Hydraulic Fracturing and Groundwater: A Consultant’s Perspective

Tim Parker, Parker Groundwater
2013 San Gabriel Valley Water Forum – October 3, 2013

Acknowledgements: Ted Johnson, Chief Hydrogeologist
Water Replenishment District of Southern California
Hydraulic Fracturing (“Fracking” or “Fracing”)

- Has helped expand oil and natural gas production in the U.S. to highest levels in decades, and could supply the country for > 100 years.

- Has unlocked large supplies of hydrocarbons in shale and other unconventional formations in many States, providing energy, jobs, and revenue.

- But as fracking grew, so did world-wide concerns about possible environmental impacts.
So What’s All The Concern Over Fracking?

Yoko Ono, Jimmy Fallon And Sean Lennon Sing 'Don't Frack My Mother'
International Issue

Fracking in Europe - the Rebellion Grows

- June 2011: UK firm Cuadrilla receives 3 licenses on 4 test wells; good introduces internal halt
- Oct 2011: Southern city of Brescia claims drilling permission for UK’s 3rd CO2 injection project
- By 29 Oct 2011: ExxonMobil stops oil license and plans a second test well; starts exploratory work on 6th well in 2012
- Sept 2011: State’s Energy Company Naftop says preliminary work for UK’s 3rd CO2 injection project will start

- July 2012: Does the UK have a future in shale exploration and development?

- By Jan 2013 the countries have passed motions for bans or moratoriums on fracking

- Oct 2011: Italy cancels plans for exploration permits for Tuscany and Schleswig Energy after mass protests; President Eamon says no fracking unless proven 'environmentally safe'

- Jan 2012: Tens of thousands demonstrate against fracking - Government responds, ExxonMobil permission to frack

TRAICHO-NONA
FRACK YOU !!!

CHINA
BECOMING ANOTHER
SHALE GAS
HOT SPOT
Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing


*Center on Global Change, Nicholas School of the Environment, Division of Earth and Ocean Sciences, Nicholas School of the Environment, and Biology, Department, Duke University, Durham, NC, 27708*

Editor: William K. Schimminger, Cary Institute of Ecosystem Studies, Millbrook, NY, and approved April 14, 2011 (received for review January 13, 2011)

Directional drilling and hydraulic fracturing technologies are dramatically increasing natural gas extraction. In aquifers underlying the Marcellus and Utica shale formations of northeastern Pennsylvania and upstate New York, we document systematic evidence for methane contamination of drinking water associated with shale-gas extraction. In active gas-extraction areas (one or more gas wells within 1 km), average and maximum methane concentrations in drinking-water wells increased with proximity to the nearest gas well and were 19.2 and 66 mg CH₄/L (p < 0.05), a potential explosion hazard. In contrast, dissolved methane samples in neighboring nonextraction sites (no gas wells within 1 km) within similar geologic formations and hydrogeologic regimes averaged only 1.1 mg CH₄/L (p < 0.05; n = 30). Average δ¹³C-CH₄ values of dissolved methane in shallow groundwater were significantly less negative for active than for nonactive sites (−37 ± 7% and −54 ± 11%, respectively; F = 0.01); these δ¹³C-CH₄ data, coupled with the ratios of methane-to-higher-chain hydrocarbons, and δ¹⁵N-CH₄ values, are consistent with deeper thermogenic methane sources such as the Marcellus and Utica shales at the active sites and matched gas geochemistry from gas wells nearby. In contrast, lower concentrations samples from shallow groundwater at nonactive sites had isotopic signatures reflecting a more biogenic or mixed biogenic/thermogenic methane source. We found no evidence for contamination of drinking-water samples with deep saline brines or fracturing fluids. We conclude that greater stewardship, data, and—possibly—regulation are needed to ensure the sustainable future of shale-gas extraction and to improve public confidence in its use.
California Issue

Welcome to California?

Water contamination news: Fracking

courtesy of John Lowe / The Daily Jeffersonian & Melissa Topey
Sandusky Register.com & santamariatimes.com

BAN FRACKING IN CALIFORNIA!

GOVERNOR BROWN BAN FRACKING NOW!

CALIFORNIA FRACKING
Local Issue: LA Basin Concern over Fracking

Protesters head to Culver City meeting to decry fracking

Oil drilling in Carson won't use 'fracking'

CARSON: Occidental now says extraction technique would hold 'no value' in project.

By Sandy Mazza, Staff Writer
Posted: 06/01/2012 07:23:59 PM PDT
Updated: 06/01/2012 09:04:56 PM PDT

A controversial hydraulic fracturing technique will not be used to extract oil and gas from deep beneath northern Carson as originally proposed, Occidental Petroleum Corp. officials announced this week.

The company would like to drill 200 wells on a 6.5-acre site in an industrial park near the Home Depot Center. The city is carefully reviewing plans for the project while Occidental is seeking
Germany Beer Issue...

German Brewers Fear Fracking Could Damage Centuries-Old Industry

A brewing association is calling for more research before Germany greenlights the controversial extraction technique

By MEG HANDLEY

May 24, 2013 | RSS Feed | Print

German brewers say fracking could adversely affect the quality of water, and therefore beer, that comes out of Germany.

German Beer Purity Law of 1516
What is Hydraulic Fracturing?

- Method to enhance oil or natural gas production. Has been done at smaller scales for decades.

- Inject fluids (water, sand, chemicals) under very high pressure to break and keep open rock to make oil and gas flow.

- Improvements in horizontal drilling technologies have led to significant increase in fracking for oil and gas in the United States.
Conventional vs. Unconventional

- **Conventional**: Fracking in permeable reservoirs like sandstone and limestone to improve flow to wells. Has been for > 50 years. Vertical or slant wells. Lower pressure and water. Common in CA and elsewhere.

- **Unconventional**: Newer drilling/fracking in hard, tight source rock that is porous but not permeable (i.e. shale). “High Volume Fracking”. TX, PA, ND, WY, MO, CO, OH. Extensive in CA too.

- **High-Rate Gravel Packing**: Small scale fracking near the well bore to install gravel pack to improve flows at the oil/gas well and/or to prevent formation sand entry (like a gravel pack in a water well).
Injection Fluids for Fracking

- Water. Average 5 million gallons per job for high volume unconventional; < 300,000 for conventional; < 100,000 gravel pack. Propane and butane being explored to replace water in water-short areas. “Dry Fracking”

- Sand/Silica (proppant) keeps fractures open; otherwise would close.

- Assorted chemical additives are site specific. Many purposes: inhibit corrosion, remove drilling mud, prevent scaling, reduce viscosity, etc.

http://fracfocus.org/water-protection/drilling-usage
Acidizing, Matrix Acid Jobs, and Fracture Acidizing

- Another method to open up tight or clogged formations and improve hydrocarbon flow to wells.

- Matrix acidizing at relatively low pressures to dissolve sediments, mud, and carbonates near the well.

- Fracture acidizing at higher pressures to break open rock and create new fractures and dissolve minerals to improve permeability.

- Use of hydrochloric acid (HCL) and hydrofluoric acid (HF) common.
Why Frack?

- Create a new energy resource. Unconventional drilling and fracking now accounts for more than half the natural gas production in the U.S. Estimated over 100 year supply.

- Allows extended production in older oil and gas fields.

- Allows recovery of petroleum from tight formations previously thought unproductive.

- Reduced price of natural gas.

- Creates jobs in energy industry.

http://energytomorrow.org/blog/natural-gas-the-70-percent/#/type/all
Job Boom in Hydraulic Fracturing

Fracking JOBS

North America is becoming the "New Middle East" due to advanced natural gas drilling methods like hydraulic fracturing ("frac"). Only politics can interfere with the prosperity.*

The USA has passed Russia as the world’s largest exporter of petroleum products and is a net exporter of petroleum products for the first time since 1949.

The natural gas revolution will create an estimated 1.1 million manufacturing jobs by 2020. That’s like creating more than 13 manufacturing jobs for every worker in Detroit over the next seven years.*

The American energy boom will create as many as 3.6 million jobs by 2020. This is like adding an economy twice the size of Florida in just seven years.*

These new jobs will add as much as $624 billion to the US economy by 2020. This is equivalent to adding a new economy just slightly smaller than Florida in just seven years.*

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Five More Ways Fracking Jobs Beat College Degrees

Posted by Fracking Jobs

If you’re college-bound, a recent college graduate, or are a parent, then you need to take a very hard-nosed look at how much college tuition will cost. Too many folks have accepted with blind faith that a degree must be pursued at all costs, to their detriment. If you haven’t already, you should read “Five More Ways Fracking Jobs Beat College Degrees”. For five more reasons...

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U.S. Employment: Oil and Gas Extraction
January 1988 to March 2013

Source: BLS

Carpe Diem Blog
Broad relatively flat lying shales with small distributed gas vesicles
The Monterey Shale & Fracking: California’s Next Mother Load?

- Potential Target for Unconventional Oil Production.

- Estimated at >15 billion barrels of OIL. Largest of its type in the Country.


- Unproven to date. Complex faulted and folded geology. Deep and difficulty to tap. Much of the oil may have leaked out to upper formations.
Hydraulic Fracturing Operations

http://www.epa.gov/hfstudy/hfwatercycle.html
Hydraulic Fracturing Operations

http://www.epa.gov/hfstudy/hfwatercycle.html
Hydraulic Fracturing Operations

1. Water Acquisition
2. Chemical Mixing
3. Well Injection
4. Flowback and Produced Water (Wastewaters)
5. Wastewater Treatment and Waste Disposal

Groundwater

Shale Oil/Gas Target Zone

http://www.epa.gov/hfstudy/hfwatercycle.html
Potential Risk to Groundwater

1. Water Acquisition
2. Chemical Mixing
3. Well Injection
4. Flowback and Produced Water (Wastewaters)
5. Wastewater Treatment and Waste Disposal

Threats: Chemicals, Metals, Saline Water, Natural Gas
http://www.epa.gov/hfstudy/hfwatercycle.html
Potential Risks to Groundwater

2012 YouTube Video of Fluid Discharge to an Unlined Pit – Kern County, CA: Central Valley RWQB is Investigating.
http://www.youtube.com/watch?v=mxb671gbmkY
Potential Risks to Groundwater

1. Water Acquisition
2. Chemical Mixing
3. Well Injection
4. Flowback and Produced Water (Wastewaters)
5. Wastewater Treatment and Waste Disposal

Threats: Chemicals, Metals, Saline Water, Natural Gas

Old Gas/Oil Well – Not Abandoned Properly

http://www.epa.gov/hfstudy/hfwatercycle.html
Oil / Gas Wells Can Leak and be Conduits

- Cement and Casing can deteriorate over time, creating pathways for gas/fluids to migrate.

- Re-abandonments often necessary.

- Documented LA Basin environmental hazards from leaking wells¹:
  - 1985 Ross Department Store Explosion.
  - Montebello leaks - homes abandoned.
  - Santa Fe Spring Oilfield Investigation – 75% of 50 wells investigated were leaking

Potential Risks to Groundwater

Threats: Chemicals, Metals, Saline Water, Natural Gas
http://www.epa.gov/hfstudy/hfwatercycle.html
Potential Risks to Groundwater

Threats:
- Chemicals
- Metals
- Saline Water
- Natural Gas

"Frack Hits"

HYDRAULIC FRACTURING:
When 2 wells meet, spills can often follow

When a geyser of oil and fracking fluid spewed out of an oil well on a farmer’s field in Innisfail, Alberta, it coated 100 trees with a fine mist. About 20,000 gallons of oil and fluid collected on a snow-covered field and had to be cleaned up.

The spill was caused by hydraulic fracturing – not the activities surrounding drilling. A series of similar incidents are being reported across the United States and Canada.

Drillers call it a "frack hit" or "downhole communication," and it could also contaminate groundwater aquifers.
Are There Risks to Groundwater?

**INDUSTRY:**

“There have been over a million wells hydraulically fractured in the history of the industry, and there is not one, not one, reported case of a freshwater aquifer having ever been contaminated from hydraulic fracturing. Not one”

Rex W. Tillerson, the chief executive of ExxonMobil - Congressional hearing on drilling (NYTimes, 8/3/2011).

**ENVIRONMENTAL:**

**In Fracking’s Wake:** New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater

NRDC, May 2012, 12-05A

> 30 potential groundwater contamination cases from hydraulic fracturing

**SCIENCE:**

“The effects of unconventional oil and gas development... on regional water quality have not been previously described despite the fact that oil and gas development in the United States began nearly 150 years ago...”

USGS, April 2012, Fact Sheet 2012-3049
Other Environmental Concerns

- Nuisance (noise, traffic, odors)
- Surface Water Contamination
- Soil Contamination
- Wastewater Disposal
- Air Pollution
- Water Supply
- Natural Habitat
- Earthquakes

This talk’s focus is on Groundwater

South Coast Air Quality Mgt. Dist.

BOARD MEETING DATE: April 5, 2013
AGENDA NO. 31

PROPOSAL: Proposed Rule 1148.2 — Notification and Reporting Requirements for Oil and Gas Wells and Chemical Suppliers

SYNOPSIS: Proposed Rule 1148.2 establishes requirements for owners and operators of onshore oil and gas wells within SCAQMD’s jurisdiction to notify the Executive Officer when conducting well drilling, well completion, and well reworking activities that involve production stimulation activities such as hydraulic fracturing, gravel packing and/or acidizing. The proposed rule also proposes emissions and chemical reporting requirements. This proposed rule will also impact suppliers of chemicals and additives used in drilling, rework, and well completion fluids.

http://www.gaslandthemovie.com/whats-fracking
FracFocus.org – Tracks Fracking & Chemicals

Over 50,000 Frack Jobs reported nationwide (as of 8/20/13)

http://www.hydraulicfracturingdisclosure.org/fracfocusfind/Map.aspx
1,017 listed in California (as of 8/20/13); 19 near the WRD service area.
http://www.hydraulicfracturingdisclosure.org/fracfocusfind/Map.aspx
### Hydraulic Fracturing Fluid Product Component Information Disclosure

**FracFocus.org Chemical Listing**

#### Hydraulic Fracturing Fluid Composition:

<table>
<thead>
<tr>
<th>Trade Name</th>
<th>Supplier</th>
<th>Purpose</th>
<th>Ingredients</th>
<th>Chemical Abstract Service Number (CAS #)</th>
<th>Maximum Ingredient Concentration in Additive (% by mass)**</th>
<th>Maximum Ingredient Concentration in HF Fluid (% by mass)**</th>
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<td>Operator</td>
<td>Carrier</td>
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<td>100.00%</td>
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<td>Bioside</td>
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<td>0.00006%</td>
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<td></td>
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<td>Crystalline Silica, Quartz (SiO2)</td>
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<tr>
<td></td>
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<td>Diatomaceous Earth, Calcained</td>
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<td>Breaker</td>
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<td>0.00081%</td>
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<td>Caustic Liquid, 25% Solution</td>
<td>Baker Hughes</td>
<td>Buffer</td>
<td>Sodium Hydroxide</td>
<td>1310-73-2</td>
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<tr>
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<td></td>
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<td>Water</td>
<td>7732-15-5</td>
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<td>0.69307%</td>
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<td>Crosslinker</td>
<td>D-Glucitol</td>
<td>50-70-4</td>
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<td>0.08736%</td>
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**Notes:**

**API Number:** 003727124

**Well Name:** DCM-1

**Operator:** Occidental Oil and Gas

**Job Date:** 1/1/2012
National Research on Fracking

EPA’s Study of Hydraulic Fracturing and Its Impact on Drinking Water Resources

At the request of Congress, EPA is conducting a study to better understand any potential impacts of hydraulic fracturing on drinking water resources. The scope of the research includes the full lifespan of water in hydraulic fracturing. The progress report was released in December 2012 and a draft report is expected to be released for public comment and peer review in 2014.

What is the hydraulic fracturing water cycle?


Hydraulic Fracturing Issues and Research Needs for the Water Community

Subject Area: Water Resources and Environmental Sustainability
Ways to Minimize Risk

- Baseline Monitoring.
- Proper well design to prevent leaks. Monitor while fracking.
- Identify all natural & artificial pathways and seal off or avoid.
- Proper waste collection, storage, and disposal.
- Monitor injection pressures, intervening “dead zone”, flowback ponds, deep and shallow groundwater, seismic monitoring.
- Vapor probes for soil gas monitoring at surface.
DOGGR Regulates CA Oil, Gas, Geothermal

- Permitting agency for oil and gas wells in the State. Oversees all oil, gas, geothermal well constructions, abandonments and injections in CA.
- Class II Injection Well Program to regulate injecting fluids for oil or gas operations, including fracking / acidizing.
- No specific regulations (yet) for hydraulic fracturing.
- Hydraulic fracturing Rulemaking process to begin soon – stay tuned.

(www.conservation.ca.gov/dog/Pages/index.aspx)
Recent CA Legislation on Fracking

2012: SB 1054 (Pavley), AB591 (Wieckowski), AB 972 (Butler). Both failed.

2013: 10 Bills Introduced

- AB 7 (Wieckowski)
- AB 288 (Levine)
- AB 649 (Nazarian)
- AB 669 (Stone)
- AB 982 (Williams)
- AB 1301 (Bloom)
- AB 1323 (Mitchell)
- SB 4 (Pavley)
- SB 395 (Jackson)
- SB 665 (Wolk)

New bills deal with fracking definitions and notifications, oversight by DOGGR and RWQCB, groundwater monitoring, banning until process is reviewed by State, chemical disclosure, hazardous waste classification and disposal, bond increases for oil and gas wells.

Only SB4 Pavley passed and was signed on Sept 20, 2013
Focus on 2 LA Groundwater Basins: Central Basin and West Coast Basin (CBWCB)

Area = 420 mi², 43 Cities, 4 Million People

> 400 Water Wells Pumping 240,000 acre feet/yr (78 billion gallons/yr)
Over 450 Groundwater Production Wells

- Central Basin
- West Coast Basin
Quaternary & Late Pliocene Coastal Aquifers
Sand & Gravel. Folded & Faulted.

Groundwater Wells Tapping Coastal Aquifers

Mid Pliocene “Bedrock”
Repetto & Lower Fernando Fms.

Modified from DWR (1962, Plate 4)
But There’s Oil & Gas in the Basins too
Over 30 Mapped Oil Fields and 9,700 Oil/Gas Wells in WRD Service Area

Central Basin

West Coast Basin
Cross-Section through LA showing Petroleum Target Zones

- Recent, Pleistocene and late Pliocene. General area of Fresh Groundwater
- Mid Pliocene to Mid Miocene. General Targets for Petroleum Recovery
- Mesozoic Schist, Granite, Slate, Metasediments, Bedrock – No Petroleum

Modified from Davis – Namson, 1998
Southern California Cross Section Study
Oil Wells & Water Wells in LA
Over 100 Years of Co-Existing
Inglewood Oil Field Fracking Controversy

Report on Baldwin Hills fracking raises community ire

Despite its findings, the environmental impact study has deepened tensions between an oil field owner and those opposed to the controversial hydraulic fracturing technique used to extract oil.
### GROUNDWATER QUALITY TESTING

**Over 100 chemicals tested in each well twice per year, or over 50,000 results on water quality annually.**

<table>
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<tr>
<th>Major Minerals</th>
<th>General Physical Properties</th>
<th>Volatile Organic Compounds</th>
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<tr>
<td>Total Dissolved Solid (TDS)</td>
<td>Apparent Color</td>
<td>Trichloroethylene (TCE)</td>
</tr>
<tr>
<td>Cation Sum</td>
<td>Lab pH</td>
<td>sec-Butylbenzene</td>
</tr>
<tr>
<td>Anion Sum</td>
<td>Odor</td>
<td>Tetrachloroethylene (PCE)</td>
</tr>
<tr>
<td>Iron, Total, ICAP</td>
<td>pH of CaCO₃ saturation(25°C)</td>
<td>1,1-Dichloroethylene</td>
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<td>Manganese, Total, ICAP/MS</td>
<td>pH of CaCO₃ saturation(60°C)</td>
<td>1,1,1,2-Tetrachloroethane</td>
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<tr>
<td>Turbidity</td>
<td>Radon</td>
<td>Chloroform (Trichloromethane)</td>
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<tr>
<td>Alkalinity</td>
<td>Specific Conductance</td>
<td>1,1-Dichloropropene</td>
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<tr>
<td>Boron</td>
<td>Metal As</td>
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<tr>
<td>Bicarbonate as HCO₃, calculated</td>
<td>Aluminum, Total, ICAP/MS</td>
<td>1,2,3-Trichlorobenzene</td>
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<td>Calcium, Total, ICAP</td>
<td>Anode, Total, ICAP/MS</td>
<td>Dibromomethane</td>
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<td>Carbonate as CO₃, Calculated</td>
<td>Arsenic, Total, ICAP/MS</td>
<td>1,1,1-Trichloroethane</td>
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<tr>
<td>Hardness (Total, as CaCO₃)</td>
<td>Barium, Total, ICAP/MS</td>
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<tr>
<td>Chloride</td>
<td>Beryllium, Total, ICAP/MS</td>
<td>Chloroethane</td>
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<tr>
<td>Fluoride</td>
<td>Chromium, Total, ICAP/MS</td>
<td>Chloromethane(Methyl Chloride)</td>
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<tr>
<td>Hydroxide as OH, Calculated</td>
<td>Hexavalent Chromium (Cr VI)</td>
<td>1,1,2,2-Tetrachloroethane</td>
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<tr>
<td>Langeder Index - 25 degree</td>
<td>Cadmium, Total, ICAP/MS</td>
<td>Chlorobenzene</td>
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<td>Magnesium, Total, ICAP</td>
<td>Copper, Total, ICAP/MS</td>
<td>Chlorodibromomethane</td>
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<td>Mercury</td>
<td>Lead, Total, ICAP/MS</td>
<td>Chloroethene</td>
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<td>Nitrate-N by IC</td>
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<td>Chloromethane</td>
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<td>Surfactants</td>
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<td>Total Nitrate, Nitrite-N, CALC</td>
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<td>Bromoform</td>
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<tr>
<td>Total Organic Carbon</td>
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<td>Bromoform</td>
</tr>
</tbody>
</table>

*Have not yet sampled specifically for fracking chemicals*
Water Quality Results near Oil Fields

- Generally Good Water Quality.
- A few wells in Oil Field areas have elevated concentrations at depth:
  - Arsenic
  - Barium
  - Boron
  - TBA
  - TDS/Chloride
  - Color/Odor
- Sources have not been identified. Either naturally occurring or from surface releases, oil field operations, or other. Difficult to determine.
- Additional testing / fingerprinting may help determine sources.
Hydraulic Fracturing is used for Water Wells Too!

California Well Standards

Water wells • Monitoring wells • Cathodic protection wells

Bulletin 74-90
(Supplement to Bulletin 74-81)

Section 14. Well Development.

"Development, redevelopment, or reconditioning of a well shall be performed with care, by methods that will not damage the well structure or destroy natural barriers to the movement of poor quality water, polluting agents, and contaminants.

Acceptable well development, redevelopment, or reconditioning methods include:

- Overpumping;
- Surging or swabbing by use of 'plungers';
- Surging with compressed air;
- Backwashing or surging by alternately starting and stopping a pump;
- Jetting with water;
- Introducing specifically-formulated chemicals into a well; and,
- Combinations of the above.

Hydraulic fracturing (hydrofracturing) is sometimes an acceptable well development and redevelopment method when properly performed. Good quality water shall be used in hydrofracturing. The water shall be disinfected prior to introduction into a well. Material used as 'propping' agents shall be free of pollutants and contaminants, shall be compatible with the use of a well, and shall be thoroughly washed and disinfected prior to placement in a well.

http://www.nhcontractors.net/2012/01/hydrofracking-nh/
Summary

- Hydraulic Fracturing has been done for over 50 years.

- New “High Volume, Unconventional” methods are proving very fruitful in shale gas but controversial worldwide – no shale gas in California.

- Fresh groundwater, oil and natural gas have been successfully produced in the CBWCB and other basins for over 100 years.

- The two reservoirs are separated by thick layers of low permeability strata, so that with appropriate precaution, construction, regulation and monitoring, the activities in one should not affect the other.

- Work with regulatory agencies continues on appropriate fracking rules. We don’t want to hamper the energy industry, we just want to ensure protection of the groundwater resource. Both can be done successfully.
Acknowledge and refer you to
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