Reasons to maintain a definition of protected groundwater equivalent to an USDW during well stimulation and oil and gas development in California

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Staff Workshop Review of Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation Definition of “Protected Water”

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Recommendations for Groundwater Monitoring in California

The panel stated monitoring at 10,000 mg/L TDS is appropriate because it aligns with EPA’s UIC program and is "technically and economically feasible to desalinate" water at this level of salinity (Esser et al. 2015).
## Reasons to maintain at least the current definition of protected water

- The current definition of protected groundwater protects brackish (up to 10,000 mg/L TDS) groundwater resources.
- Population growth, drought and climate change in California will necessitate use of brackish groundwater resources.
- California has significant brackish groundwater resources, including that in oil and gas producing areas.
- Desalination of brackish groundwater is: (1) economically and technically feasible, and (2) less energy intensive and produces less brine than desalination of seawater.
- Desalination of brackish groundwater resources in oil and gas producing areas is technically feasible.
- The federal government professional organizations, including API, have recommended the use of a 10,000 mg/L TDS criterion to define protected groundwater during well stimulation.
- Other states have an explicit definition of protected groundwater equivalent to a USDW.
- In the context of drought, population growth and climate change and given that desalination is possible for water with >10,000 mg/L TDS, California could consider increasing the definition of protected groundwater to a TDS threshold >10,000 mg/L.
Maintaining the current definition of protected groundwater and adequate vertical separation can protect brackish groundwater resources.
Shallow Hydraulic fracturing near brackish groundwater in the Los Angeles Basin

Table 4.3-14. Groundwater TDS data compared to the depth to the top of select hydraulic fracturing well intervals (TDS data from field rules).

<table>
<thead>
<tr>
<th>Field</th>
<th>Base of freshwater (&lt;3,000 mg/L TDS) (m [ft])</th>
<th>Deepest reservoir with water &lt;10,000 mg/L TDS (m [ft])</th>
<th>Shallowest reservoir listed with water &gt;10,000 mg/L TDS (m [ft])</th>
<th>Top of stimulation well interval for selected operations (m [ft])</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inglewood*</td>
<td>~90 (~300)</td>
<td>290 (950)</td>
<td>320 (1,050)</td>
<td>419-427 (1,377-1,404)</td>
</tr>
<tr>
<td>Montebello</td>
<td>490 (~1,600)</td>
<td>NA</td>
<td>670 (2,200)</td>
<td>2,281 (7,506)</td>
</tr>
<tr>
<td>Playa Del Rey</td>
<td>210 (~700)</td>
<td>NA</td>
<td>1,880 (6,200)</td>
<td>1,765 (5,807)</td>
</tr>
<tr>
<td>Whittier*</td>
<td>46-200 (150-650)</td>
<td>490 (1,600)</td>
<td>1,230 (4,050)</td>
<td>440 (1,446)</td>
</tr>
<tr>
<td>Wilmington*</td>
<td>~460-590 (~1,500-1,950)</td>
<td>NA</td>
<td>670 (2,200)</td>
<td>789-1,728 (2,595-5,688)</td>
</tr>
</tbody>
</table>

Depth (m) Depth (ft)
- 0 to 1,500
- 1,500 to 10,000
- 10,000 to 20,000
- >20,000

TDS in mg/L
- (approximate)

Figure 4.3-11. Depth of 3,000 mg/L TDS and data bracketing the depth of 10,000 mg/L TDS relatively unconstrained in each field with the hydraulically fractured wells selected for study (data from field rules and DOGGR (1992)). The heavy black horizontal line indicates the shallowest well interval hydraulically fractured in each field.
Population growth, drought and climate change in California will necessitate the increased use of brackish groundwater to supplement freshwater demand.

Figure from Roy et al. (2012)
Updated Estimates of Fresh and Brackish Groundwater Resources in the Central Valley

Estimated fresh groundwater (<3,000 mg/L TDS to 305m) ~ 1,000 km³ (Bertoldi et al. 1991)
Fresh groundwater ~ 2,700 km³ (Kang and Jackson 2016)
Brackish groundwater (3,000 – 10,000 mg/L TDS) ~ 3,900 km³ (Kang and Jackson 2016)

~60% of groundwater resources are brackish
Tulare Basin, where substantial oil & gas development occurs, contains significant brackish groundwater resources

Figures from Kang and Jackson (2016)
USGS Study on Brackish Groundwater Resources in the U.S.

Figure from Stanton et al. (2017)

~3% saline
~7% brackish
USGS Study on Brackish Groundwater Resources in the U.S. Geostatistical Mapping of a Portion of the San Joaquin Valley

Figures from Stanton et al. (2017)
Increased Desalination of Brackish Water Could Assist in Meeting Increasing Freshwater Demand

649 plants in 2010 – 67% municipal, 18% industry, 9% power, 6% other

Most desalination plants for brackish groundwater. Most desalination is by reverse osmosis. Less costly than seawater. Less brine production than seawater. Costs continue to decrease.


Figures from Stanton et al. (2017)
There is an Increasing Trend in Comprehensive Sustainable Groundwater Management (e.g., Desalination + Aquifer Storage and Recovery) That is Applicable to California

- Opened early 2017
- 99.9% dissolved solids removal
- 12 million gallons per day
- Reverse osmosis
- 1 gallon brine produced per 10 gallons treated
- Brine disposed in underlying saline aquifer (not USDW receiving aquifer exemption)

Figure from http://www.saws.org/Your_Water/WaterResources/Projects/desal.cfm
Water well and produced water concentrations used to delineate depths of fresh and brackish groundwater resources.

Figures from Metzger and Landon (2018)
American Petroleum Institute (API)  

“At a minimum, it is recommend that surface casing be set at least 100 ft below the deepest USDW encountered while drilling the well...If intermediate casing is not cemented to the surface, at a minimum the cement should extend above any exposed USDW or any hydrocarbon bearing zone.” (API 2009)

Groundwater Protection Council (GWPC)  

“Hydraulic fracturing in oil or gas bearing zones that occur in non-exempt USDW’s should either be stopped, or restricted to the use of materials that do not pose a risk of endangering ground water and do not have the potential to cause human health effects.” (GWPC 2009)
Produced Water < 10,000 mg/L TDS

Data (n=18,762) from the USGS National Produced Waters Geochemical Database (Blondes et al. 2014)

Oil and gas development in 27 states but development in brackish groundwater primarily in 17 states.
Definitions of protected groundwater during well stimulation in 17 states having significant brackish groundwater resources

Interpretation of regulations from DiGiulio et al. (2018)

- **USDW or equivalent to USDW**
- **USDW limited to CBM (IN) or horizontal wells (IL)**
- **Undefined or geographically dependent (KS, CO)**
- **3,000 mg/L TDS**
- **Protection removed**
- **O&G state not considered in our analysis**
Conclusions

Maintaining a definition of protected groundwater during well stimulation and other forms of oil and gas development using a criteria established for an USDW is reasonable and defensible.

California should maintain current standards to join other states in having explicit criteria for protection of groundwater equivalent to that of an USDW during well stimulation.

California should implement similar requirements for groundwater monitoring during all oil and gas development, not only for well stimulation.

In the context of drought, climate change and population growth and given that desalinization is possible for water with >10,000 mg/L TDS, California could consider increasing the definition of protected groundwater to a TDS threshold above 10,000 mg/L.
References


Federal Register, Vol. 80, No. 58, March 26, 2015, Part III, Department of the Interior, Bureau of Land Management, 43 CFR Part 3160, Oil and Gas; Hydraulic Fracturing on Federal and Indian Lands; Final Rule.


References


References


Thank You

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A Clear Explicit Definition of Protected Groundwater is Necessary to Protect Groundwater Resources

California currently protects brackish groundwater during well stimulation in effect limiting well stimulation to formations containing saline groundwater.
## Maximum Allowable TDS Levels for Water Distribution and Protection of Water Resources in California

<table>
<thead>
<tr>
<th>Maximum TDS (mg/L)</th>
<th>Distribution/Resource</th>
<th>Applicability to O&amp;G Industry</th>
<th>Enforceability</th>
<th>Overseeing Agencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>Municipal water supply</td>
<td>None</td>
<td>SMCL, recommended</td>
<td>EPA, SWRCB</td>
</tr>
<tr>
<td>1,000</td>
<td>Municipal water supply</td>
<td>None</td>
<td>SMCL, upper limit, CA Code Reg., Title 22, § 64449</td>
<td>SWRCB</td>
</tr>
<tr>
<td>1,500</td>
<td>Municipal water supply</td>
<td>None</td>
<td>SMCL, short term limit, CA Code Reg., Title 22, § 64449</td>
<td>SWRCB</td>
</tr>
<tr>
<td>3,000 to undefined</td>
<td>Surface water and groundwater</td>
<td>Land disposal, produced water ponds</td>
<td>SWRCB Resolution No. 88-63 as modified by Res No. 2006-0008, Beneficial use as a domestic or municipal water supply. Maximum TDS levels for agricultural and other beneficial use are undefined.</td>
<td>SWRCB</td>
</tr>
<tr>
<td>Undefined</td>
<td>“Freshwater”</td>
<td>Conventional O&amp;G Development</td>
<td>PRC § 1722.22 for casing requirements</td>
<td>DOGGR</td>
</tr>
<tr>
<td>10,000</td>
<td>groundwater</td>
<td>Well stimulation</td>
<td>USDW, CA Water Code § 10783(k)(2)</td>
<td>DOGGR, SWRCB</td>
</tr>
<tr>
<td>10,000</td>
<td>groundwater</td>
<td>UIC Program</td>
<td>UDSW, protected unless exempted, 40 C.F.R. 144.3</td>
<td>EPA, DOGGR</td>
</tr>
<tr>
<td>10,000</td>
<td>groundwater</td>
<td>O&amp;G development on federal or tribal land</td>
<td>Onshore Oil &amp; Gas Order No. 2, 53 Federal Register 46798</td>
<td>BLM, DOGGR, SWRCB</td>
</tr>
</tbody>
</table>
USGS Study on Mapping TDS in Fruitvale and Rosedale Ranch Areas.

Water well samples, produced water samples, formation resistivity logs, Archie’s Equations with optimized parameters, temperature and HCO$_3^-$ correction, and geostatistical methods were used to delineate TDS levels.

Use of resistivity logs to estimate TDS has considerable uncertainty but reasonable estimates of TDS can be made.
Estimation of Depths (ft) to 10,000 mg/L in Southern San Joaquin Valley

Produced water samples, formation resistivity logs, Humble approximation of Archie’s Equations, assumption of porosity at 30% used to delineate TDS levels.

Figures from Gillespie et al. (2017)