WATER CHEMISTRY OF THE GULF COAST AQUIFER

Kelsey Calvez, Environmental Scientist, Freese & Nichols, Inc.

Penn State University, MGIS Graduate Studies Peer-Review Report Presentation

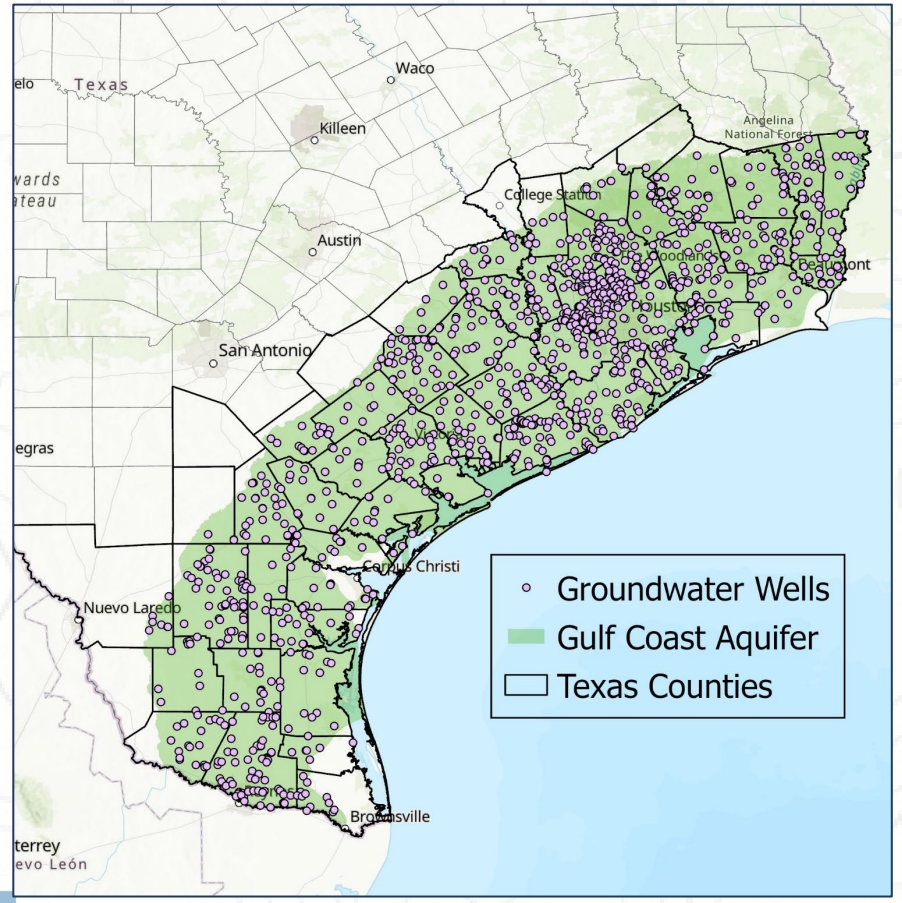
Texas Water Development Board

GROUNDWATER DATA VIEWER

- Database of **private and public groundwater wells** across the entire state

- Water quality and water level monitoring data dating back to early 1900s

- **3,000 groundwater wells** in the Gulf Coast Aquifer



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STUDY OBJECTIVES

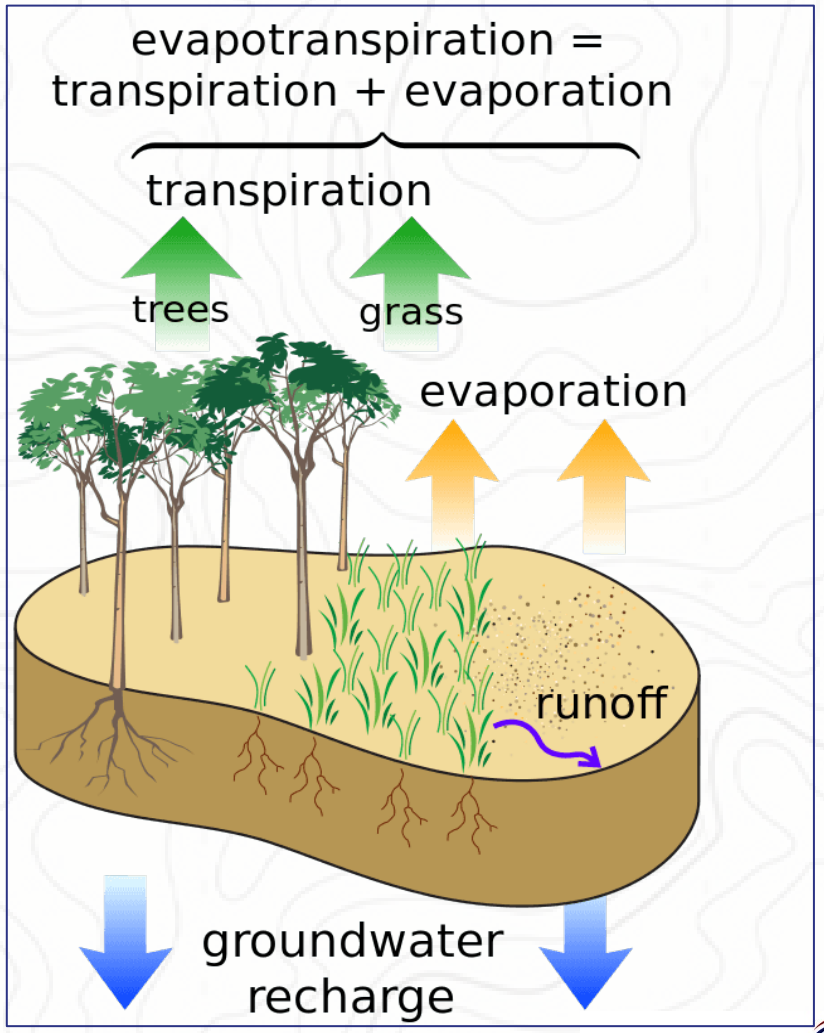
- Evaluate the full suite of chemical compounds (all 33) against land use and climate data for the **Gulf Coast Aquifer**.
- **Total Dissolved Solids** (TDS) used a dependent variable (the variable that's being predicted).
- TDS has been used as an **indicator of groundwater contamination** in previous studies.
- **Fluoride**
  - Natural and anthropogenic sources (coal burning, oil refining, fertilizer plants)
  - Beneficial and harmful impacts above MCL
  - Texas known as a state to have high fluoride concentrations

LAND USE IMPACTS ON GROUNDWATER

- ↑ land development ↓ supply of groundwater

- Impervious surfaces (roads, driveways, roofs) replace forests and wetlands, rainfall/precipitation no longer replenishes aquifers

- Texas has been in a drought for awhile and already has depleted groundwater resources

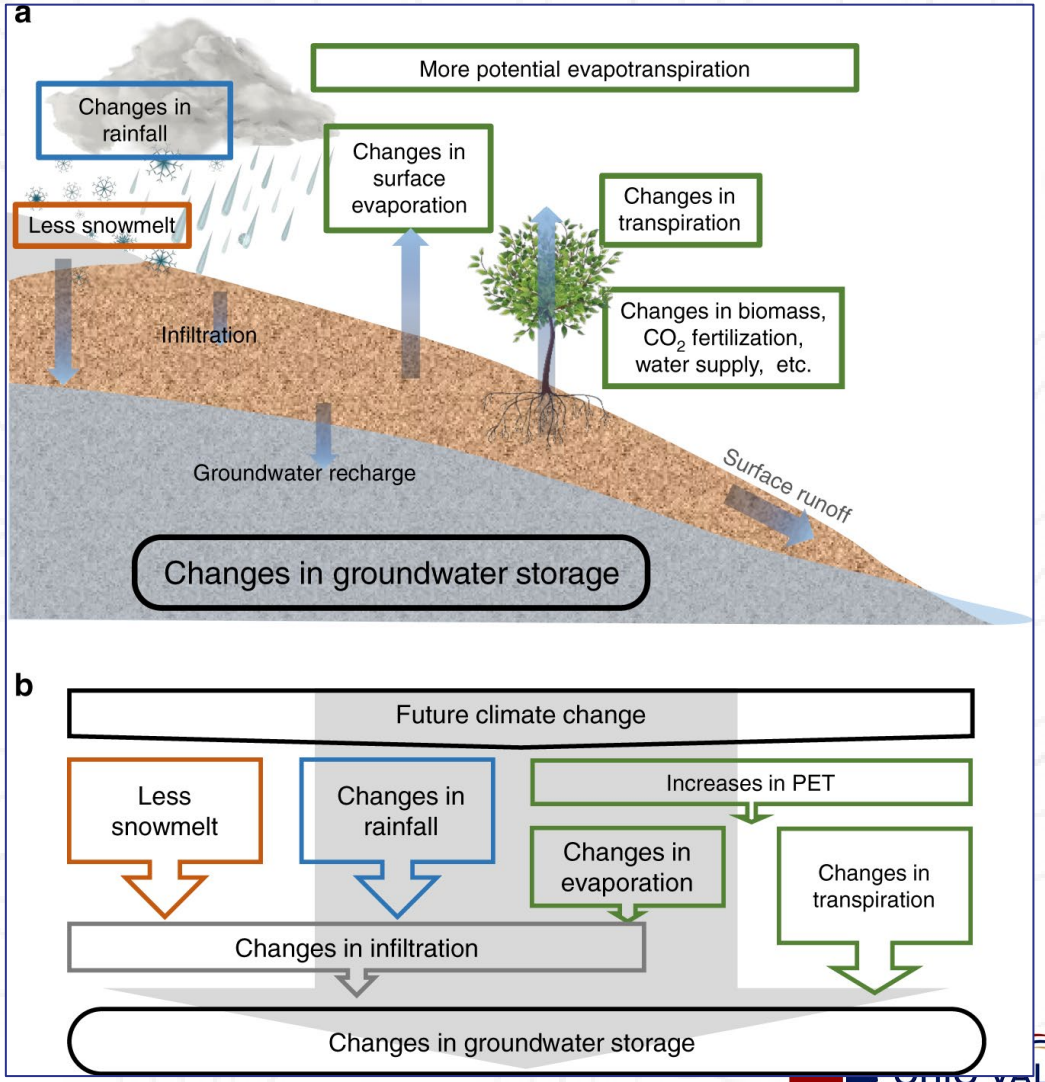


CLIMATE INFLUENCE ON GROUNDWATER

- Less precipitation and less recharge back into the groundwater

- Increased pumping due to less surface water resources

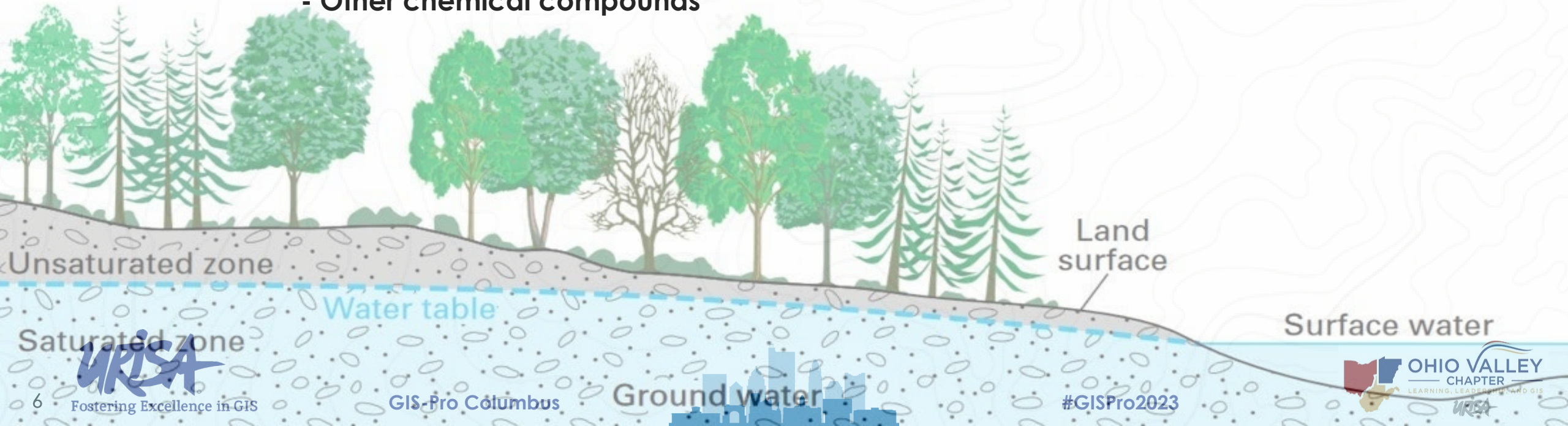
- Decreased soil moisture, increased runoff, and decreased soil infiltration



STUDY OBJECTIVE (CONT.)

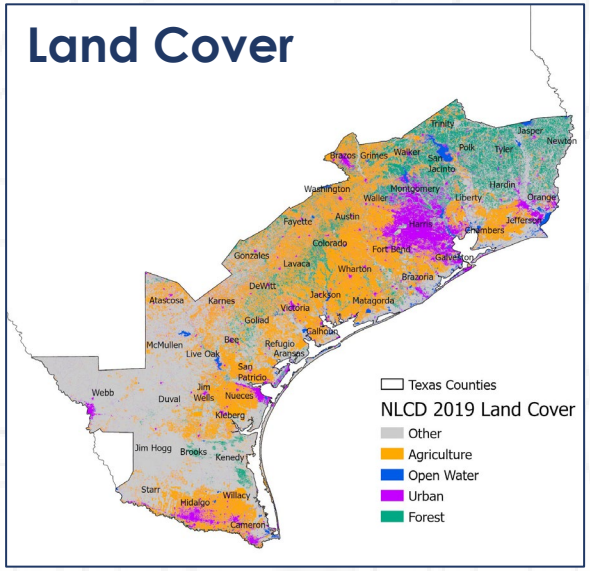
Question: What primary or secondary drivers are affecting groundwater quality and thus groundwater contamination?

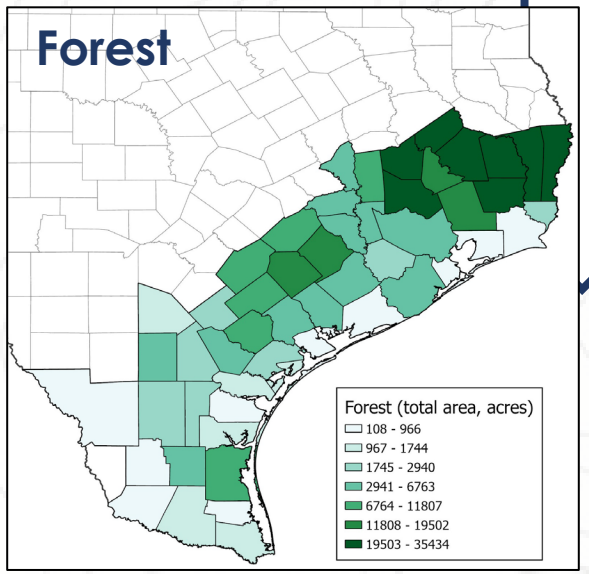
- Independent variable – **Total Dissolved Solids (TDS)**
- Dependent variables:
  - **Land use (primary)**
  - **Climate (secondary)**
  - **Other chemical compounds**

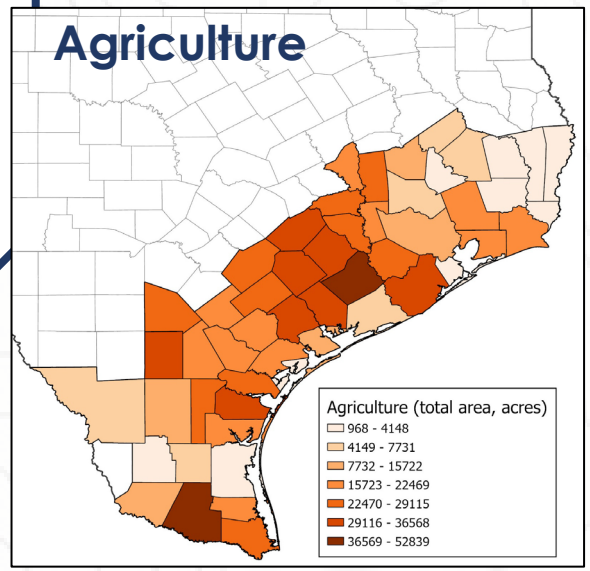


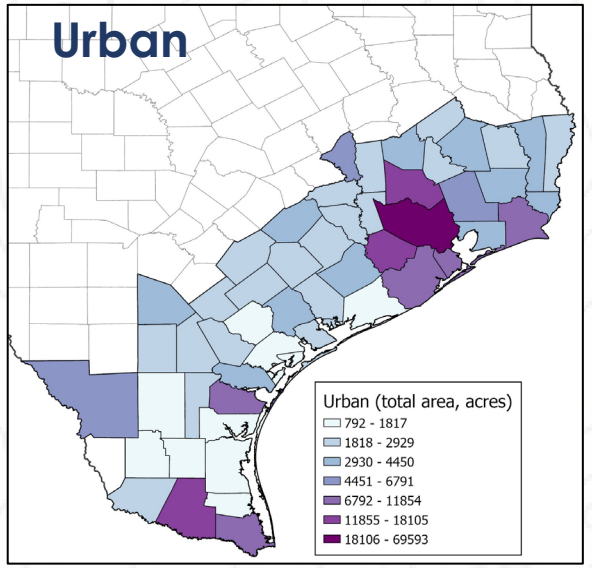
LAND USE MODEL VARIABLES

Land Cover | Soil Moisture | Drought Severity | Streamflow | Groundwater Recharge | Precipitation | **Groundwater Quality**









CLIMATE MODEL VARIABLES

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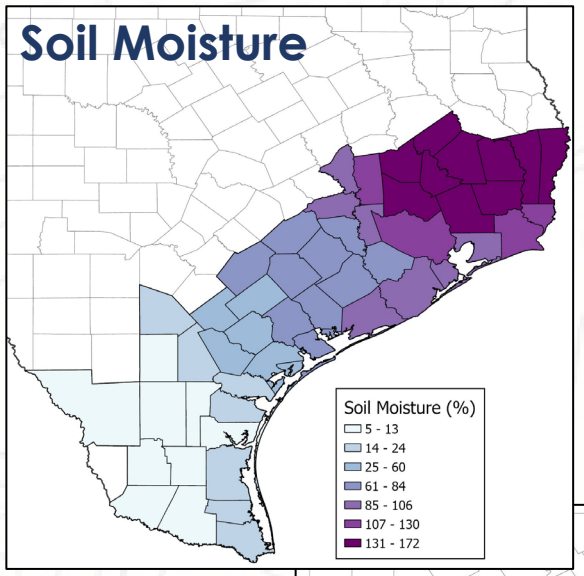

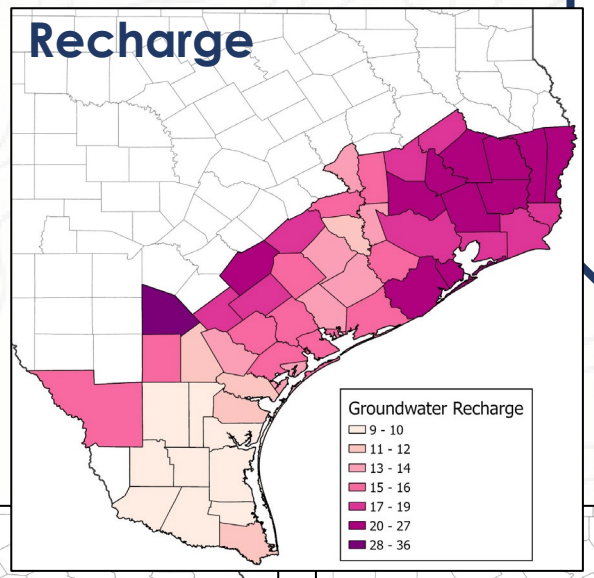

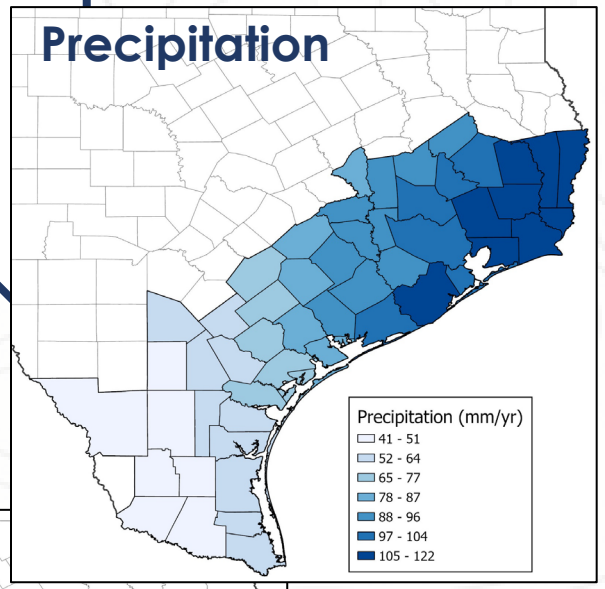

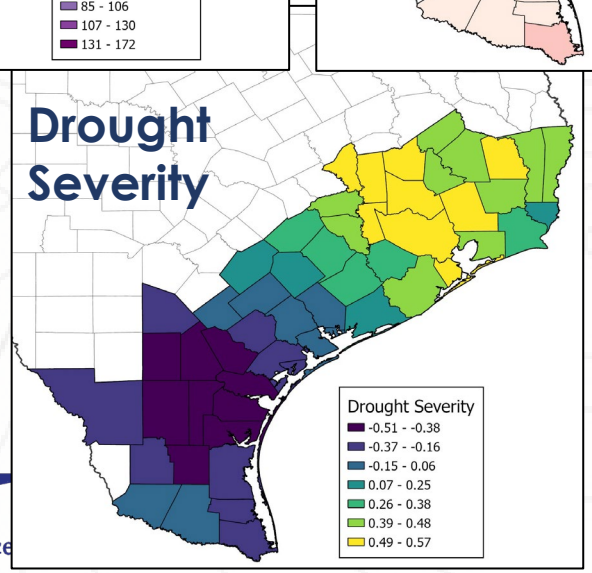

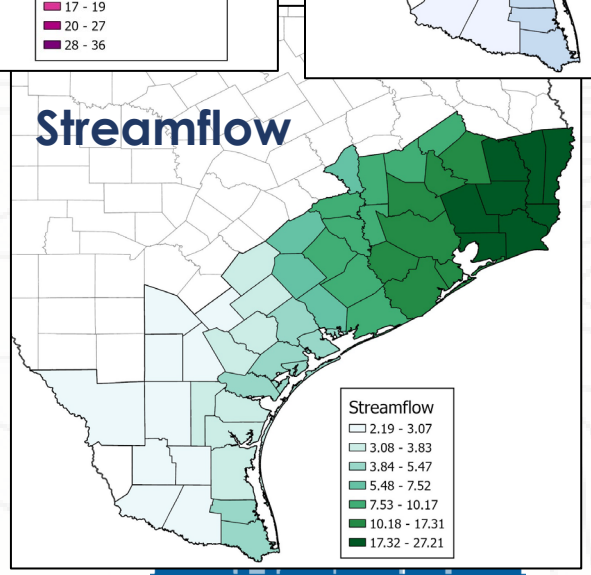

Over 33 chemical compounds analyzed, including:

- Antimony
- Arsenic
- Barium
- Beryllium
- Boron
- Bromide
- Cadmium
- Chromium
- Fluoride
- Lithium
- Mercury
- Nitrate
- Nitrite
- Selenium
- Thallium

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GLOBAL & LOCAL REGRESSION MODELS

Global Models

- Exploratory Regression
- Ordinary Least Squares (OLS)
- Spatial Autocorrelation (Global Moran's I)

Local Model

- Multiscale Geographically Weighted Regression (MGWR)

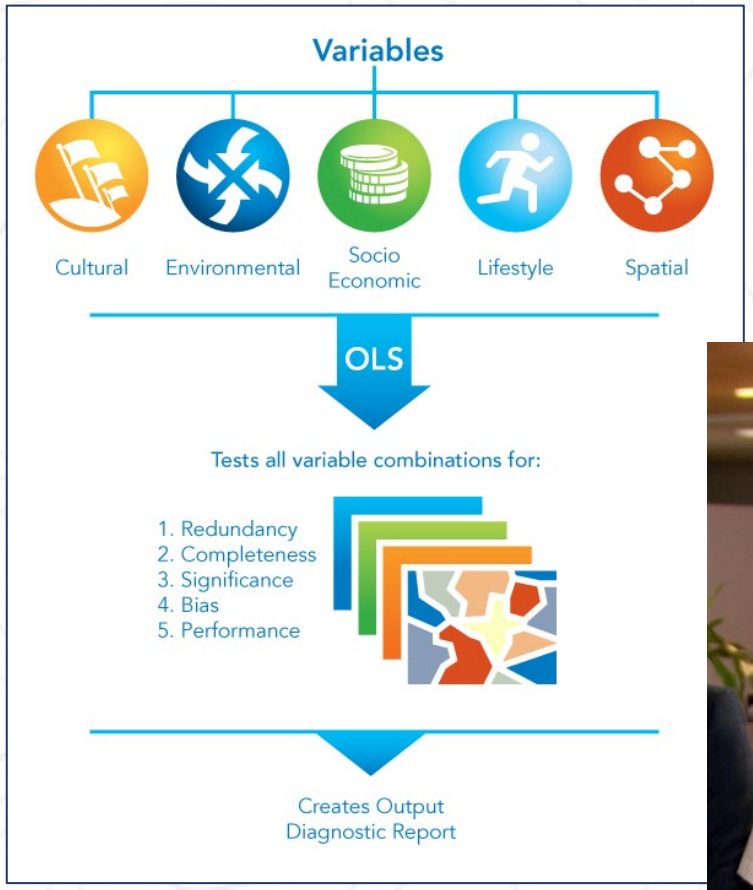
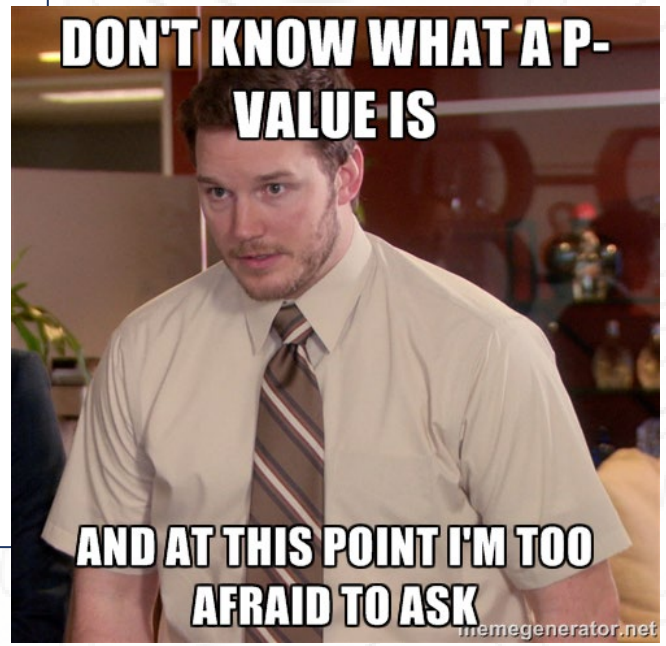


Photo Credit: ESRI, 2023. Exploratory Regression. ArcGIS Pro Documentation.



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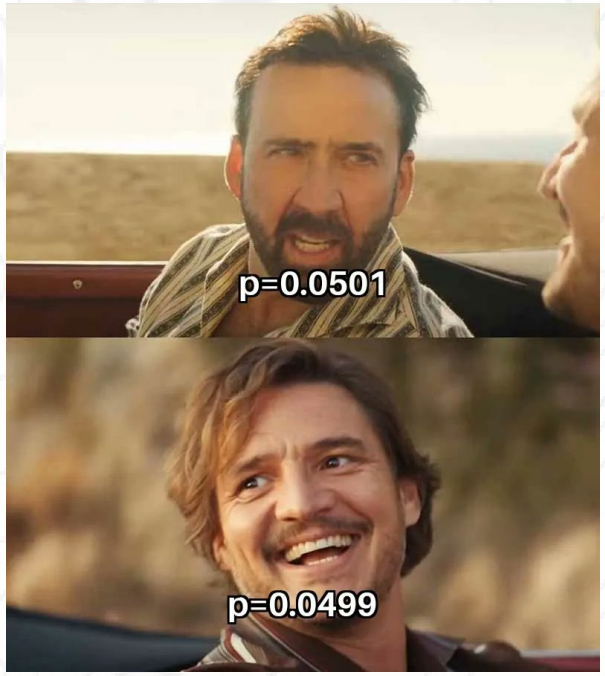

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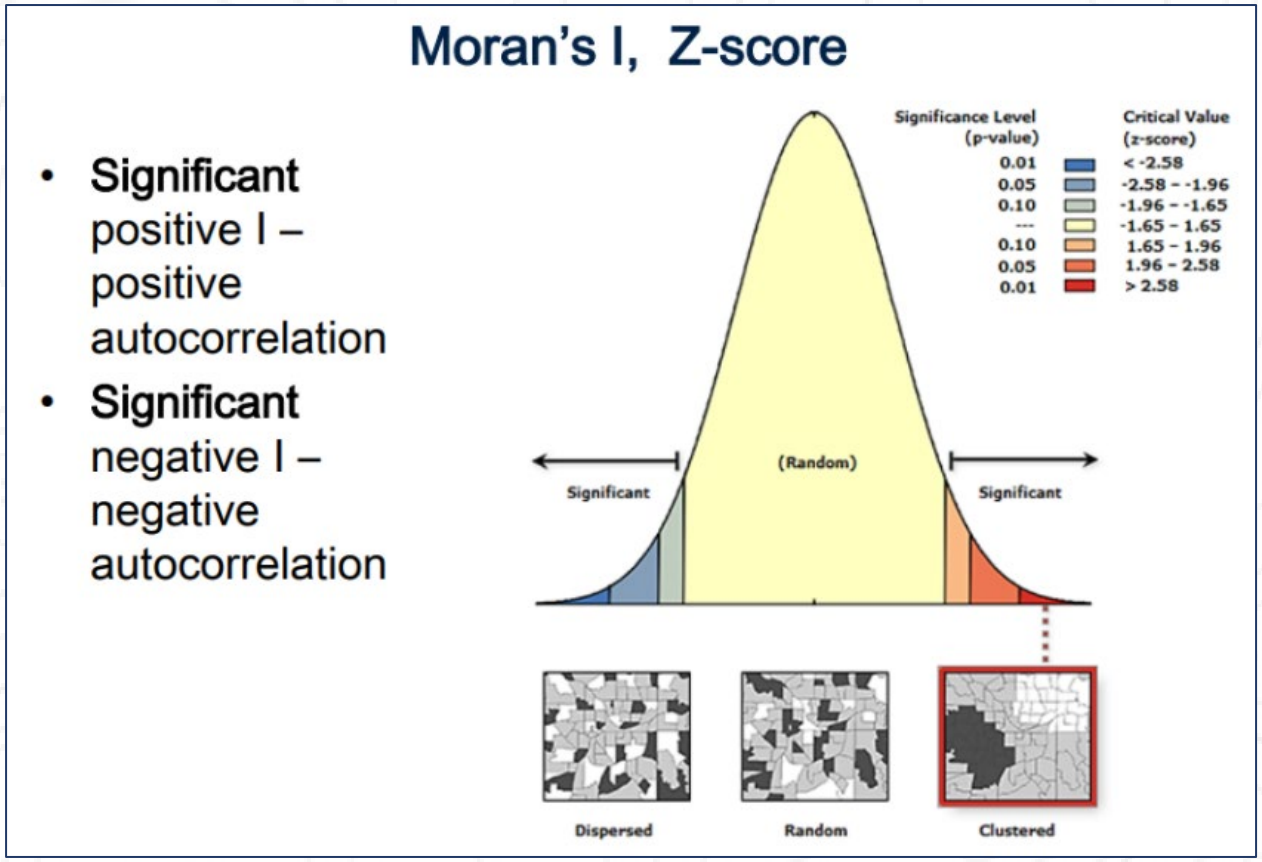

Photo Credit: ESRI, 2023. Spatial Autocorrelation (Global Moran's I). ArcGIS Pro Documentation.

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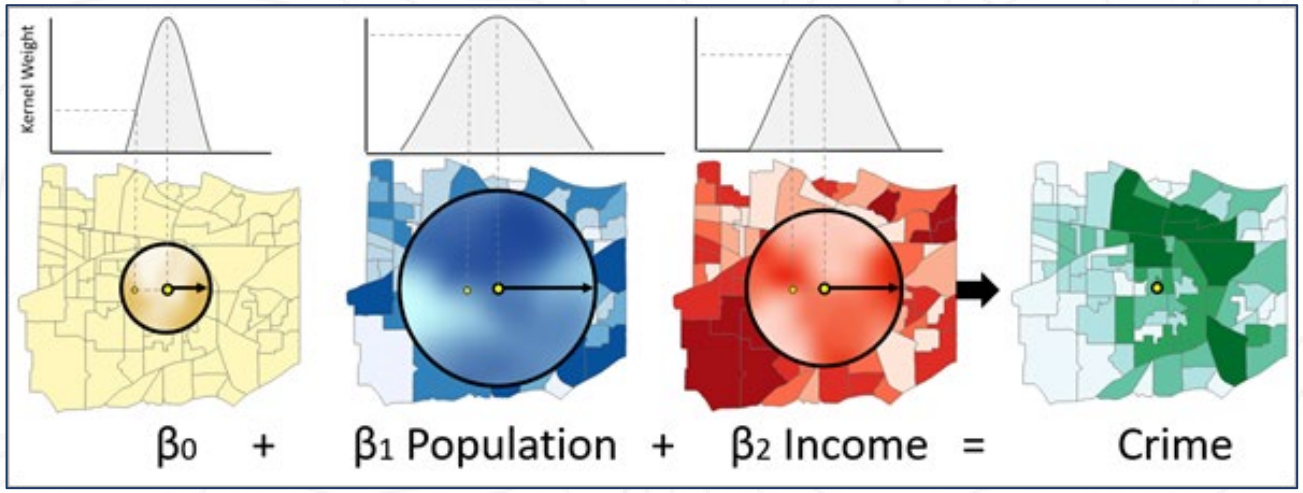


Photo Credit: ESRI, 2023. Multiscale Geographically Weighted Regression (mGWR). ArcGIS Pro Documentation.

Local Model

- Multiscale Geographically Weighted Regression (MGWR)

*Local models allow you to visualize your data in a **geographic framework***

CLIMATE MODEL EXPLORATORY REGRESSION

Adjusted R-Squared	K(BP)[1]	Passing Models[2]
0.81	0.04	+fluoride*** -streamflow***
0.82	0.04	+fluoride*** -recharge*** -streamflow***
0.91	0.01	+barium*** +boron*** +thallium** +streamflow**
0.92	0.02	+barium*** +boron*** +cadmium*** -soil moisture** +streamflow*** +PDSI**
0.91	0.02	+barium*** +boron*** +phosphorus** +thallium** +streamflow**

[1]Koenker (BP) Statistic p-value; [2]Model Variable significance (= 0.10; ** = 0.05; *** = 0.01).*

LAND USE MODEL EXPLORATORY REGRESSION

Adjusted R-Squared	K(BP)[1]	Passing Models[2]
0.80	0.03	+fluoride*** -forest**
0.95	0.02	+boron*** +bromide*** -nitrate*** +agriculture***
0.86	0.01	-barium** +cadmium*** +fluoride*** -forest***
0.93	0.04	+barium** + boron *** +cadmium** -nitrite*** -fluoride***
0.93	0.04	+ boron *** +cadmium** -chromium** +fluoride*** -forest***
0.87	0.01	-barium** +fluoride*** +thallium** +agriculture** -forest** -urban**

[1]Koenker (BP) Statistic p-value; [2]Model Variable significance (= 0.10; ** = 0.05; *** = 0.01).*

VARIABLES

Land Cover | Soil Moisture | Drought Severity | Streamflow | Groundwater Recharge | Precipitation | Groundwater Quality

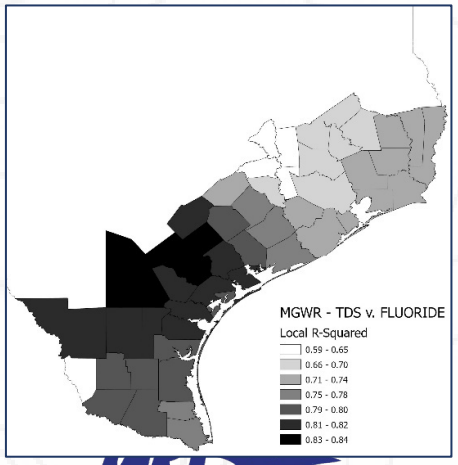
Exploratory Regression Model

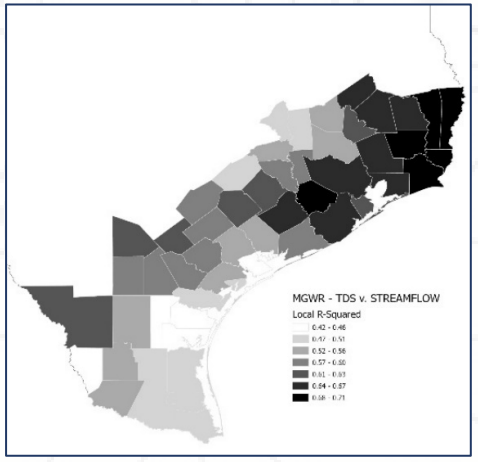
Passing Climate Model:
+fluoride, -streamflow

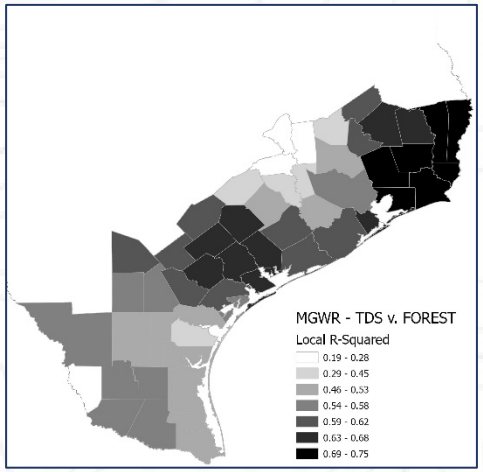
Passing models then run through OLS to check for:
redundancy, completeness, significance, bias, performance

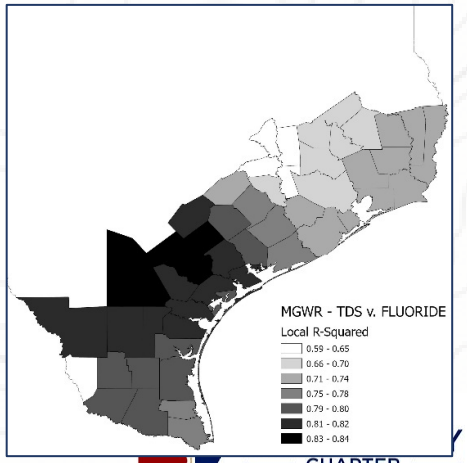
Passing Land Use Model:
+fluoride, -forest

mGWR









LAND USE MODEL – MGWR RESULTS
TDS, +FLUORIDE, -FOREST

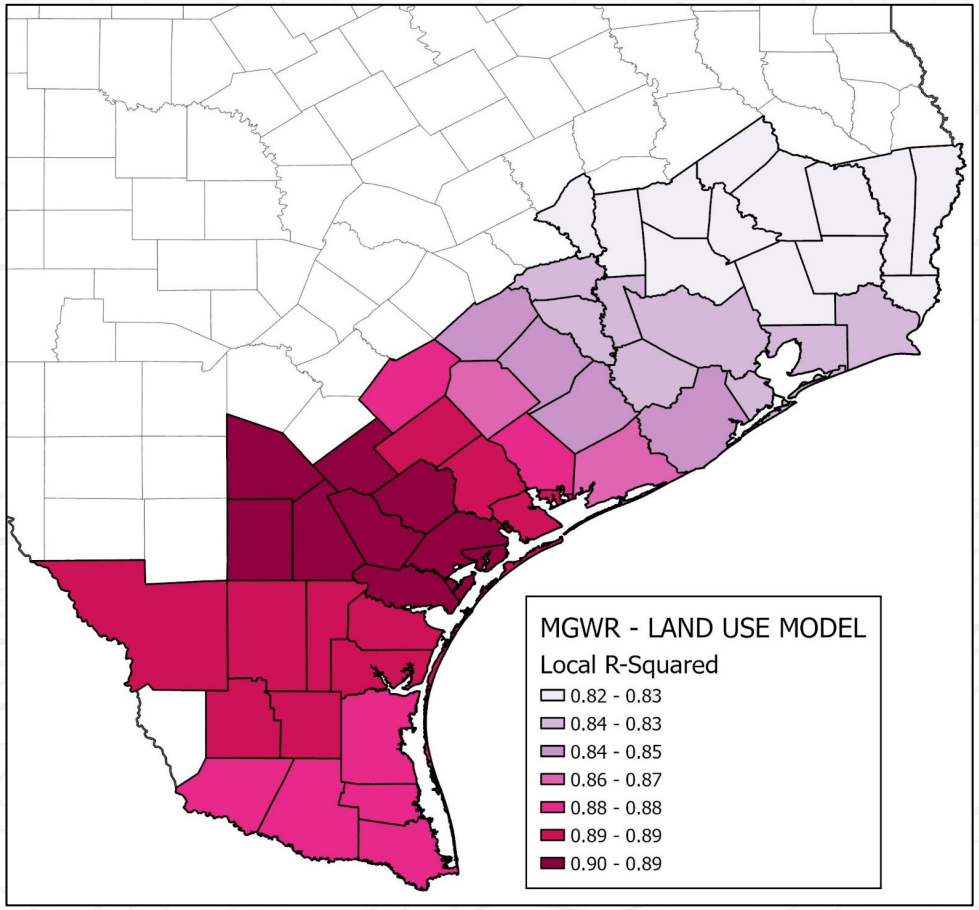
Question: What primary drivers are impacting groundwater quality?

mGWR:

- **TDS and fluoride are highly correlated** (high r^2) in the south-west counties

- There is a **lack of forest** in these counties, both due to the natural landscape of TX and due to increased development and agricultural practices

- Forest and other herbaceous land covers (i.e., wetlands) **filter contaminates** before they reach the aquifers



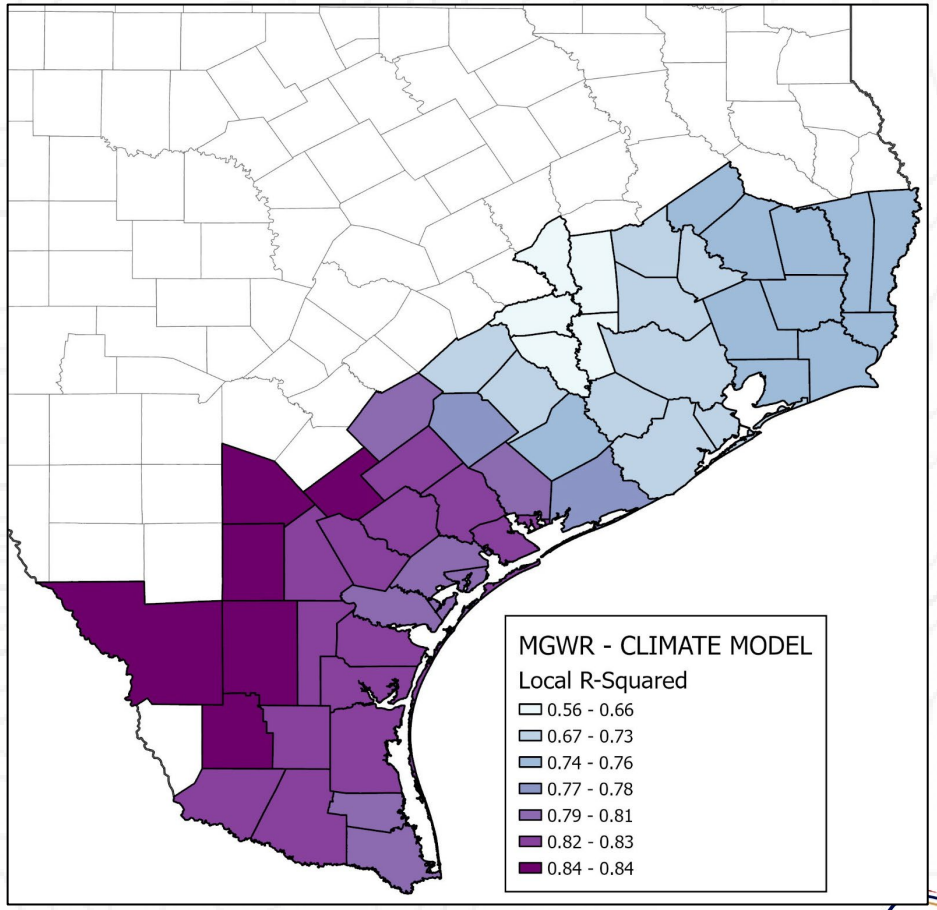
CLIMATE MODEL – MGWR RESULTS
TDS, +FLUORIDE, -STREAMFLOW

Question: What secondary drivers are impacting groundwater quality?

- Indicative of **overall climate change** that is occurring

- Less precipitation, less streamflow, **less dilution** of contaminates in groundwater

- Intensification of the water cycle which is propagating a drought = **less infiltration** of surface water into the aquifers



THANK YOU!

Kelsey Calvez

Kelsey.Calvez@freese.com

Dr. Brandi Gaertner

bah6009@psu.edu