Occurrence and Distribution of Nitrate in Groundwater in the Central Valley

Matthew K. Landon, Miranda S. Fram

U.S. Geological Survey, California Water Science Center

Irrigated Lands Regulatory Program Workshop
April 15, 2009

GAMA Priority Basins Project

USGS science for a changing world

Water Boards

Acknowledgements

Groundwater Ambient Monitoring and Assessment (GAMA) Priority Basin Project Cooperators and partners:

- State Water Board
- Lawrence Livermore National Laboratory
- Department of Public Health (CDPH)
- Department of Pesticide Regulations (CDPR)
- Department of Water Resources
- Well Owners

USGS National Water Quality Assessment (NAWQA) Program

USGS science for a changing world

Water Boards

Outline

- Nitrate concentrations in the portion of the Central Valley aquifers used for public supply
- Relation of nitrate concentrations to depth
- Distribution of geochemical conditions favorable for nitrate degradation and evidence for degradation in some locations

USGS science for a changing world

Water Boards

Central Valley (CV) Nitrate Datasets

- USGS-GAMA Priority Basin Project
- California Department of Public Health (CDPH)
- USGS-National Water Quality Assessment (NAWQA) Program – Summary of selected results in San Joaquin Valley

USGS science for a changing world

Water Boards

Representing Nitrate Concentrations

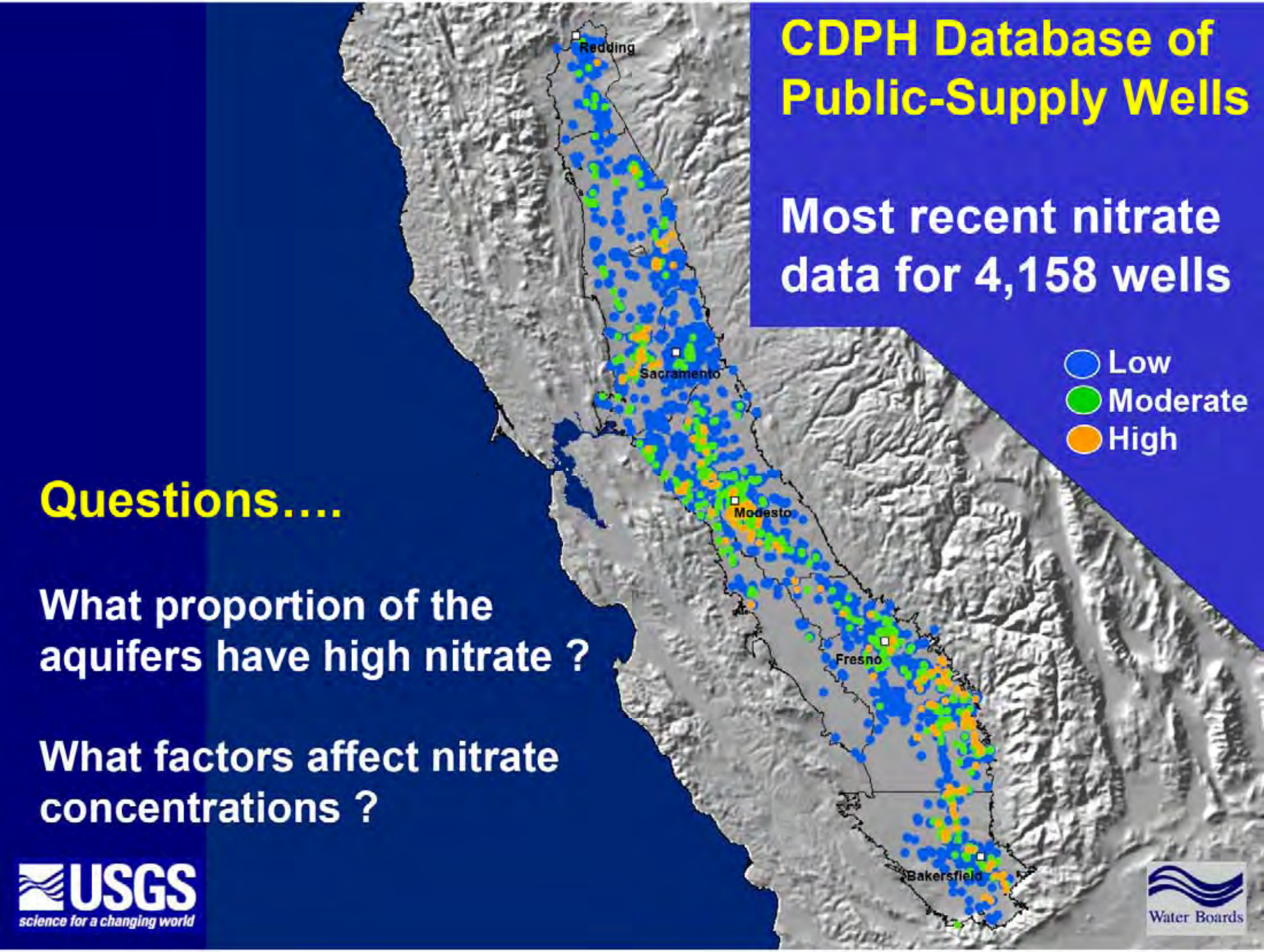
- Relative concentration

$$RC = \frac{\text{Measured nitrate concentration}}{\text{USEPA MCL for nitrate}}$$

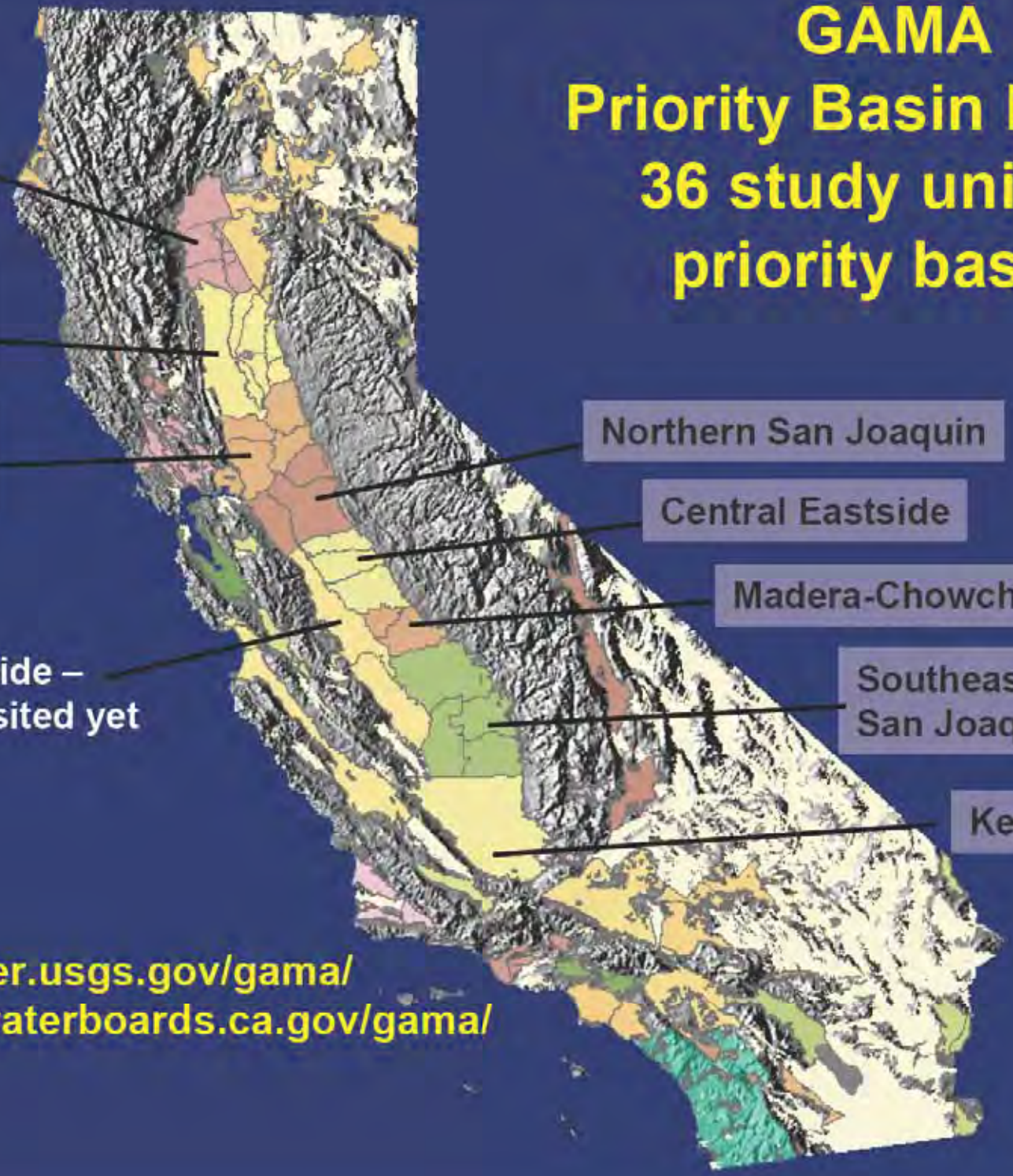
- Color coding
  - Low $RC \leq 0.5$
  - Moderate $0.5 < RC \leq 1$
  - High $RC > 1$

USGS science for a changing world

Water Boards


CDPH Database of Public-Supply Wells
Most recent nitrate data for 4,158 wells
Low
Moderate
High
Redding
Sacramento
Modesto
Fresno
Bakersfield
Questions….
What proportion of the aquifers have high nitrate ?
What factors affect nitrate concentrations ?
USGS
science for a changing world
Water Boards

GAMA
Priority Basin Project
36 study units in priority basins



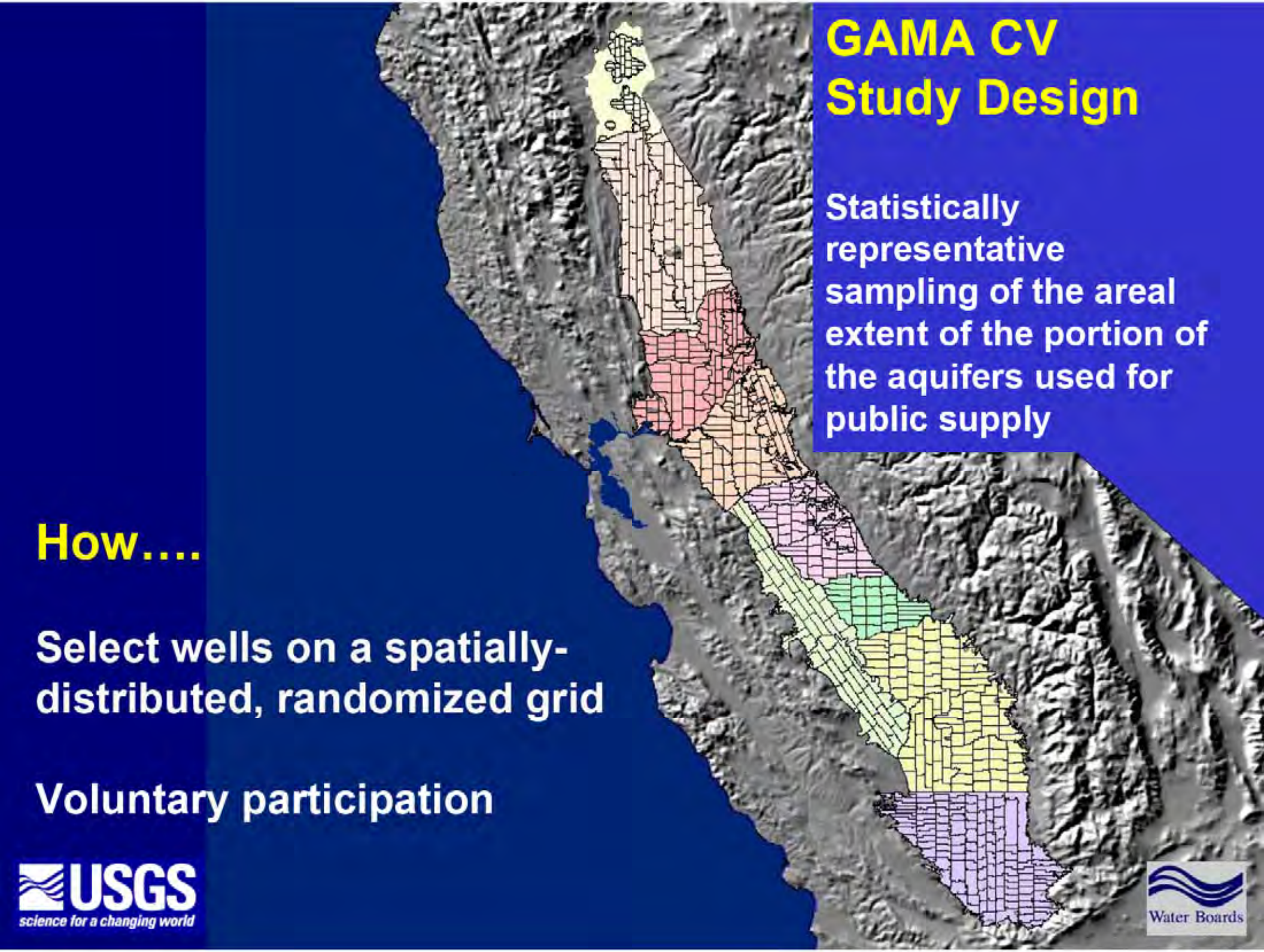
http://ca.water.usgs.gov/gama/
http://www.waterboards.ca.gov/gama/

USGS science for a changing world

Water Boards

GAMA CV Study Design

Statistically representative sampling of the areal extent of the portion of the aquifers used for public supply



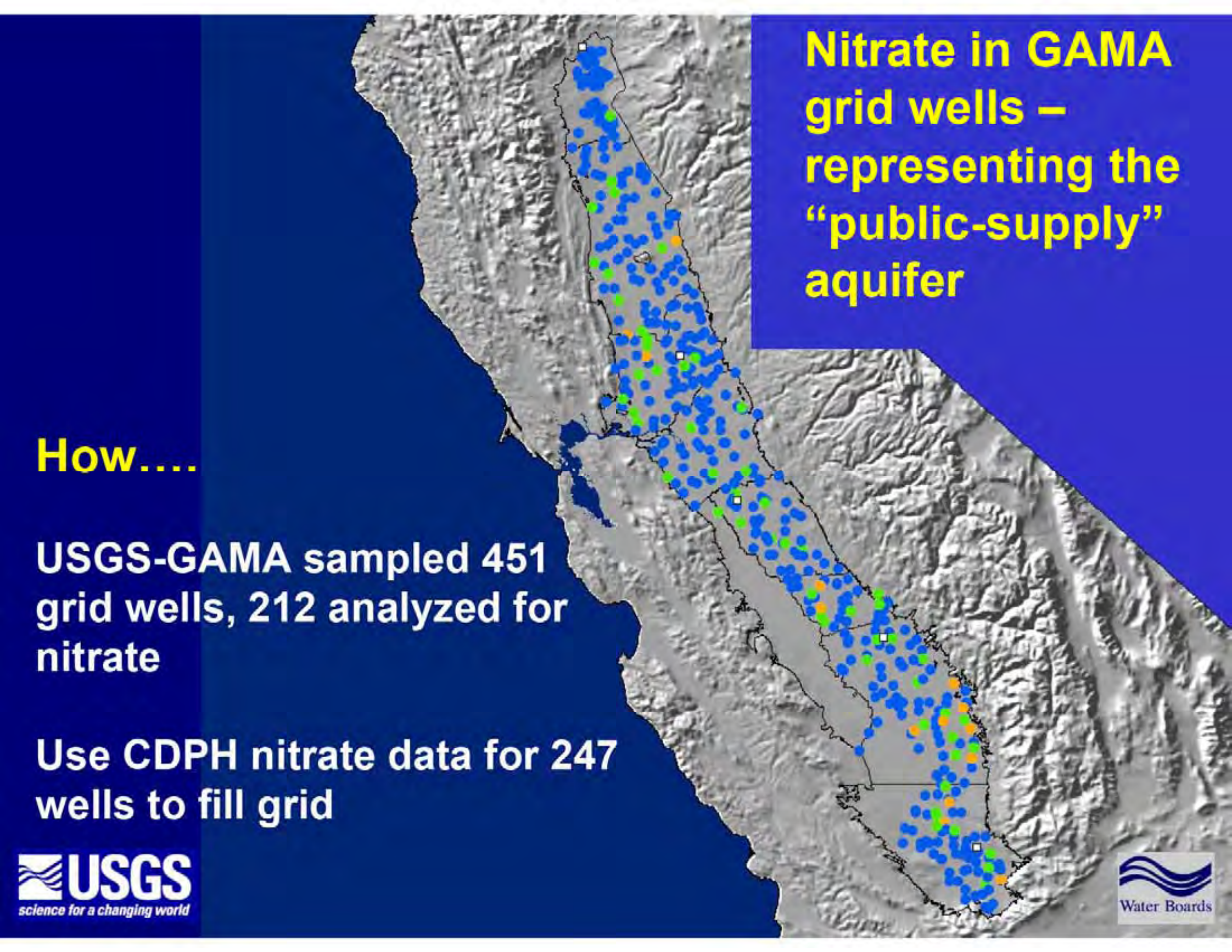
How….

Select wells on a spatially-distributed, randomized grid

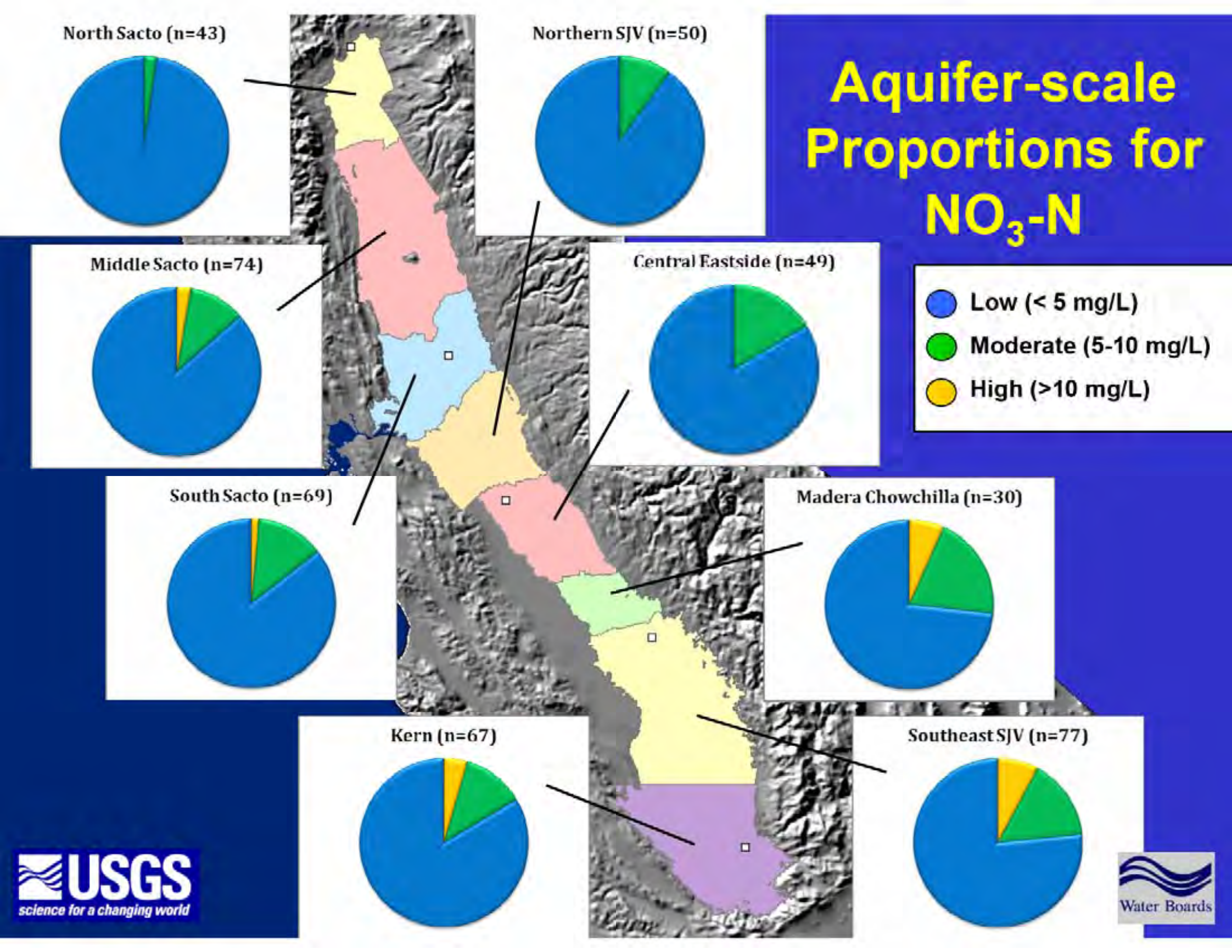
Voluntary participation

USGS science for a changing world

Water Boards


Nitrate in GAMA grid wells – representing the "public-supply" aquifer
How….
USGS-GAMA sampled 451 grid wells, 212 analyzed for nitrate
Use CDPH nitrate data for 247 wells to fill grid
USGS
science for a changing world
Water Boards

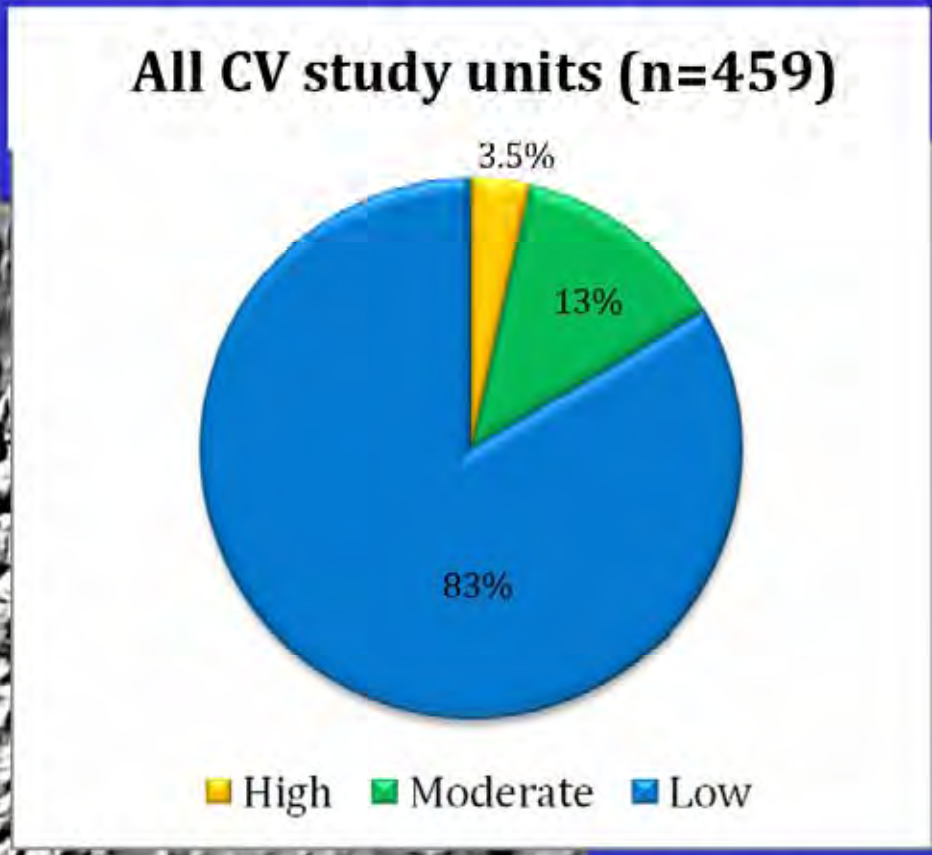
Aquifer-scale Proportions for NO_3-N



USGS science for a changing world

Water Boards

Aquifer-scale proportions for nitrate in portion of Central Valley aquifers used for public supply



USGS science for a changing world

Water Boards

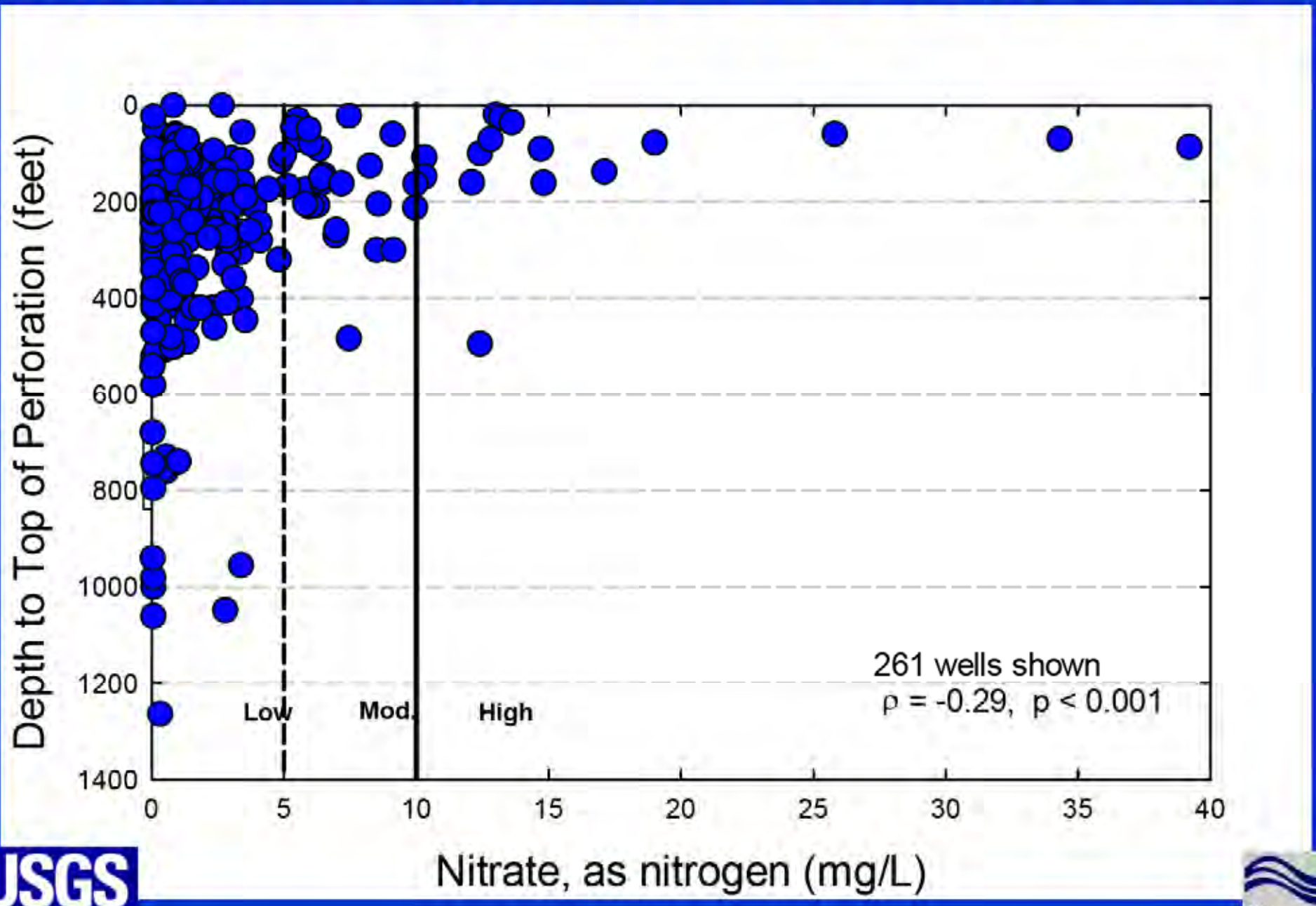
Outline

- Nitrate concentrations in the portion of the Central Valley aquifer used for public supply
-
- **Relation of nitrate concentrations to depth**
- Distribution of geochemical conditions favorable for nitrate degradation and evidence for degradation in some locations

USGS science for a changing world

Water Boards

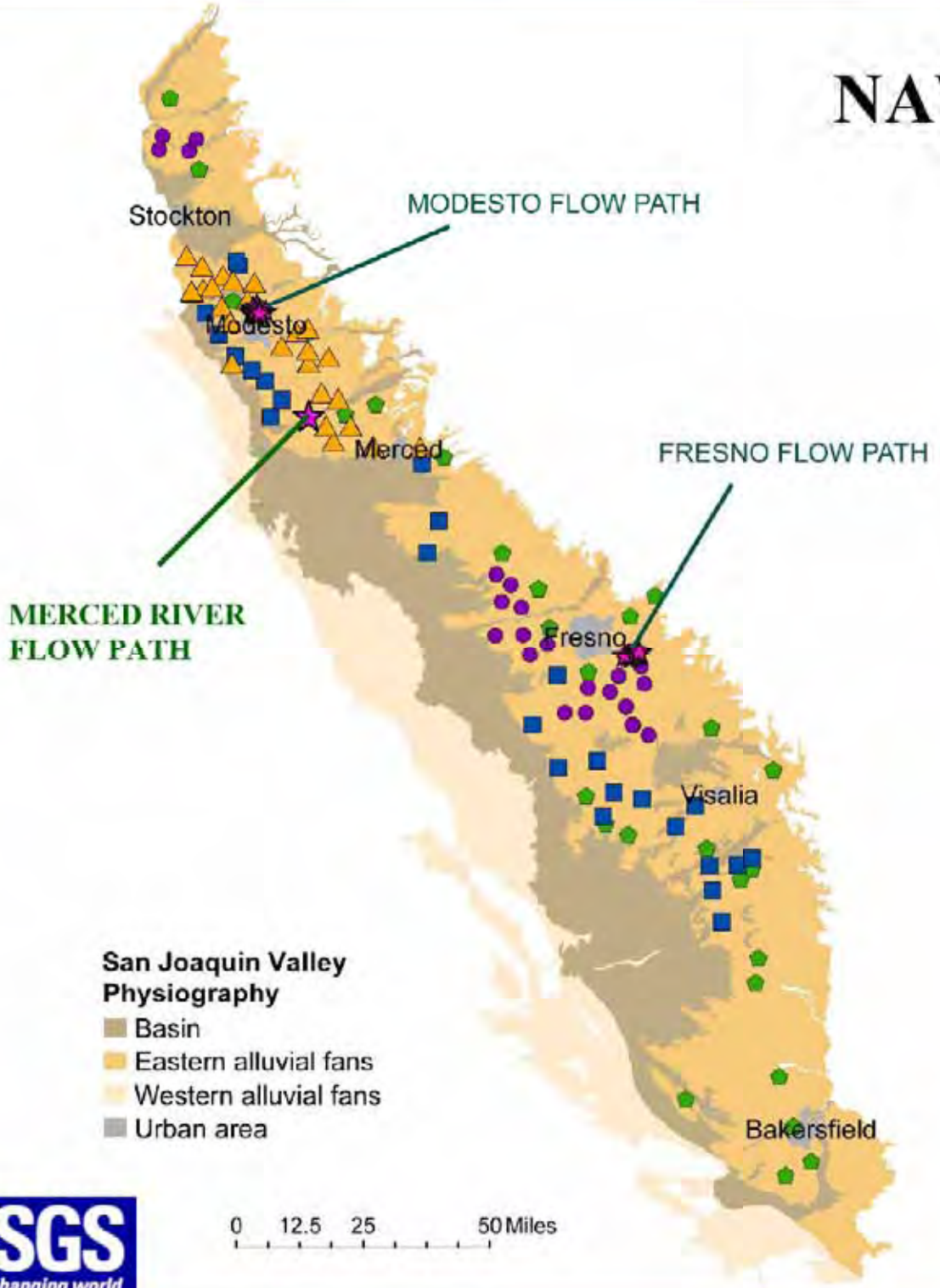
Nitrate – Depth: USGS GAMA data



USGS science for a changing world

Water Boards

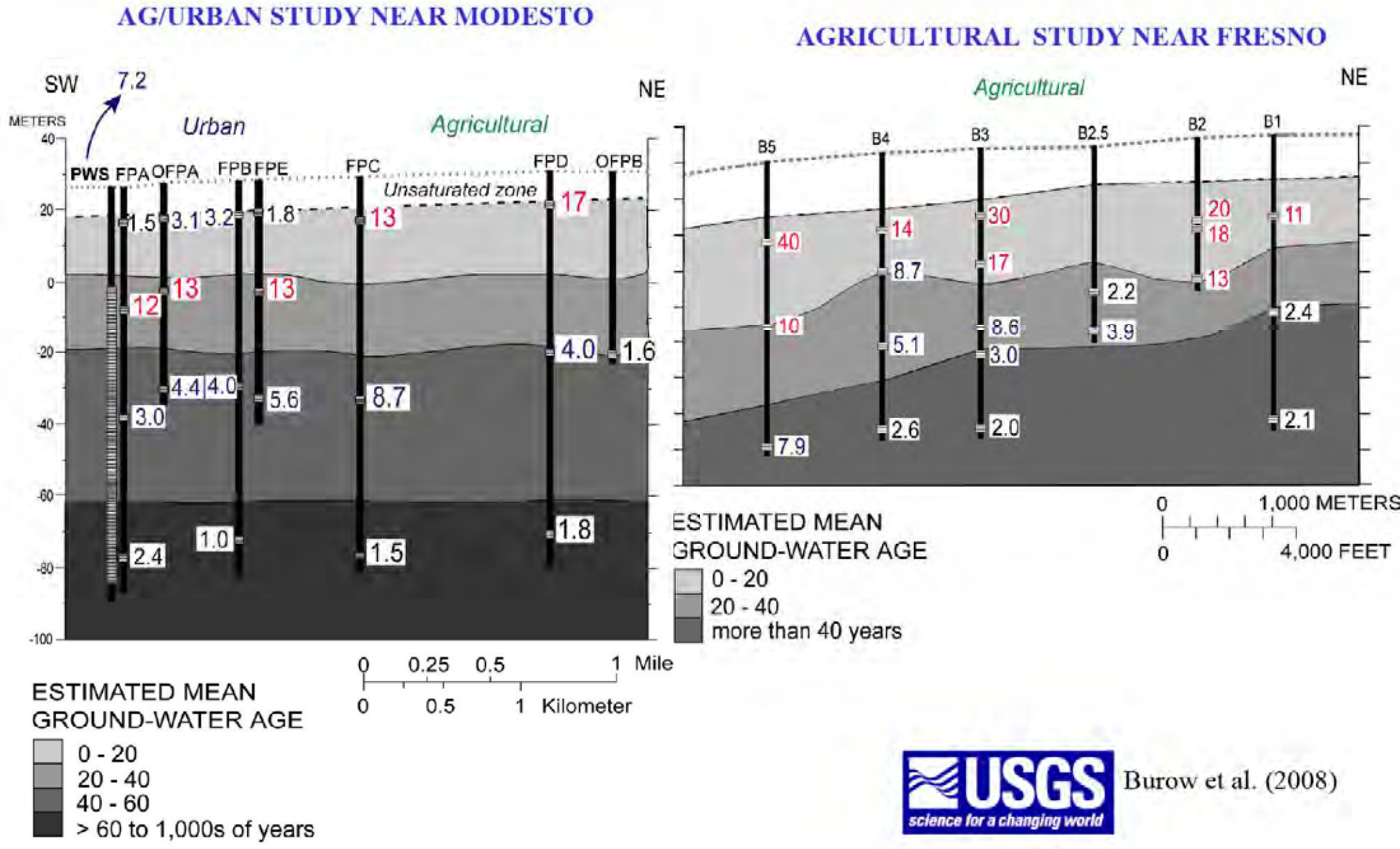
NAWQA monitoring networks



Burow et al. (2008)

USGS
science for a changing world

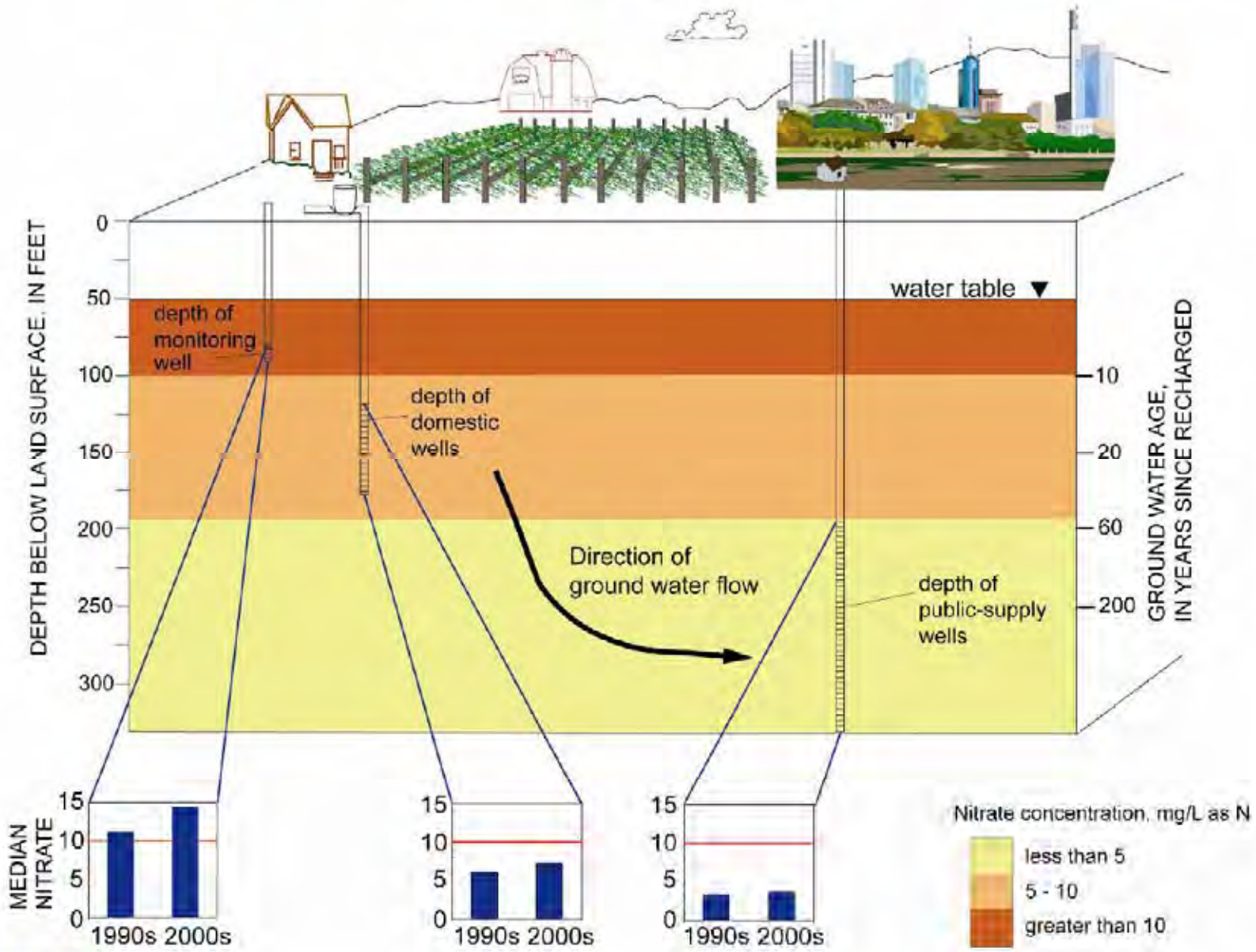
Monitoring well transects
Nitrate Concentrations Decrease with Depth and Age



USGS science for a changing world

Burow et al. (2008)

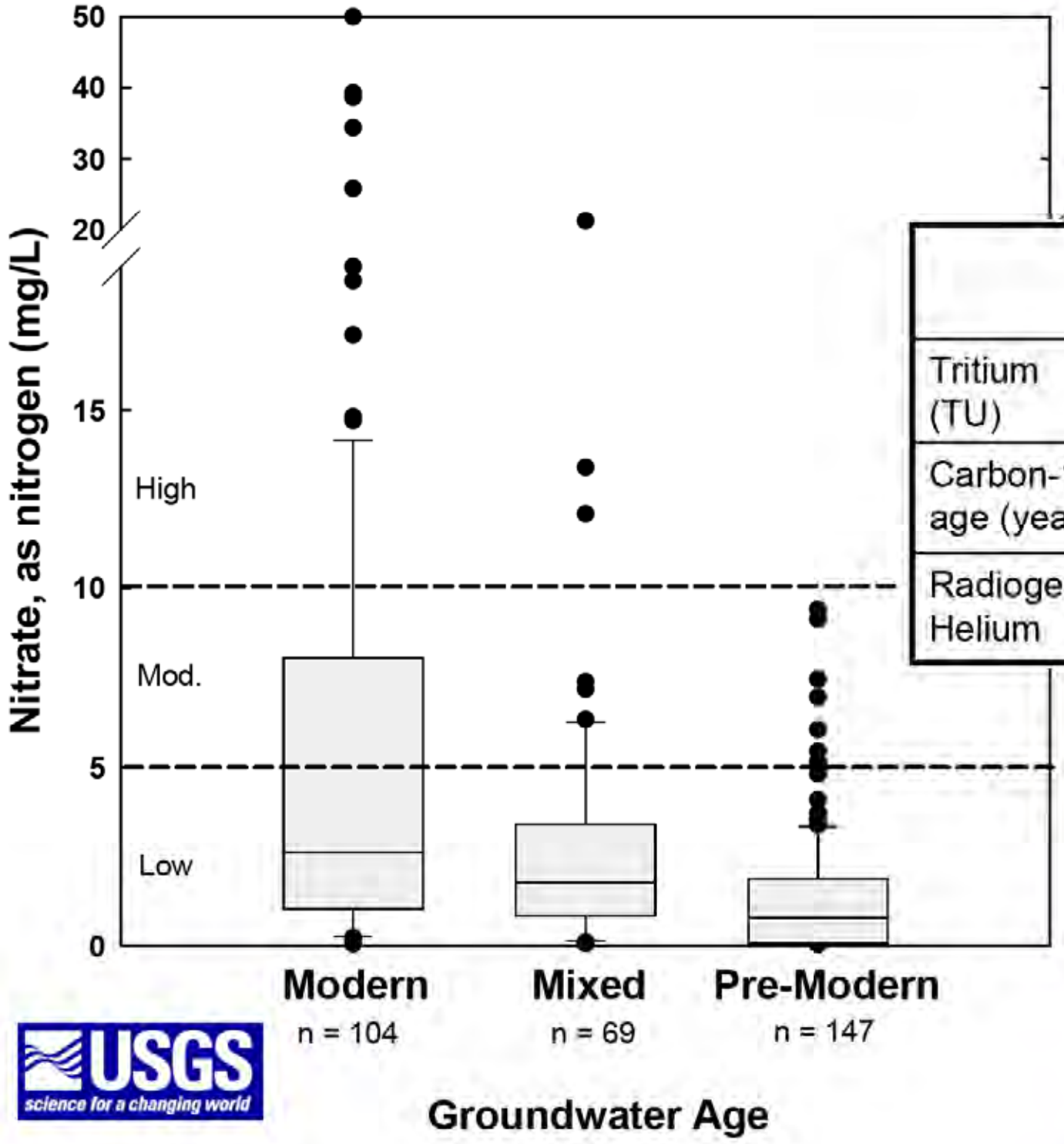
Nitrate: Regional trends in concentrations



USGS science for a changing world

Burow et al. (2008)

Nitrate – Age: USGS GAMA data



	Modern	Mixed	Pre-Modern
Tritium (TU)	> 1	> 1	< 1
Carbon-14 age (years)	< 1,000	> 1,000	> 1,000
Radiogenic Helium	< 5 %	> 5 %	> 5 %

USGS science for a changing world

Water Boards

Outline

- Nitrate concentrations in the portion of the Central Valley aquifer used for public supply
-
- Relation of nitrate concentrations to depth

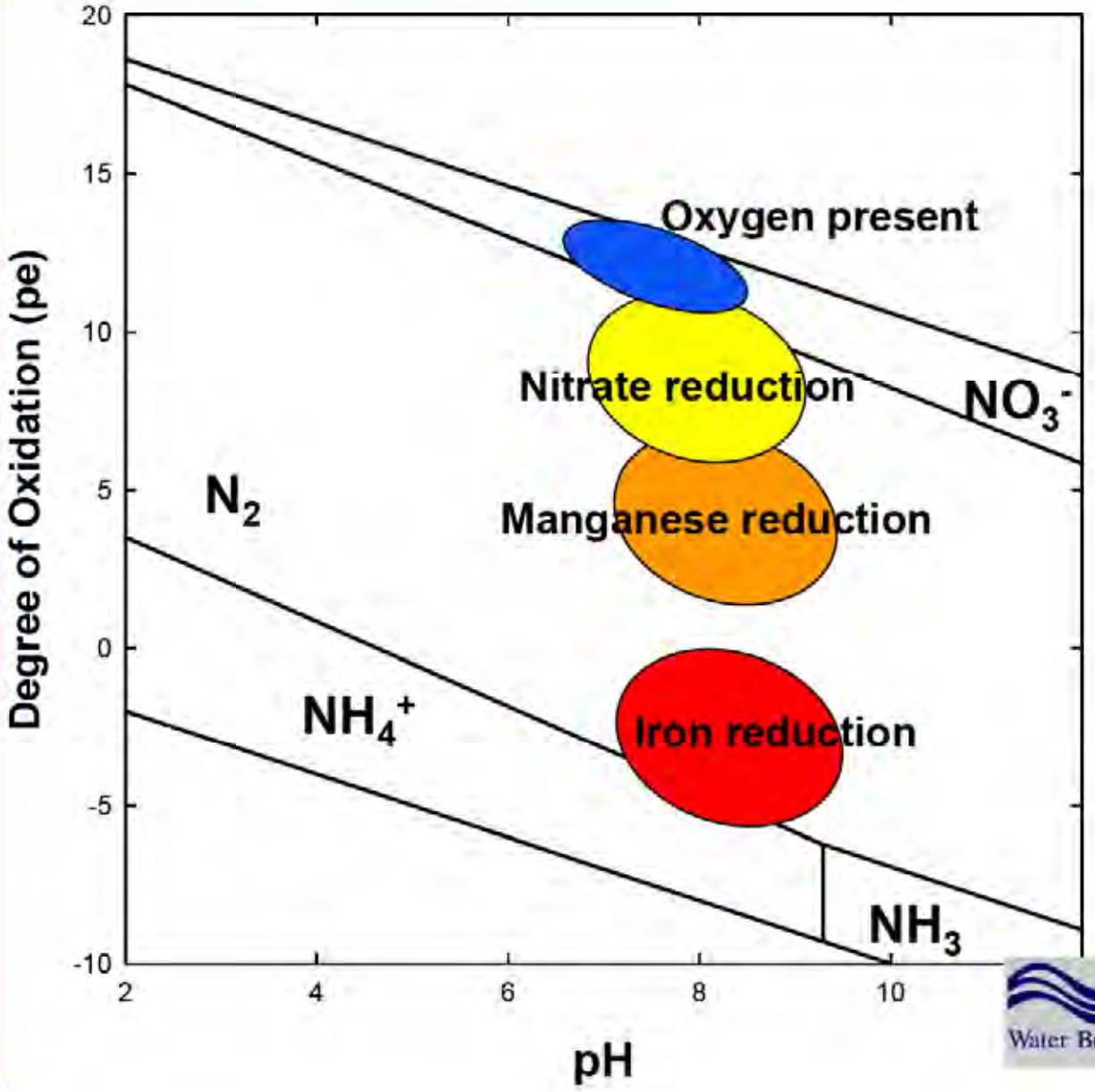
- Distribution of geochemical conditions favorable for nitrate degradation and evidence for degradation in some locations

USGS science for a changing world

Water Boards

Nitrate Degradation

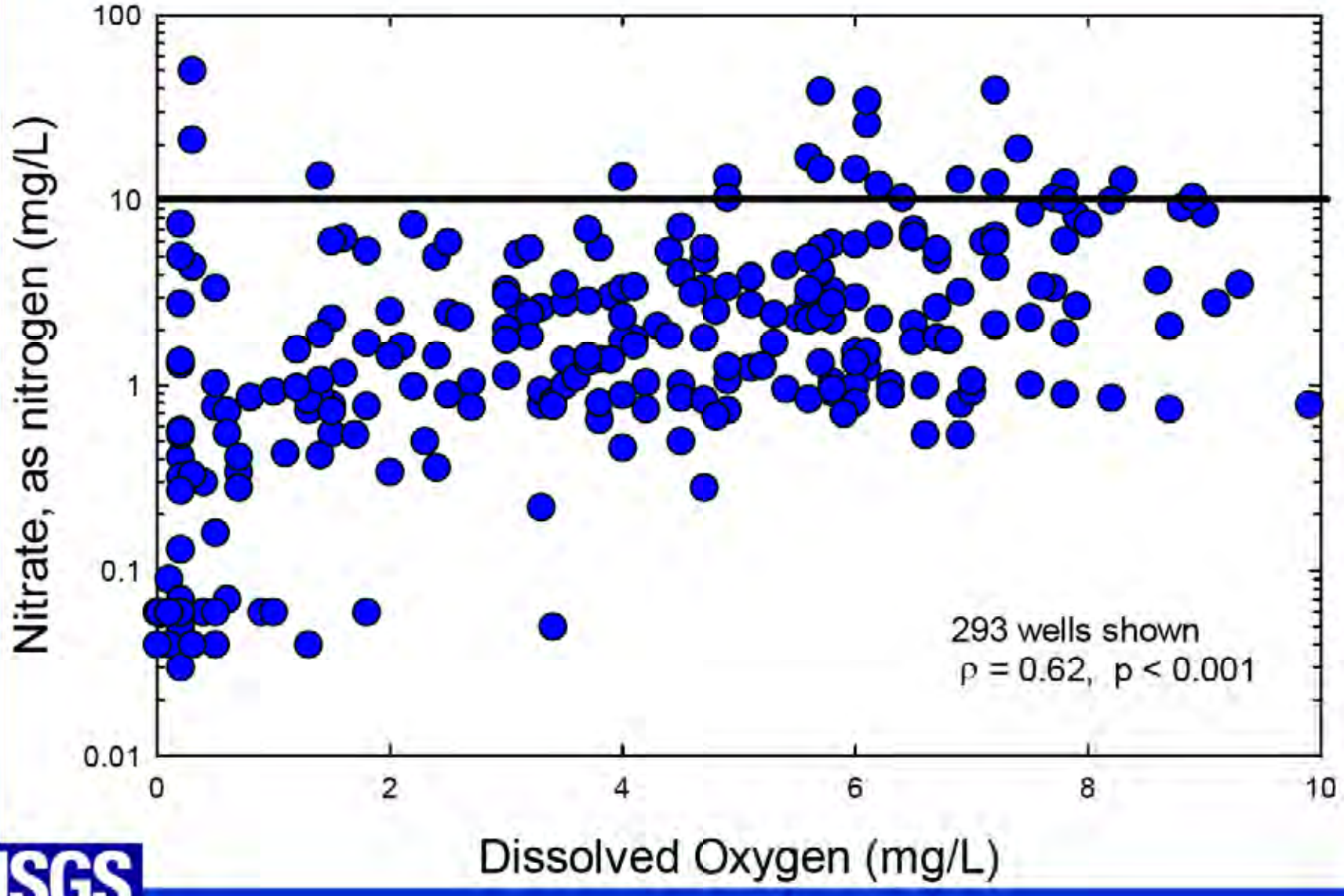
- Nitrate degrades under anoxic conditions
- Microbially-mediated reduction to nitrogen gas



USGS science for a changing world

Water Boards

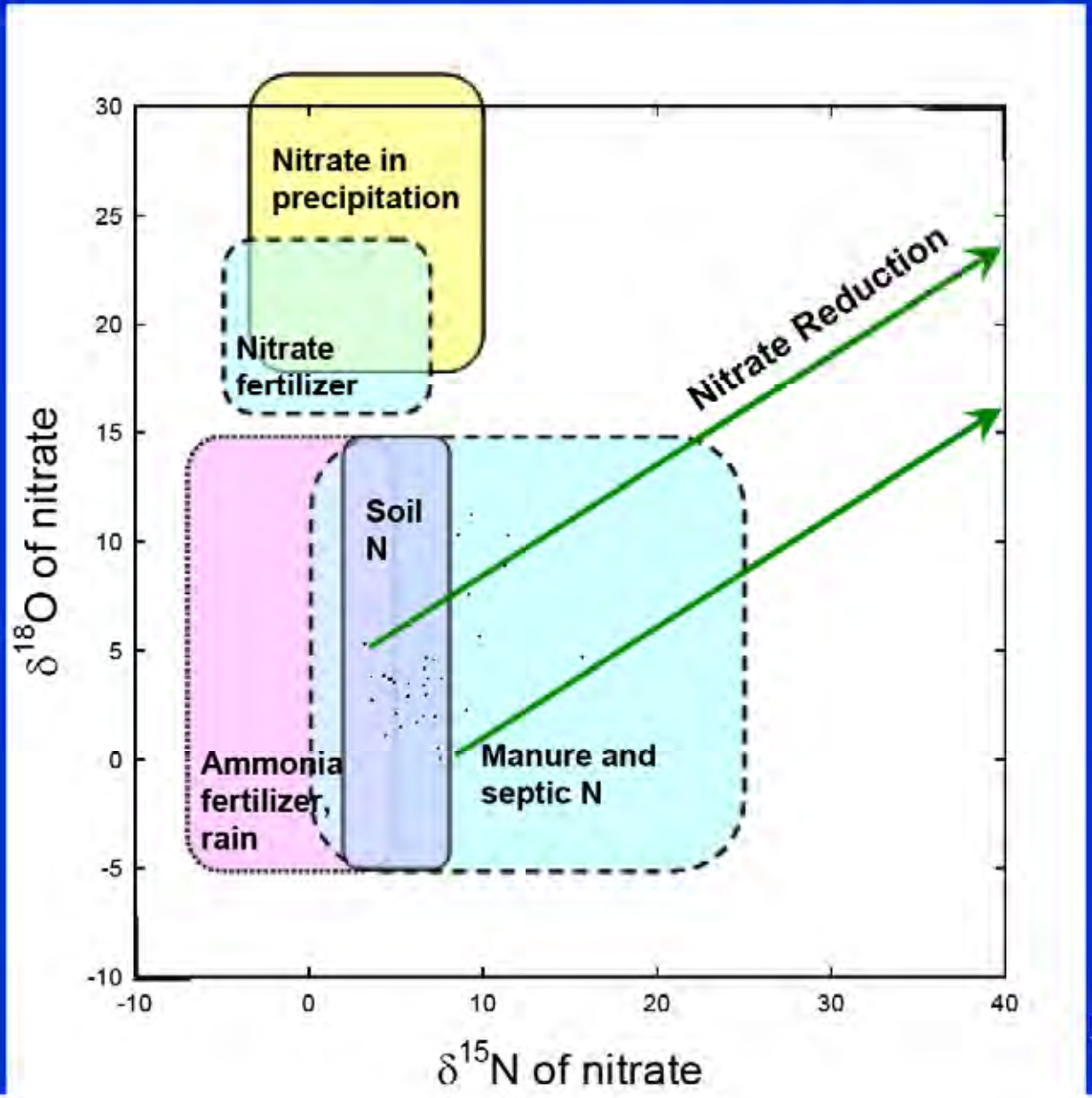
Nitrate – DO: USGS GAMA data



USGS science for a changing world

Water Boards

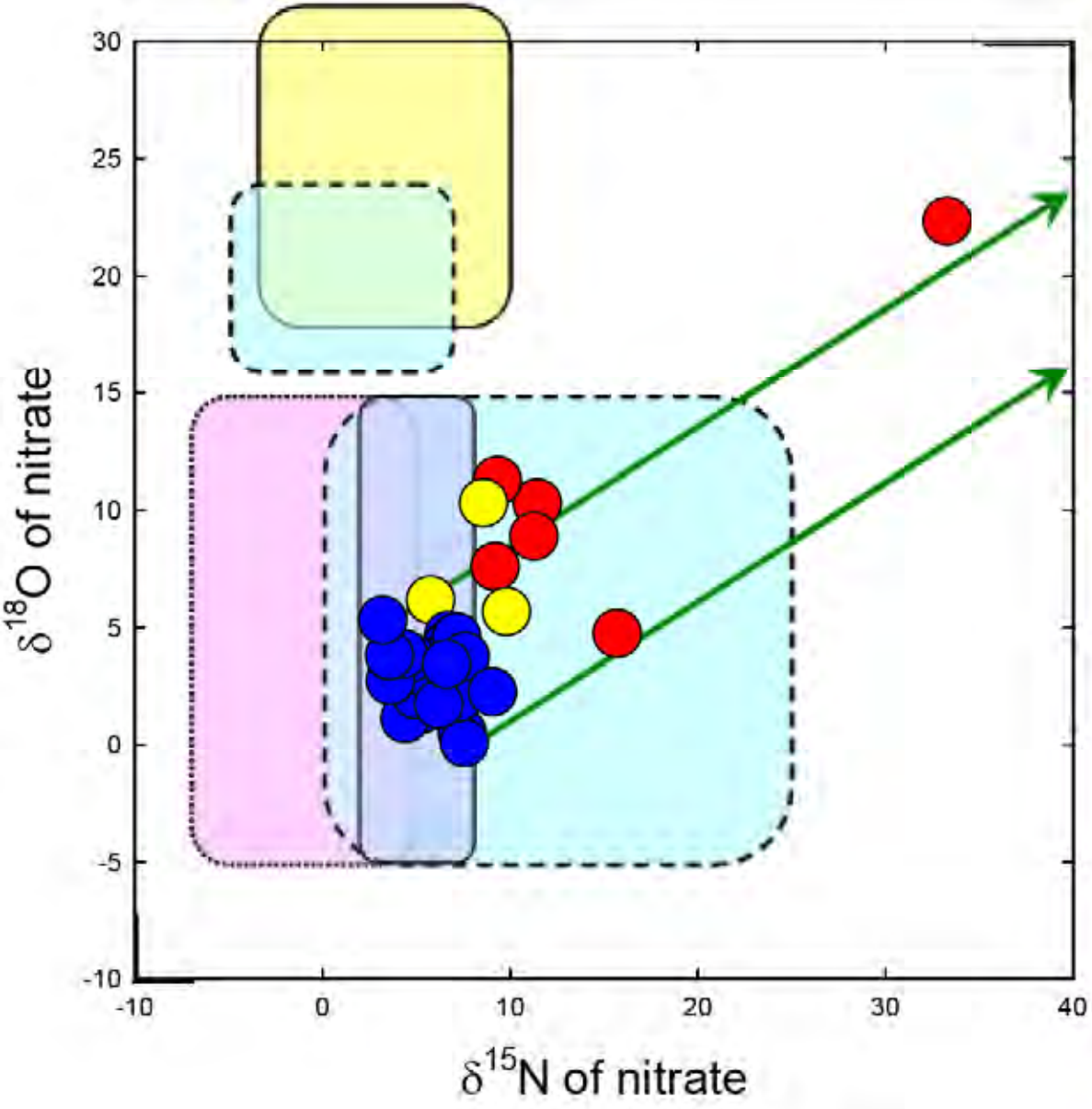
Evidence for Nitrate Degradation – Stable Isotopes of Nitrate



Kendall et al. (1998)

USGS science for a changing world

Evidence for Nitrate Degradation – Stable Isotopes of Nitrate



USGS-GAMA Central Eastside

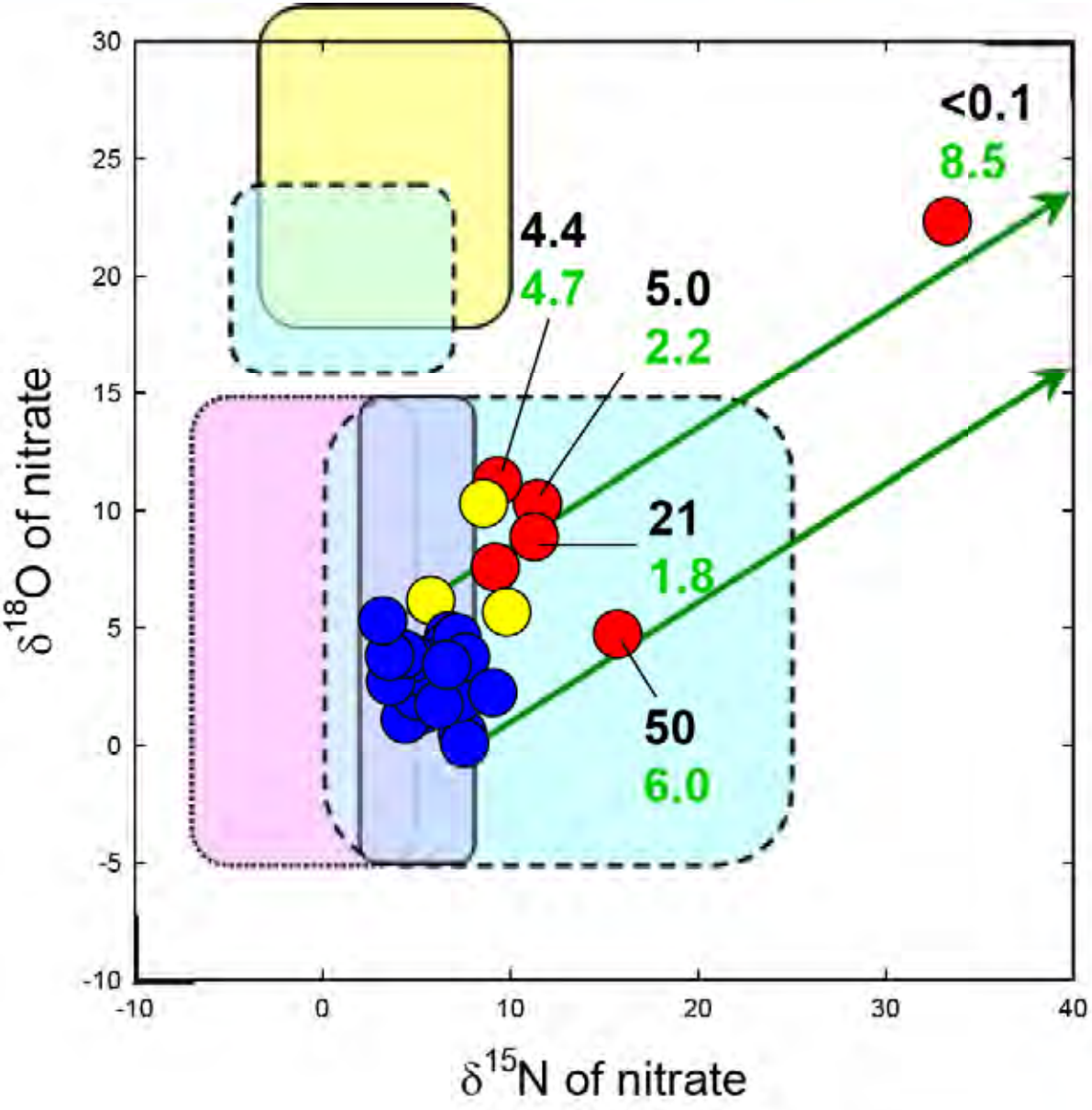
Dissolved Oxygen

- **> 2 mg/L**
- **0.5 to 2 mg/L**
- **< 0.5 mg/L**

USGS science for a changing world

Water Boards

Evidence for Nitrate Degradation – Stable Isotopes of Nitrate



Nitrate conc. (mg/L)

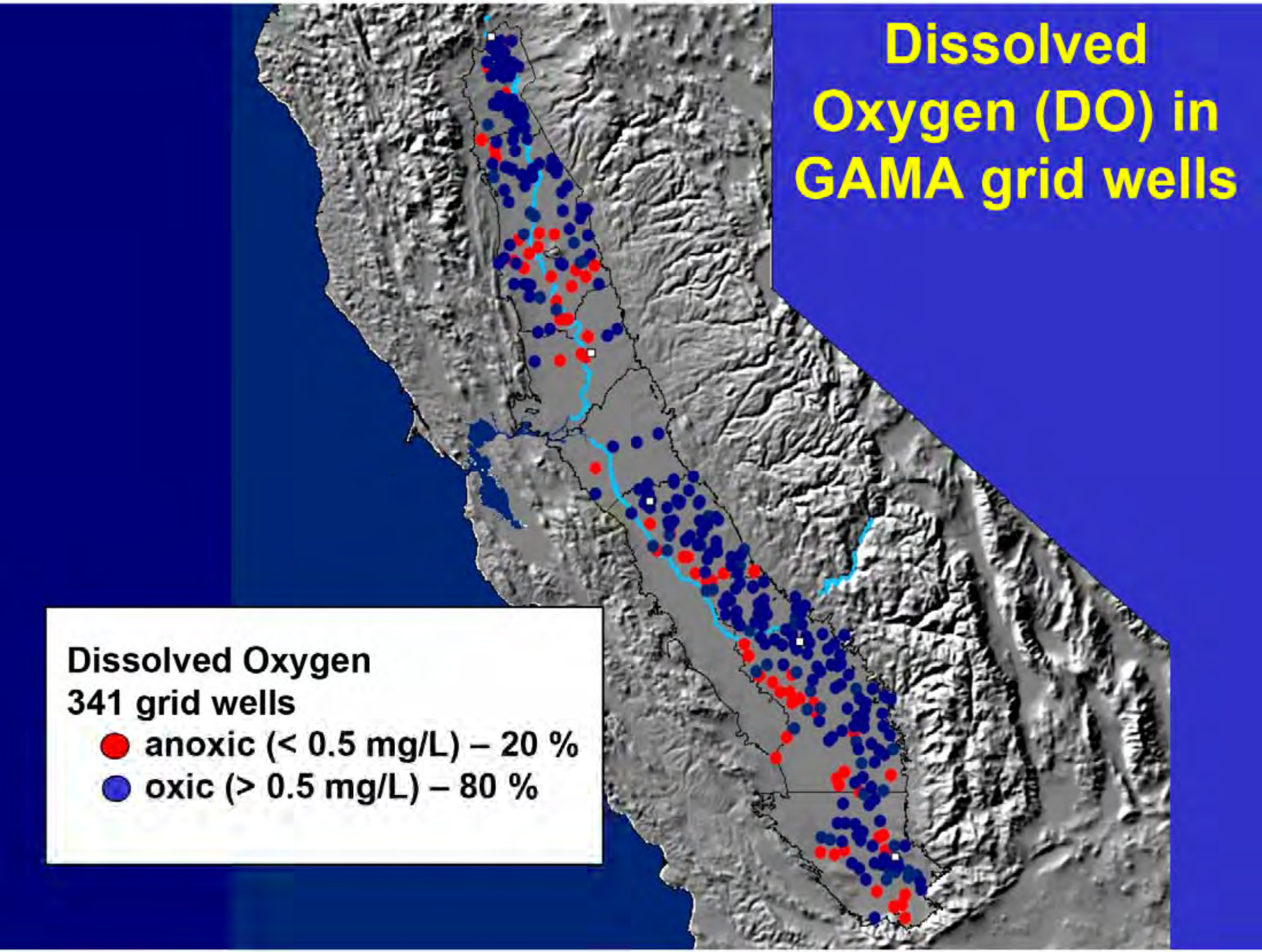
<0.1

8.5

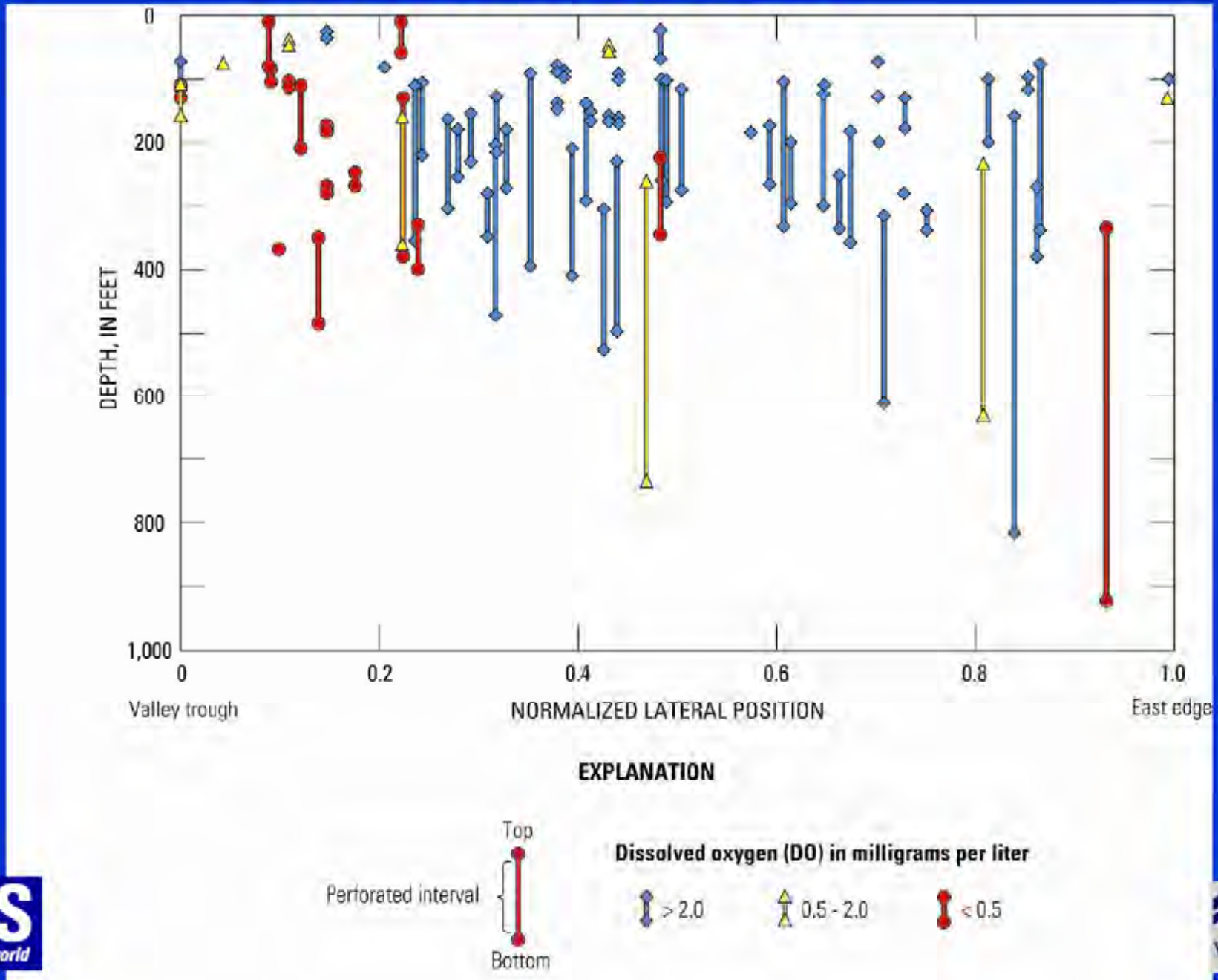
Nitrogen gas (as mg/L of nitrate denitrified)

USGS science for a changing world

Water Boards


Dissolved Oxygen (DO) in GAMA grid wells
Dissolved Oxygen
341 grid wells
anoxic (< 0.5 mg/L) – 20 %
oxic (> 0.5 mg/L) – 80 %

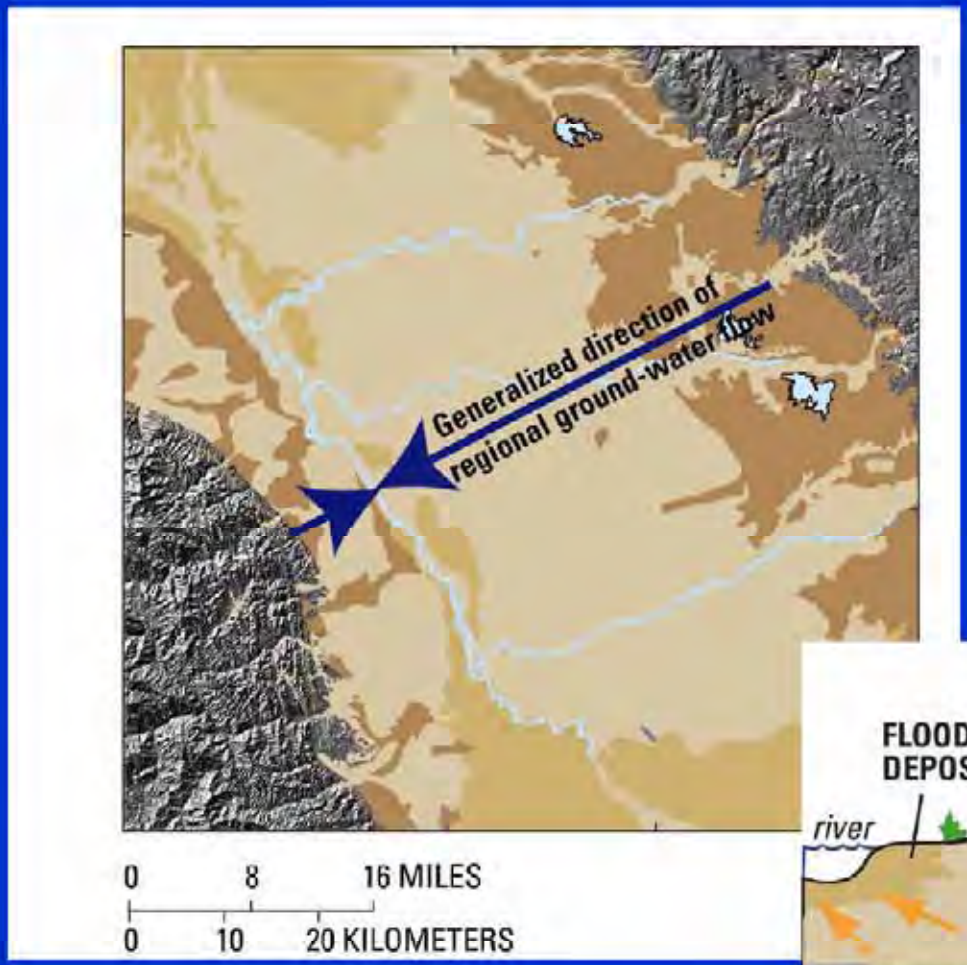
Dissolved oxygen cross-section for Central Eastside SJV

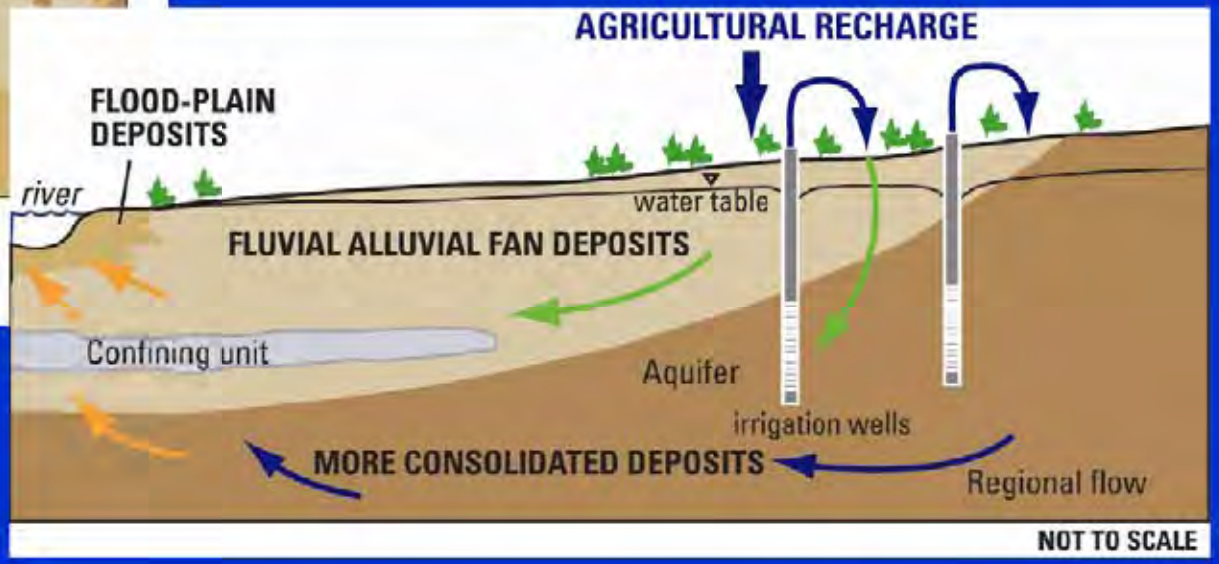


USGS science for a changing world

Water Boards

Conceptual geochemical conditions





USGS science for a changing world

Burow et al. (2008)

Preliminary Results

- Nitrate concentrations were higher than the MCL in about 3.5% of wells at depths of the aquifer used for public supply
- Nitrate concentrations are highest in shallow ground water and decrease with depth and age
- Most Central Valley ground water is oxic and nitrate degradation is not expected
- Some Central Valley ground water is reduced and partial nitrate degradation may occur

USGS science for a changing world

Water Boards

Additional Thoughts

- Nitrate concentrations will continue to increase with depth and time unless input concentrations are decreased
- Further quantitative analysis needed to predict effects of change in management
- Better "bulk" denitrification rates needed
- Continued monitoring is needed

USGS science for a changing world

Water Boards

CALIFORNIA'S GAMA* PROGRAM

CONTACTS
Miranda Fram (mfram@usgs.gov, 916-278-3088)
Matt Landon (landon@usgs.gov, 619-225-6109)
Ken Belitz (kbelitz@usgs.gov, 619-225-6150)

http://ca.water.usgs.gov/gama/
http://www.waterboards.ca.gov/gama/

* Groundwater Ambient Monitoring and Assessment

USGS science for a changing world

Water Boards