site is an area where PFAS contamination has been found in groundwater above Michigan's criteria.



MPART works with the local health departments to:

- Determine if there are residential/private drinking water wells near the site.
- Review well records to identify wells that are potentially at risk of PFAS contamination.
- Access property and conduct water sampling of the wells identified to be potentially at-risk.
- Share results with well owners and among agencies, as well as provide filters to residents if necessary.
- Expand sampling areas if results indicate additional potential impact.

266 PFAS Sites by Type



Protecting Drinking Water

FY23 Infrastructure Projects

- $20.8 million in grants were awarded to address PFAS contamination in drinking water.

<u>Projects included:</u>

o Watermain extensions to begin connection of ~646 homes to existing municipal drinking water systems.

o A $491,122 grant to the City of Ann Arbor to treat PFAS

Filters and Residential Well Sampling:

- Provided more than 125 PFAS-reducing filters to impacted residents.
- Provided more than 1,060 replacement cartridges for PFAS-reducing filters.
- Sampled more than 400 drinking water wells that had not been previously sampled.
- Re-sampled more than 820 drinking water wells that had been sampled in previous years.

Health Effects in Humans and Animals

- Changes in the body’s hormones and immune system
- Decreased fertility
- Immune system suppression
- Increased cholesterol
- Increased risk of certain kidney and testicular cancer
- Thyroid disease
- Pregnancy-induced hypertension

Home Drinking Water Treatment

- Granular Activated Carbon Filters
- Aquasana, Culligan, and eSpring have NSF P473 Approved Carbon Filters
- Tap filters for low levels
- Whole House Filters for high levels
- All need testing to verify performance

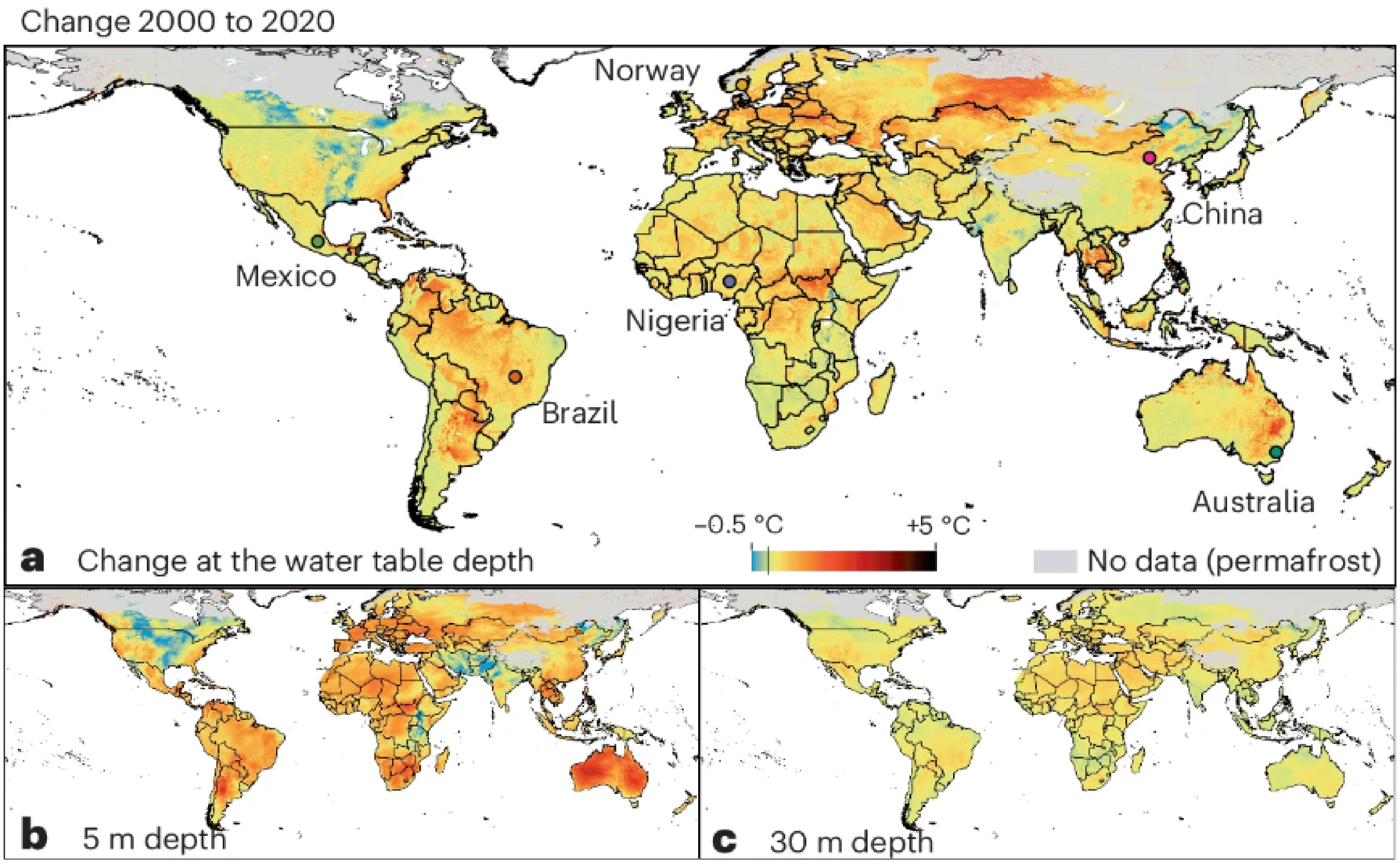
Thermal Pollution

New study* simulates current and projected groundwater temperatures at the global scale.

Groundwater at the depth of the water table is conservatively projected to warm on average by 2.1 °C between 2000 and 2100 under a medium emissions pathway.

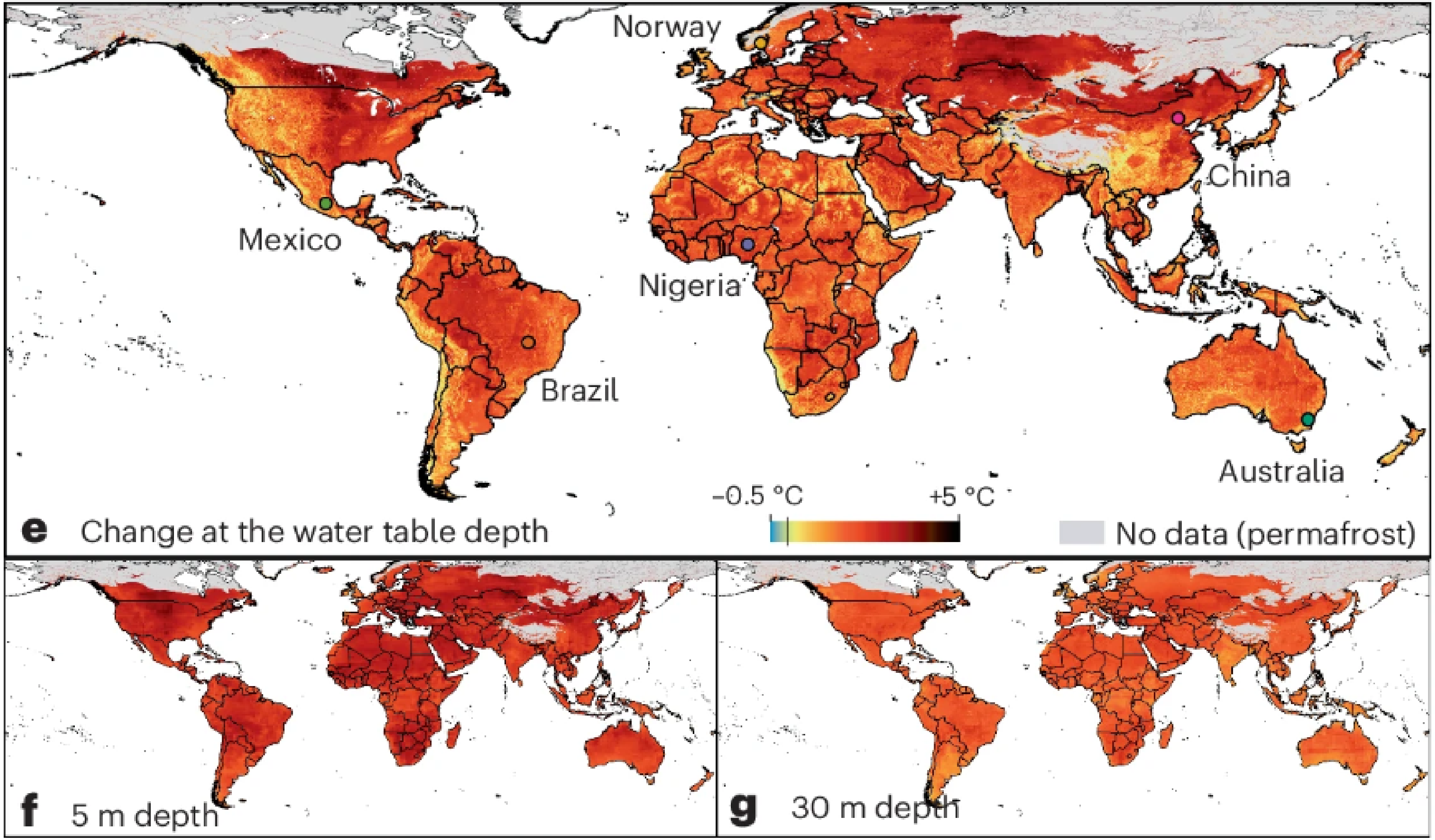
However, regional shallow groundwater warming patterns vary substantially due to spatial variability in climate change and water table depth.

Benz et al. (2024) Global groundwater warming due to climate change. *Nature Geoscience*



Benz et al. (2024) Global groundwater warming due to climate change. *Nature Geoscience*

Change 2000 to 2100 (SSP 2–4.5, median projections)



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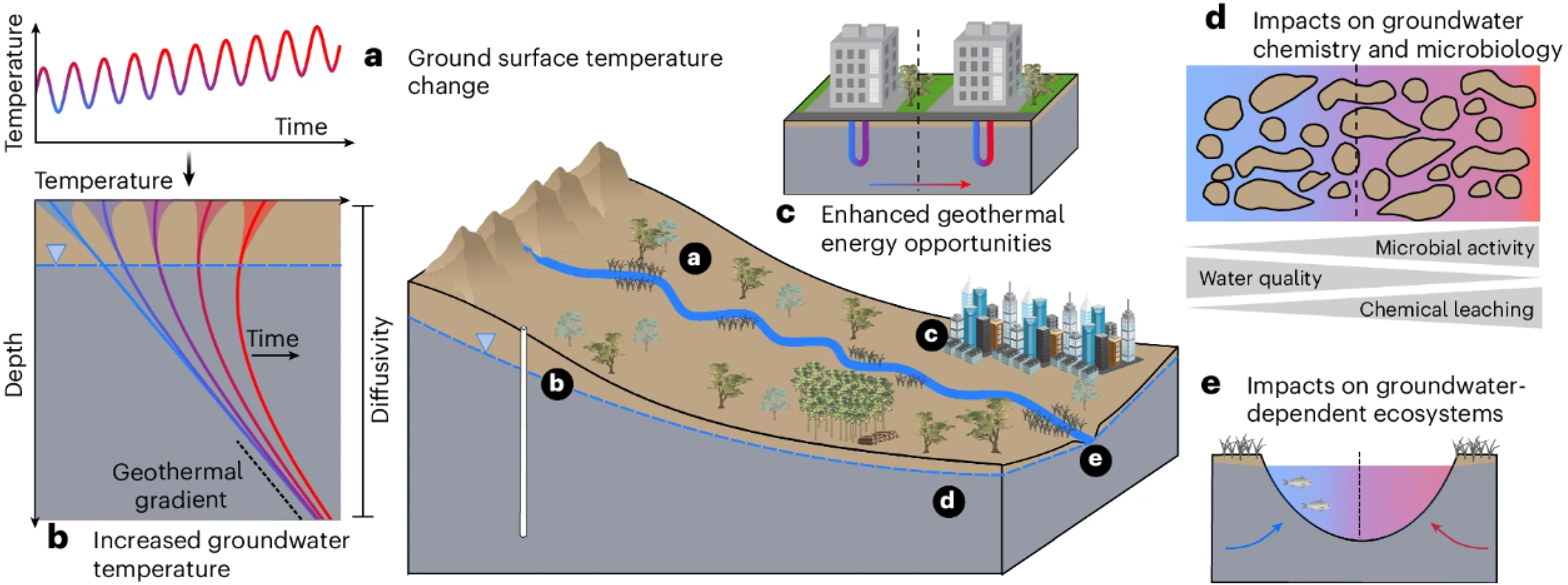
Implications



Benz et al. (2024) Global groundwater warming due to climate change. *Nature Geoscience*

Moving Forward

Groundwater in Crisis?

Addressing Groundwater Challenges in Michigan as a template for the Great Lakes

Steering Committee:

Alan D. Steinman (lead), Grand Valley State University
Philip Chu, NOAA/Great Lakes Environmental Research Laboratory
Patrick Doran, The Nature Conservancy
Lauren Fry, NOAA /Great Lakes Environmental Research Laboratory
Carol J. Miller, Wayne State University
Don Uzarski, Central Michigan University
Tom Zimnicki, Michigan Dept of Agriculture and Rural Development

Technical Recommendations

- Develop a statewide groundwater budget
- Establish a coordinated information management system
- Improve the Water Withdrawal Assessment Tool
- Develop a statewide groundwater monitoring program focused on contaminants
- Develop an early warning system to envision the future state of supply and demand

Non-Technical Recommendations

- Improve our public education and outreach efforts on groundwater
- Create new information and visualization tools to explain groundwater science and policy
- Instill the importance of water conservation
- Garner more input from underrepresented communities to obtain multiple perspectives

Summary

- Groundwater is a critical, but underappreciated, natural resource
- Groundwater is threatened from overwithdrawal (quantity) and contaminants (quality)
- There is increasing recognition of groundwater’s importance but more education is needed
- There is reason to be hopeful; budget authorizations are providing resources to gain greater understanding of groundwater in Michigan, although the funding is running out.

Gratitude

Steinman Lab


Jacquie Molloseau


Ellen Foley


Allison Passejna

Mike Hassett
Katie Tyrrell
Alison Romanski

Funders

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- Cooperative Institute for Great Lakes Research
- Church Lake Homeowners Ass’n
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Paul Sachs
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Marge Potter

Questions?

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