Design of Regional Monitoring of the Potential Effects of Oil and Gas Development on Groundwater Resources in California


Cooperators

- California State Water Resources Control Board
  - SB4 Regional Monitoring Program - Water Quality in Areas of Oil and Gas Production
- U.S. Bureau of Land Management

In coordination with:
- Regional Water Quality Control Boards
- California Division of Oil, Gas, and Geothermal Resources
- Local water agencies
Outline

- Project Background
- Planned components of regional monitoring
  - Salinity Mapping
  - Produced Water/End-Member Characterization
  - Regional Groundwater Risk Zone Analysis Near Oil Fields
Project Background

- California Senate Bill 4 (2013) mandated monitoring of the effects of Well Stimulation Treatment (WST) on groundwater quality
- California State Water Resources Control Board developed monitoring criteria to be fully implemented Jan. 1, 2016
- Operators conduct local-area monitoring; USGS & State Water Board cooperating on regional monitoring
Project Background

- In CA, the full range of effects of oil and gas development are likely to have greater effect on water quality than WST
  - Long history of oil/gas development (100+ years), enhanced recovery methods (60+ years), underground waste disposal
  - WST in CA occurs in same petroleum reservoirs developed using other methods, not new reserves (shales) (CCST, 2015)
  - CA petroleum reservoirs relatively permeable: WST wells sub-vertical, relatively smaller volumes of fluids & contaminants compared to WST elsewhere (CCST, 2015)
- These factors make it difficult to separate effects of WST from legacy oil and gas development
Regional Monitoring Question

- Has oil and gas development as a whole contributed to changes in groundwater quality at regional scales?
Technical Scope

- 2014-15: statewide, regional, and pilot-scale analyses providing technical support for design and planning of regional monitoring program
- 2016- regional monitoring program implementation

Relative Prioritization of Oil Fields for Regional Monitoring of Groundwater Based on Vertical Proximity, Well Density, & Injection Volumes

Prioritization categories for consideration in implementing regional groundwater monitoring adjacent to oil fields

*Davis et al. (in review)*

Subject to revision
Collaborations

- USGS
  - California Water Science Center (many)
  - Colorado Water Science Center (McMahon)
  - Crustal Geophysics and Geochemistry Center (Ball et al.)
  - Branch of Geophysics (Lane, Day-Lewis et al.)
  - National Research Program & Research Labs (Aiken, Cozzarelli, Hunt, Kharaka, Kraus, Lorah, Orem et al.)
- Cal St Univ. – Sacramento (Shimabukuro et al.)
- Cal St Univ. – Bakersfield (Gillespie)
- Oxford University (Ballentine, Barry)
- Duke University (Vengosh et al.)
Salinity Mapping - Components

- Objective: map protected (<10K TDS) water near oil fields
- Analysis of existing water sample data
- Salinity from borehole geophysical logs
- Surface and airborne geophysics (Electromagnetic)

Wilmington (LA)
Salinity Mapping - Outcome

- Where are protected groundwater resources in relation to oil & gas development
- What lies between protected resources and oil & gas operations?

New resistivity data in buffer

5 km buffer

Extrapolate from sites with data using geostatistics

Oil field footprint

existing chemistry data—all wells

Analyze borehole logs
Produced Water Sampling

- Characterization of oil-field source waters (library)
- Oil-field water chemistry varies
- Augments other sampling efforts

McMahon et al. (in review)
Subject to revision
Regional Groundwater Risk Zone Analysis

- Identify whether fluids from oil and gas areas may be moving into groundwater
- For priority fields or groups of fields
  - 4.1 Existing data compilation
  - 4.2 Existing data visualization/monitoring design
  - 4.3 Groundwater sampling
  - 4.4 Hydrogeologic framework analysis
  - 4.5 Drilling/well installation
- Reporting (interim and final)
Existing Data & Geologic Framework Analysis

- Large amounts of oil/gas & water well construction, geophysical log, and lithology data being digitized so it can be used in numerical analysis (CSUS, USGS)
- Three dimensional representation of subsurface formations and/or lithology
- Provides context for understanding fluid movement & groundwater quality

(Sweetkind et al., 2013)
Wells Montebello Oil Field (LA)

2,600 meters

5,600 meters

Geologic Model – Ponti et al. (2014)
Groundwater Sampling Network Design

- Shallow, mid-depth, and deep wells along multiple flow paths in & downgradient of oil field

Well types
- Existing wells
- Depth-dependent sampling in existing wells
- Drill new monitoring wells to fill key gaps as necessary after initial sampling of existing wells
Analytes for Produced Water & Groundwater

- C1-C6 gas concentrations and isotopes
- VOCs and semi-volatiles
- DOC, fractions, fluorescence, absorbance
- Major ions, trace elements
- Nutrients
- Ra isotopes
- δD, δ^{18}O
- Sr, B, Li isotopes
- Noble and atmospheric gases
- Tritium, ^{14}C
- Low-molecular weight organic acids

Kulongoski et al. (in review)

Samples are being analyzed at USGS, University, and Commercial laboratories

Unique to regional analyte list
Summary

- Designed to determine where and to what degree groundwater quality is potentially at risk from oil and gas production activities
- Includes salinity mapping, produced water characterization, and regional groundwater monitoring & analysis in priority areas
- Early regional monitoring (2016-17) in Kern County: begin in areas of differing hydrogeologic setting on east & west side of Central Valley
Questions?
References Cited

