ASSESSING THE QUALITY OF OUR NATION'S GROUNDWATER – A COMPREHENSIVE ASSESSMENT

NAWQA Liaison Meeting
Washington, D.C.
April 8, 2016

National Water Quality Program

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National Water Quality Assessment Project

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Bruce Lindsey, Groundwater Status & Trends

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NAWQA – THREE POLICY QUESTIONS

- **What is the quality of the Nation's groundwater?**
- **Is it getting better or worse?**
- **How might groundwater quality change in the future?**

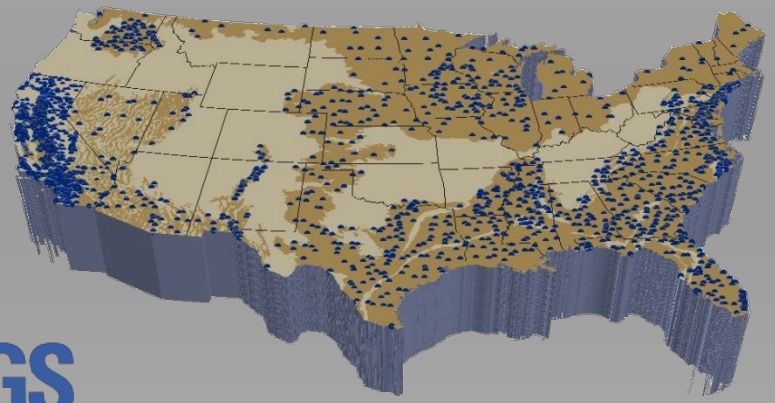
What is the quality of the Nation's groundwater?

- The Quality of Deep Groundwater Used for Public Supply
- Maps of Groundwater Corrosivity
- Effects of Unconventional Oil & Gas Production on Groundwater Quality

HOW DOES NAWQA CHARACTERIZE A THREE DIMENSIONAL RESOURCE AT A NATIONAL SCALE?

Land Use Studies
typically observation wells
~ 20 to 50 feet

Major Aquifer Studies
typically domestic wells
~ 50 to 150 feet



Principal Aquifer Studies
typically Public Supply wells
~ 150 to 750 feet deep

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WHICH CONSTITUENTS DOES NAWQA ANALYZE FOR?

- **Water quality constituents with benchmarks**
  - **Geologic sources: trace elements, radionuclides, (nitrate)**
  - **Human sources: nutrients, volatile organic compounds, pesticides and pesticide degradates, microbiological constituents**
  - **Nuisance constituents: iron, manganese, dissolved solids, hardness, …**
- **Water quality constituents without benchmarks**
- **New analytes ("emerging" concern)**
  - **Pharmaceuticals, Hormones, Polonium, Enteroccocci …**

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WHICH CONSTITUENTS DOES NAWQA ANALYZE FOR?

- **Geochemical indicators**
  - **Major ions, redox, pH, DO, T**
- **Tracers of groundwater age**
  - **Tritium, SF6, CFCs, carbon-14, noble gases**
- **Low-level detection methods**
  - **VOCs and pesticides, < parts per billion (PPB)**
  - **Indicator of human "fingerprint"**

USGS TYPICALLY SAMPLES AT THE WELL HEAD

Public Supply Well

Domestic Well

Observation Well

- **Water can be treated or blended prior to use**

- **NAWQA evaluates the quality of untreated groundwater**

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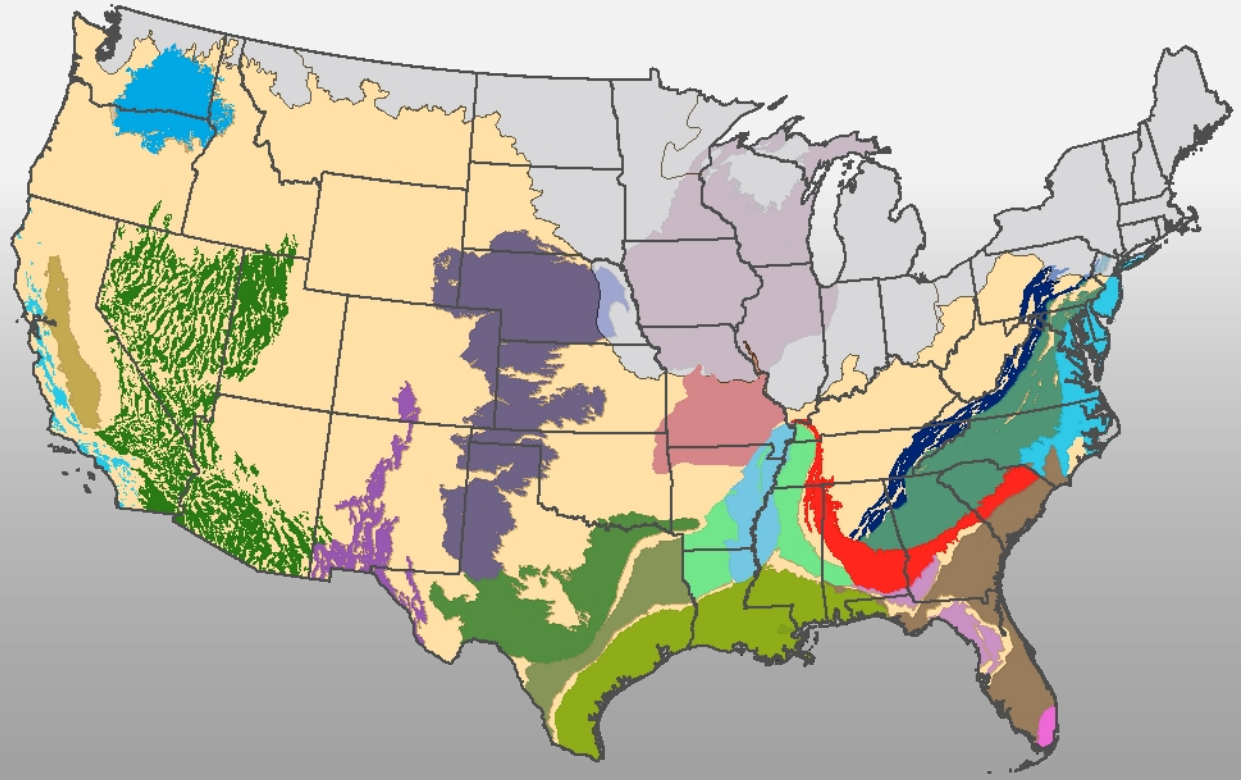
PRINCIPAL AQUIFERS PROVIDE A FRAMEWORK FOR ASSESSMENT



20 Principal Aquifers, 2013-2023

90% of pumping for public supply

85% of pumping for domestic supply

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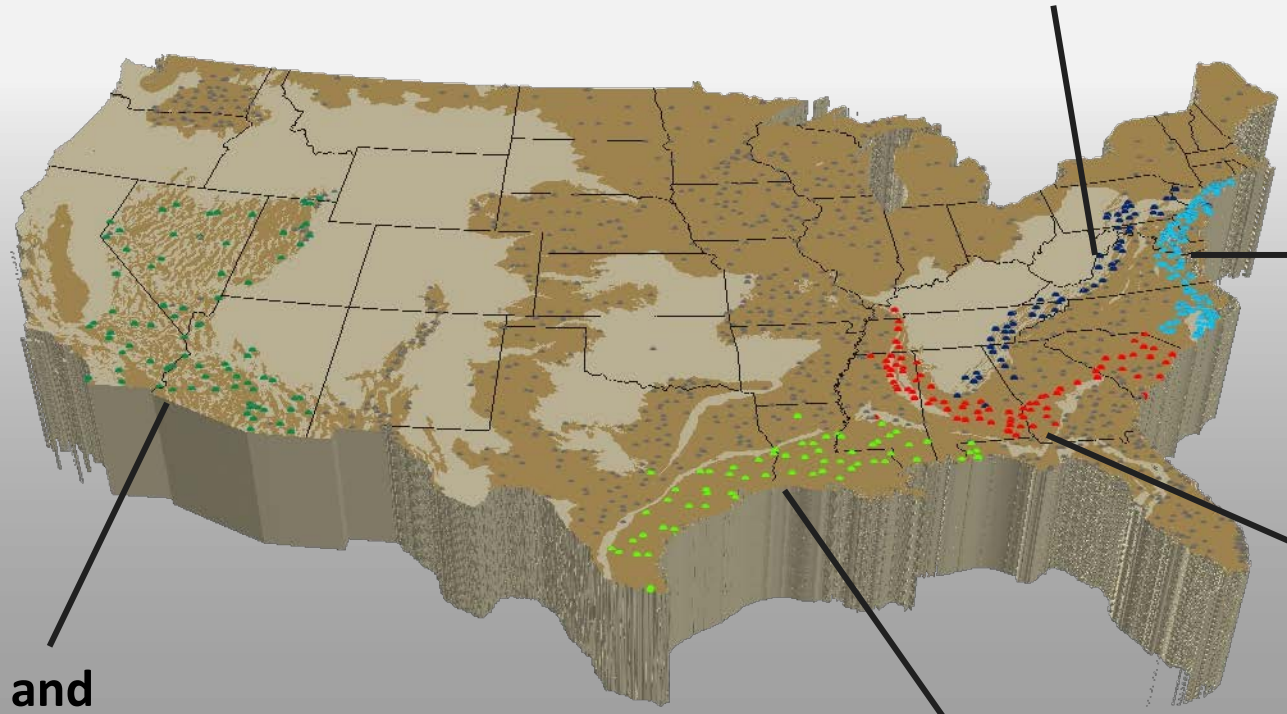
PRINCIPAL AQUIFERS – FIVE FACT SHEETS



~ 400 wells

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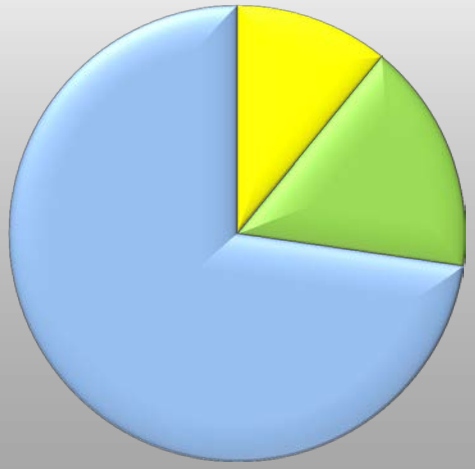
HOW DOES NAWQA CHARACTERIZE GROUNDWATER QUALITY AT A REGIONAL SCALE?

Proportion of the resource with high, moderate, and low concentrations

HIGH Concentration > benchmark



MODERATE

LOW conc. < 1/10 of benchmark for organic
conc. < 1/2 of benchmark for inorganic

Organic constituents are generally introduced by people

Inorganic constituents occur naturally or can be introduced by people

Proportion scale-invariant

Confidence of estimate depends on the number of samples

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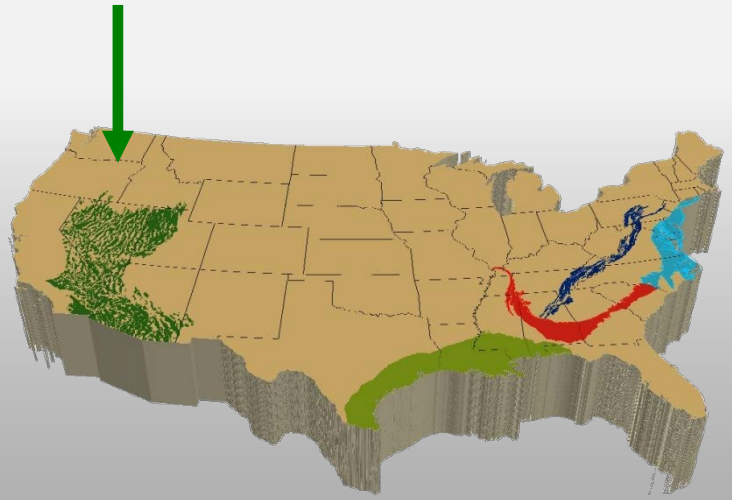
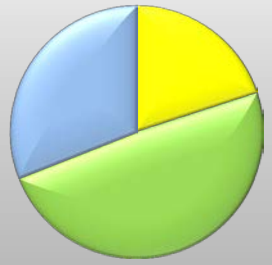
Which contaminants are most prevalent at high concentrations?

Basin and Range

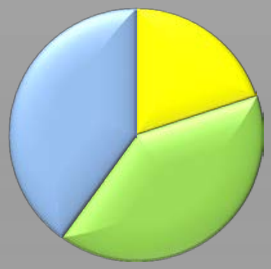


Inorganic



Organic

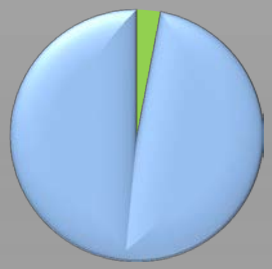
Trace elements



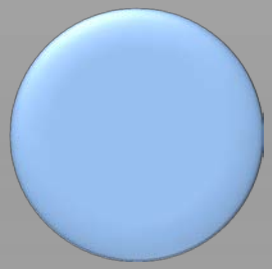
Radioactivity

Nitrate

VOCs



Pesticides



Constituent concentrations

High | Moderate | Low or not detected

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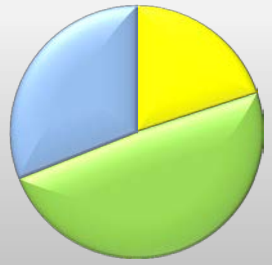
Which contaminants are most prevalent at high concentrations?

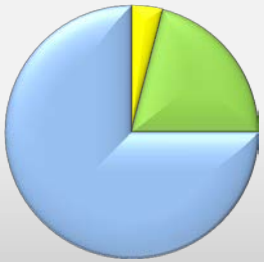
Basin and Range

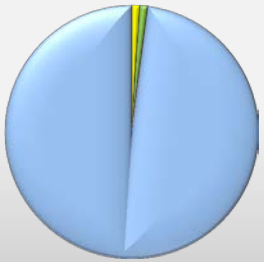
Inorganic



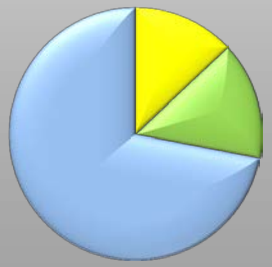
Organic

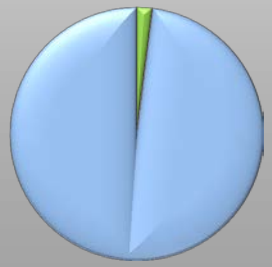
North Atlantic Coastal Plain





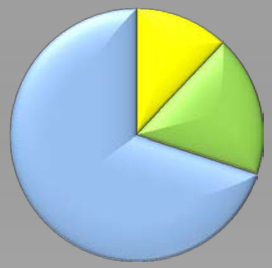
Valley & Ridge – Piedmont – Blue Ridge

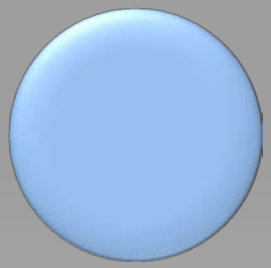




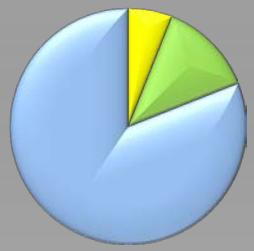
~ 400 wells

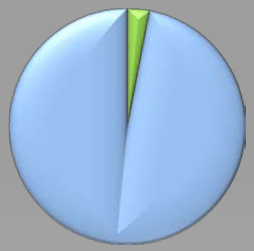
Coastal Lowlands





Southeastern Coastal Plain





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Constituent concentrations

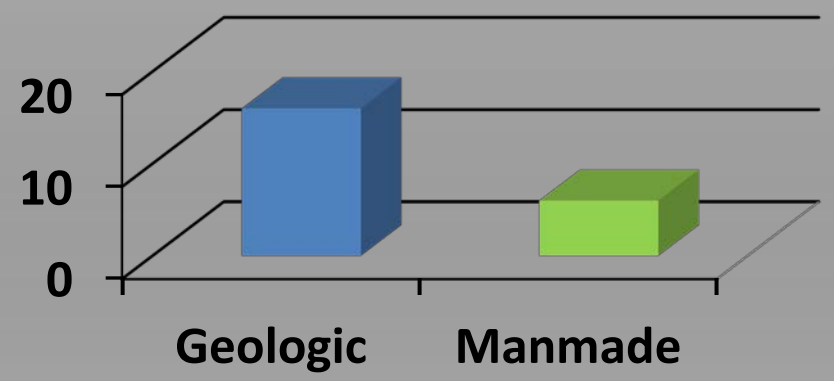
High | Moderate | Low or not detected

Which contaminants are most prevalent at high concentrations?

- **Five Principal Aquifers at the depth zone used for public supply**
  - **Prevalence at high concentrations**

    Trace elements > nitrate > organic compounds
  - **Constituents of note:**

    Manganese (5), arsenic (4), gross alpha radioactivity (4), fluoride (3), nitrate (2)
- **National synthesis of data from domestic wells (~1400 wells)**

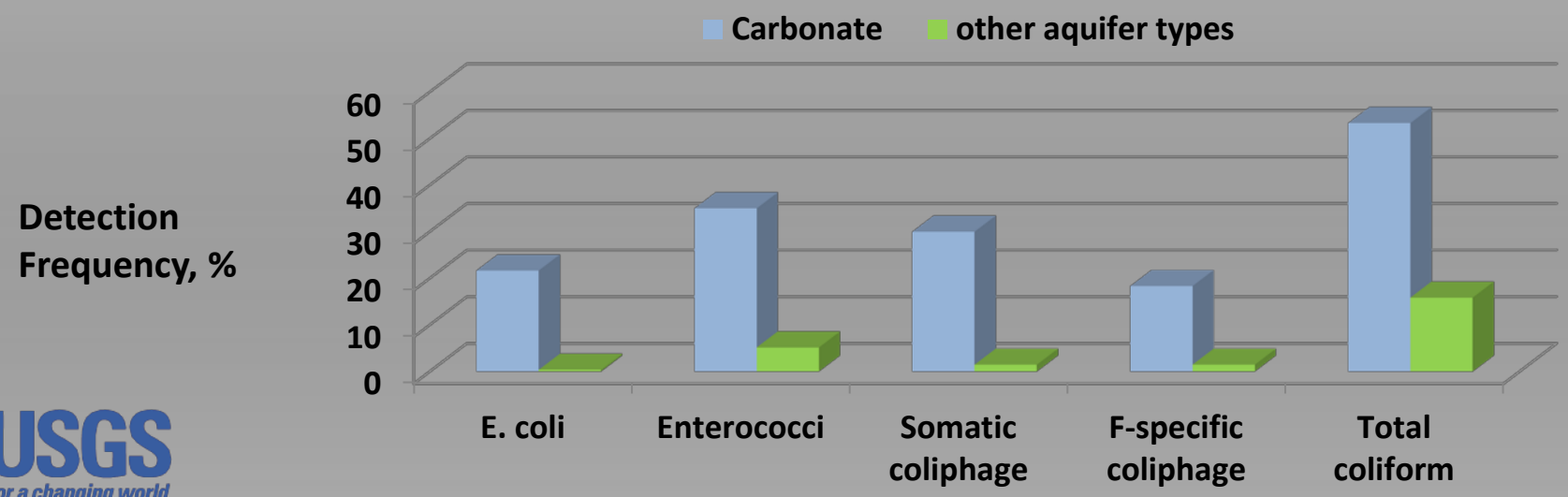


Desimone and others, USGS Circular 1360

What is NAWQA learning about emerging contaminants?

Microbiological constituents

- Can be indicative of human and (or) natural sources
- E.coli and Total coliform were often collected, 1991-2012
- Expanded, 2013-2023
  - Added constituents: Enterococci, Coliphage (somatic, f-specific)
  - Sampled at all drinking water wells
- Preliminary results, 5 PAs



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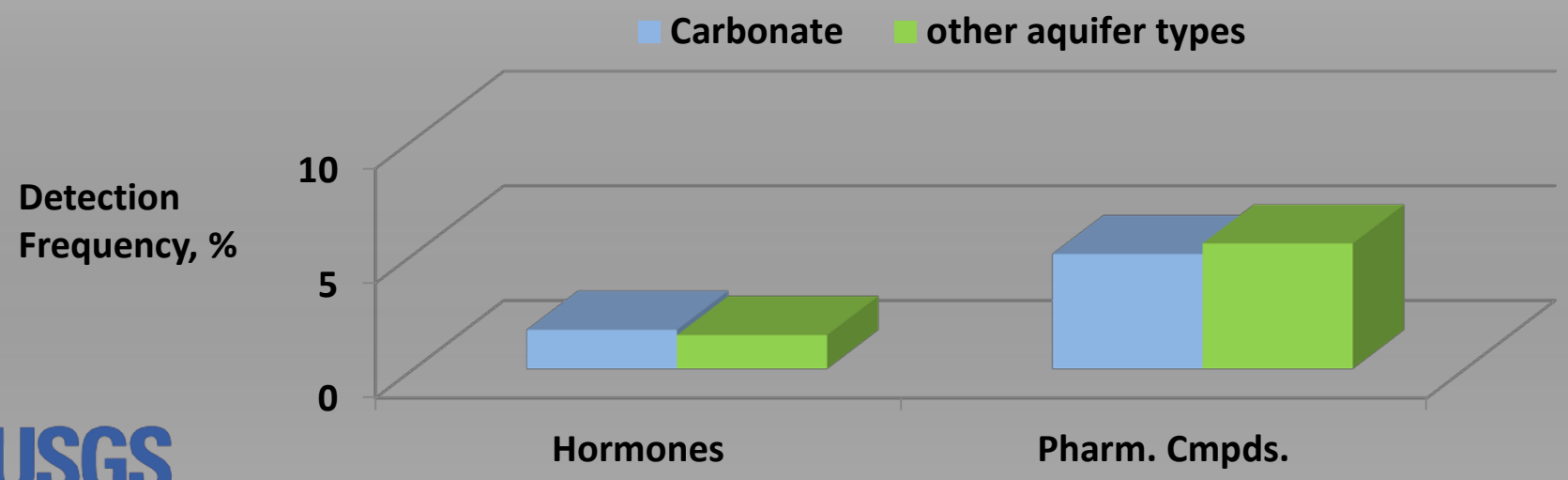
What is NAWQA learning about emerging contaminants?

Hormones and pharmaceutical compounds

- Pharmaceutical compounds only at selected locations, 1991-2012
- Pharmaceutical and hormone compounds routinely evaluated at all wells used for drinking supply

- Preliminary results, 5 PAs



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ASSESSING THE QUALITY OF OUR NATION'S GROUNDWATER – A COMPREHENSIVE ASSESSMENT

The Quality of Deep Groundwater Used for Public Supply

QUESTIONS?

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What is the quality of the Nation's groundwater?

- The Quality of Deep Groundwater Used for Public Supply
- **Maps of Groundwater Corrosivity**
- **Effects of Unconventional Oil & Gas Production on Groundwater Quality**

How can source water affect the occurrence of lead in household water supply?

- **Previous studies: source water can interact with pipes**
  - **VA study (>2100 private systems) : nearly 20% of "first-flush" water exceeded 15 μg/L (EPA action level)**
- **Mineral deposition (scaling)**
  - **Can protect pipes from corrosion**
  - **Lead can be removed from the water (sequestered)**
- **Corrosion**
  - **Dissolution of lead, if present**
  - **Presence of copper can enhance the dissolution of lead**
  - **Galvanic corrosion**

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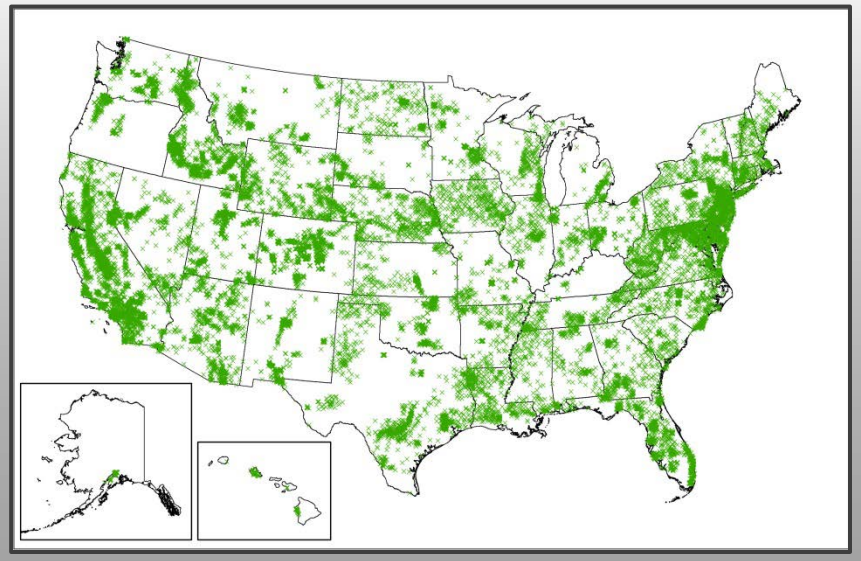
Pieper and others, 2015. Incidence of waterborne lead in private drinking water systems in Virginia. *Journal of Water and Health*, *13*(3), pp.897-908

How can source water affect the occurrence of lead in household water supply?

USGS is mapping two indicators of corrosivity at >22,000 locations



Langelier Saturation Index (LSI)

- Potential to deposit scale

Potential for Galvanic Corrosion

- Levels of concern based on Chloride-to-Sulfate Mass Ratio (CSMR) and alkalinity

Corrosivity of source water is one of many factors that can affect the occurrence of lead in household water supply

Langelier, W. F., 1936, “The Analytical Control of Anti-Corrosion Water Treatment,” Journal (American Water Works Association), 28(10), 1500–1521.

Nguyen, Caroline and others, 2010, "Impact of chloride: sulfate mass ratio (CSMR) changes on lead leaching in potable water." *WaterRF., Denver*.

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How can source water affect the occurrence of lead in household water supply?

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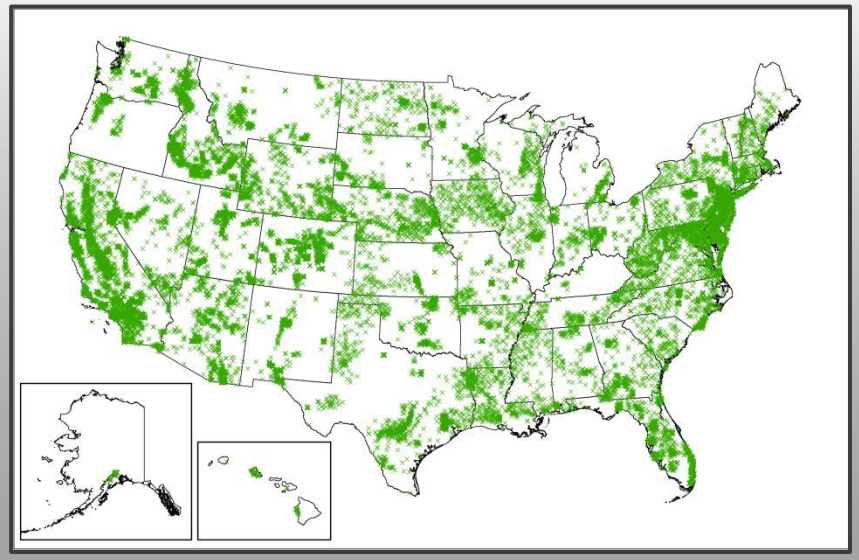

- **National maps, 4 to 6 weeks**
- **Additional research, ongoing**
  - **Geochemical modeling**

Belitz and others, in press, "Langelier Saturation Indices Computed for U.S. Groundwater, 1991-2015; Water Well Data," USGS Data Release

Belitz and others, in press, "Langelier Saturation Indices Computed for U.S. Groundwater, 1991-2015; Characteristic Values for States," USGS Data Release

Belitz and others, in press, "Potential for Galvanic Corrosion of Lead Based on Chloride-to-Sulfate Mass Ratio and Alkalinity for U.S. Groundwater, 1991-2015; Water Well Data and Characteristic Values for States, USGS Data Release

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ASSESSING THE QUALITY OF OUR NATION'S GROUNDWATER – A COMPREHENSIVE ASSESSMENT

Maps of Groundwater Corrosivity

QUESTIONS?

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What is the quality of the Nation's groundwater?

- The Quality of Deep GroundwaterUsed for Public Supply
- Maps of Groundwater Corrosivity
- **Effects of Unconventional Oil & Gas Production on Groundwater Quality**

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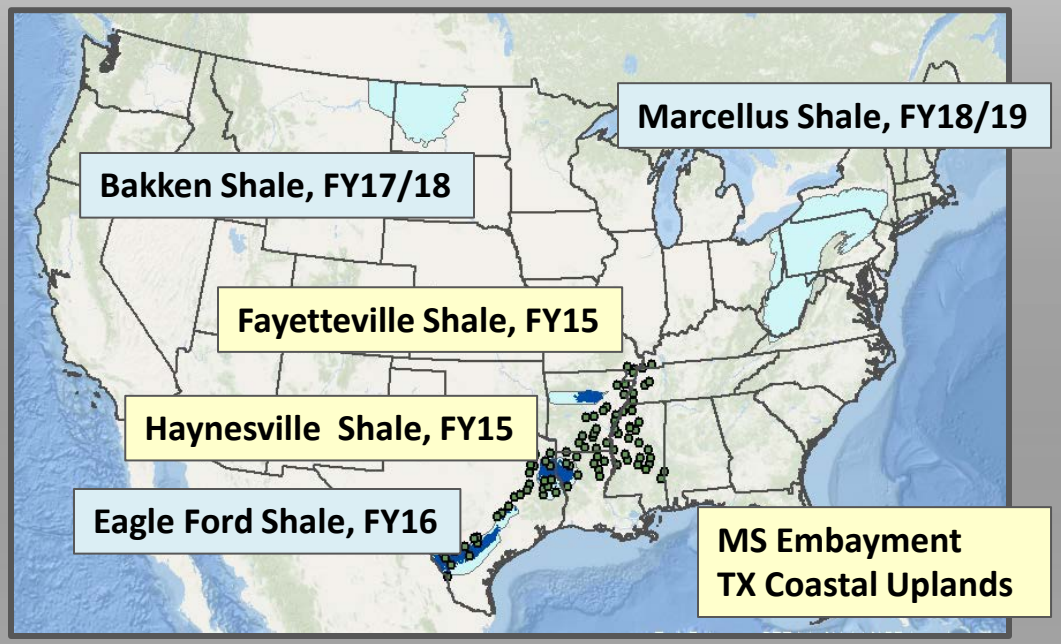
Does unconventional oil and gas production affect the quality of groundwater used for drinking water supply?

- **Five focus areas (and 1 Principal Aquifer for context)**
- **Focus areas: stratified, randomized sampling approach**

  Wells proximal to (< 1 km) and distal from (> 1 km) UOG production



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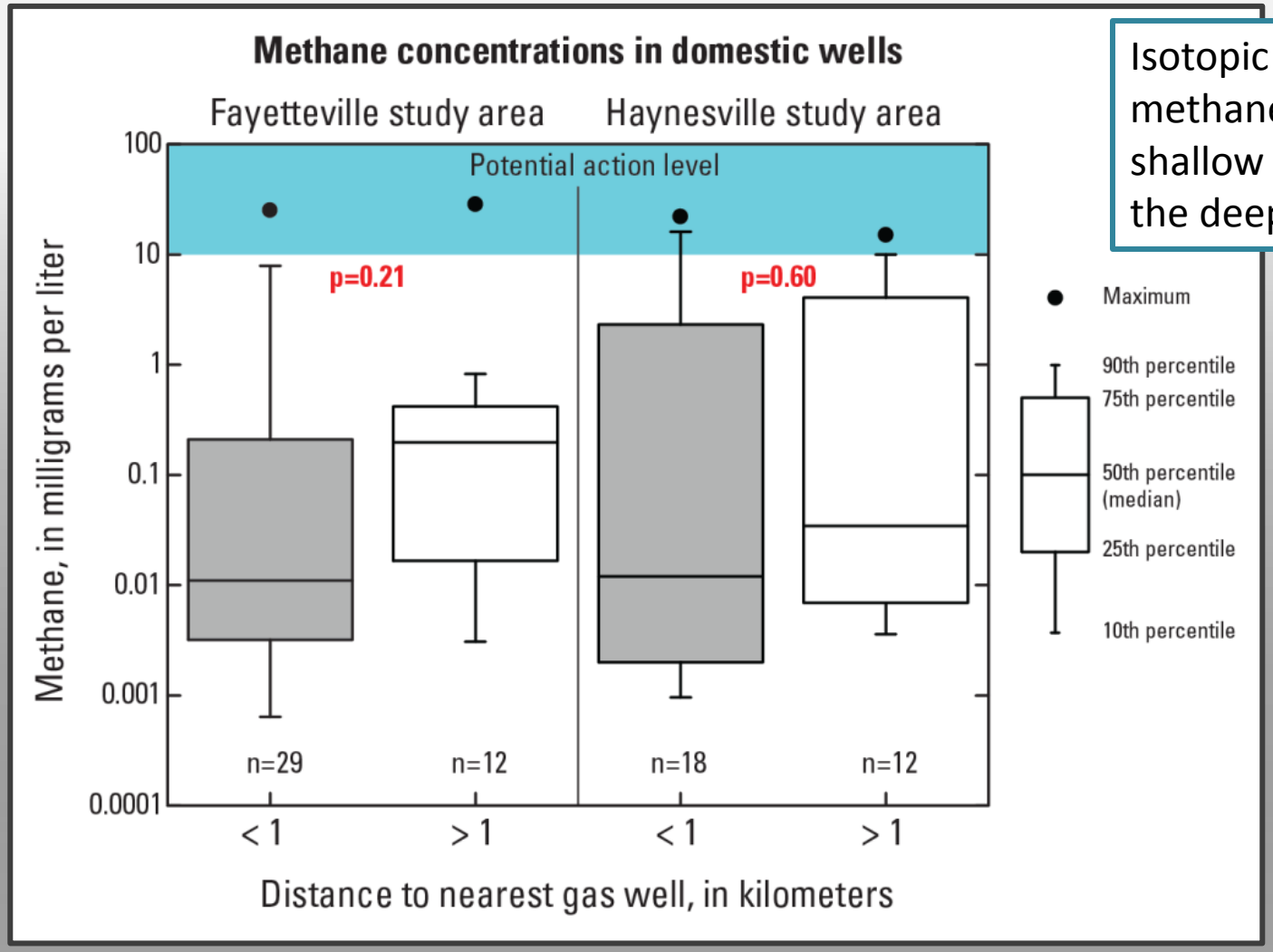
Are methane concentrations in domestic wells affected by proximity to gas wells?



Isotopic data show that methane was from relatively shallow biogenic sources, not the deeper UOG activity

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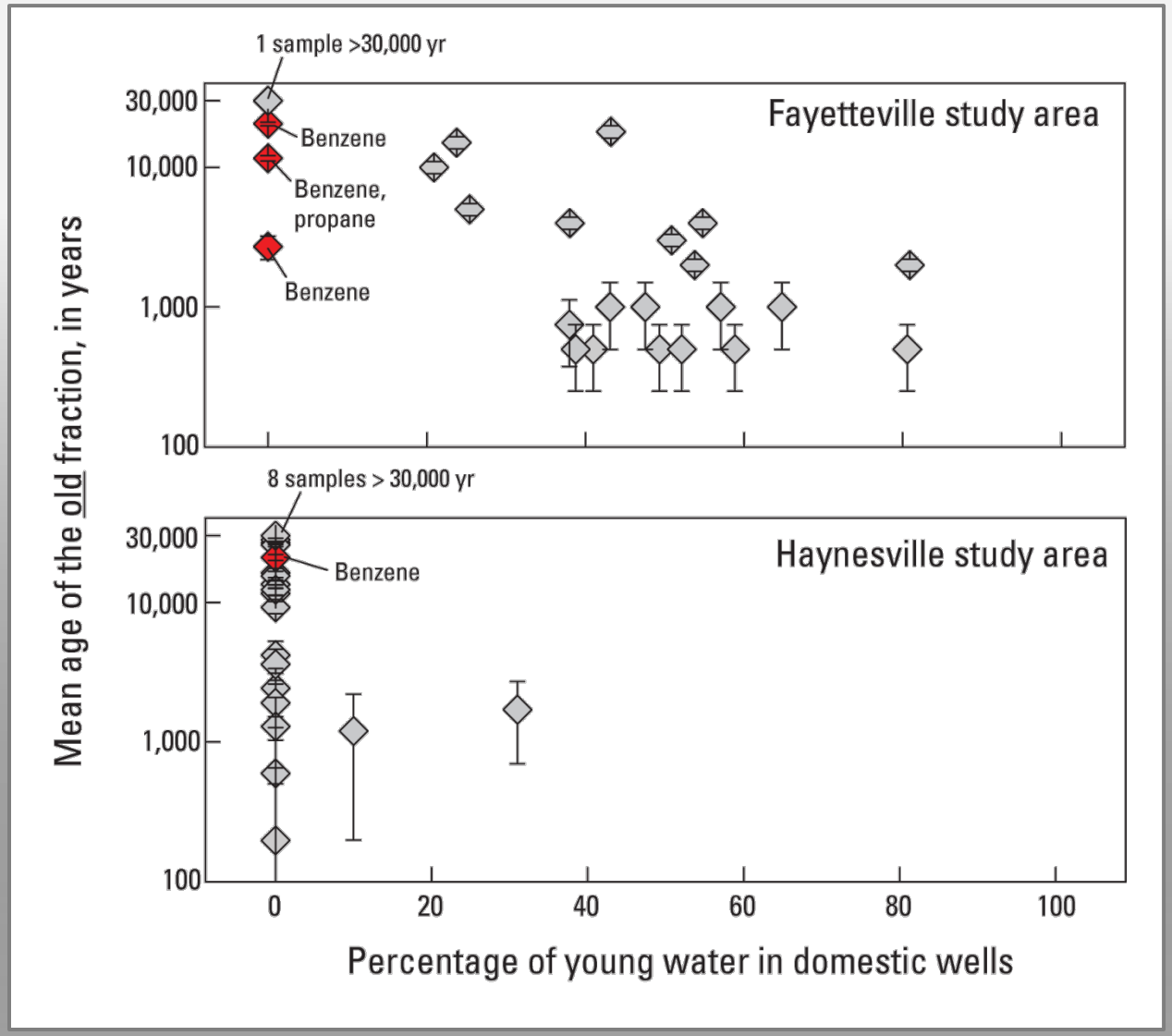
McMahon and others, 2016. Groundwater quality and age in the Fayetteville and Haynesville shale gas production areas, Arkansas, Louisiana, and Texas. ACS National Meeting, San Diego, CA

Benzene was detected in five domestic wells. What is the source?



Benzene occurred at very low concentrations, well below the drinking-water standard

Groundwater can be a mix of young and old water

Fayetteville
- Young water in many samples

Haynesville
- Mostly old water

Benzene detections were in old groundwater

Subsurface sources
- natural fluid migration
- leaky oil/gas wells

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McMahon and others, 2016. previous citation.
Landon and Belitz, 2012. Geogenic Sources of Benzene in Aquifers Used for Public Supply, California. *Environmental Science & Technology*,*46*(16), pp.8689-8697.

ASSESSING THE QUALITY OF OUR NATION'S GROUNDWATER – A COMPREHENSIVE ASSESSMENT

Effects of Unconventional Oil & Gas Production on Groundwater Quality

QUESTIONS?

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ASSESSING THE QUALITY OF OUR NATION'S GROUNDWATER – A COMPREHENSIVE ASSESSMENT

Is groundwater quality getting better or worse?

Decadal Changes In Groundwater Quality

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Evaluating changes

- Decadal resampling of selected networks provides a National perspective on change.
- NAWQA has been collecting groundwater-quality data since 1988.

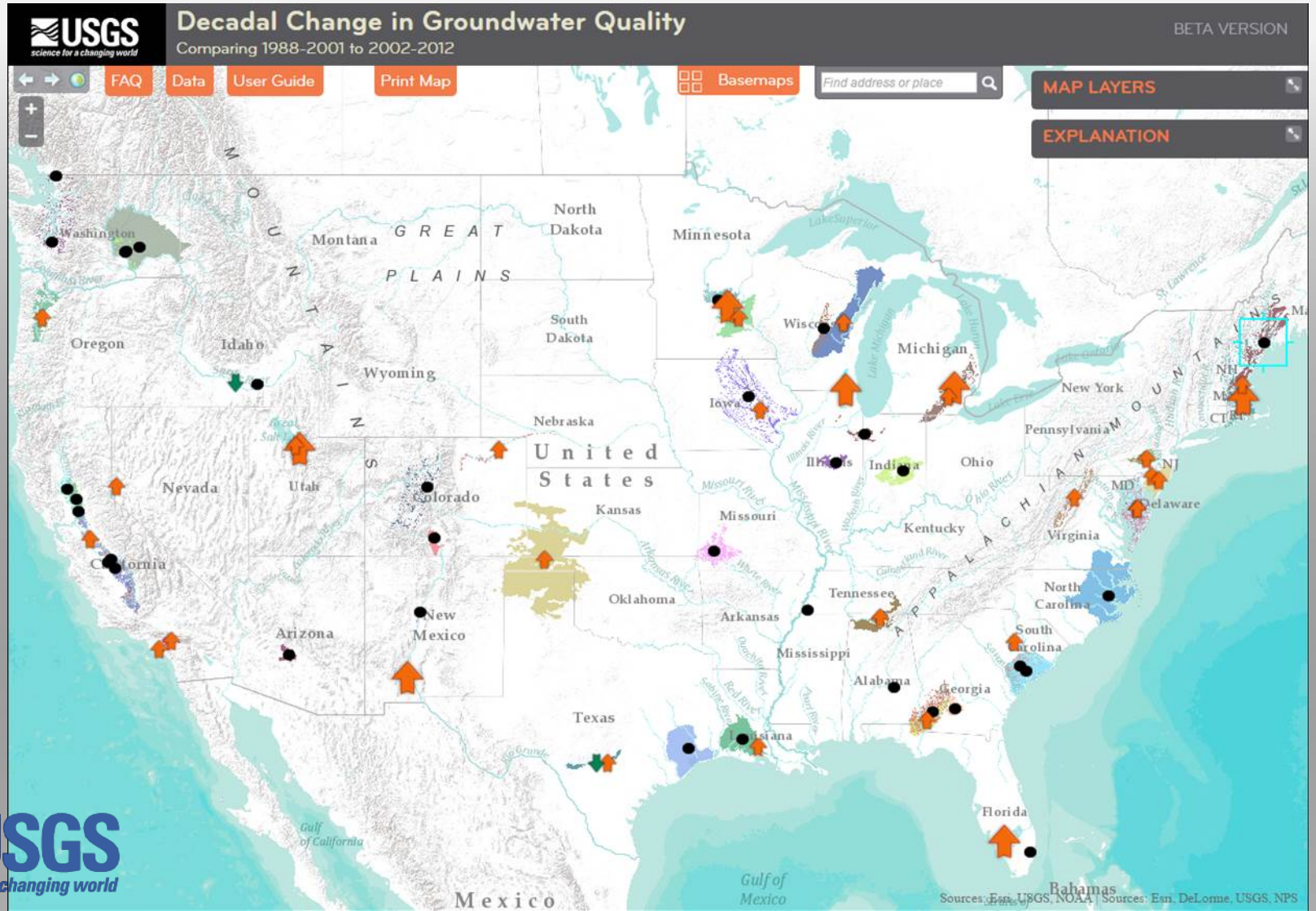
Which contaminants are changing?

An interactive web-based map provides information on decadal-scale changes in groundwater quality.

Contaminants are mapped:

- **If they are present at high concentrations**
- **Frequently detected organic compounds**

A national map illustrates that many networks have increasing concentrations of chloride, especially in urban areas of the Northeast and Upper Midwest.



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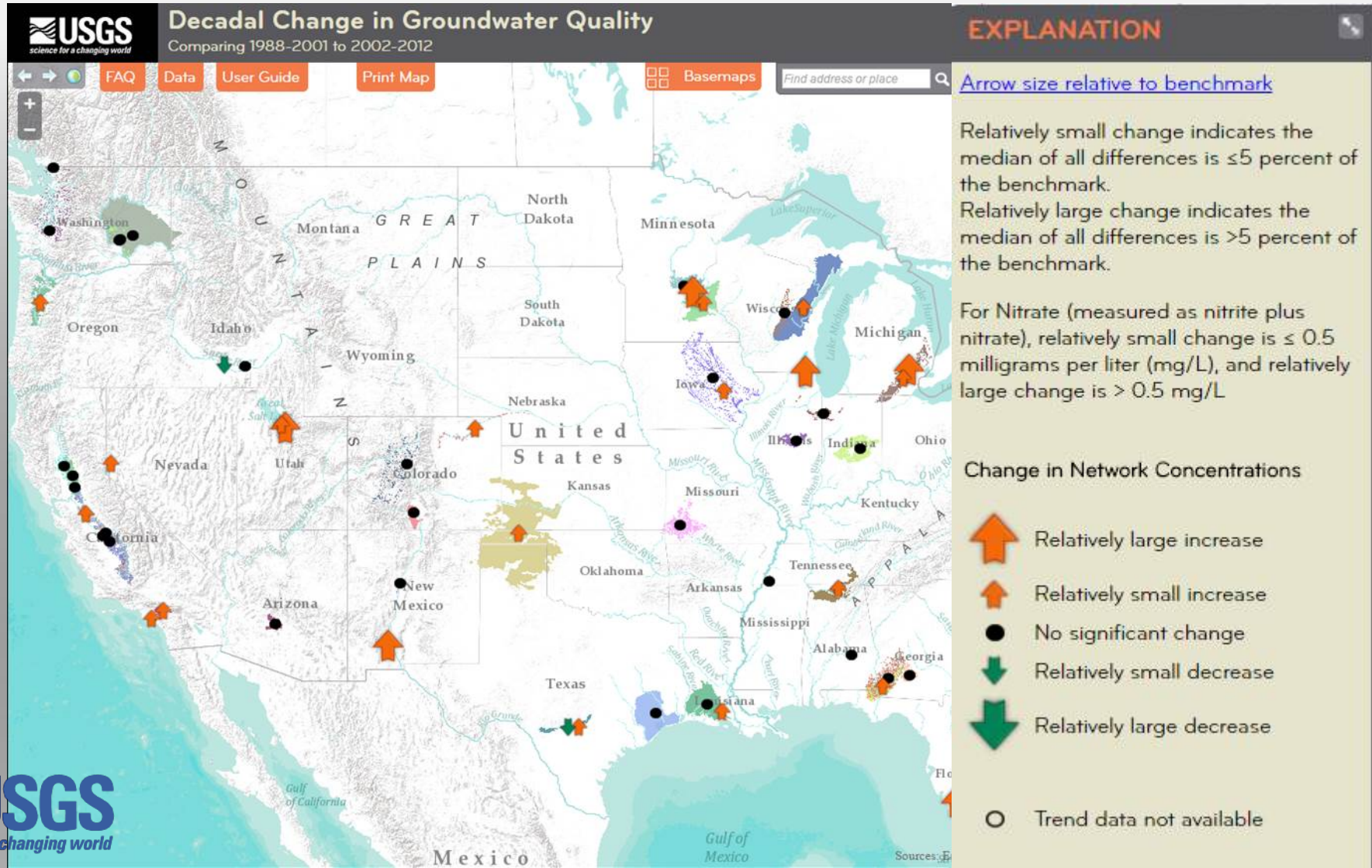
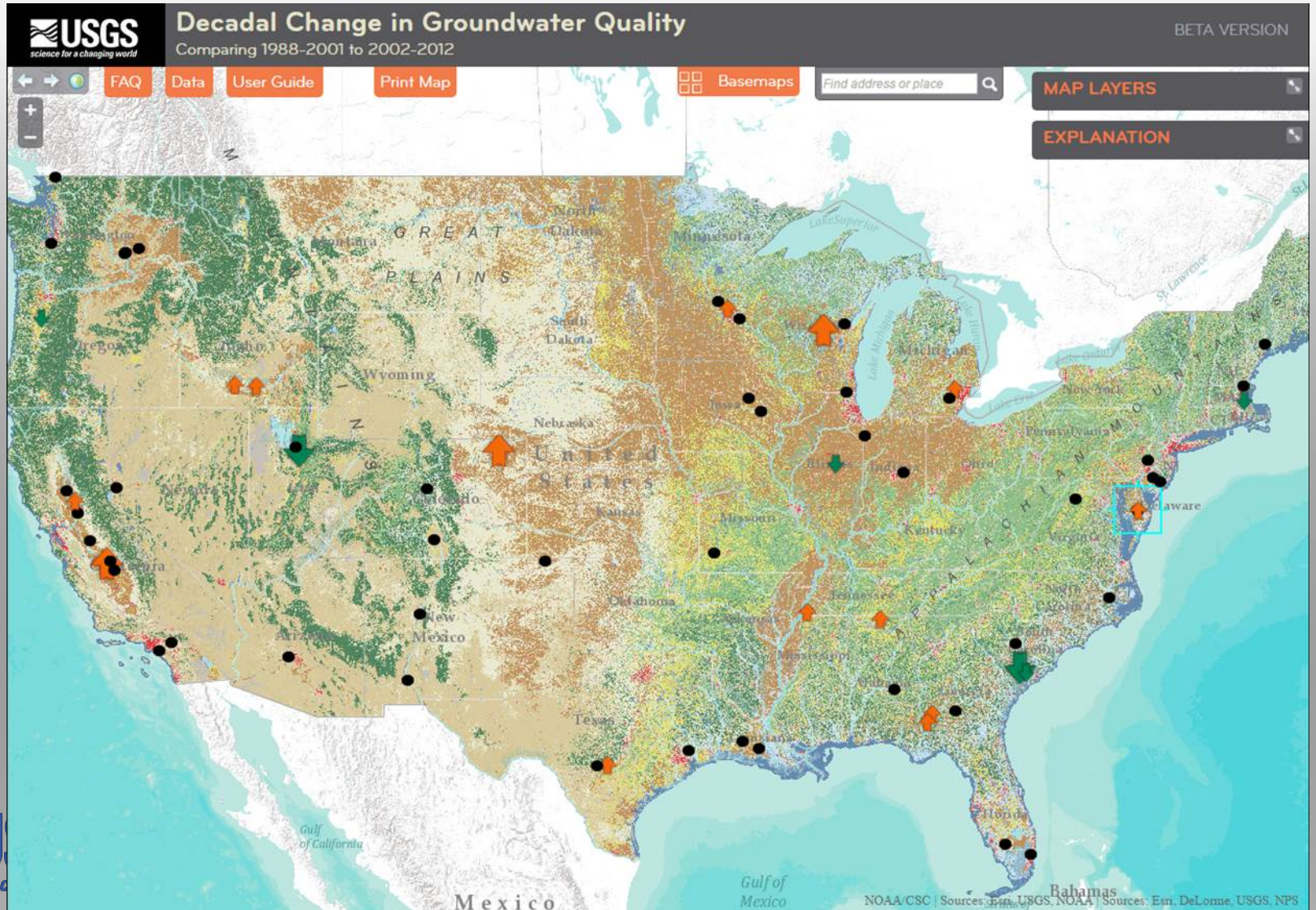
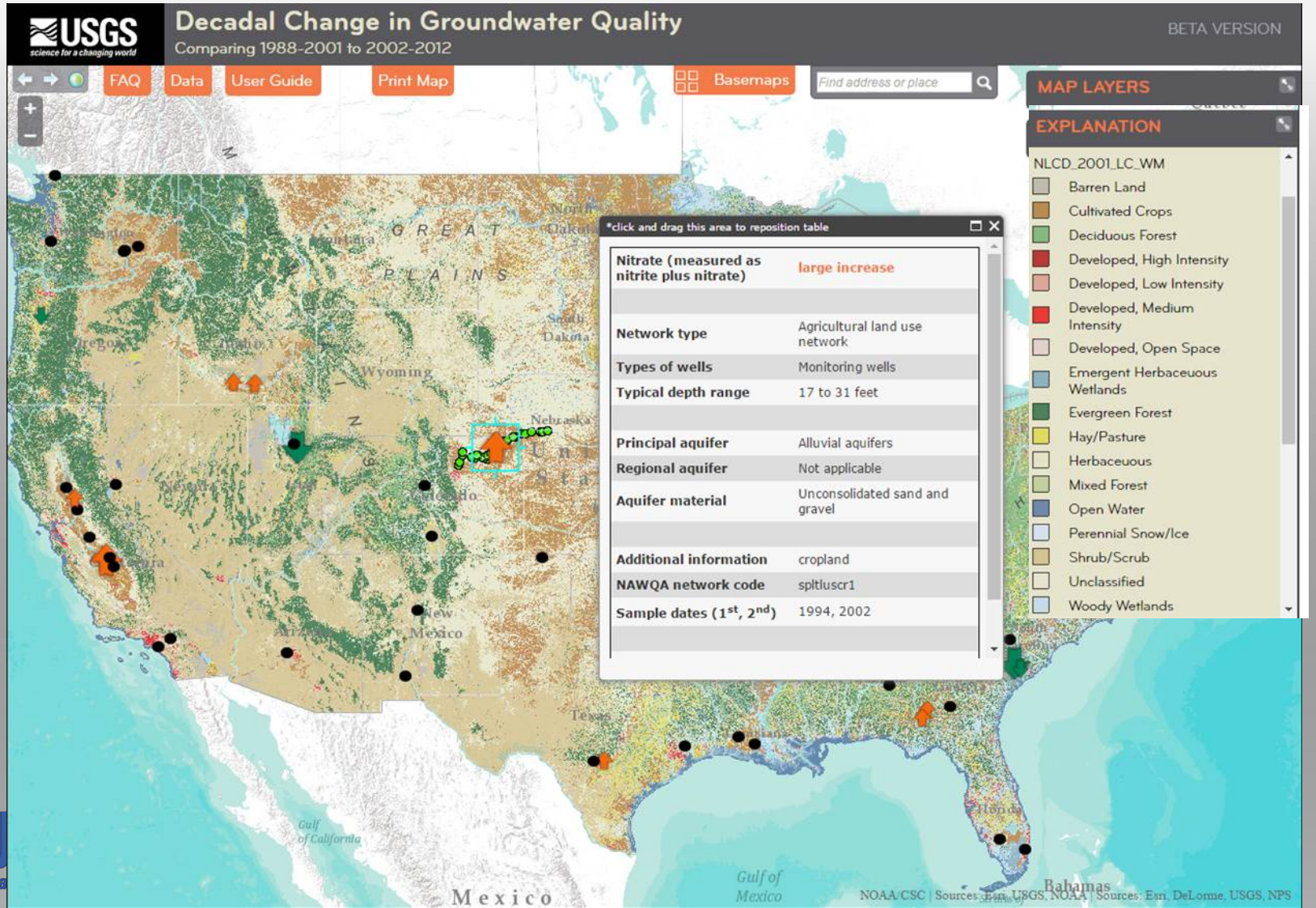
The map shows the location of 67 networks, which are typically groups of 20-30 wells. The arrows and circles illustrate whether concentrations have increased, decreased, or stayed the same over the decadal period.



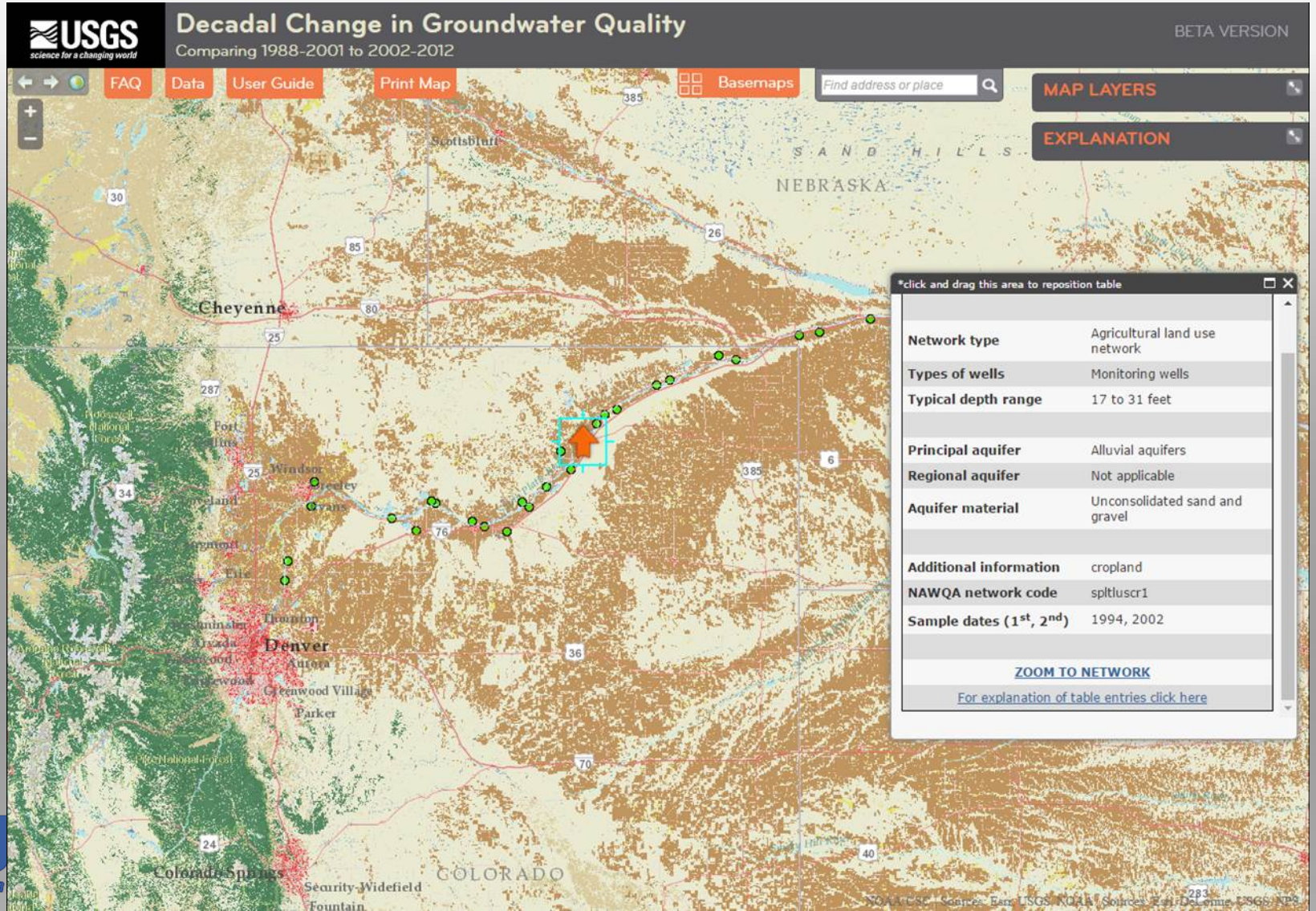
Concentrations of nitrate are increasing in more than twice as many networks as they are decreasing. Land use layer shows that increasing concentrations are common in agricultural areas.



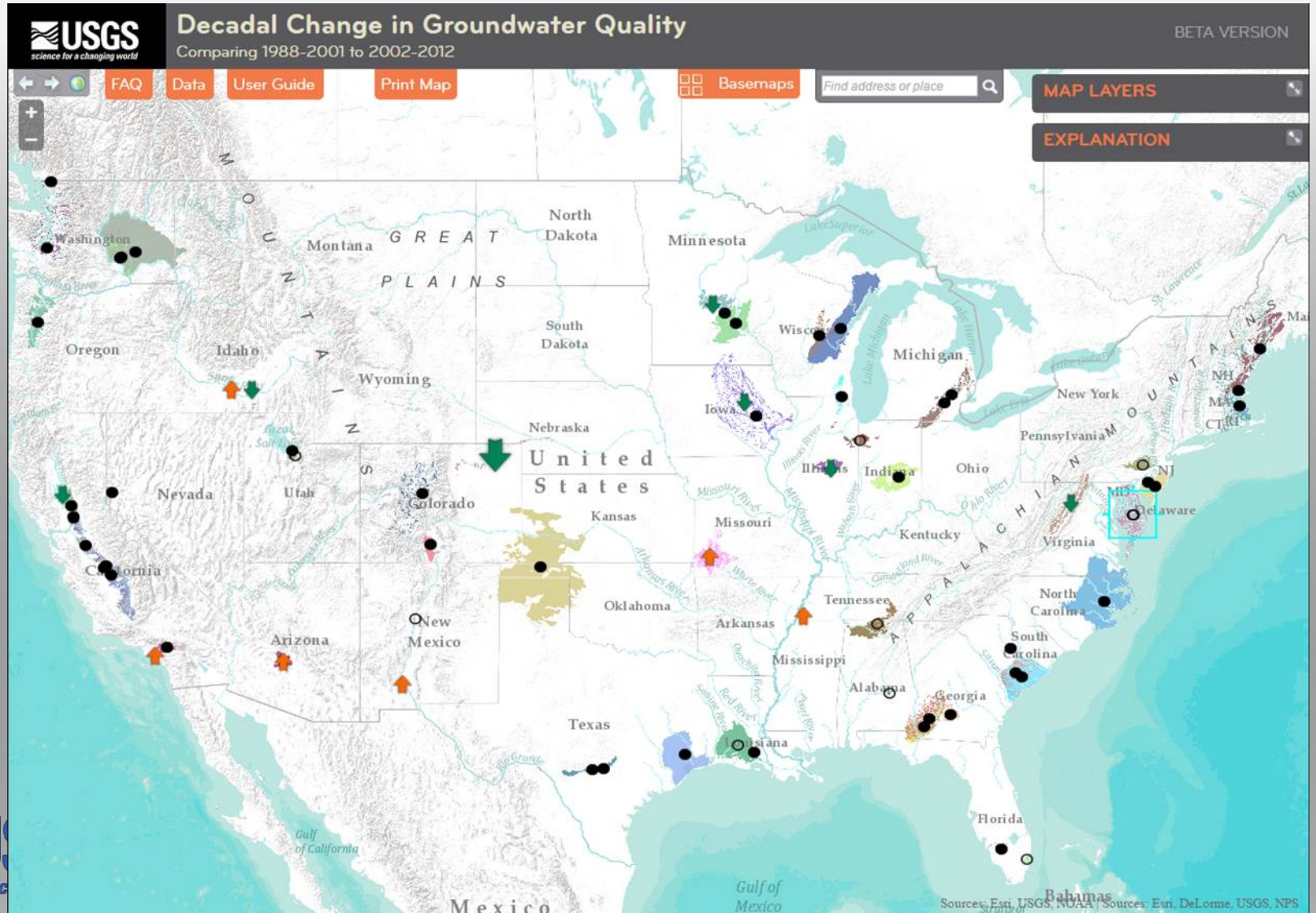
Selecting an icon brings up a popup with information about the statistical change, the type of network, and other relevant information about the network. The explanation describes the land-use types.



Selecting the ‘zoom to network’ link shows a close-up view of the network and the well locations.



Atrazine concentrations are decreasing in slightly more networks than they are increasing.



FAQ's, Data, and a User Guide are available for further information

A variety of base maps are available for the user to select

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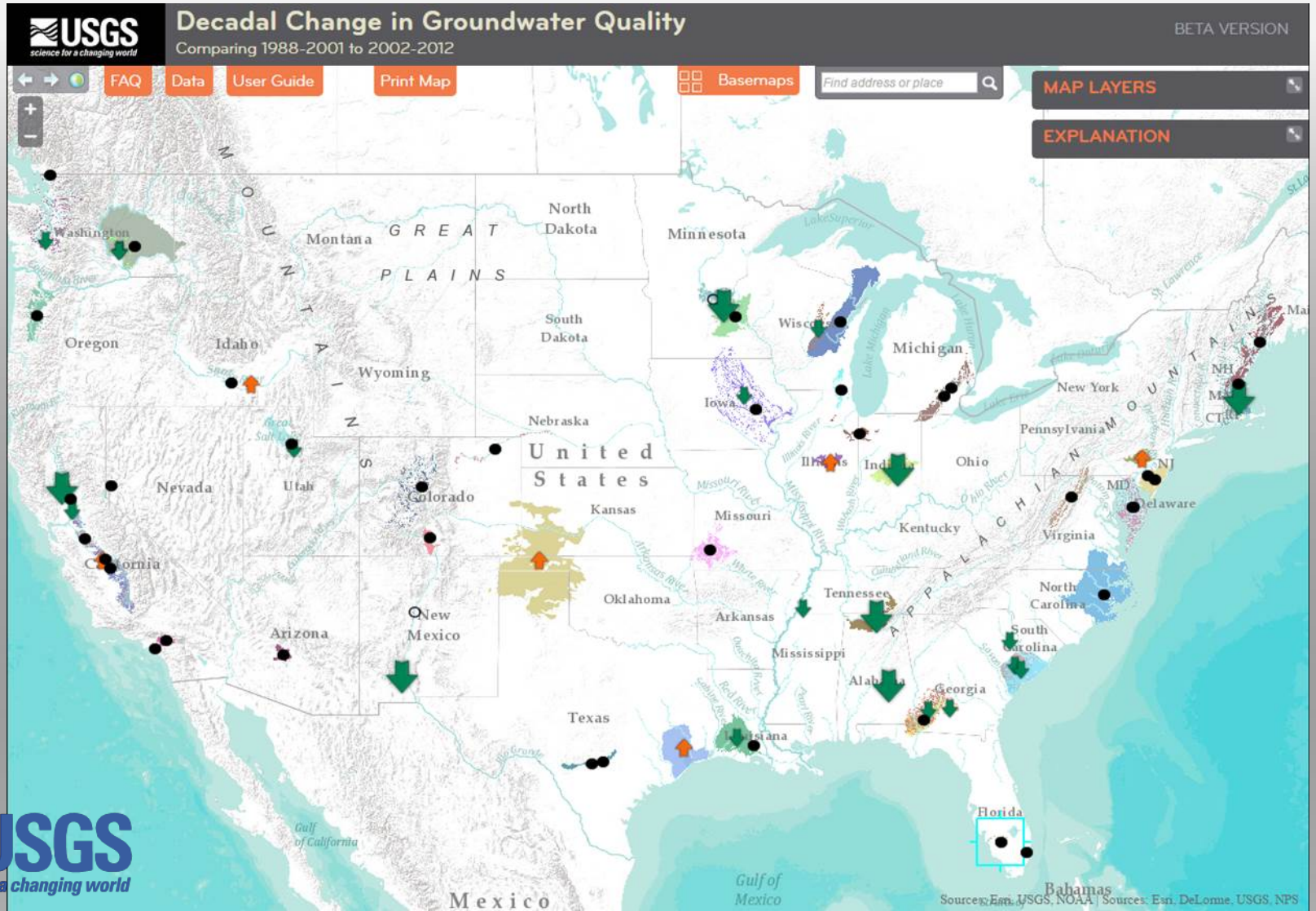
Manganese concentrations are decreasing in many networks, illustrating that concentrations of naturally occurring constituents are not constant.



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We are interested in your feedback on the web mapper:

What do you like?

What don’t you like?

We are looking for specific feedback on the clarity of the explanation and the alternative presented.

EXPLANATION

Arrow size relative to benchmark

Relatively small change indicates the median of all differences is ≤5 percent of the benchmark.
Relatively large change indicates the median of all differences is >5 percent of the benchmark.

For Nitrate (measured as nitrite plus nitrate), relatively small change is ≤ 0.5 milligrams per liter (mg/L), and relatively large change is > 0.5 mg/L

Change in Network Concentrations

- Relatively large increase
- Relatively small increase
- No significant change
- Relatively small decrease
- Relatively large decrease
- Trend data not available

EXPLANATION

Information on arrow size and benchmarks

Median change in concentration

- Increase more than **5** percent
- Increase **5** percent or less
- No significant change
- Decrease **5** percent or less
- Decrease more than **5** percent
- Trend data not available

Benchmark for **chloride** is **250 milligrams per liter (mg/L)**

Click on symbols on the map for additional information

Relatively small change indicates the median of all differences is ≤ **5 percent** of the benchmark or **12.5 mg/L**.
Relatively large change indicates the median of all differences is > **5 percent** of the benchmark or **12.5 mg/L**.
For **chloride,** the benchmark of **250 milligrams per liter** is a **Secondary Maximum Contaminant Level**.

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Decadal changes in groundwater quality

QUESTIONS?

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How might groundwater quality change in the future?

Modeling geochemical conditions in support of groundwater-quality prediction.

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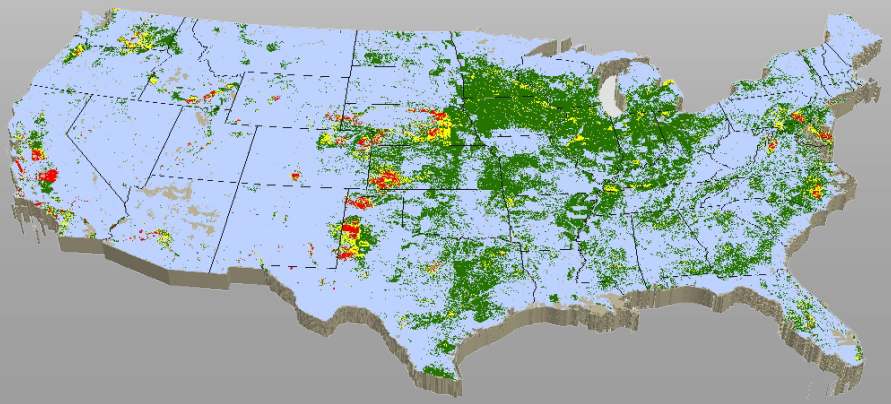
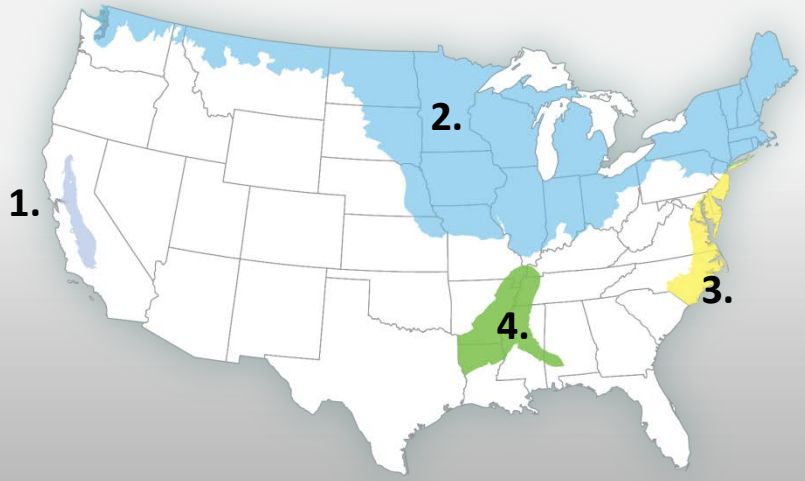
WHY MODELS? WHY NOW?

Groundwater at Depth Used for Domestic Supply



Nitrate concentration, mg/L

<1 1-5 5-10 >10



1. Central Valley (2013 – 2018)
2. Glacial (2014 – 2019)
3. Northern Atlantic Coastal Plain (2015 – 2020)
4. Mississippi Embayment (2016 – 2021)

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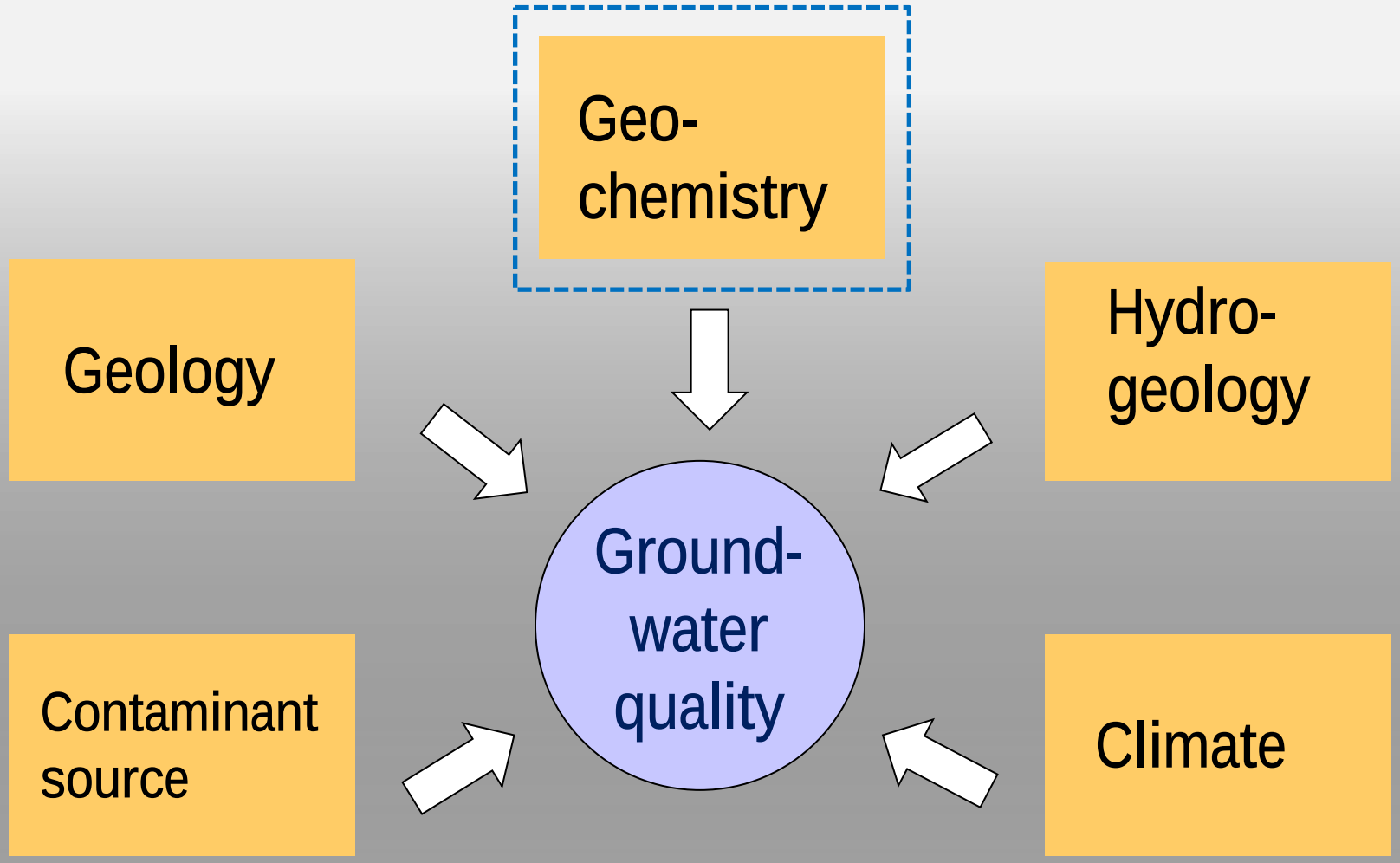
Nolan et al. 2006

FACTORS THAT AFFECT GROUNDWATER QUALITY

MOBILITY & PERSISTENCE



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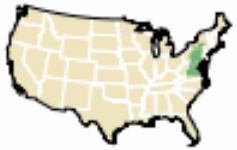
SPATIALLY-CONTINUOUS GEOCHEMISTRY – PROOF OF CONCEPT

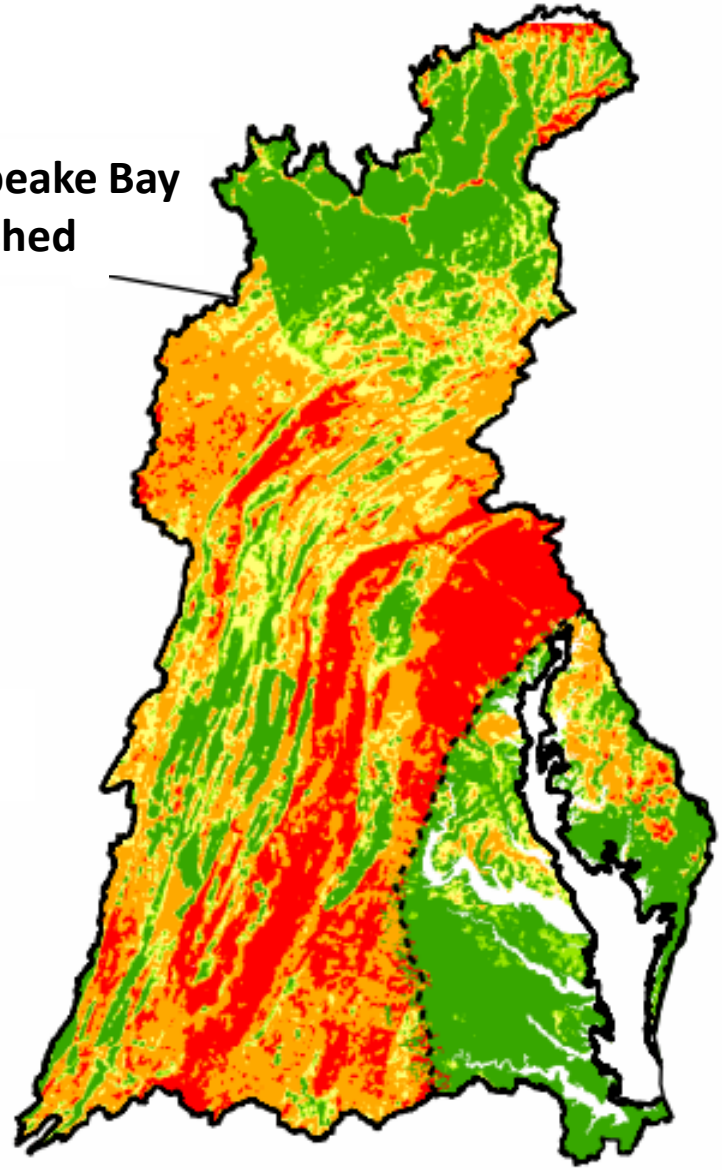


Chesapeake Bay Watershed

Depth at Which Dissolved Oxygen (DO) Is No Longer Present, in meters

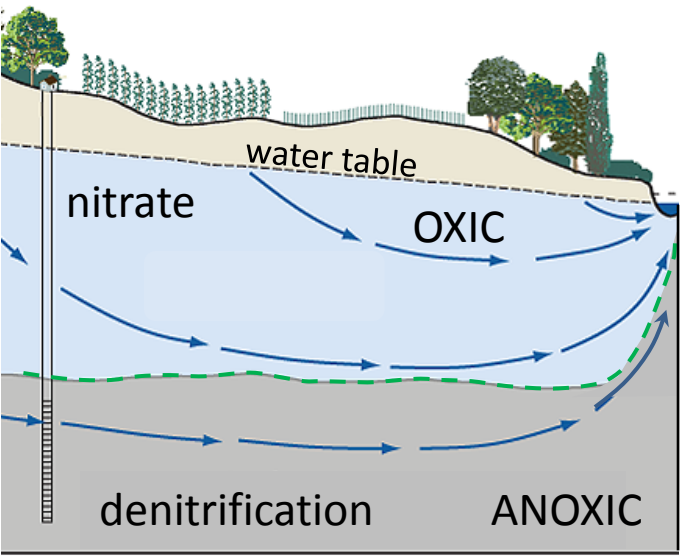
< 10

> 80

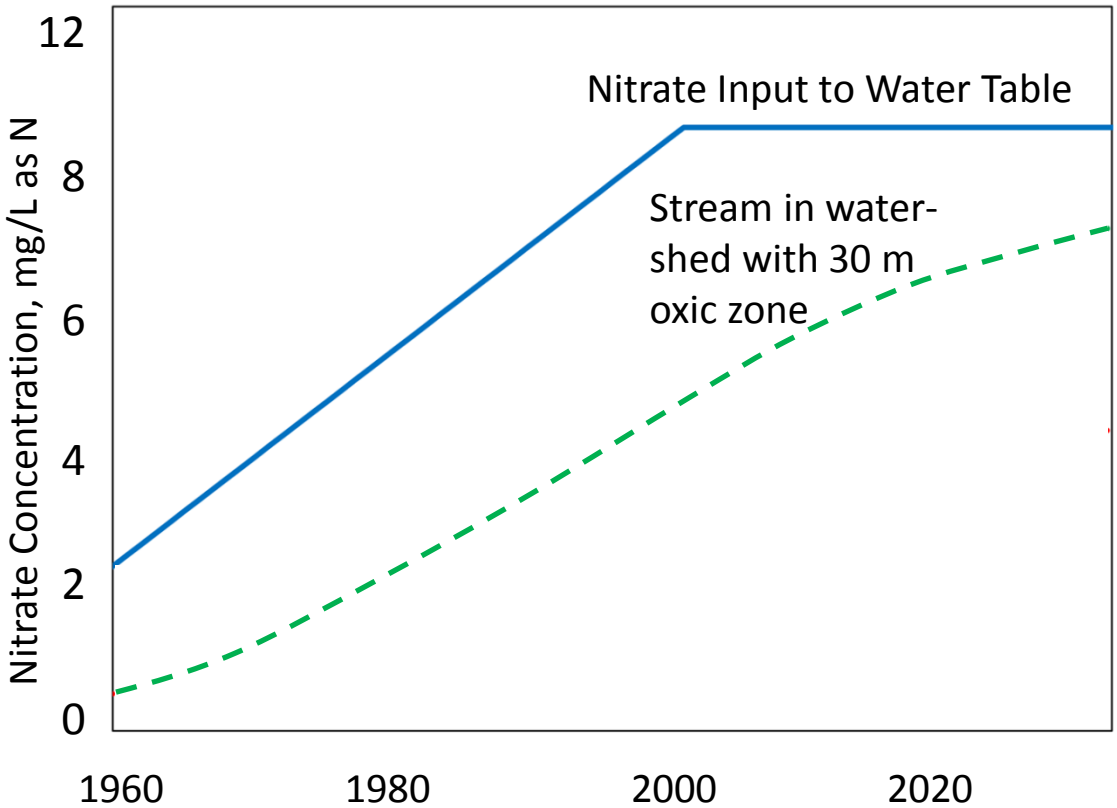


Tesoriero et al. 2015

WHY REDOX BOUNDARIES MATTER FOR PREDICTION

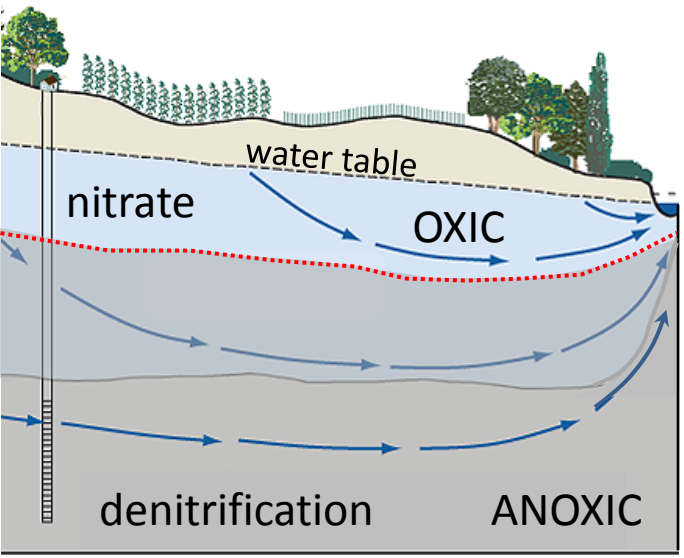


not to scale

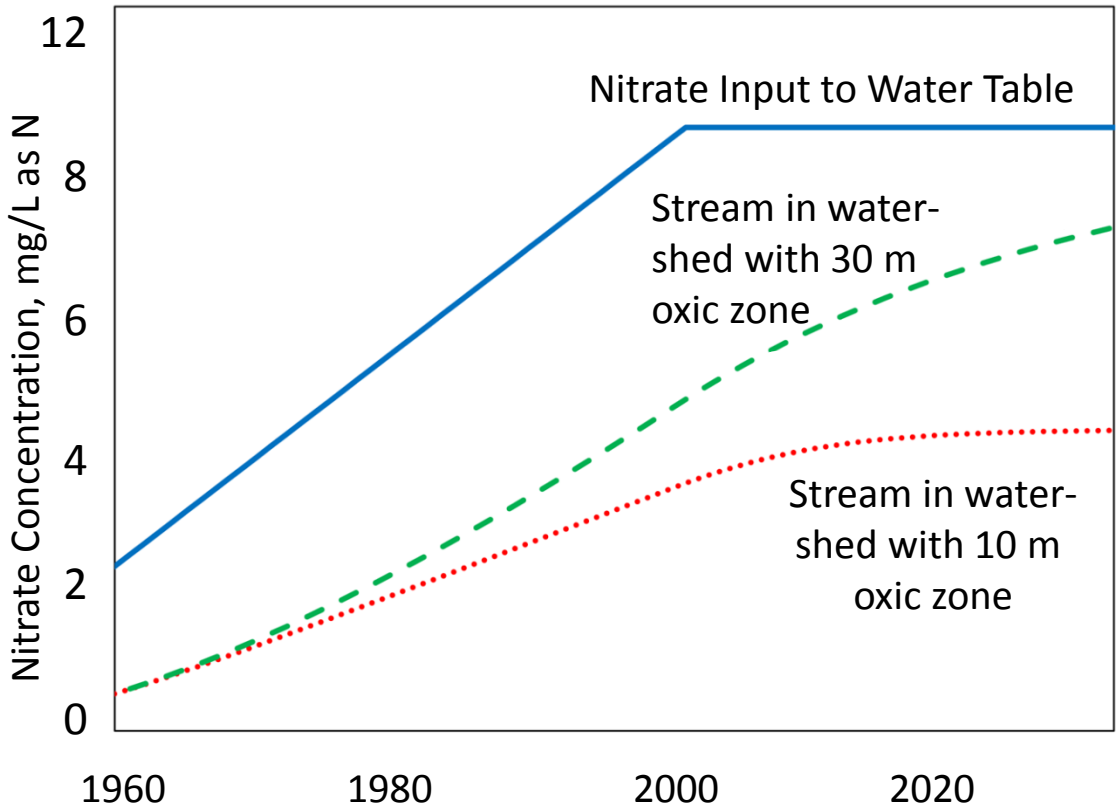


Tesoriero et al. 2015

WHY REDOX BOUNDARIES MATTER FOR PREDICTION Cont.



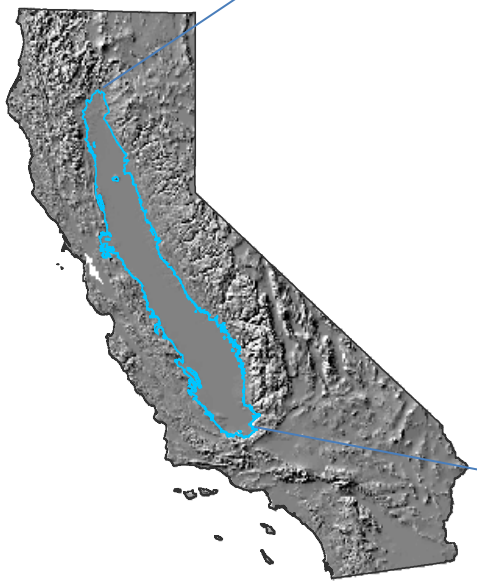
not to scale

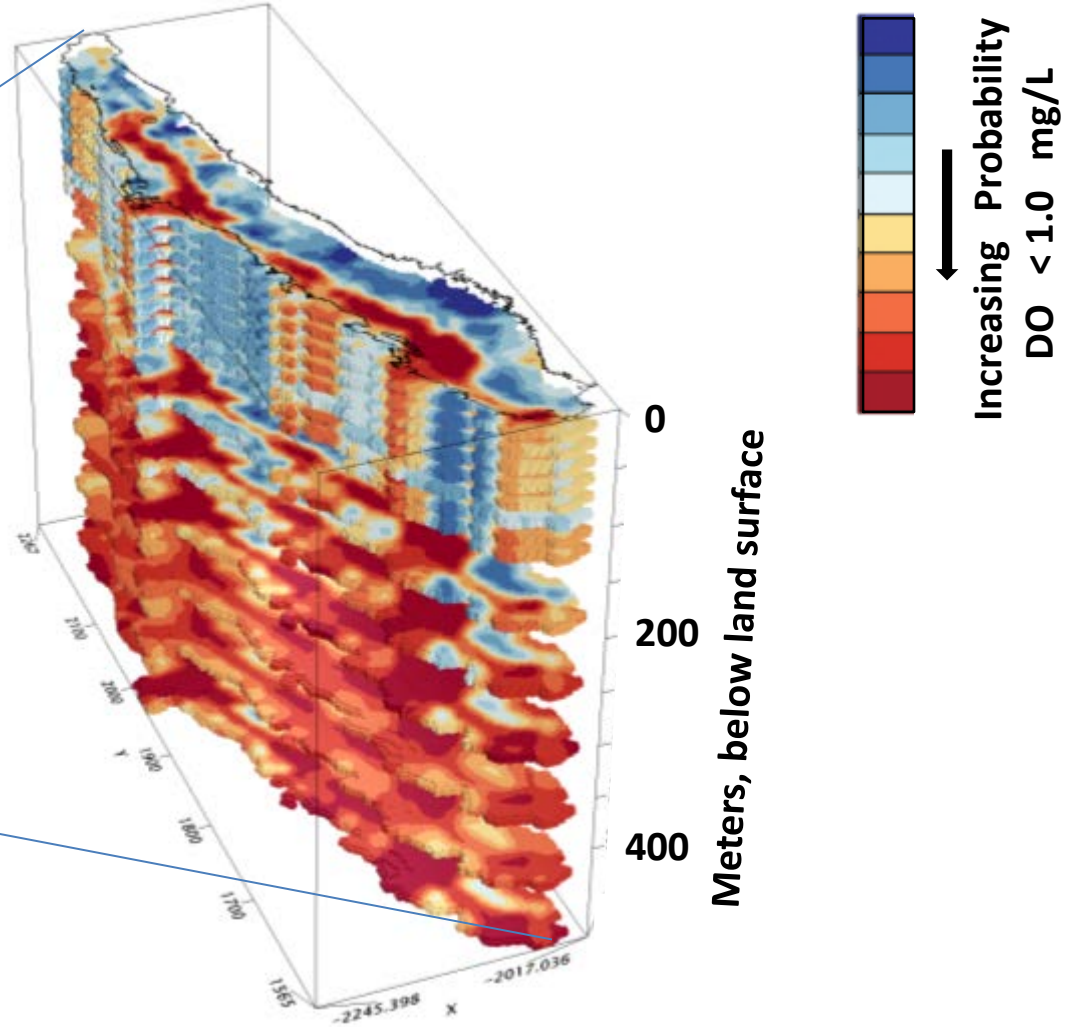


Tesoriero et al. 2015

3D CHARACTERIZATION OF ANOXIC GROUNDWATER

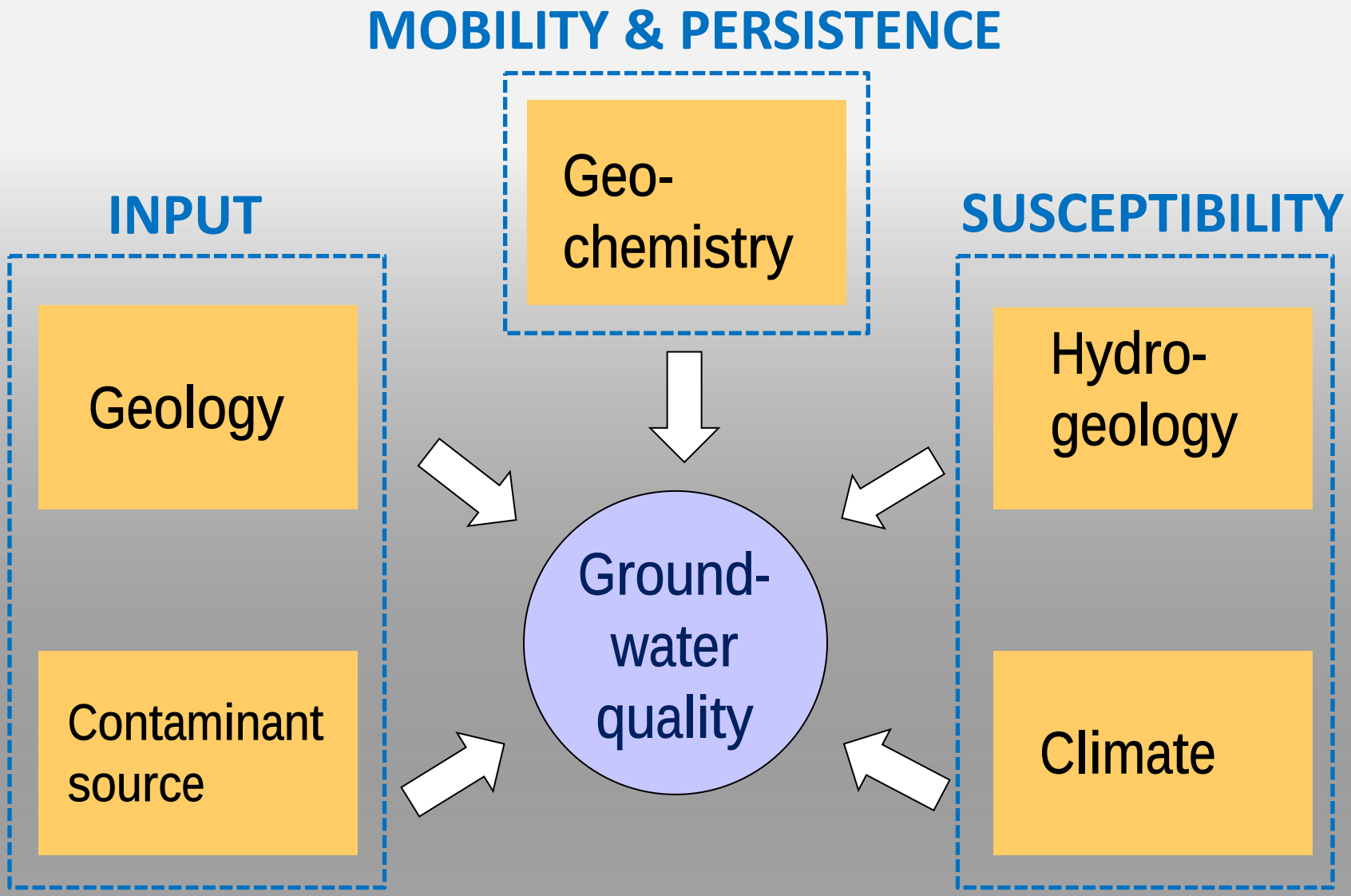
Central Valley, CA





Preliminary, subject to revision
Rosecrans et al., written communication

FACTORS THAT AFFECT GROUNDWATER QUALITY



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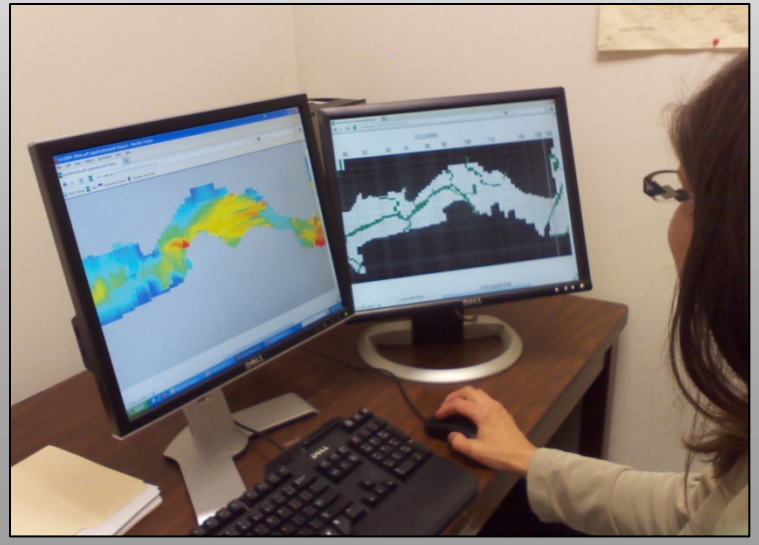
HOW WATER-QUALITY MAPS CAN BE USED

- **Anticipate water quality in unsampled areas or depth zones [not necessarily individual wells]**
- **Design monitoring programs**
- **Inform protection practices**
- **Plan for treatment**
- **Locate new wells**
- **Evaluate sustainability of a groundwater source of drinking water**



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ASSESSING THE QUALITY OF OUR NATION'S GROUNDWATER – A COMPREHENSIVE ASSESSMENT

What is the quality of the Nation's groundwater?
Selected findings for depths used for drinking-water supply …

- Trace elements more prevalent at high concentrations than nitrate or organic compounds
- Microbiological constituents more common in carbonates versus other aquifer materials
- Broad impact of unconventional oil & gas development on GW quality not detected thus far

Is groundwater quality getting better or worse?
Selected findings on decadal trends in groundwater quality …

- Chloride concentrations are increasing in urban areas
- Nitrate is increasing in more areas than it is decreasing
- Concentrations of naturally occurring constituents are not necessarily constant

How might groundwater quality change in the future?
Selected findings from modeling & mapping activities …

- Redox conditions can be characterized in 3D in support of contaminant prediction

ASSESSING THE QUALITY OF OUR NATION'S GROUNDWATER – A COMPREHENSIVE ASSESSMENT

QUESTIONS?

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