



Investigation of Groundwater Geochemistry and Water Quality in the Fayetteville Shale Play

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Acknowledgements

- **Van Buren County Study**
 - **Arkansas Water Resources Center**
 - **U.S. Geological Survey**
 - **Shirley Community Development Center**
- **Faulkner County Study**
 - **Faulkner County**
- **Duke University – All Laboratory Analyses**

Outline of Discussion

- **Background**
- **Project activities**
- **Discussion of water-quality data**
 - **Comparison of source and historical QW data**
 - **Geochemical evolution of groundwater**
 - **Reduction/oxidation processes**
- **Summary of results**

Likely Avenues for GW Contamination

- **1. Surface Sources:**

- Leaking ponds
- Pipe leaks
- Spills



- **2. Subsurface Sources:**

- Casing failure
- Migration along abandoned wells
- Migration during FRACKING along faults/fractures

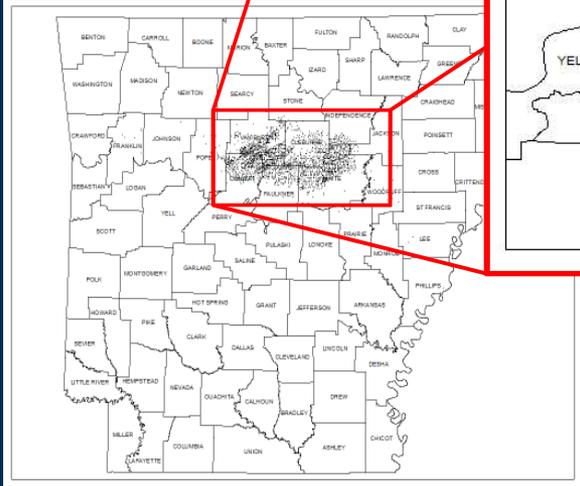
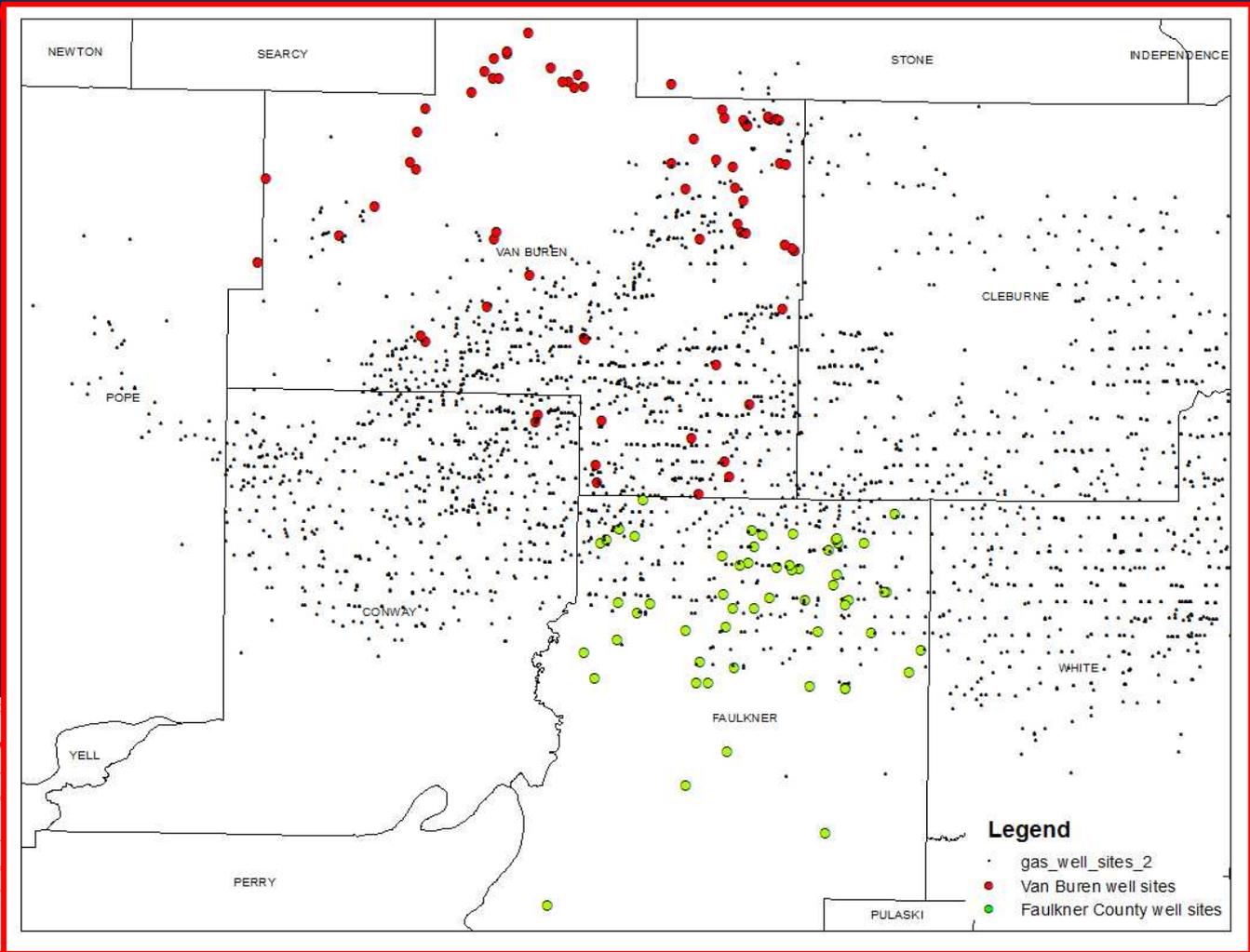
Problems in Identifying Impacts

- **Lack of pre-development QW data**
- **Local domestic wells completed in shale formations**
- **Shale naturally contain elevated salts, iron, sulfides, and methane**
- **Anecdotal evidence can be unreliable**
- **Results of mixing similar water**

Groundwater Study Activities

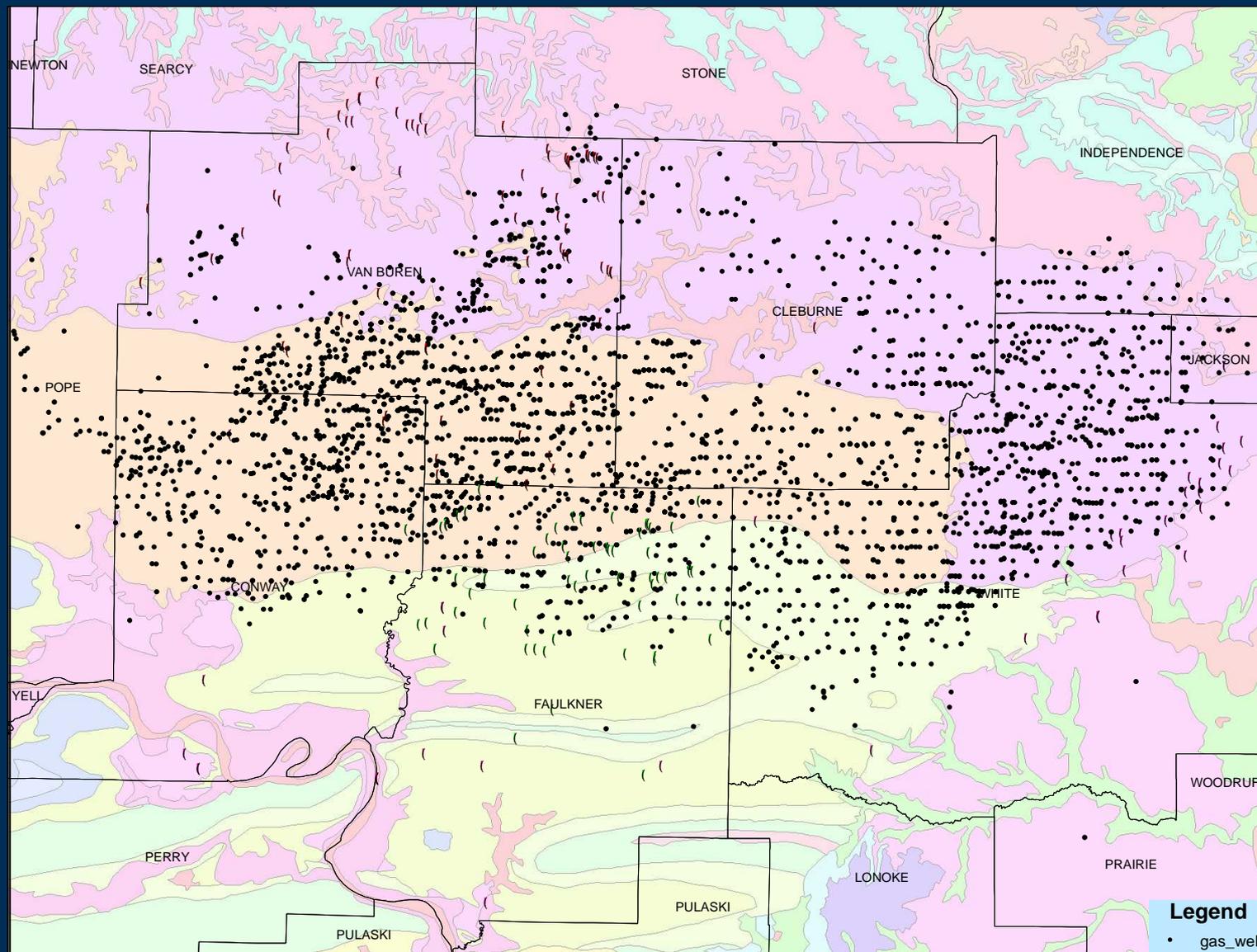
- Sites located in Van Buren and Faulkner Co.
- 127 samples with major ions and trace metals
- 51 samples with methane gas concentration
- Subset of the samples with O, H, B, C, and Sr isotopes





Location of Study Area

Groundwater Sampling Locations



Legend

- gas_well_sites_2
- (Van Buren well sites
- (Faulkner County well sites
- (historic_wells



Process Pond (flowback) Analysis

Analyte	Concentration
pH	
Temperature (deg Celsius)	
Specific Conductance ($\mu\text{S}/\text{cm}$)	
Total Dissolved Solids	
Calcium (mg/L)	13
Magnesium (mg/L)	9
Sodium (mg/L)	1840
Potassium (mg/L)	<10
Bicarbonate (mg/L)	6
Sulfate (mg/L)	42
Chloride (mg/L)	2180
Iron, dissolved ($\mu\text{g}/\text{L}$)	

Historical QW Statistics (44 wells)

Analyte	Min	Max	Median
pH	5.9	8.2	6.8
Temperature (deg Celsius)	11	22	18
Specific Conductance ($\mu\text{S}/\text{cm}$)	32	1840	378
Total Dissolved Solids	29	1210	170
Calcium (mg/L)	7.9	107	23
Magnesium (mg/L)	0.3	211	9.1
Sodium (mg/L)	2.0	145	24
Potassium (mg/L)	0.4	11	1.6
Bicarbonate (mg/L)	6	980	125
Sulfate (mg/L)	0.8	255	10
Chloride (mg/L)	1.6	378	20
Iron, dissolved ($\mu\text{g}/\text{L}$)	0	6,300	5

Groundwater Data Statistics (127 wells)

Analyte	Min	Max	Median
pH	3.7	8.6	6.5
Temperature (deg Celsius)	14.8	26.2	17.0
Specific Conductance ($\mu\text{S}/\text{cm}$)	7.1	909	244
Total Dissolved Solids	6.7	687	211
Calcium (mg/L)	0.1	87.8	16.6
Magnesium (mg/L)	0.2	45.7	4.2
Sodium (mg/L)	0.6	159	9.1
Potassium (mg/L)	NA	NA	NA
Bicarbonate (mg/L)	1.0	430	125
Sulfate (mg/L)	0.1	151	4.3
Chloride (mg/L)	0.9	70.1	3.7
Iron, dissolved ($\mu\text{g}/\text{L}$)	<50	5,680	190

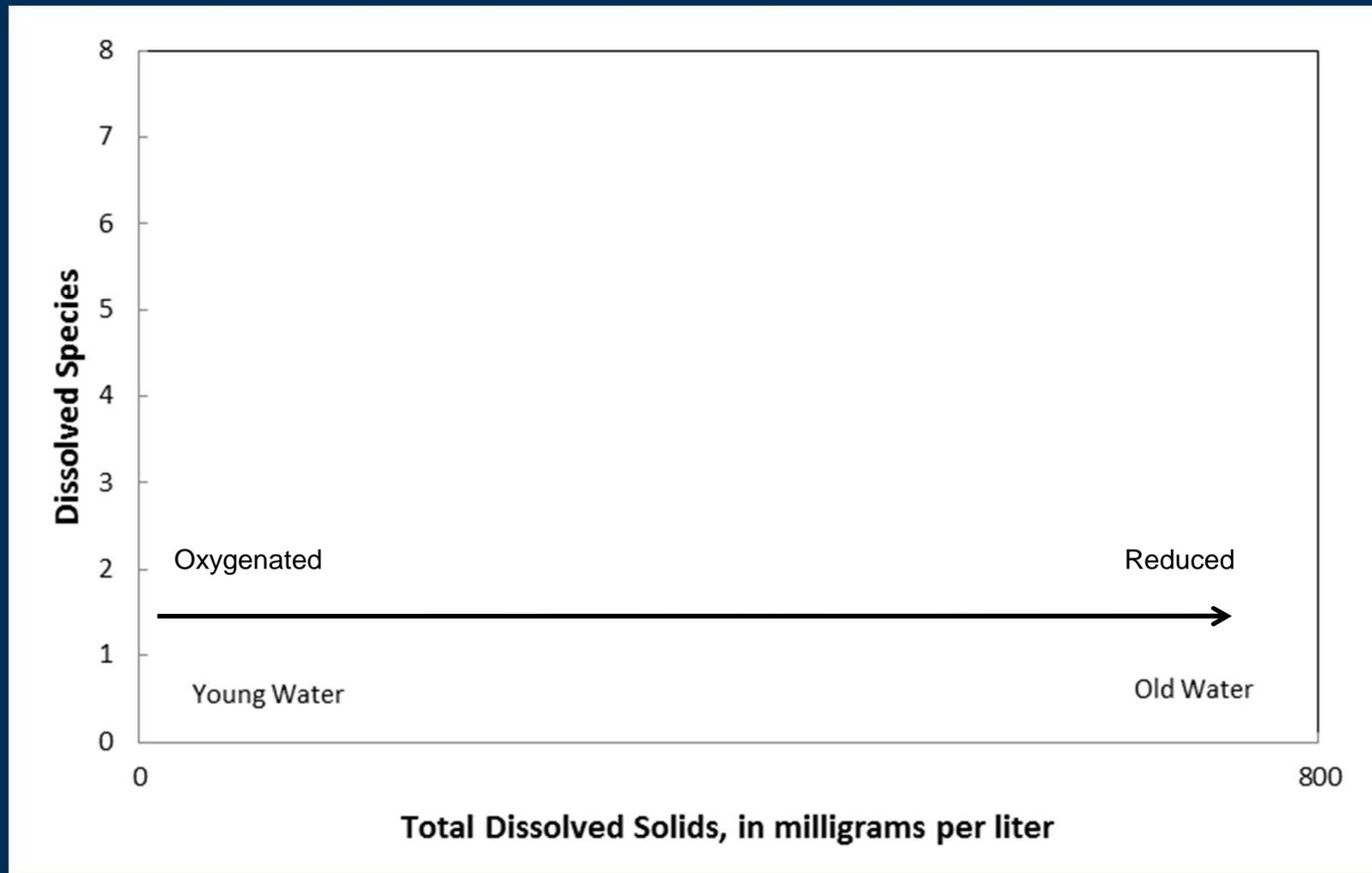
Geochemical Evolution of Groundwater

- **Infiltration of low TDS precipitation**
- **Chemical reactions along flow path**
 - **dissolution**
 - **cation exchange**
- **Reduction/oxidation reactions**

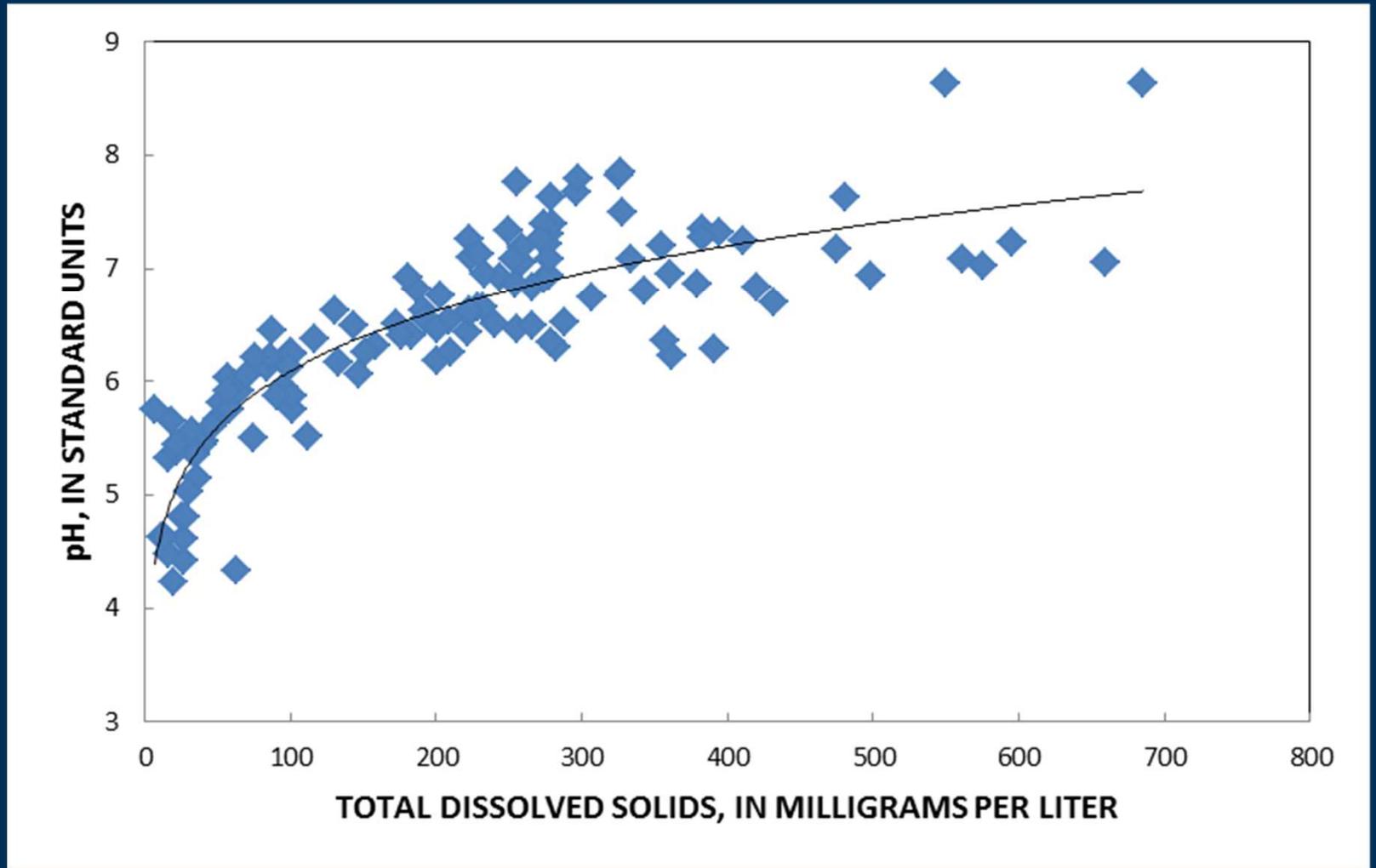
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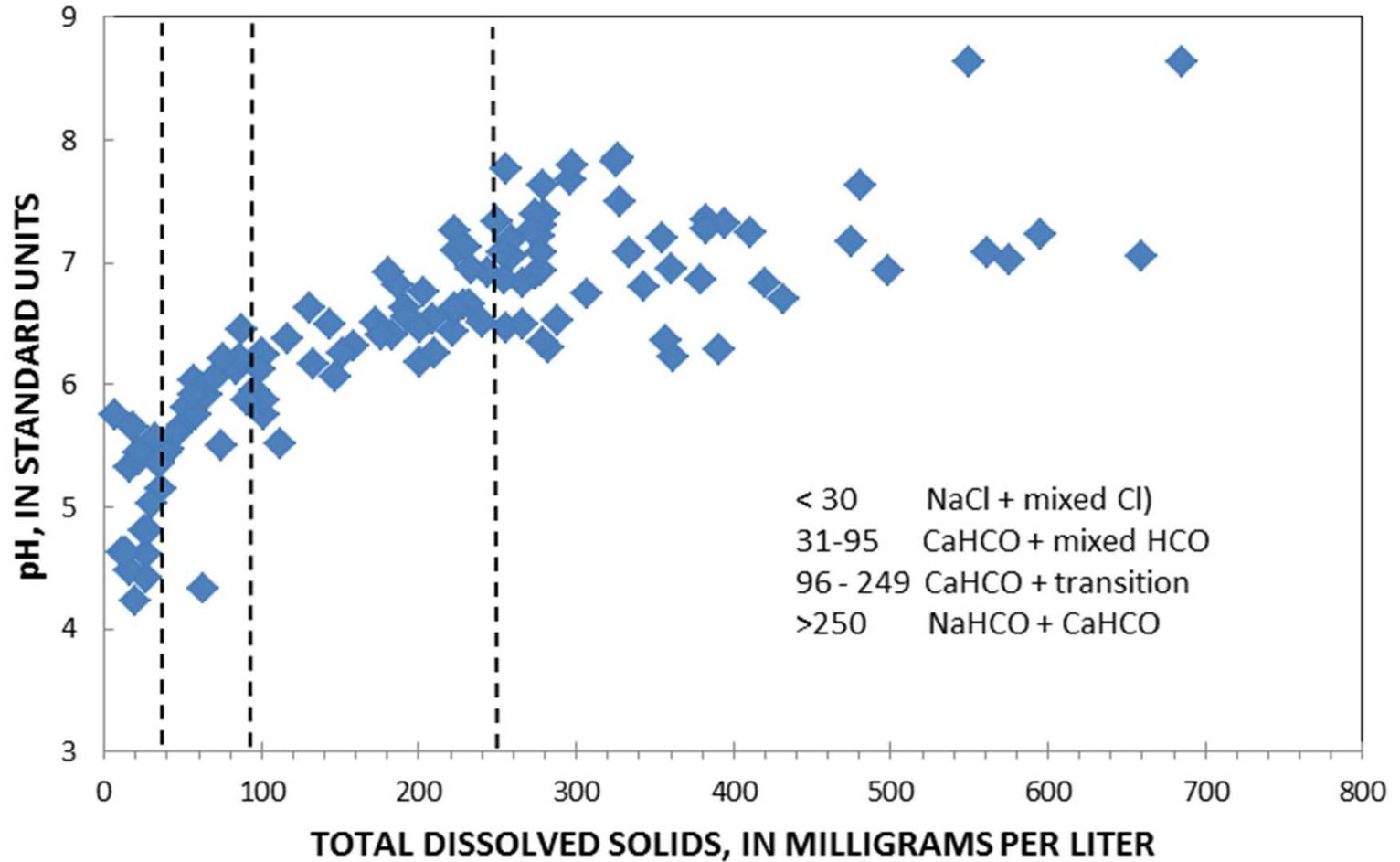
Geochemical Evolution Along Flow Path



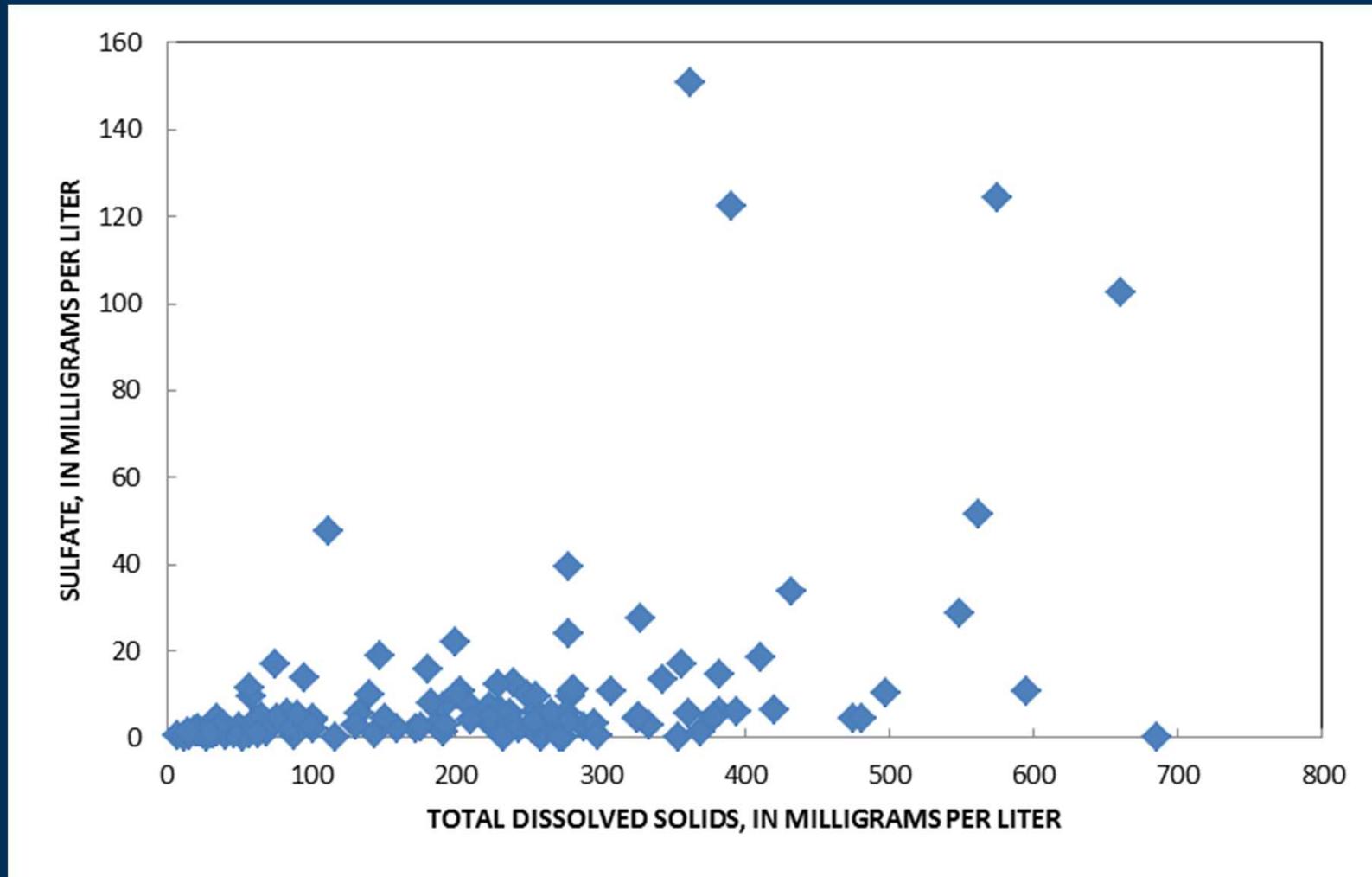
Total Dissolved Solids and pH



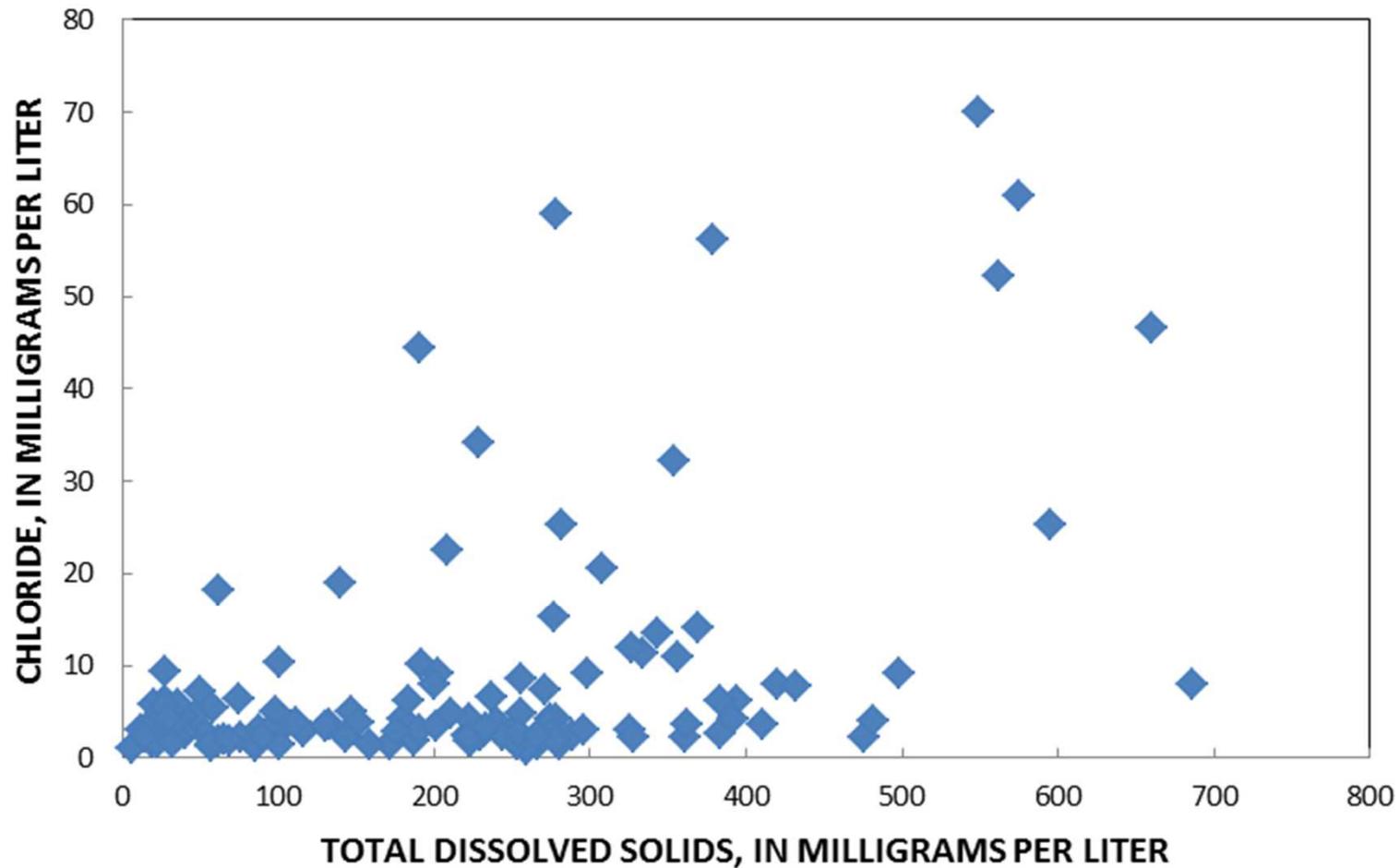
Groundwater Chemistry Type



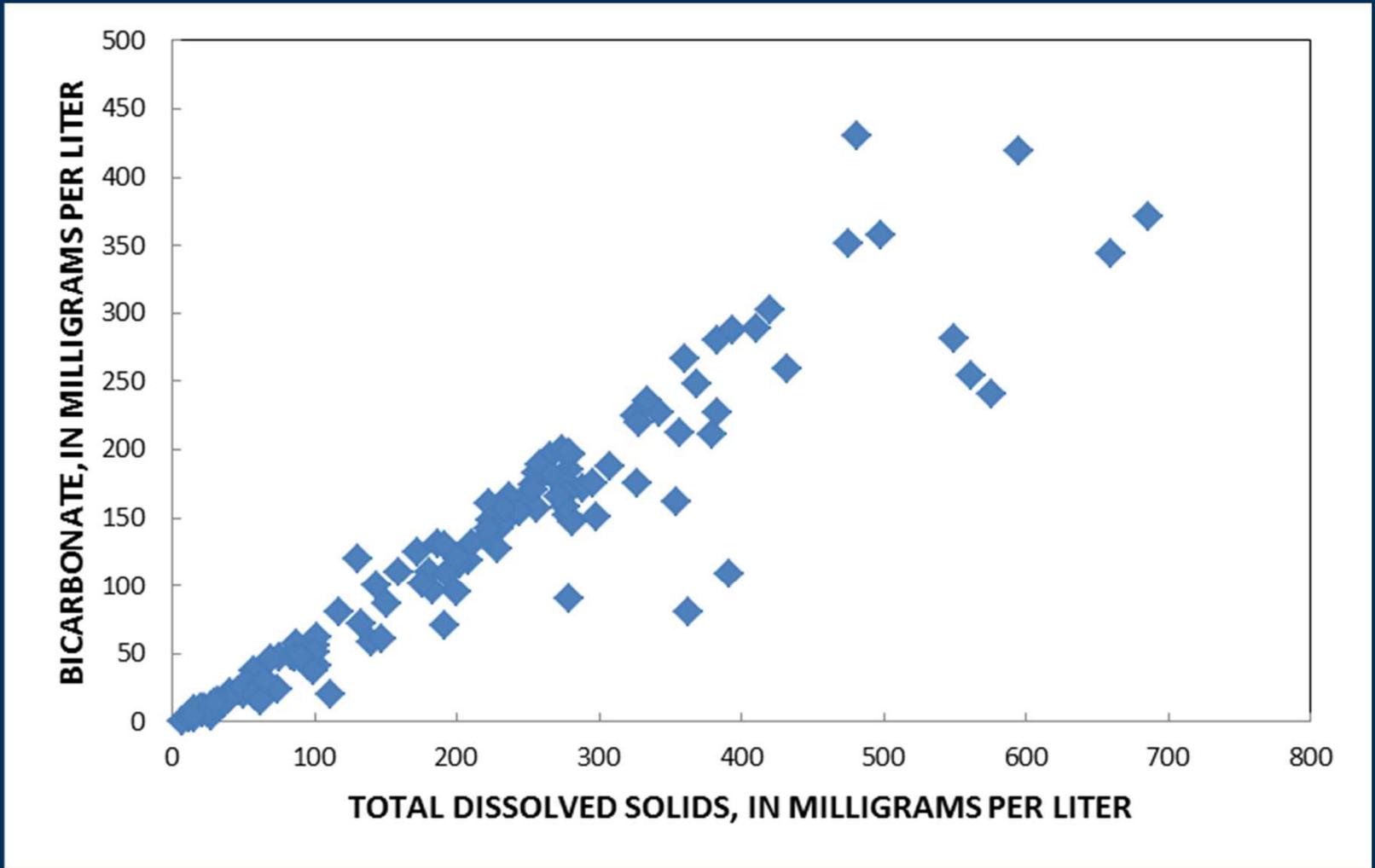
Total Dissolved Solids and Sulfate



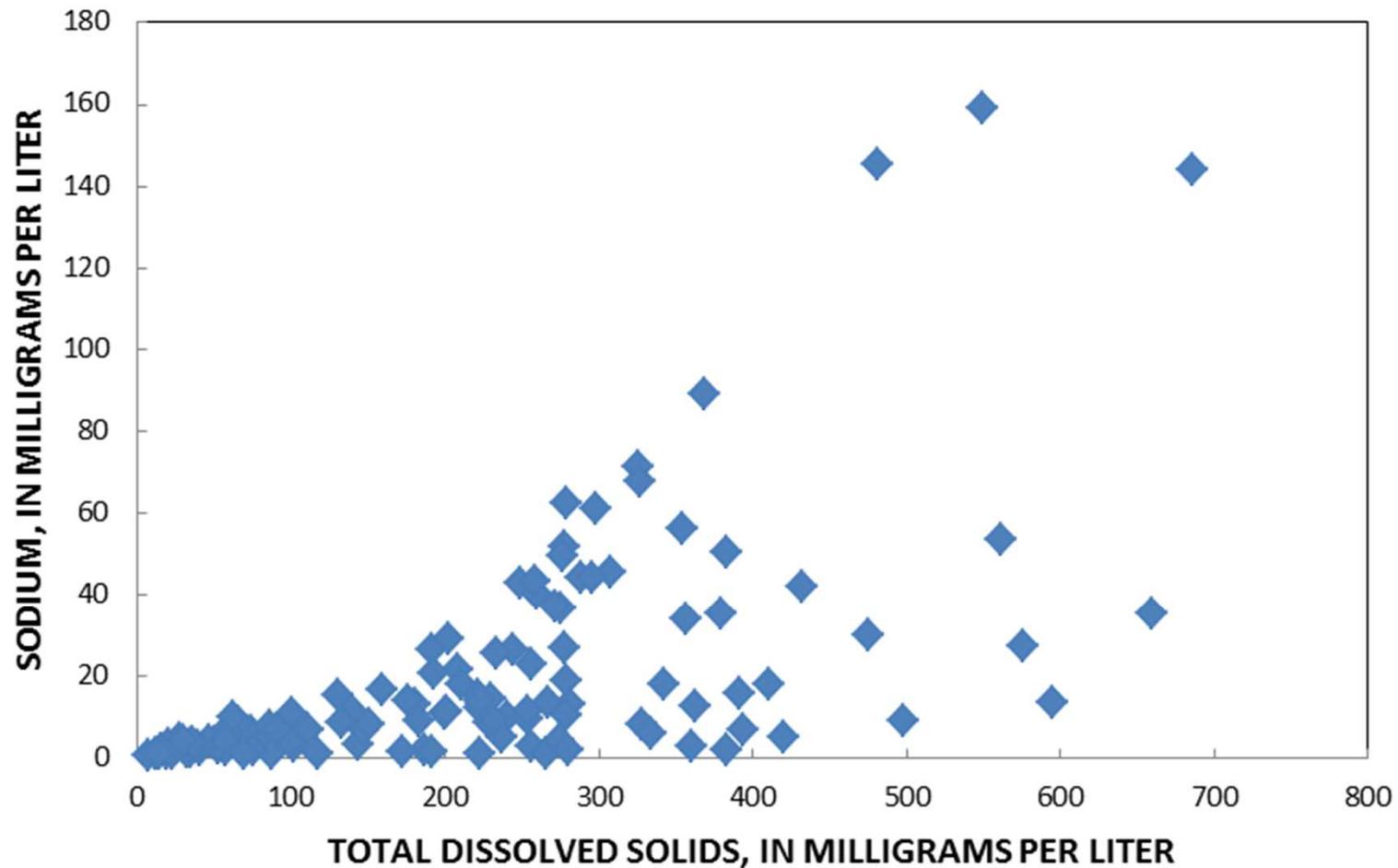
Total Dissolved Solids and Chloride



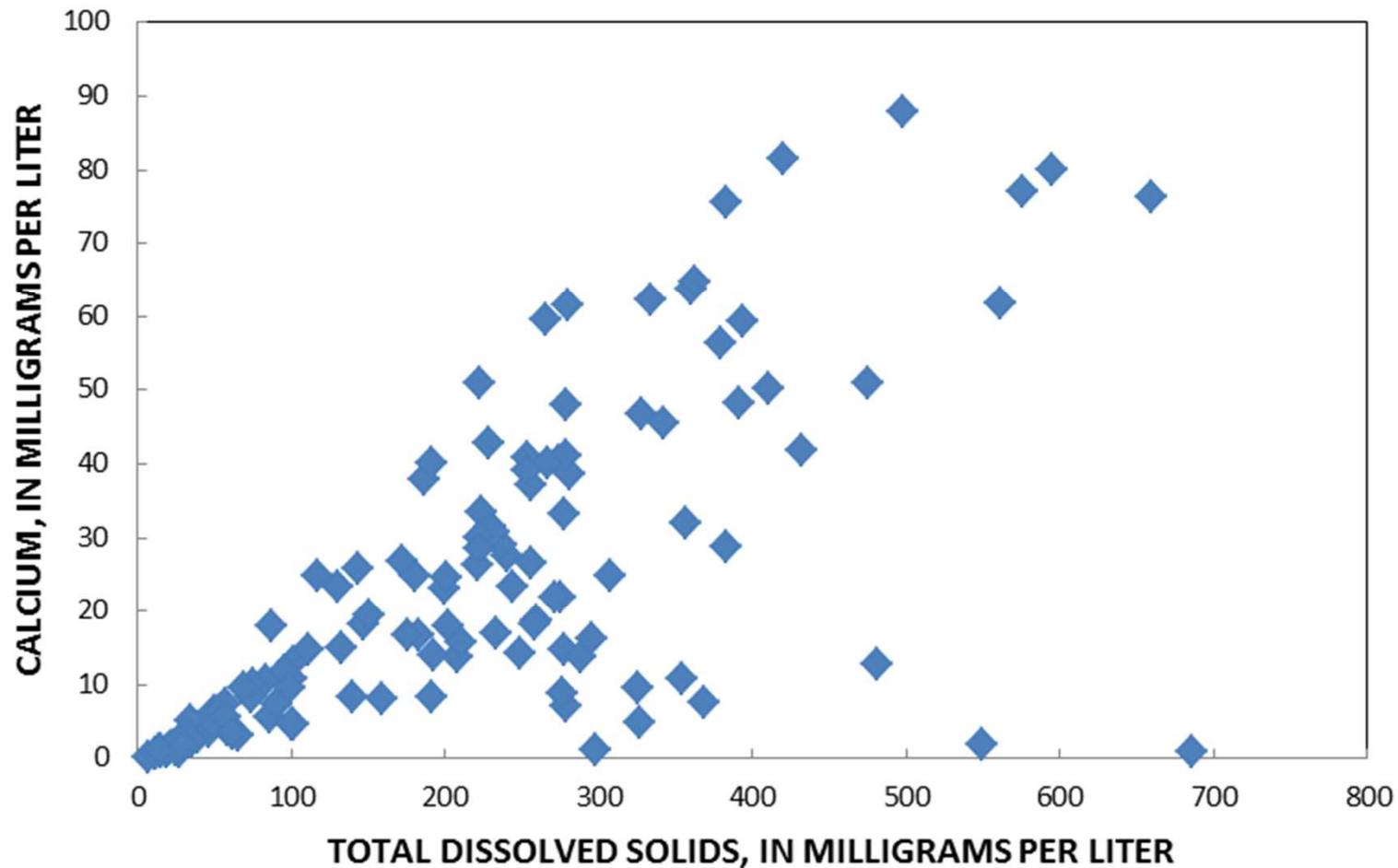
Total Dissolved Solids and Bicarbonate



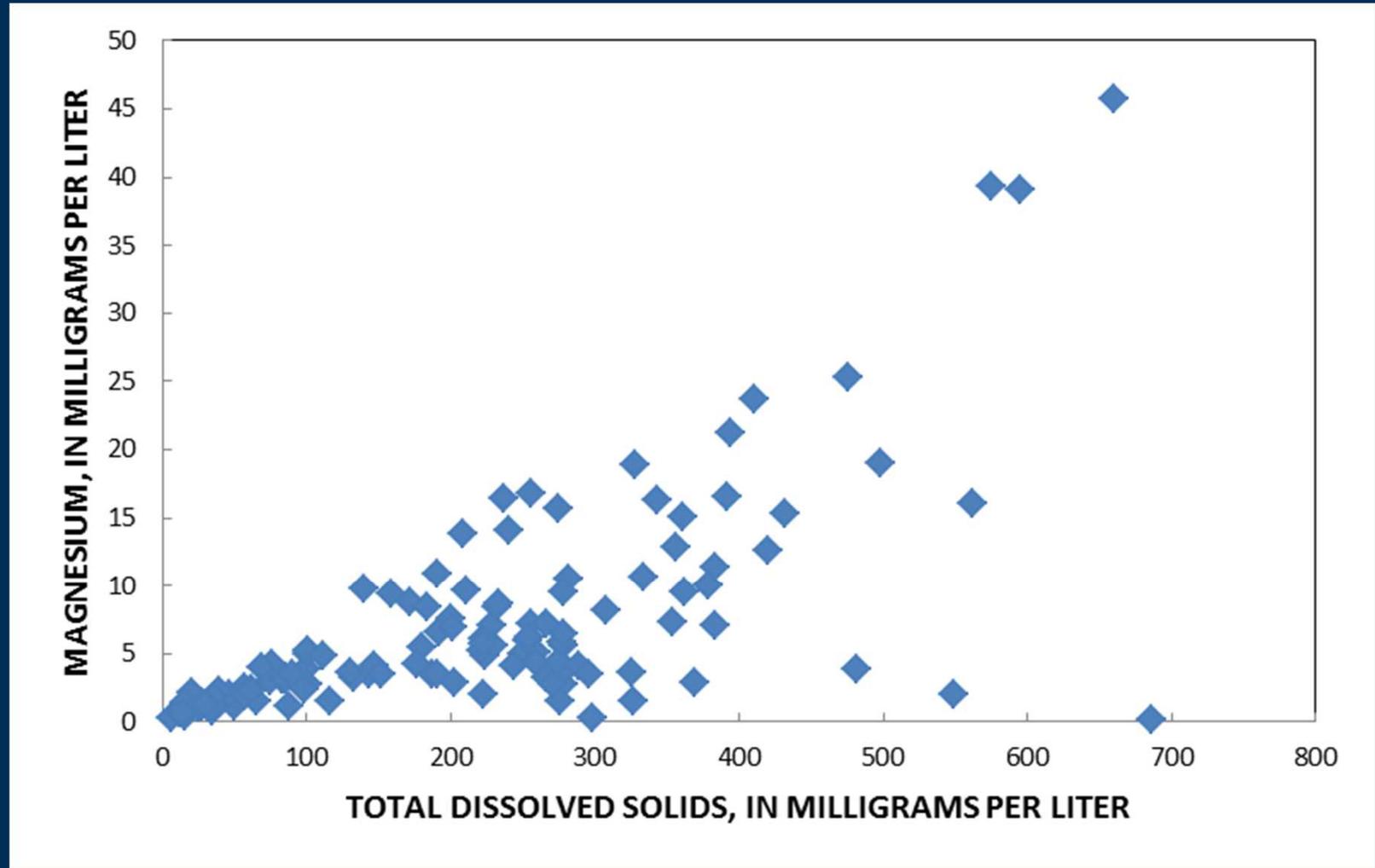
Total Dissolved Solids and Sodium



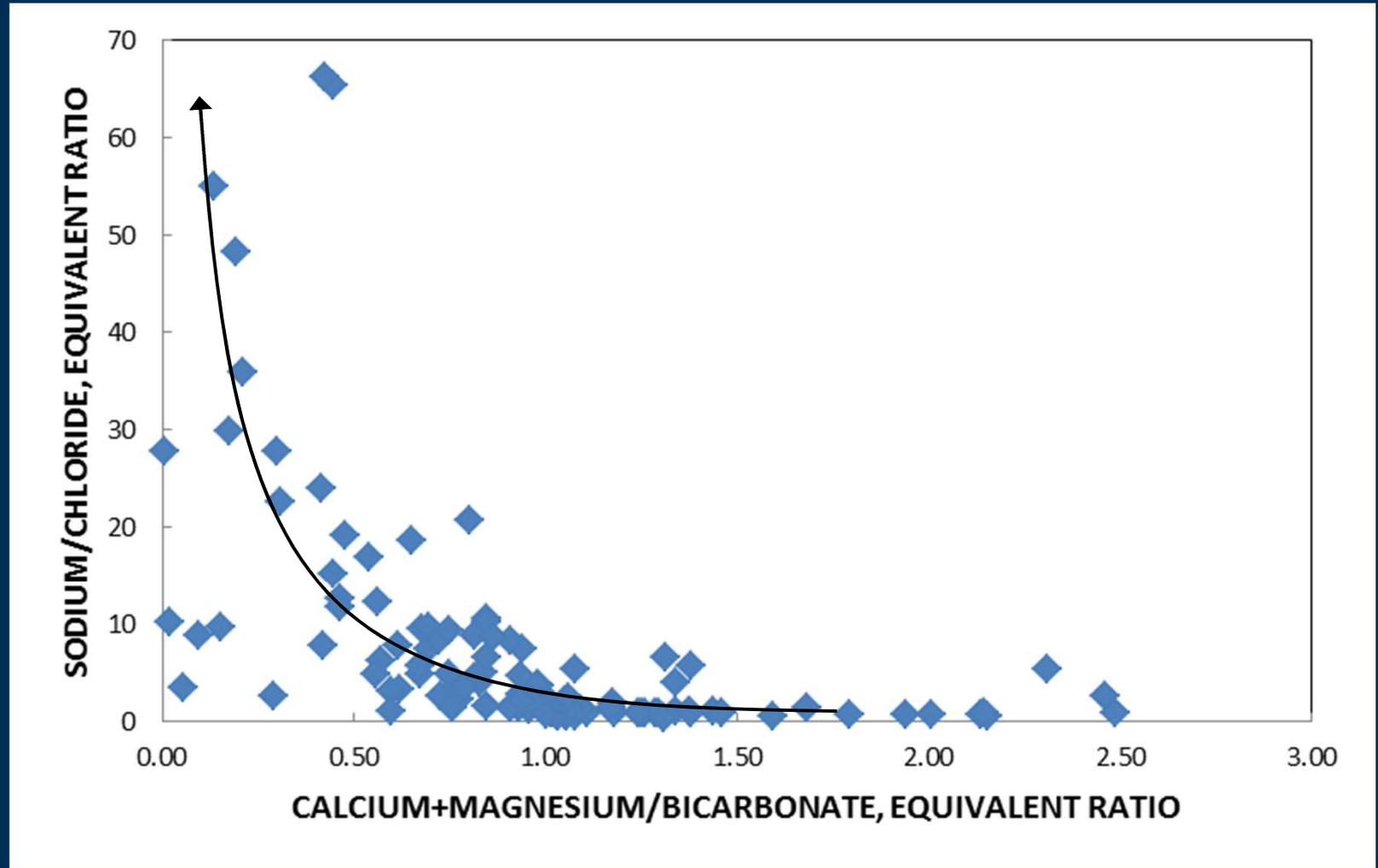
Total Dissolved Solids and Calcium



Total Dissolved Solids and Magnesium



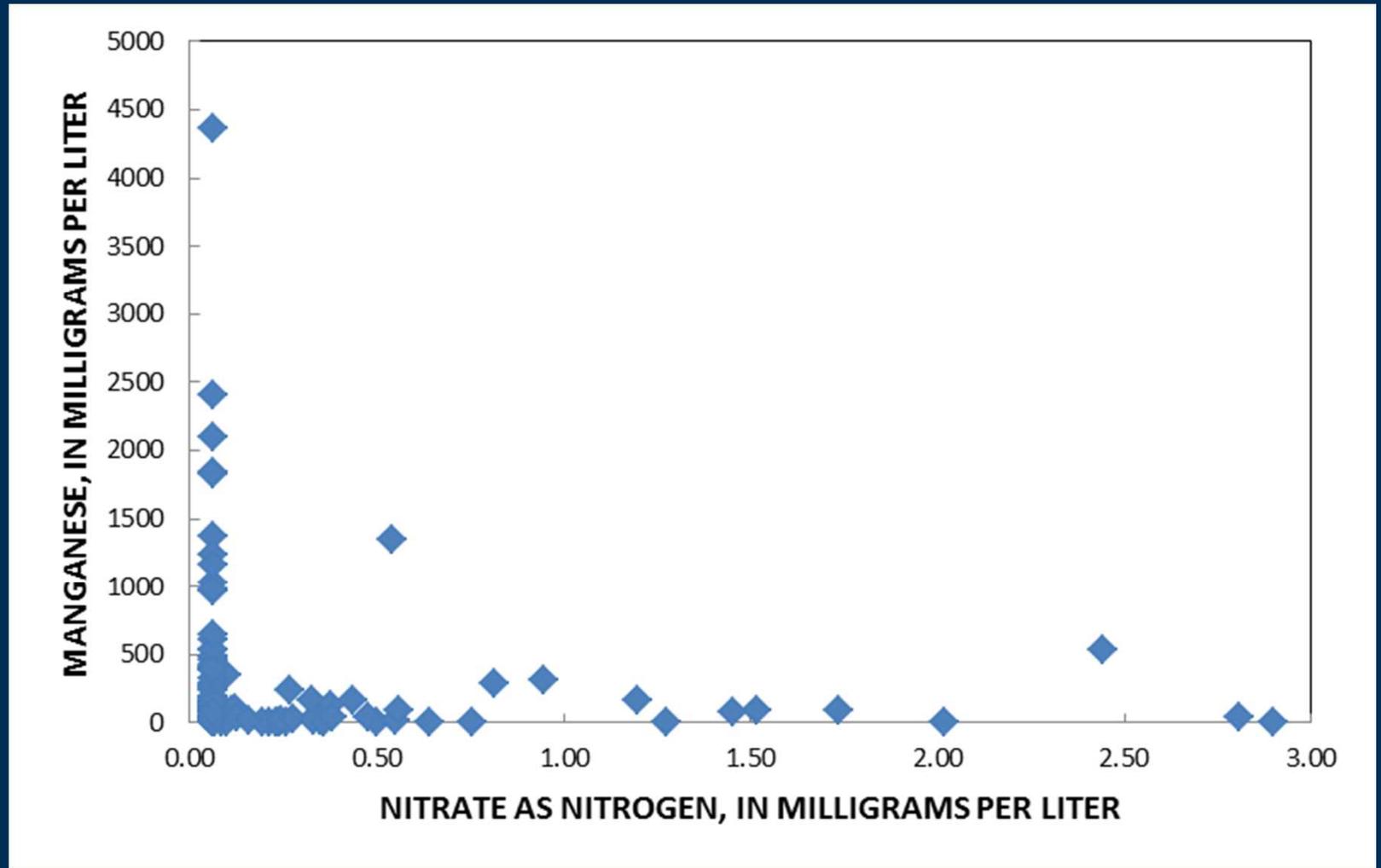
Sodium/Chloride and Ca+Mg/Bicarbonate



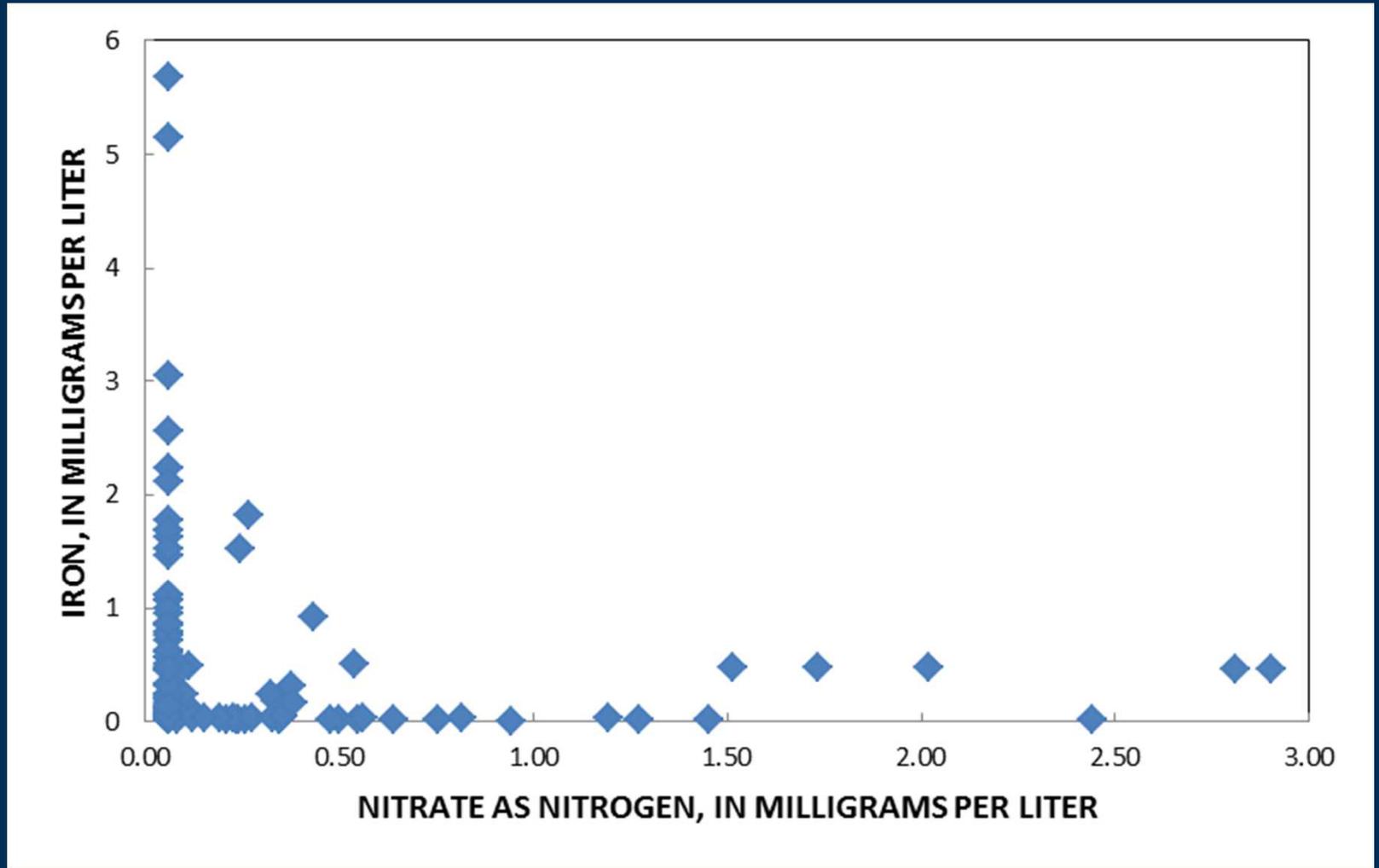
Geochemical Evolution of Groundwater

- **Cradle – precipitation followed by dissolution of minerals through rock/water interaction**
- **Chemical reactions along flow path – cation exchange, precipitation with supersaturation, further dissolution of rock/minerals, effects of changes in pH**
- **Microbially driven reactions – redox zonation with availability of organic matter and electron acceptors**

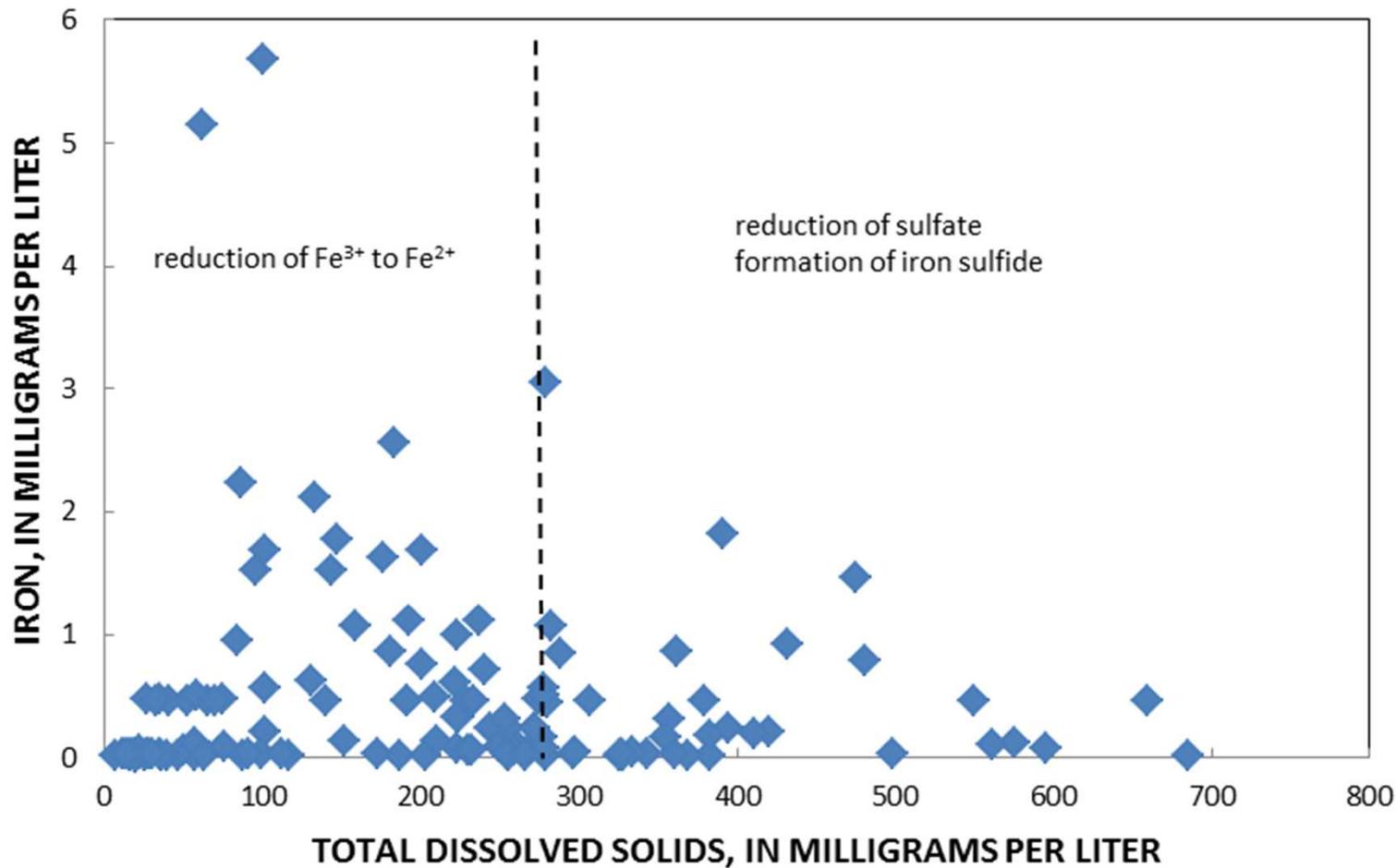
Nitrate and Manganese



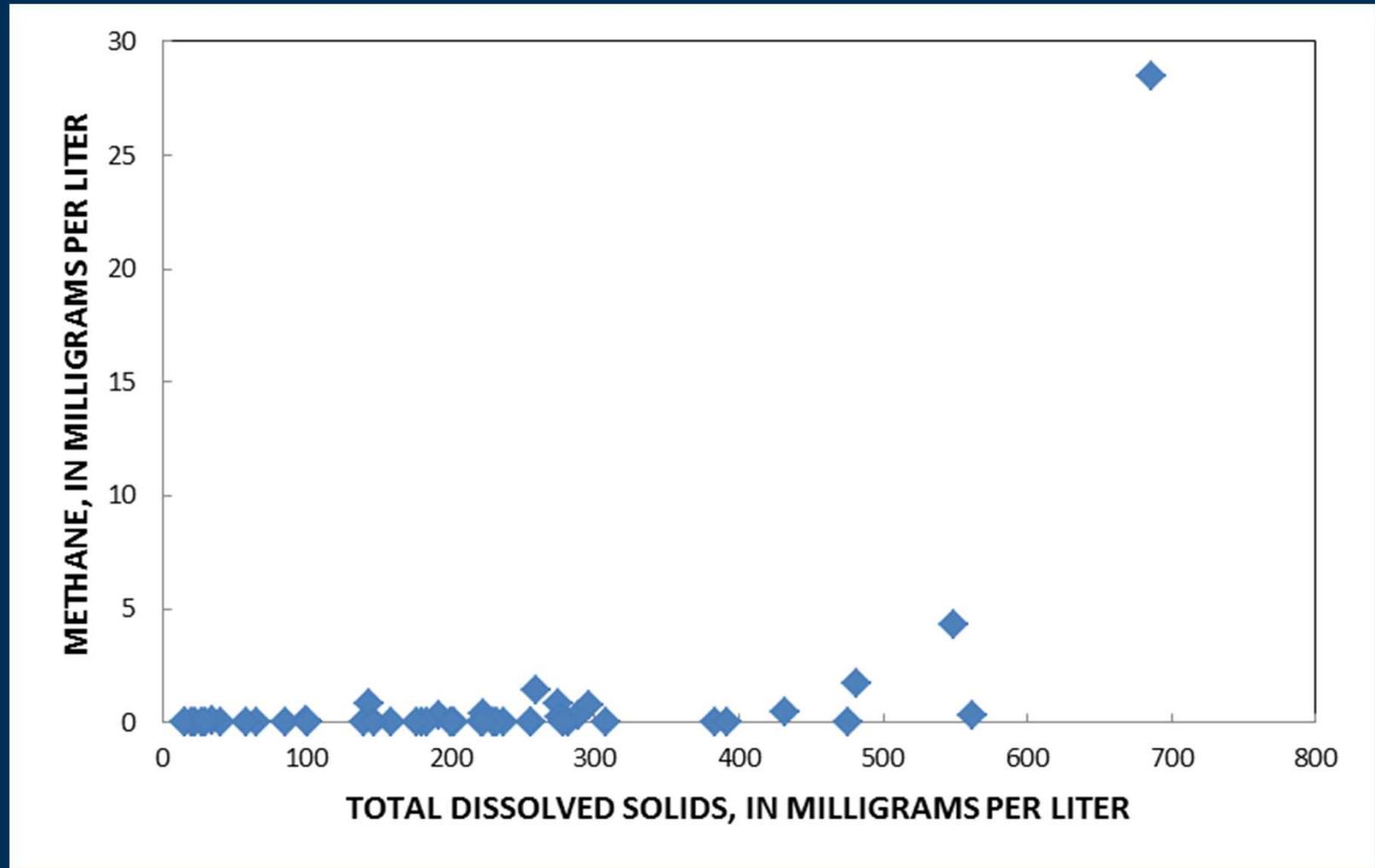
Nitrate and Iron



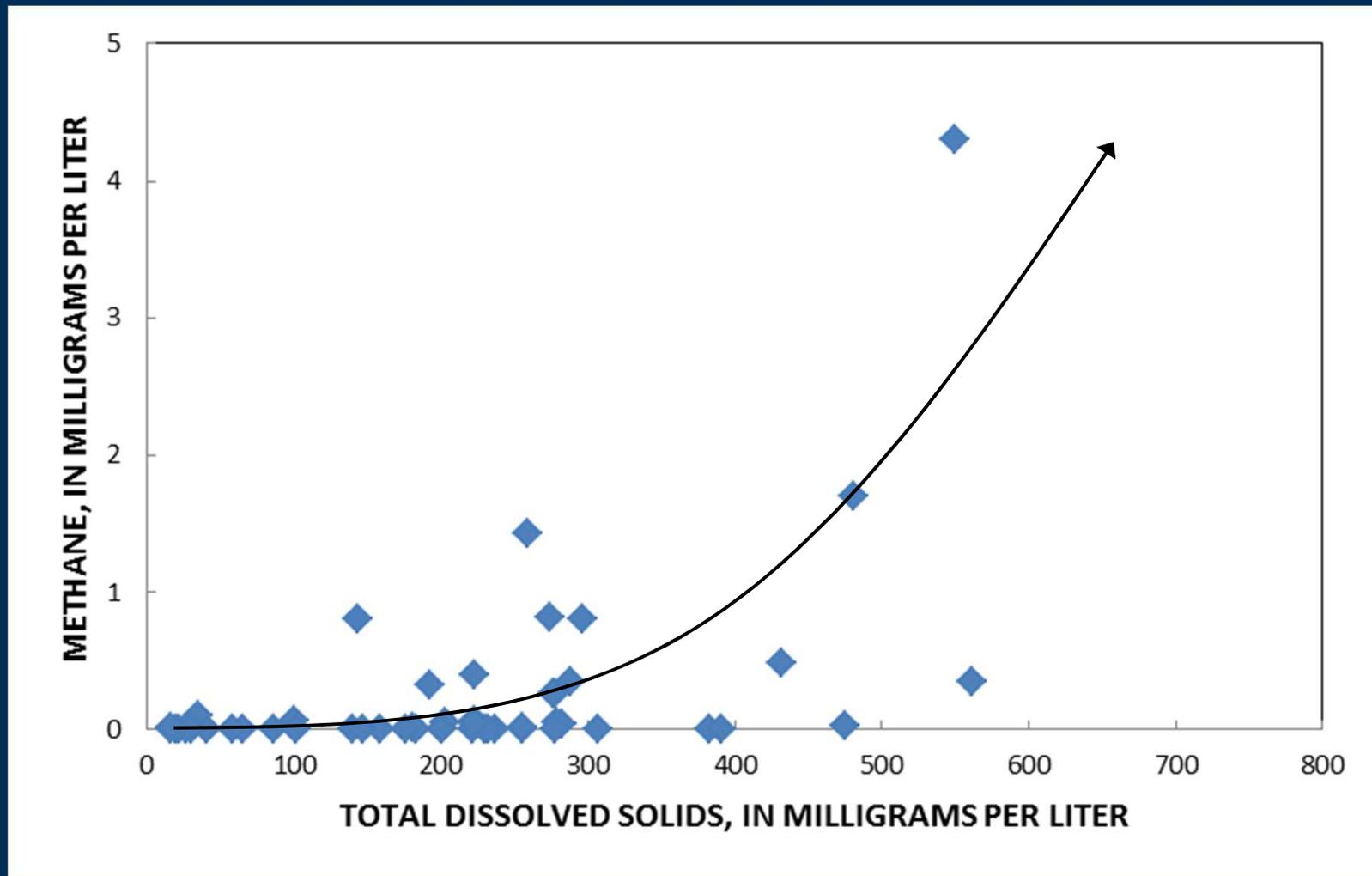
Total Dissolved Solids and Iron



Total Dissolved Solids and Methane



Total Dissolved Solids and Methane – High Methane Concentration Removed



CONCLUSIONS

- No evidence of regional or systemic effects on groundwater from shale gas industry
- All parameters, including chloride, within range of historical concentrations
- Geochemical evolution of Ca/HCO type water to Na/HCO water
- Reduction along a continuum from depletion of oxygen to generation of methane
- Relation of methane to higher TDS and sodium bicarbonate water