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Different Approaches in Assessing Background Groundwater Quality

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Contents

Ken:

- What is “background”?
- Multiple lines of evidence approach

Elizabeth:

- Case studies

  - Aluminum

  - Barium

Both:

- Wrap-Up

Fallout from AENV Tier 1 Guidelines

- Alberta Environment (AENV) Tier 1 Guidelines:
- Several low guideline values from consideration of the Domestic Use Aquifer (DUA) and Freshwater Aquatic Life (FAL) receptors
- Groundwater quality “exceedances” often appear to be background, particularly metals

  e.g. Al, As, Cd, Cu, Ba, Mn, Se, U, Zn

  also nitrite & nitrate

  chloride, sodium, chloroform (urban areas)

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Site Impact or Background?

- Are Tier 1 exceedances impact from anthropogenic point sources or background?

- What is background?

  - Natural background in absence of anthropogenic influence (can be used in place of Tier 1 guidelines)

  - Anthropogenic background from diffuse or non-point anthropogenic sources

  e.g. urban areas - road salting, leaky sewer & water lines, fertilizers

AENV (2009) Guidance & Site Challenges

- AENV Guidance

  - Natural concentration in a particular groundwater zone in absence of any anthropogenic sources or activities

  - Will vary spatially & temporally (moving target)

  - Must consider groundwater quality data from several wells

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Site Challenges

- Site Challenges

  - How many sites have several “background” wells?

  - Who has baseline pre-development data and enough data for statistical or non-parametric analysis?

  - Who has access to extensive databases in public domain?

  - Who has budget for extensive analysis?

  - What is “natural” in an urban or agricultural environment?

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How best to find the answers? Multiple lines of evidence

- Five-point checklist of questions (may not have answers for all):

  - Origin (natural and/or anthropogenic)?
  - Compare with published data?
  - Correlation with other Site data?
  - Concentration distribution?
  - Controls on aqueous concentrations?

Where can parameters potentially originate from?

- Natural occurrences in the environment vs rural, urban, industrial, etc, anthropogenic occurrences

- Some sources of information:
  - CCME Environmental Quality Guidelines
  - Health Canada monographs
  - Groundwater geochemistry and pollution books
  - Other books, publications, reports
  - Experience

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How do the data compare with published data or other reports?

- Some sources of information for Alberta sites:
  - Prairie Farm Rehabilitation Administration groundwater assessments
  - Farm well water quality studies
  - Geological Survey of Canada studies of the Paskapoo bedrock aquifer
  - Alberta Geological Survey reports
  - University research and theses
  - In-house consultant reports
  - Etc.

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Are there apparent correlations with other site data or information?

- Apparent correlations
  - Locations and depths/ elevations?
  - Lithology and provenance?
  - Soil quality?
  - Sampling methods?
  - Groundwater quality and chemistry?

- Potential use of next-generation database management tools coupled with GIS software

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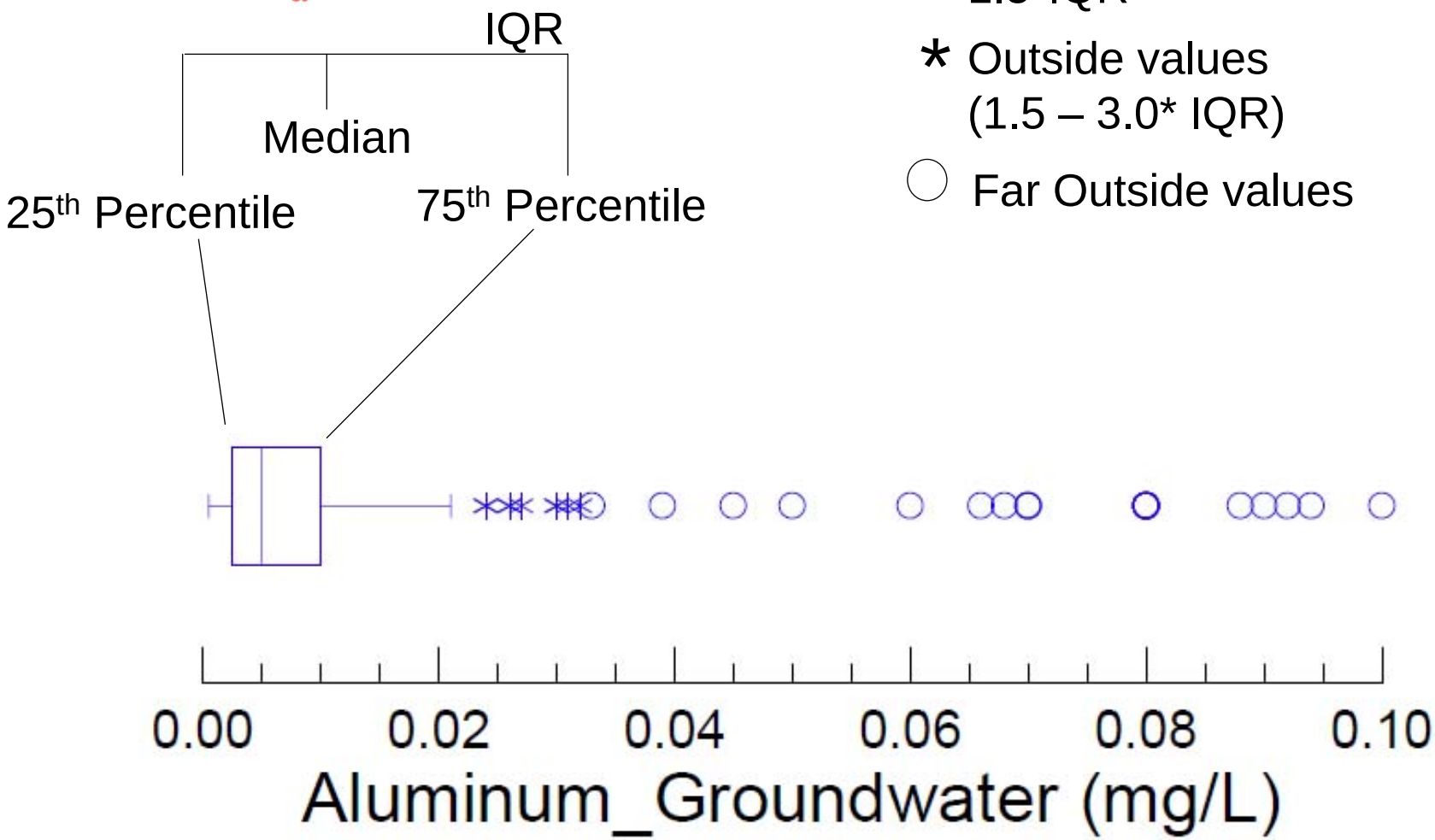
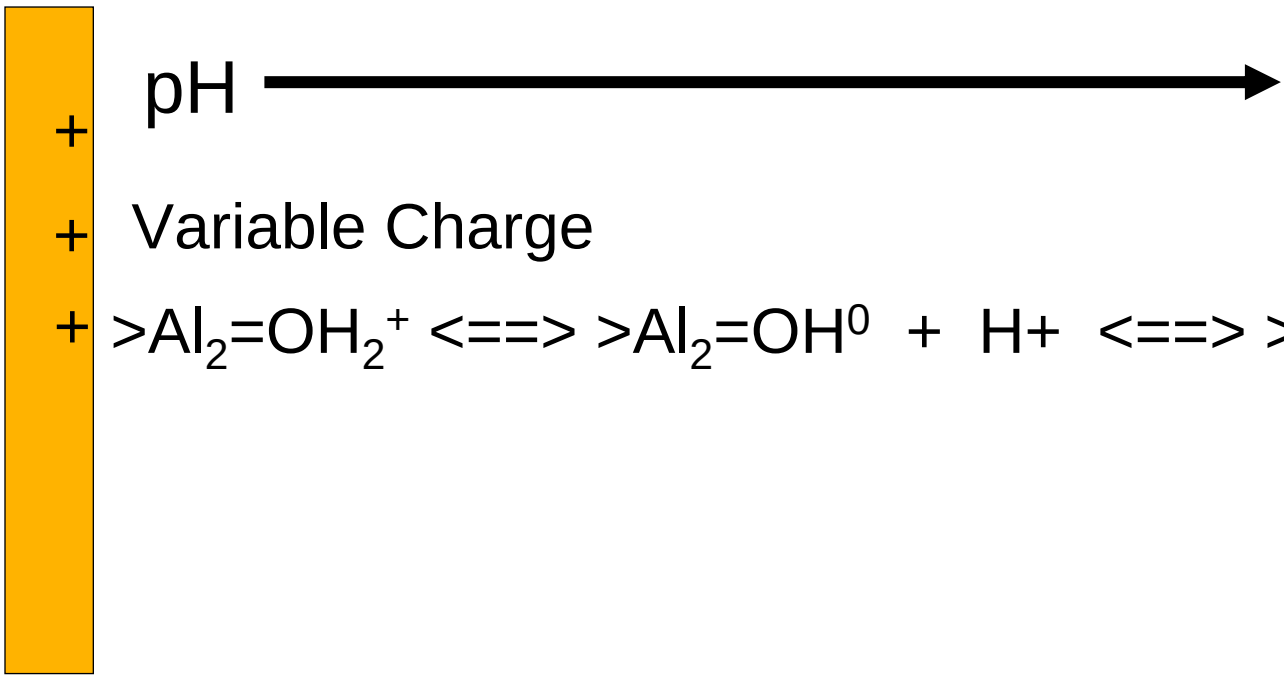
What does the distribution of data look like?

- Non-parametric box-and-whisker plots
- Five number summary:
  - median,
  - 25th & 75th quartiles
  - 1.5 & 3.0 x Interquartile Range
- 95% within 1.5xIQR if normally distributed

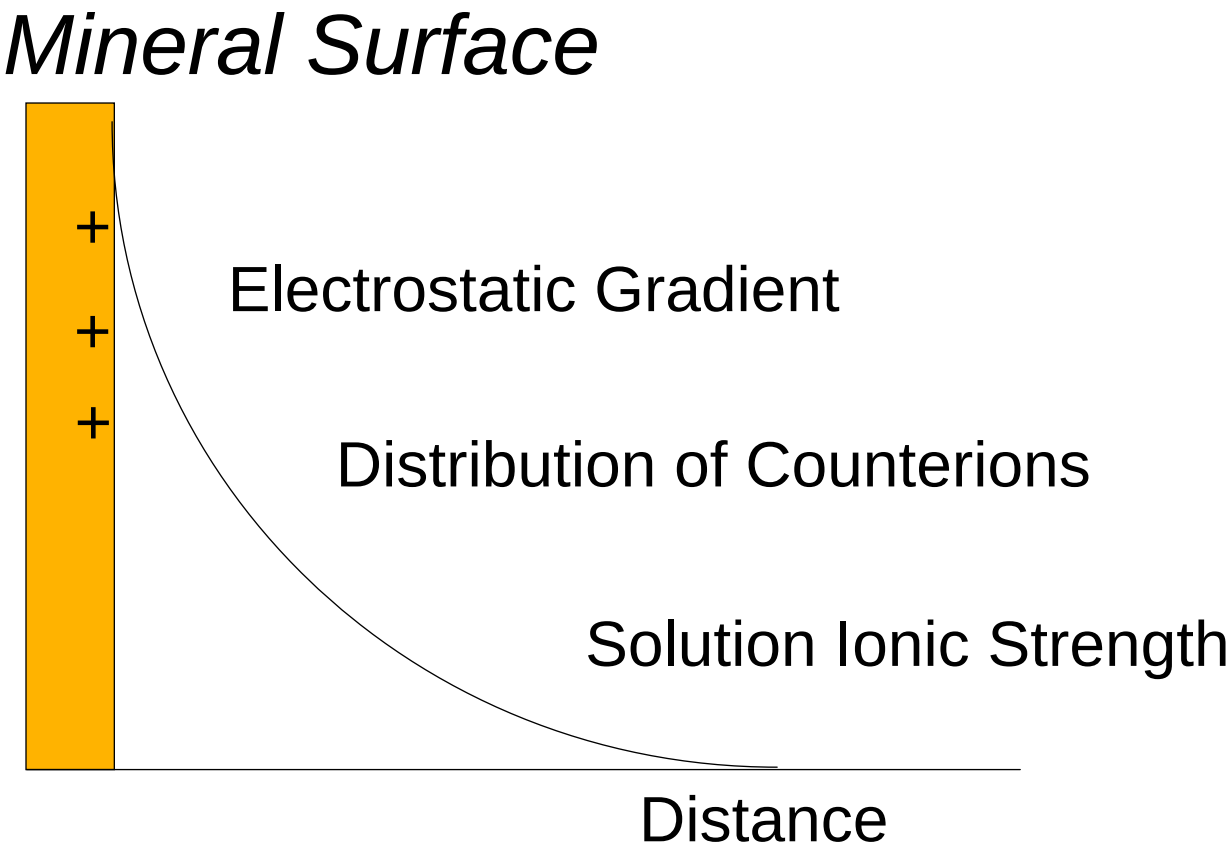

Whisker
1.5*IQR
* Outside values
(1.5 – 3.0* IQR)
Far Outside values
IQR
Median
25th Percentile
75th Percentile
0.00
0.02
0.04
0.06
0.08
0.10
Aluminum_Groundwater (mg/L)

What controls concentrations in groundwater?

Mineral Surface



What controls concentrations in groundwater?



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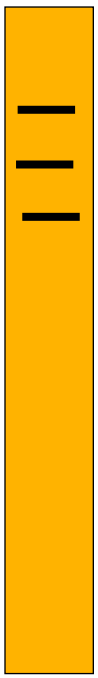
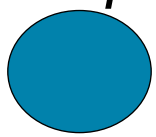


Permanent Charge

Cation Exchange Capacity (mmol charge)

$$\approx 2[Ca] + 2[Mg] + [K] + [Na] + 3[Al]$$

Species X



Speciation

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What controls concentrations in groundwater?

- Cation or anion?
- pH?
- Redox or non-redox active?
- Expected speciation over site conditions?
- Solubility controls?
- Major or trace metal concentrations?
- Mineral or organic matter adsorption?
- Ionic strength of solution?
- Colloidal behaviour?

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Aluminum Case Study (In-house Data for Calgary Area)

- Tier 1 guideline 0.1 mg/L (Receptor: FAL)
- Shallow Groundwater, Calgary, 300 analyses, several sites
- Occasional exceedances, ranging up to 1.7 mg/L

Multiple Lines of Evidence Checklist

- Potential Origins:
  - Natural sources: most abundant metal in earth's crust
  - General anthropogenic sources: vehicle parts, aircraft frames, pharmaceuticals, flocculants in water treatment (Health Canada 1998)
  - Potential site sources: Calgary drinking water 0.028 to 0.445 mg/L from water plant treatment (City of Calgary, 2009)

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Aluminum Case Study continued

- Published Data:

  - 13 of 816 Alberta farm well samples > 0.2 mg/L (Fitzgerald et al. 2001)

- Other Correlations:

  - Most wells completed in silt, clay, Paskapoo mudstone indicating weathering of alumino-silicates

  - Scattered locations

- Data Distribution:

  - Upper box plot whisker (0.02 mg/L) about the same as upper limit for dissolved aluminum in near neutral pH range (Appelo & Postma 2007)

- Concentration Controls:

  - Clay mineral gibbsite ($Al(OH)_3$) crystals stable at diameter of 0.1 µm (Hem 1985)

  - Compare field filtration 0.45 µm

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Aluminum Case Study continued

- Conclusion: likely represent natural background

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Barium Case Study
In-house Data Shallow Groundwater

- Tier 1 Guideline: 1 mg/L (Receptor: Domestic Use Aquifer)
- Rare to occasional exceedances, ranging up to 2-3 mg/L

<u>Multiple Lines of Evidence Checklist</u>

- Potential Origins (Health Canada 1990):
  - Natural sources: trace element igneous and sedimentary rocks, most commonly as barite ($BaSO_4$)
  - General anthropogenic sources: use in plastics, rubber, electronics, textiles, ceramic glazes and enamels, glass and paper, fuel oil additive, lubricant additives (drilling mud)
  - Potential site sources: fuel oil, drilling mud

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Barium Case Study Continued

- Published Data:

  - 2 of 816 Alberta farm well samples > 1 mg/L (Fitzgerald et al. 2001)

- Other Correlations

  - No apparent lithologic correlation
  - Scattered locations

- Data Distribution

  - Upper box plot whisker 0.7 mg/L

- Concentration Controls

  - Solubility
  - Sorption – Cation Exchange

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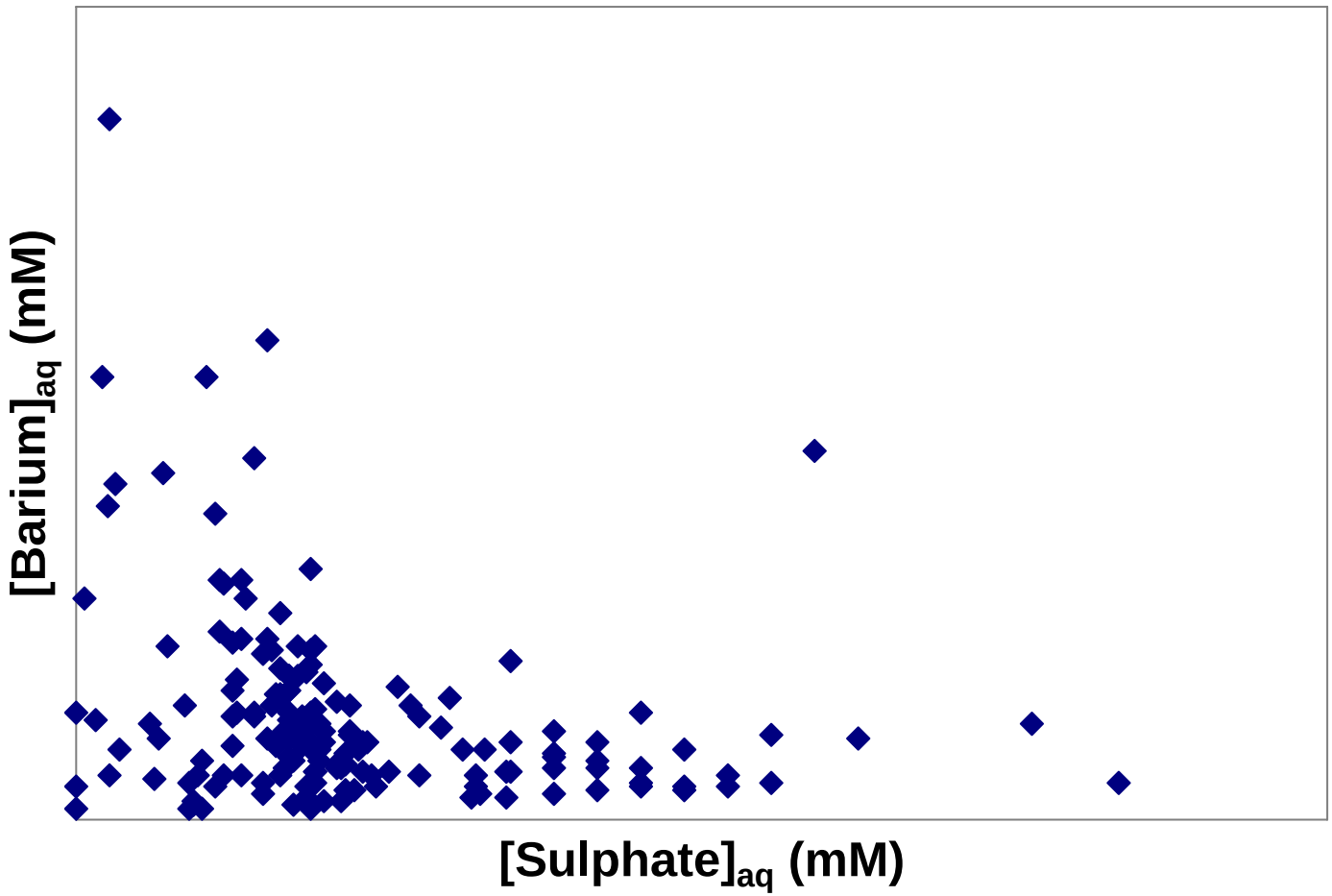
Barium Solubility Control
Barium vs Sulphate



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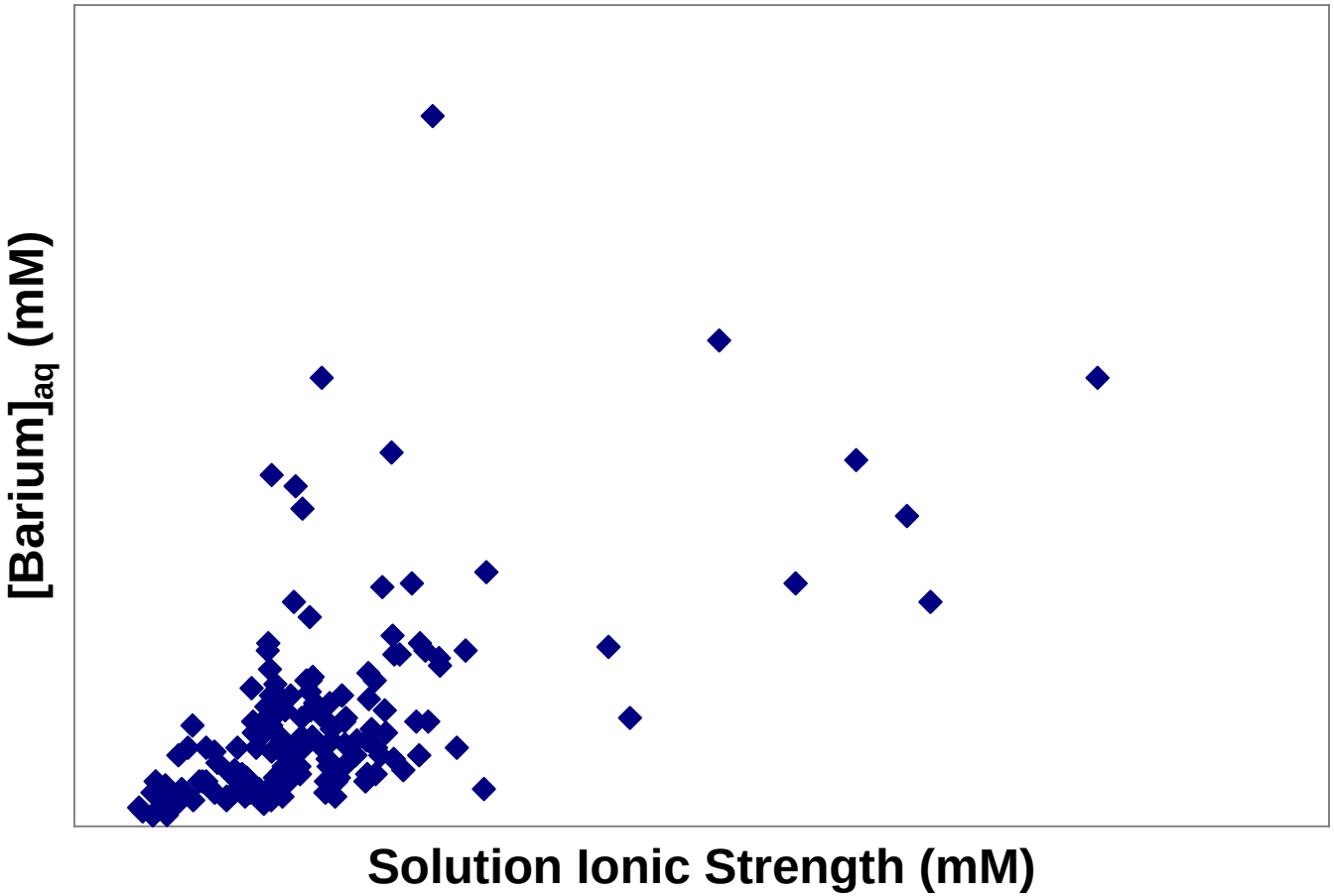
Barium Cation Exchange Control
Barium vs Solution Ionic Strength



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Barium Case Study continued

- Conclusion: likely reflects anthropogenic source
  - Direct from drilling muds or diesel fuel additives; or
  - Indirect from anthropogenic salinity related impacts

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Some Wrap-up Thoughts

- Can be detailed but necessary exercise in dealing with Tier 1 Guidelines
- Becomes more efficient as knowledge “base” and database management systems developed
- Potential application to upstream well fields
- Ultimately an exercise in professional judgment
- Future challenges and study

  - Compilation and dissemination of data sets in the public domain

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THANK YOU!

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