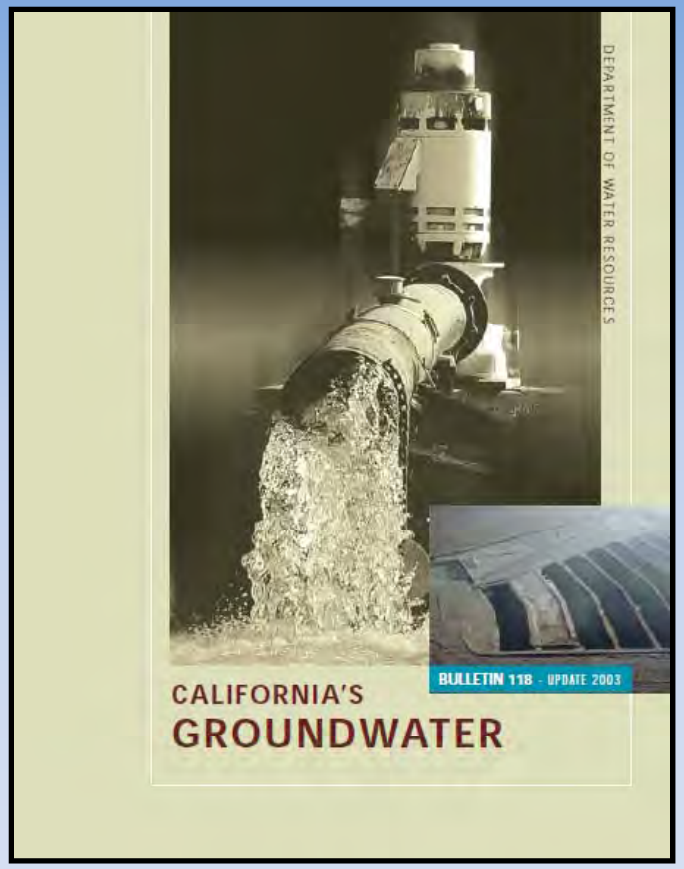
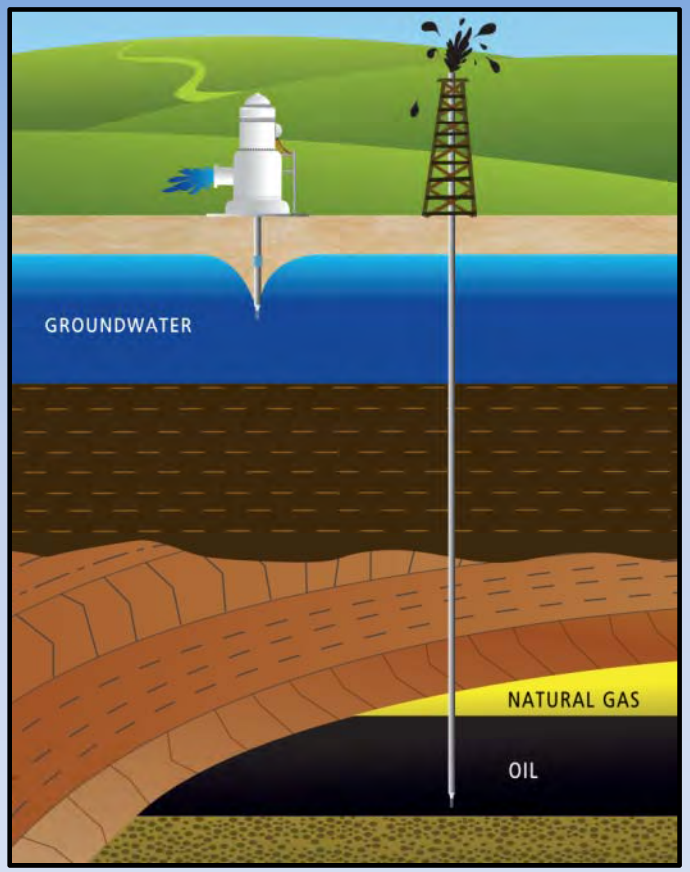
Hydraulic Fracturing and Groundwater: A Los Angeles Water District Perspective





By: Ted Johnson, Chief Hydrogeologist
Water Replenishment District of Southern California
January 24, 2013 – for LABGS

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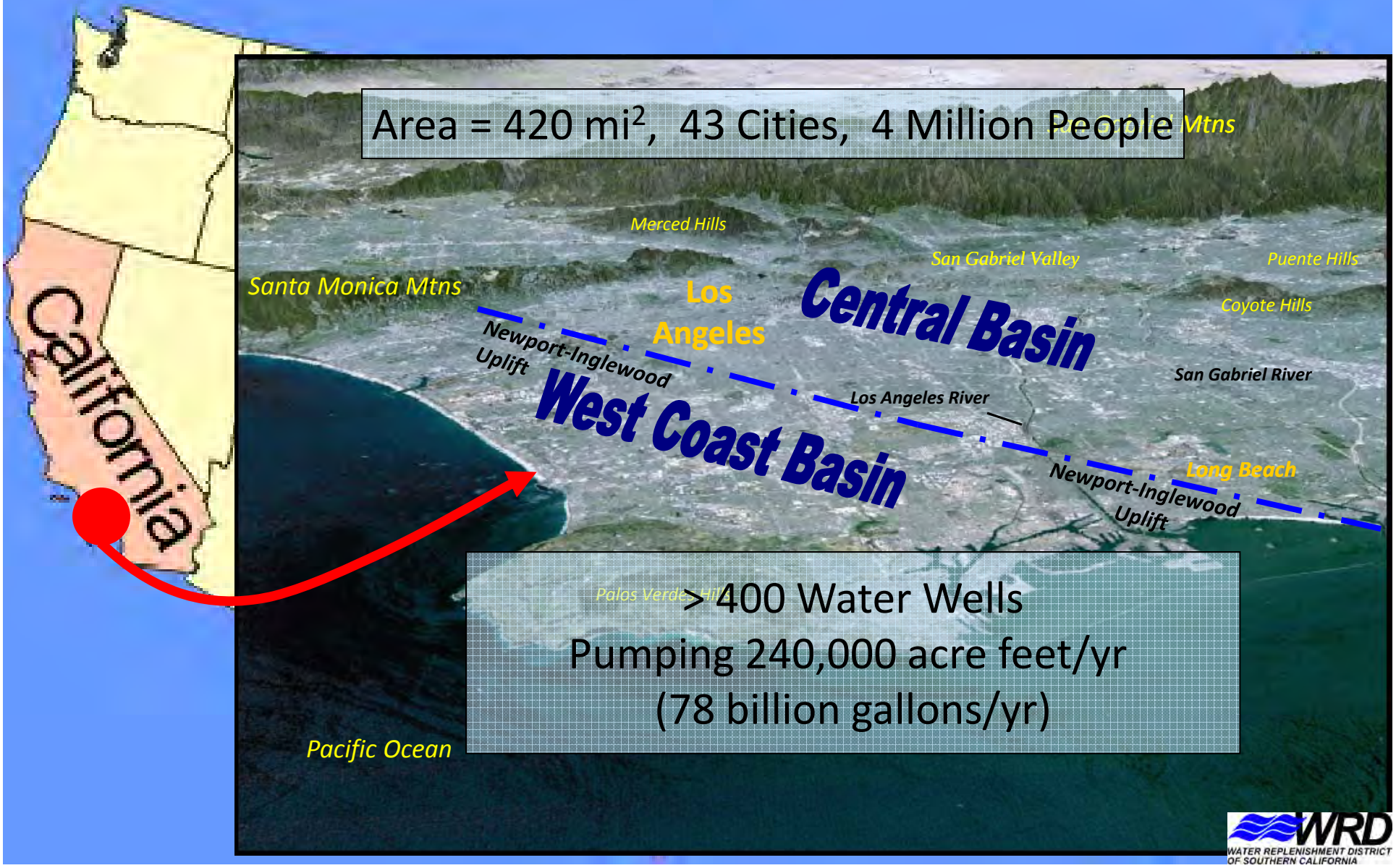
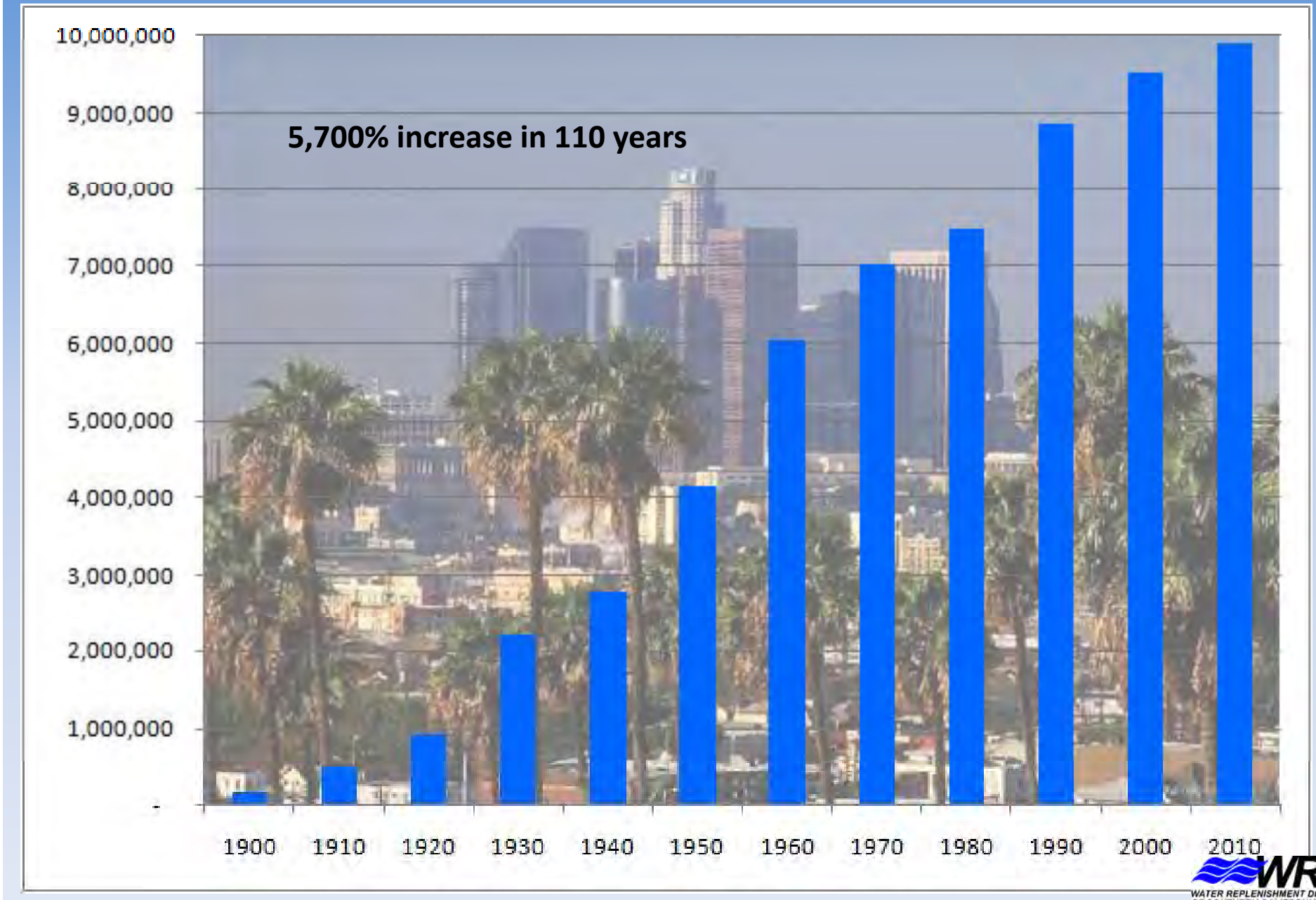
Focus on 2 LA Groundwater Basins: Central Basin and West Coast Basin (CBWCB)



LA County Population Growth



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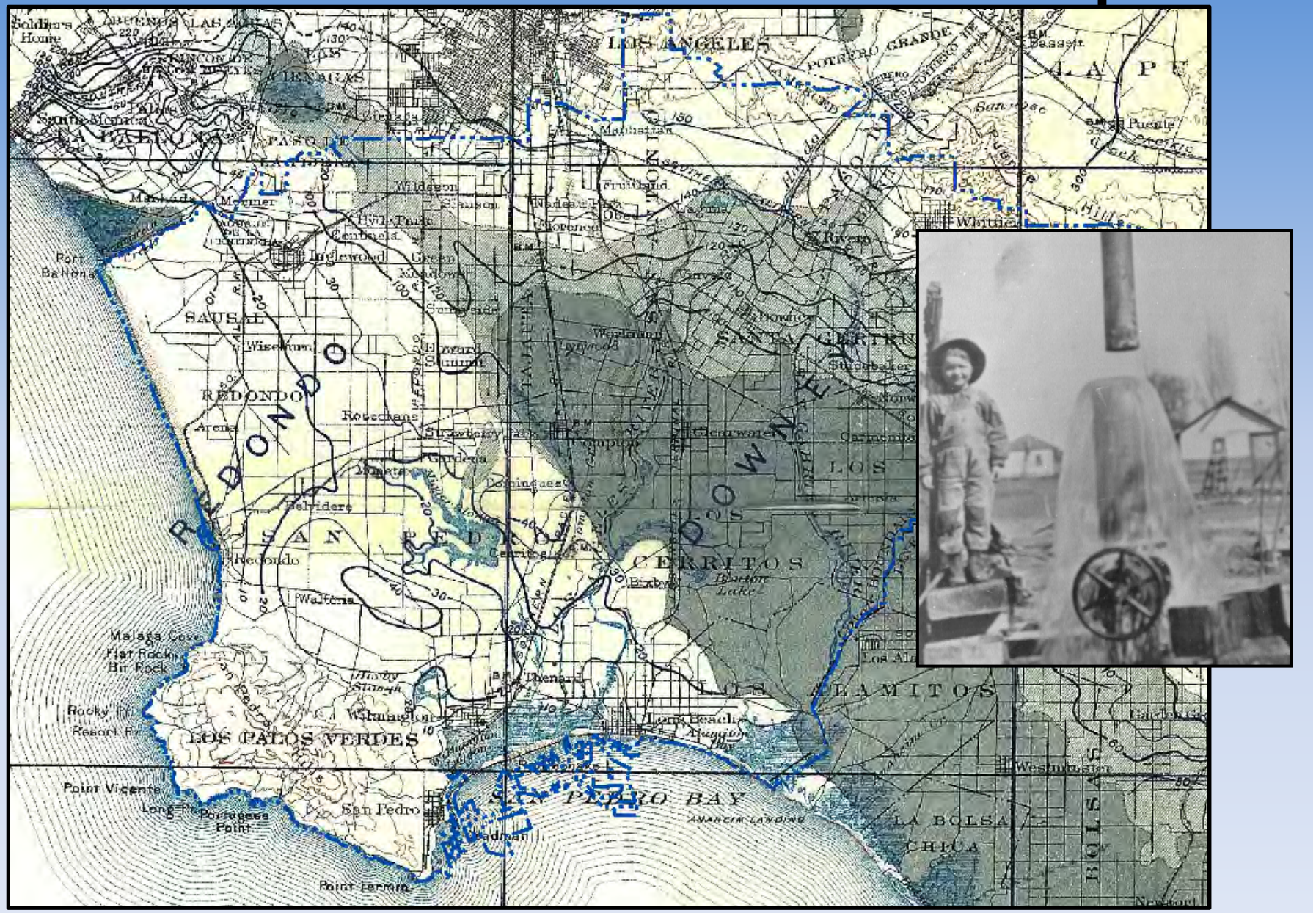
1904 LA Groundwater Contour Map



1904 Groundwater Contour Map (Mendenhall, 1905). Gray shading indicates areas of flowing artesian wells

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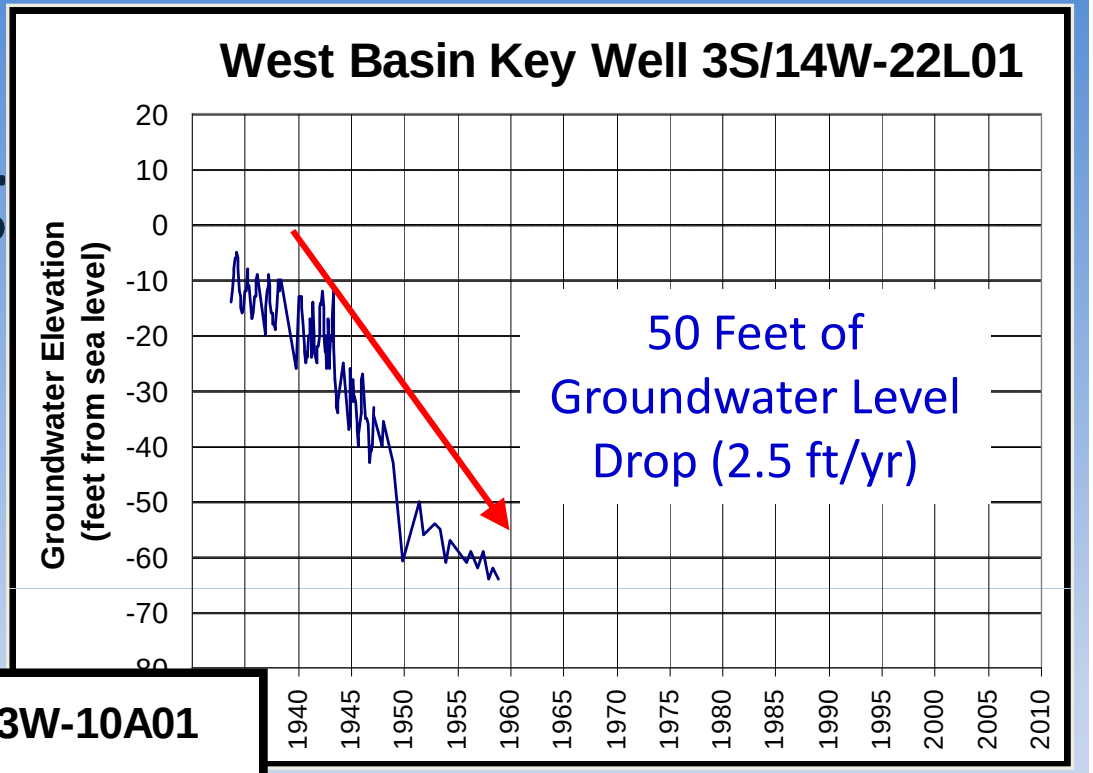
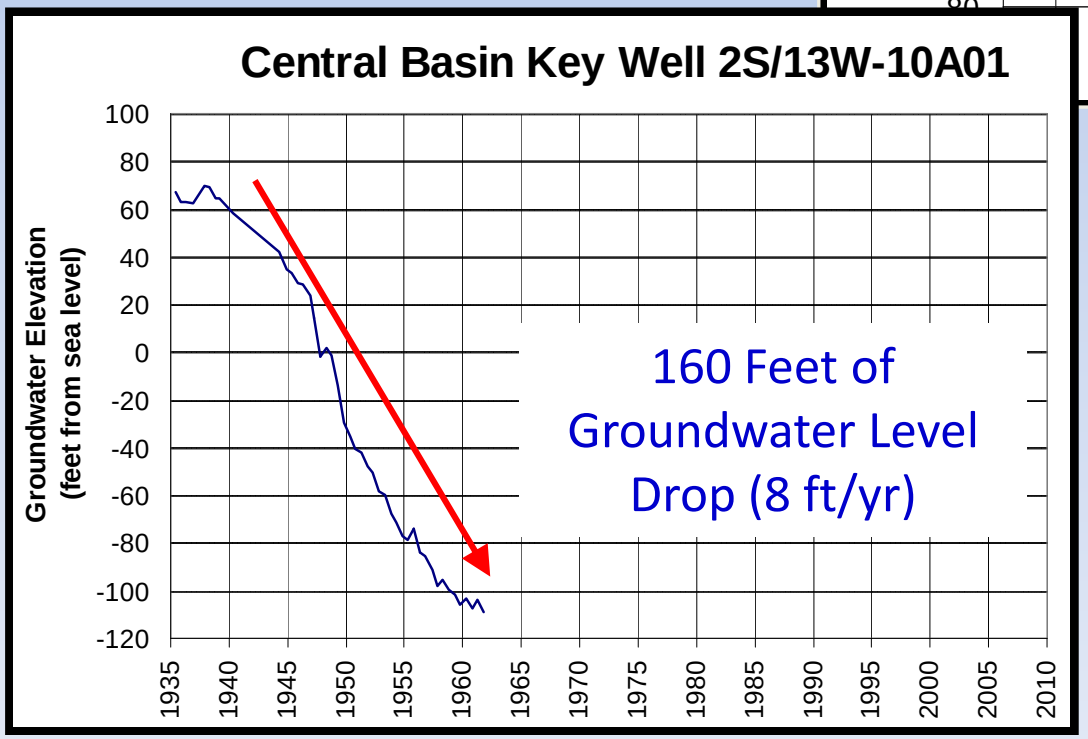
1900s-1950s Excessive Pumping caused Groundwater OVERDRAFT





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Groundwater Management Solutions

- SEAWATER BARRIER WELLS: LA County installed injection wells along 16 miles of coastline to form a barrier to halt seawater intrusion into the coastal aquifers. Started in 1950s.

- NEW REPLENISHMENT WATER: WRD formed in 1959 by a local election to perform managed aquifer recharge to make up the annual overdraft.

- CONTROL EXTRACTIONS: Legal Action (adjudication) in 1960s reduced pumping to 281,835 acre feet per year (still greater than natural safe yield). Relied on WRD replenishment water to make up the difference and create an operational safe yield.

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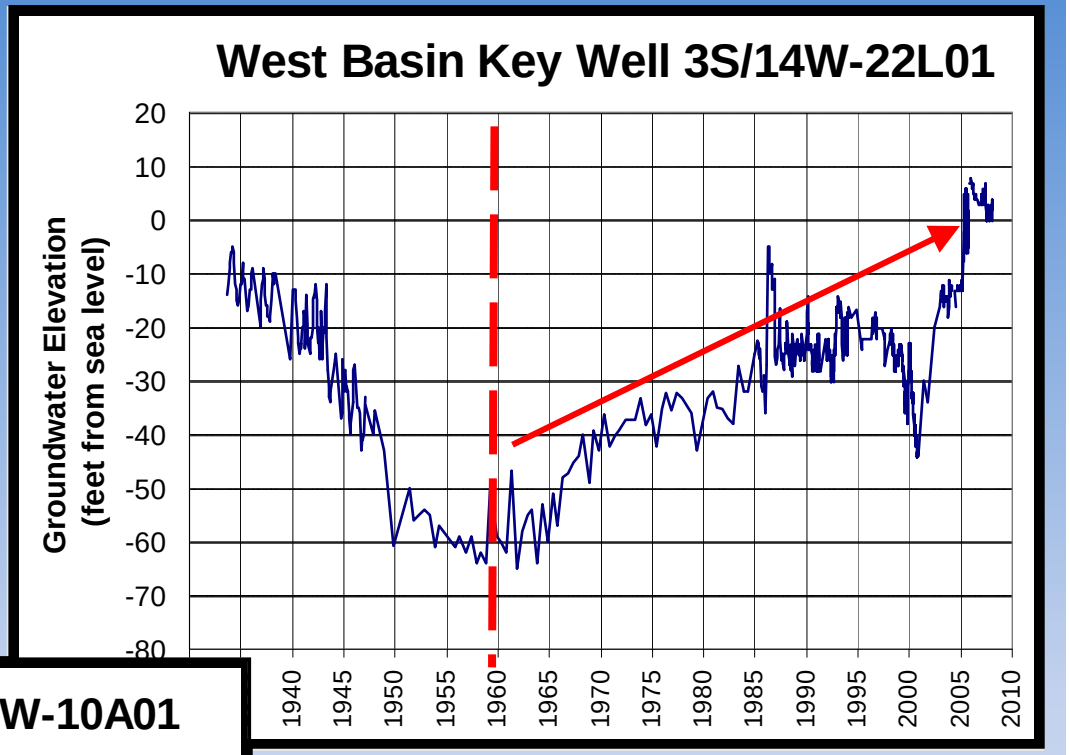
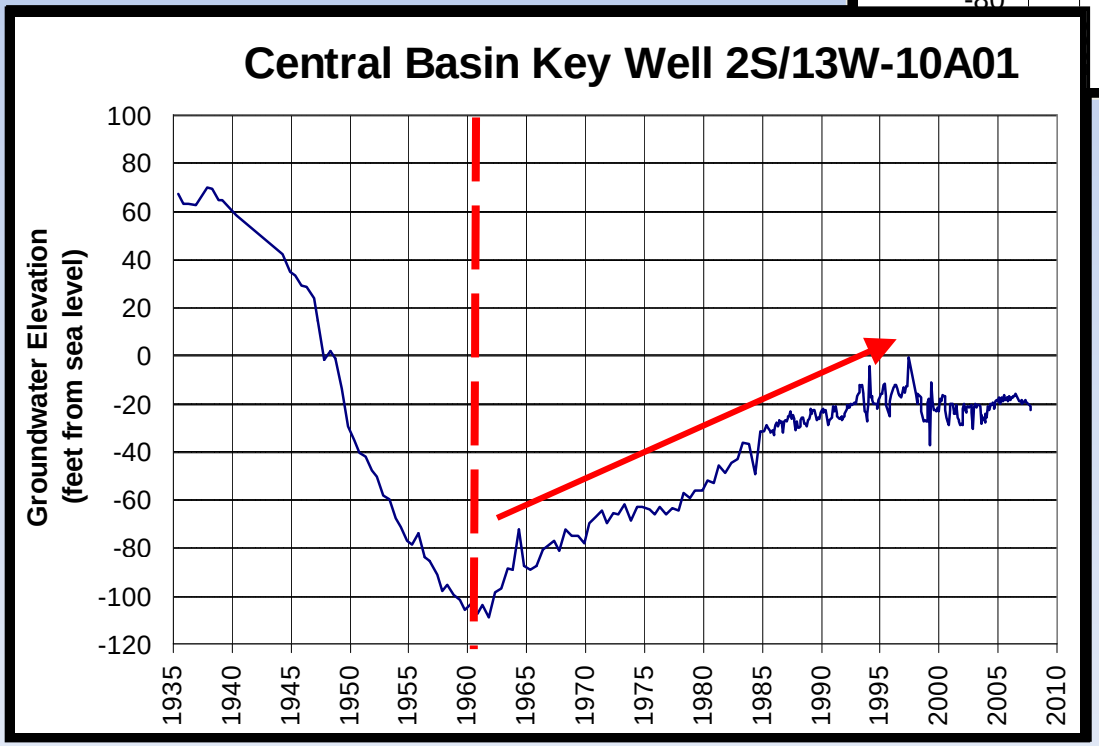
RESULTS of Groundwater Management …





… Rising Water Levels & Drought Protection

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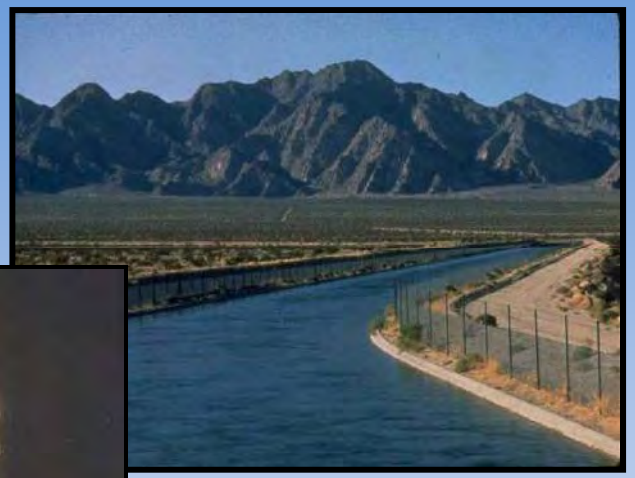
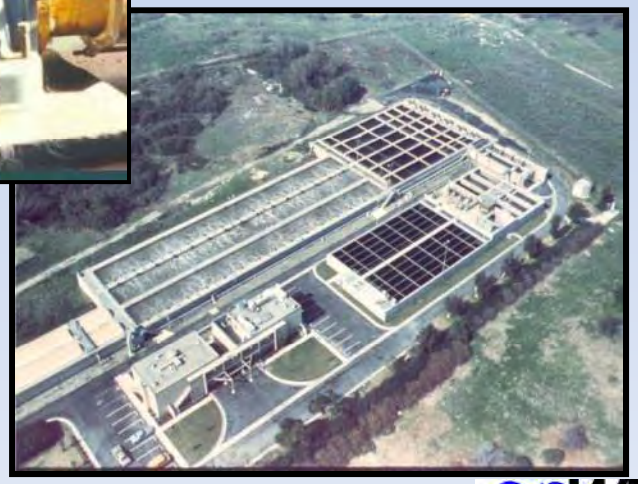
Where do CB and WCB get their Water?

- Imported River Water: 60%



- Groundwater: 40%

- Recycled Wastewater: Growing uses (irrigation, industrial applications, groundwater recharge)



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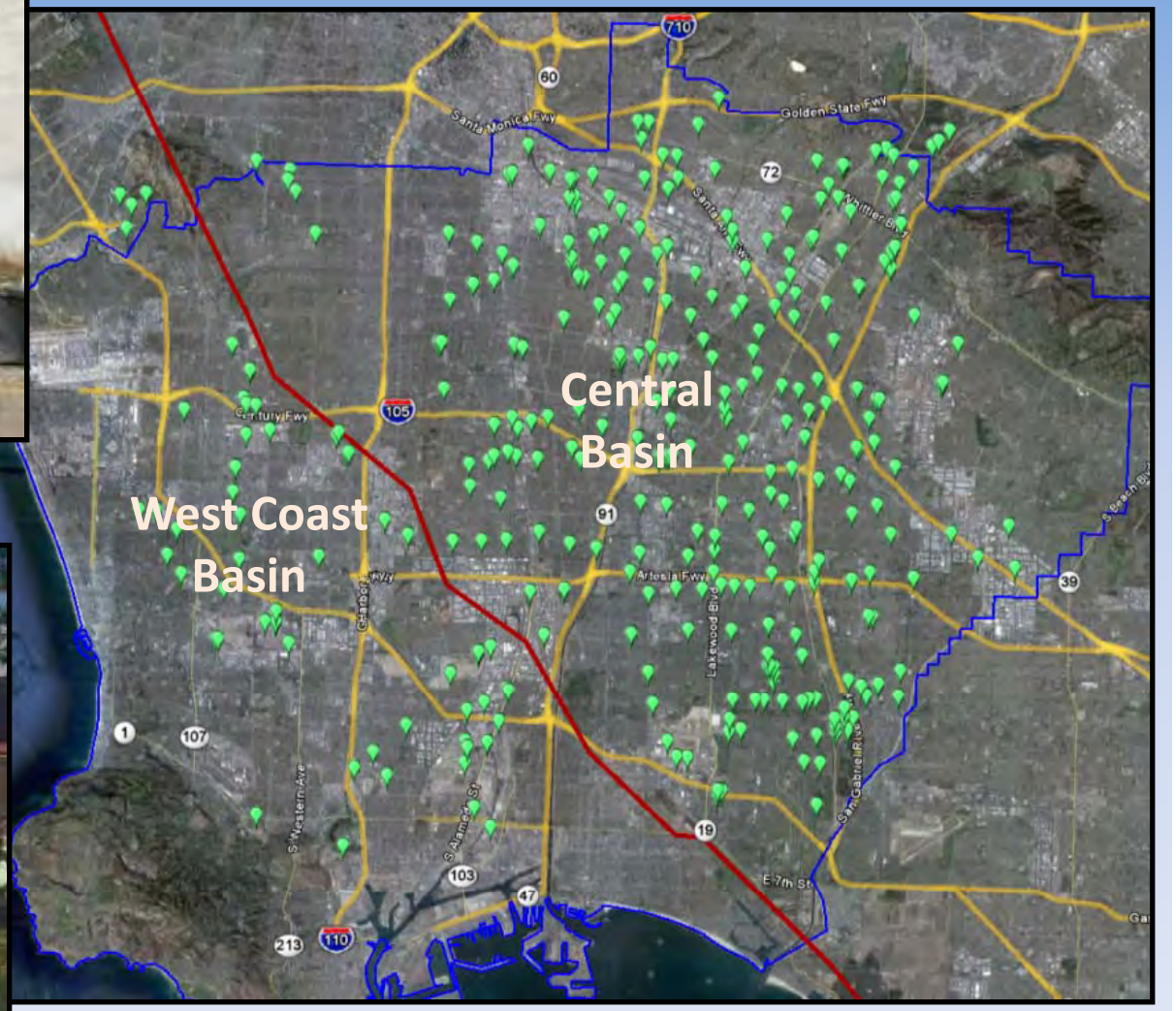
Over 400 Groundwater Production Wells Operated by Various Cities and other Public/Private Entities



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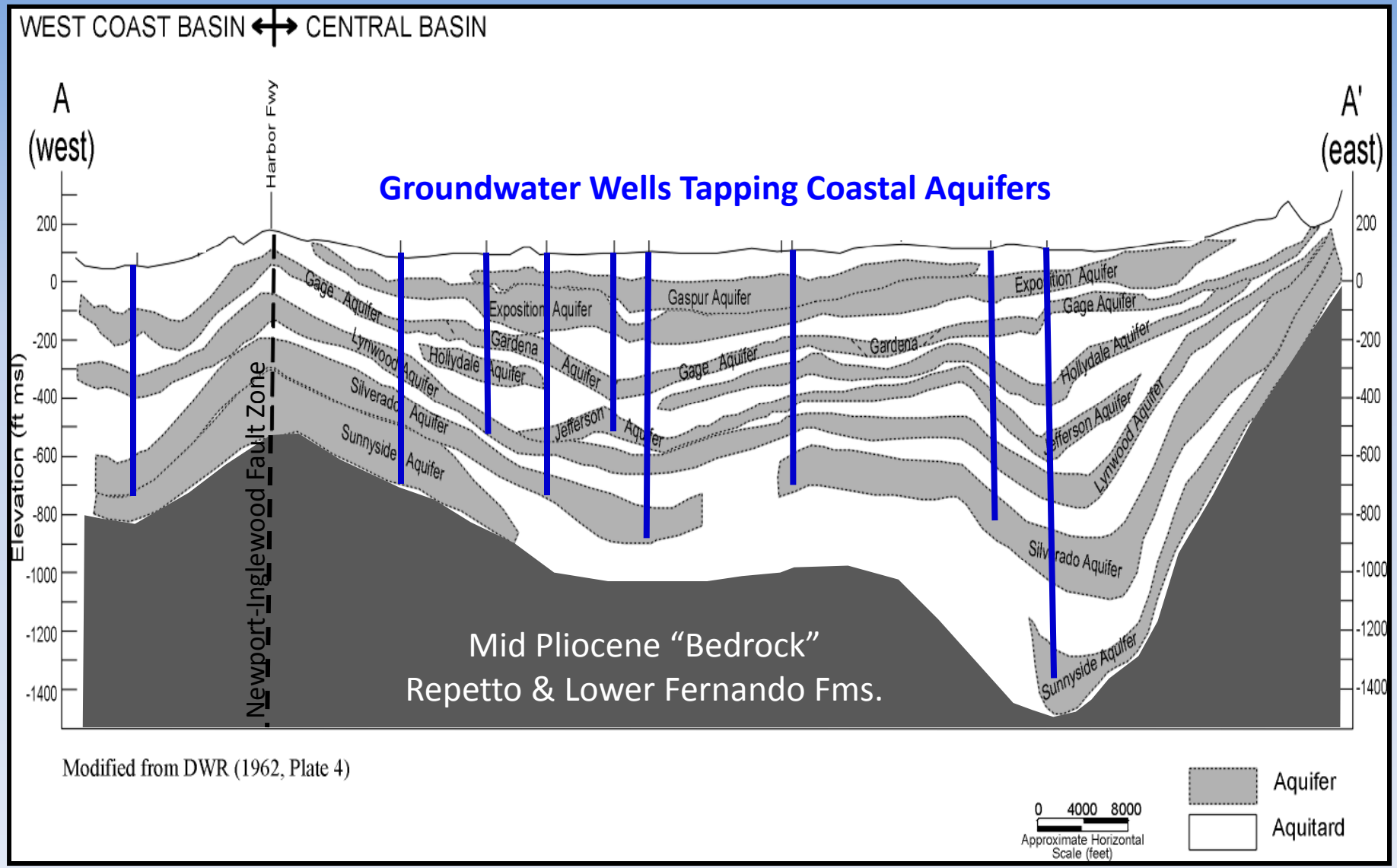
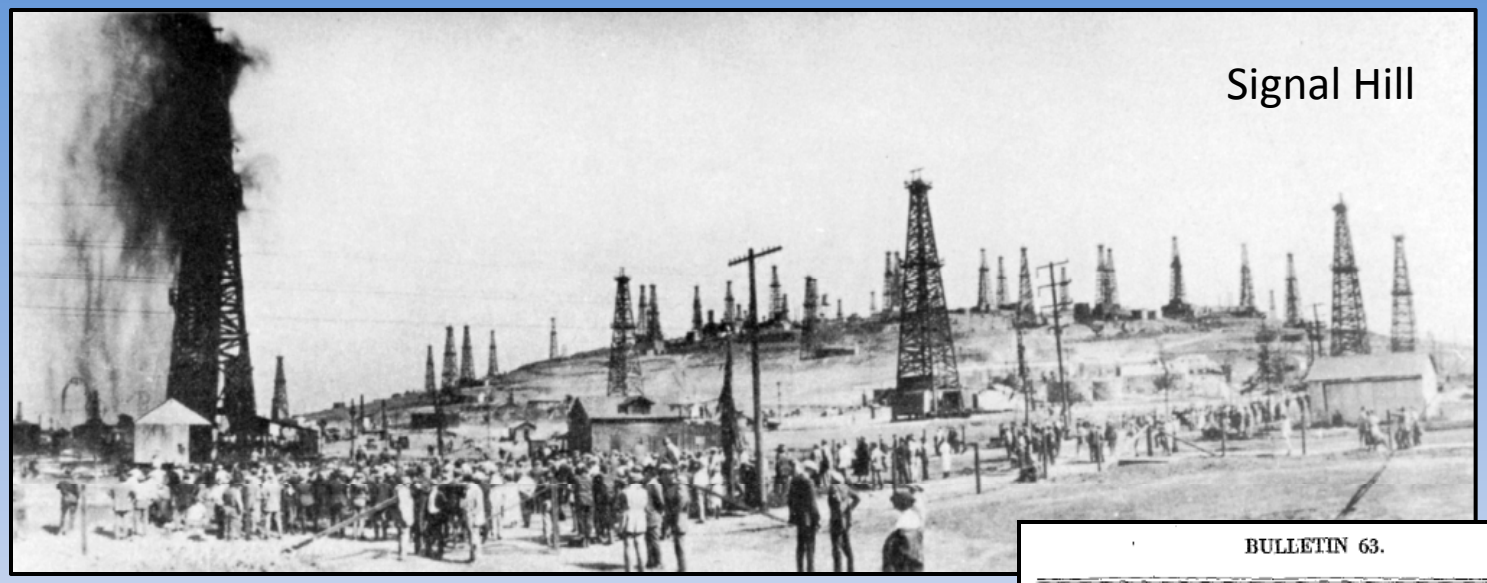
Quaternary & Late Pliocene Coastal Aquifers
Sand & Gravel. Folded & Faulted.



But There's Oil & Gas in the Basins too



BULLETIN 63.

PETROLEUM

IN

SOUTHERN CALIFORNIA

1913

COMPILED BY

PAUL W. PRUTZMAN

ISSUED BY

CALIFORNIA STATE MINING BUREAU

F. McN. HAMILTON

State Mineralogist

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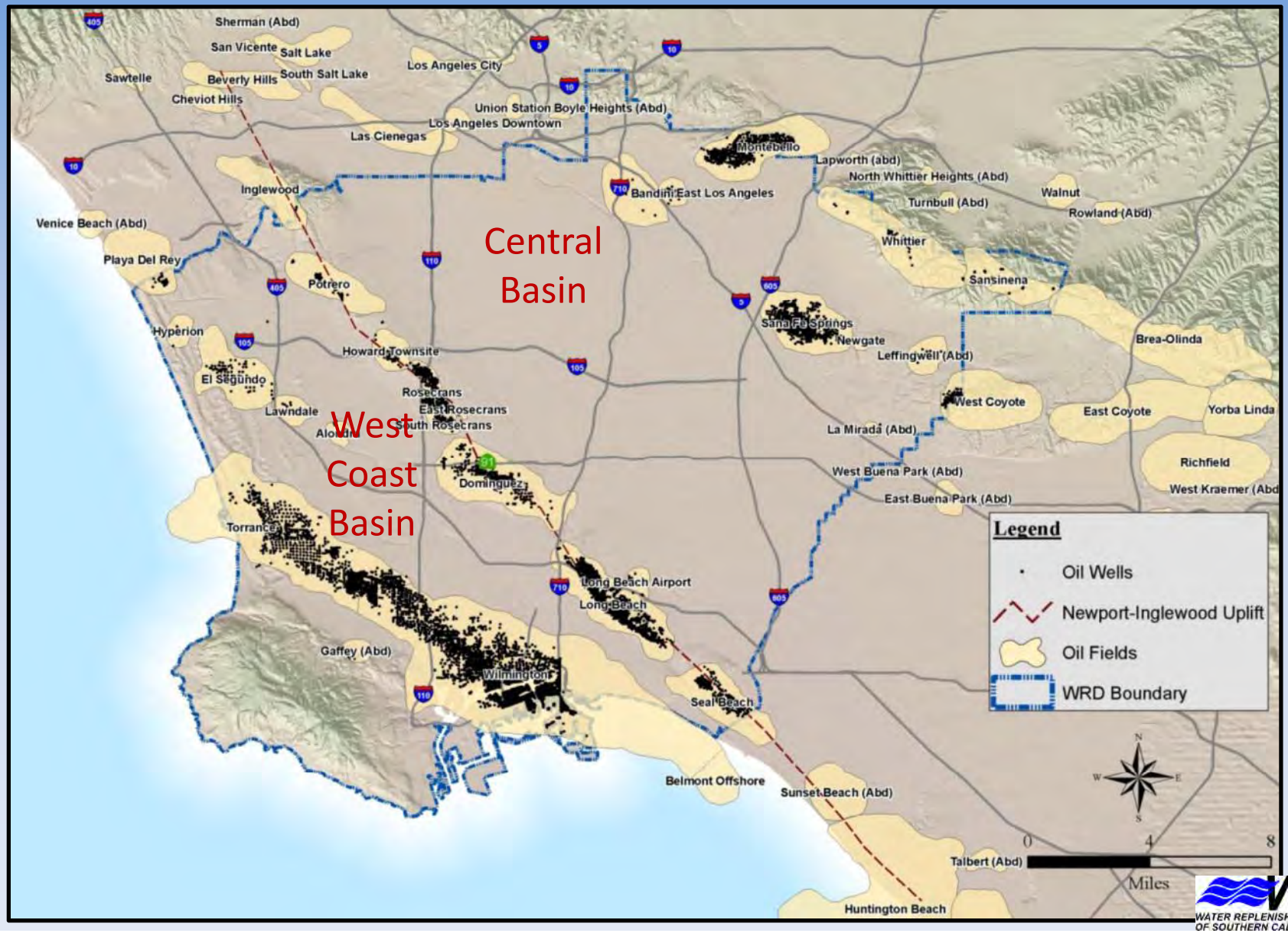
Over 30 Mapped Oil Fields and 9,700 Oil/Gas Wells in WRD Service Area



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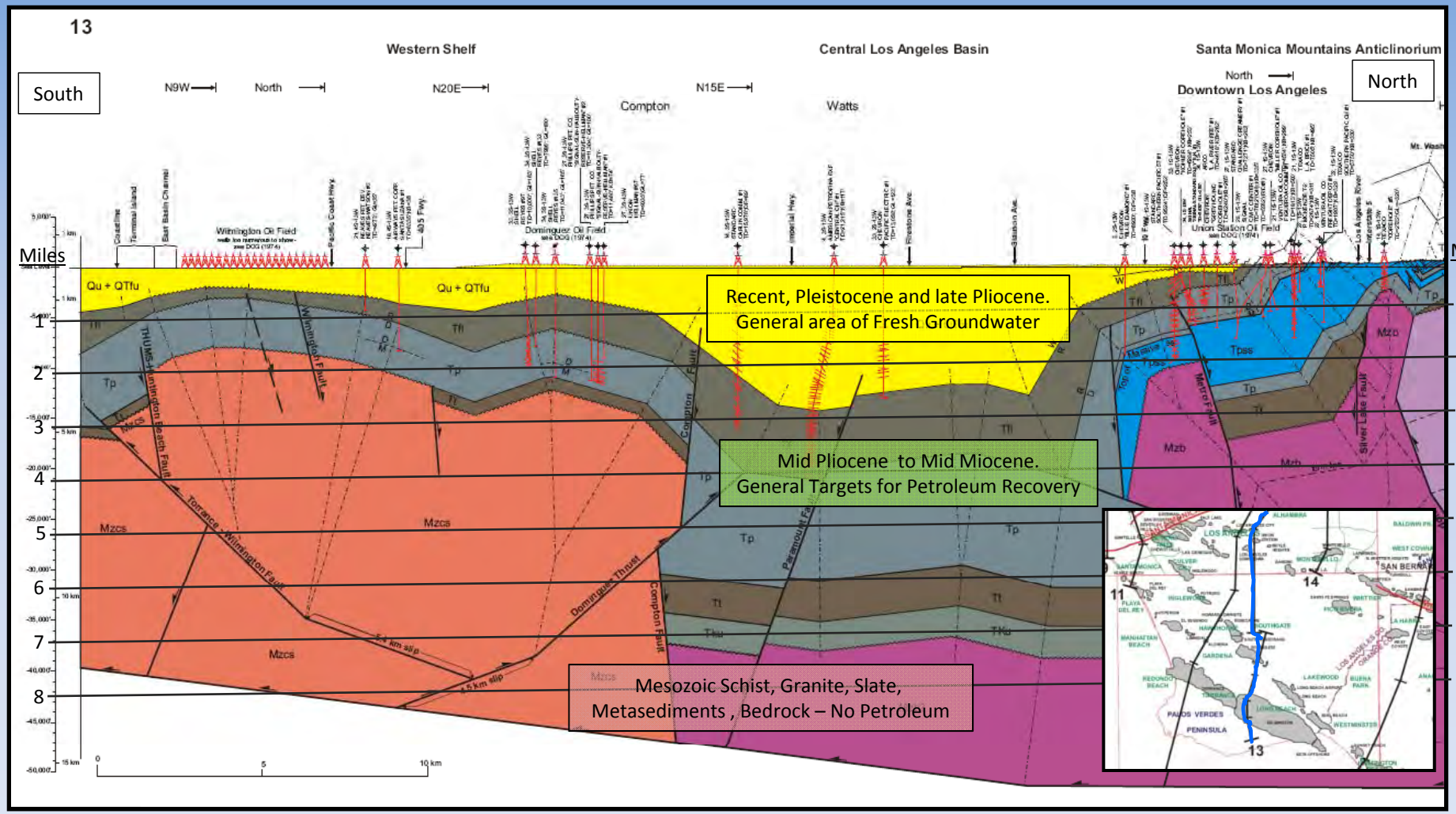
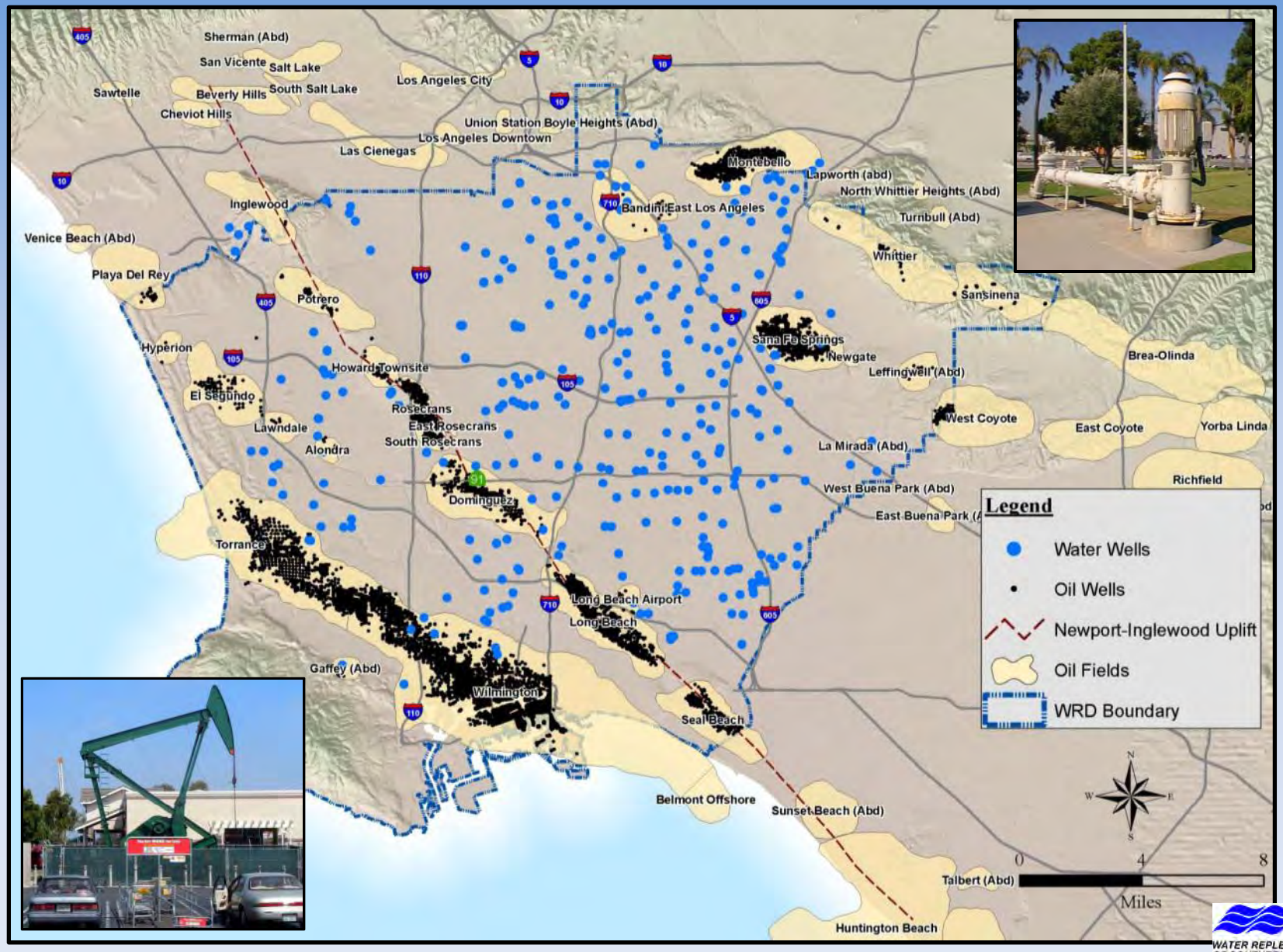
Cross-Section through LA showing Petroleum Target Zones



Modified from Davis – Namson, 1998
Southern California Cross Section Study

Oil Wells & Water Wells in LA
Over 100 Years of Co-Existing



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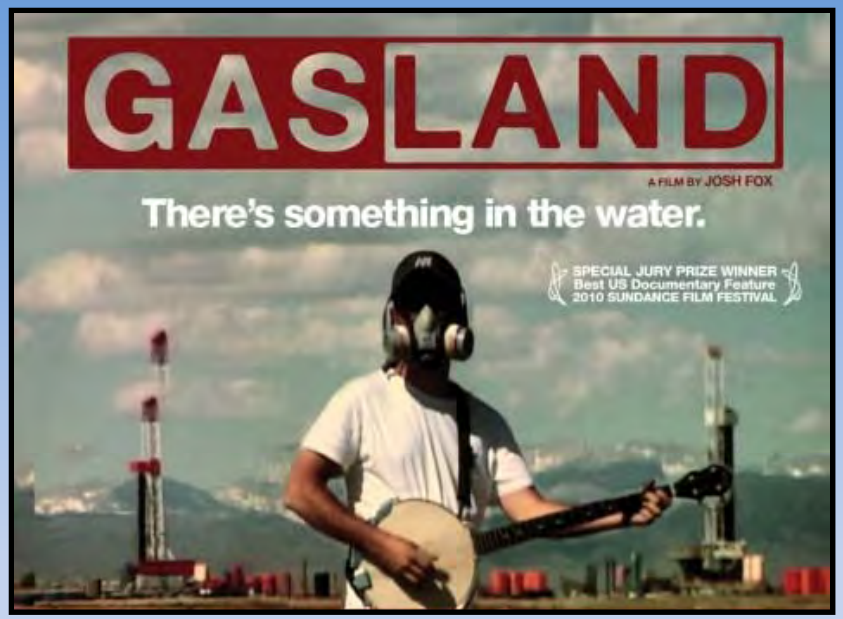
So Why All The Concern Over Fracking?



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

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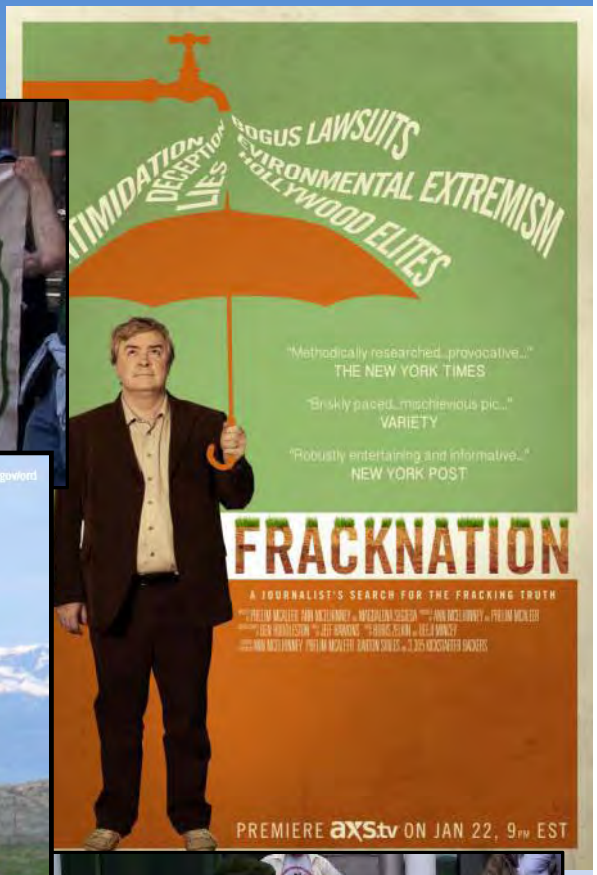
National Issue



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

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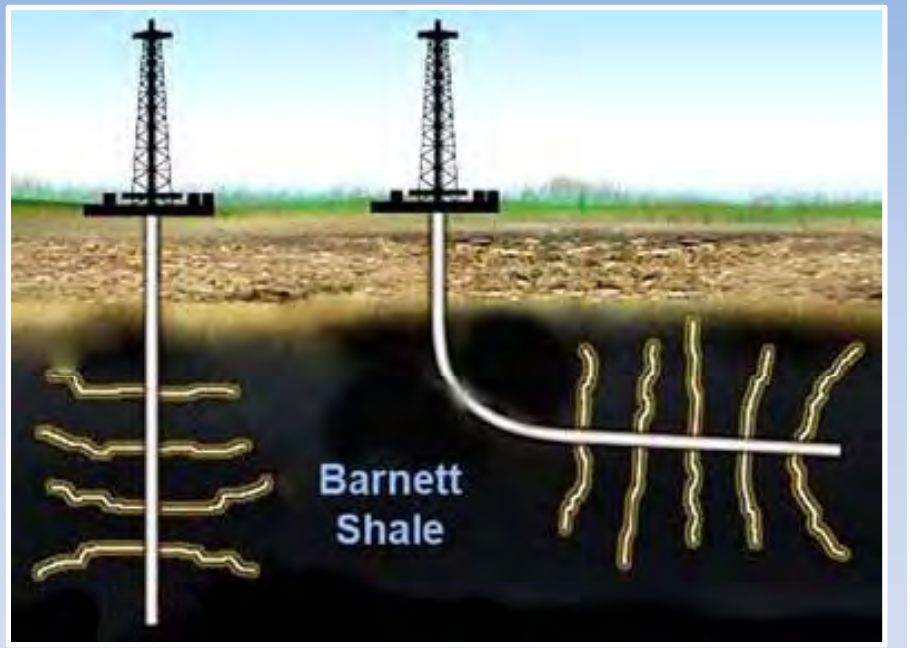
What is Hydraulic Fracturing (Fracking)?

- Method to enhance oil or natural gas production.

- Inject fluids (water, sand, chemicals) under high pressure to break open rock to enhance permeability and oil/gas flow.

- Improvements in horizontal drilling technologies have led to significant increase in fracking for gas, especially in the eastern and middle United States.



Vertical and Horizontal wells and Fracking

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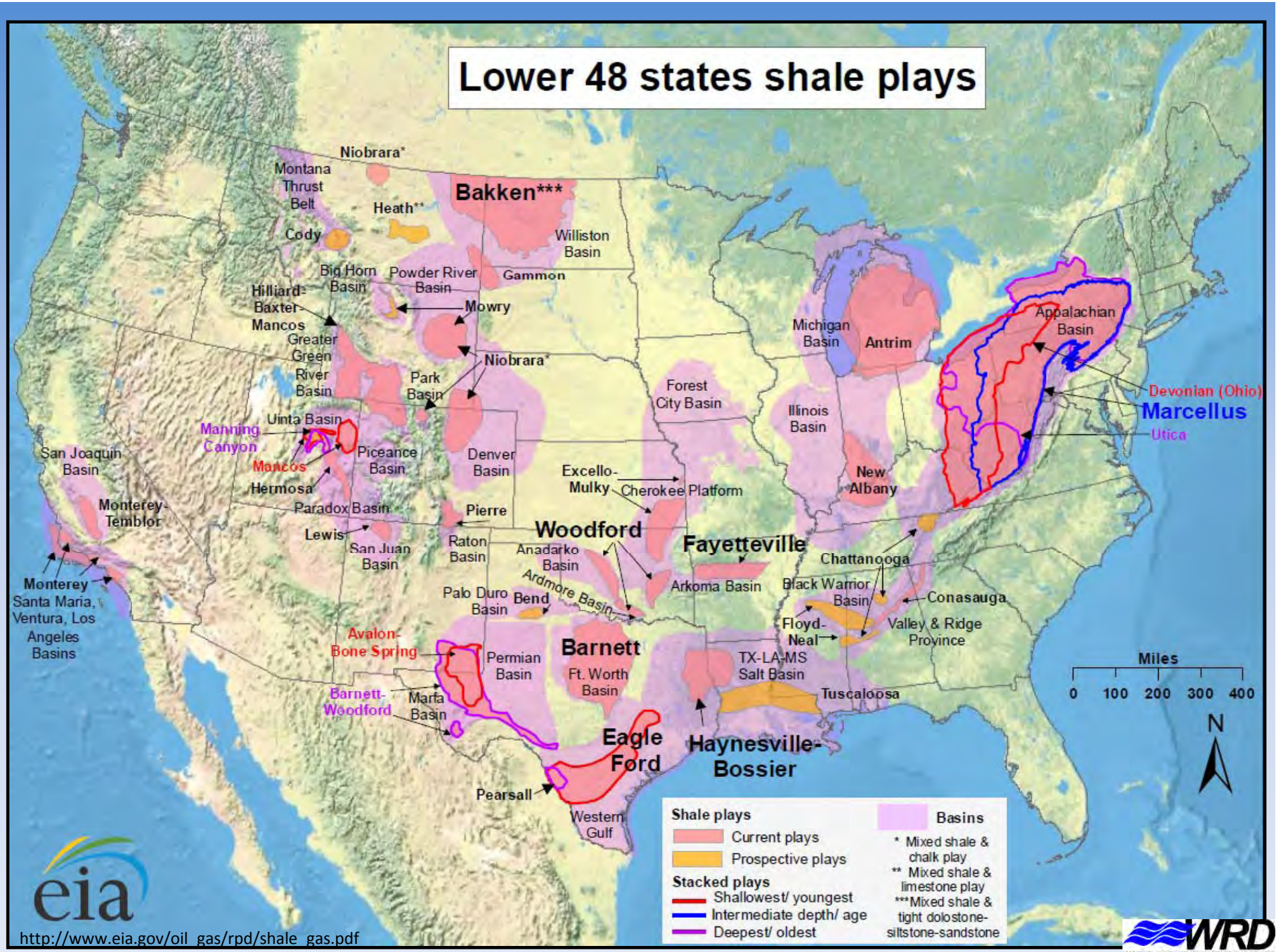

eia

http://www.eia.gov/oil_gas/rpd/shale_gas.pdf

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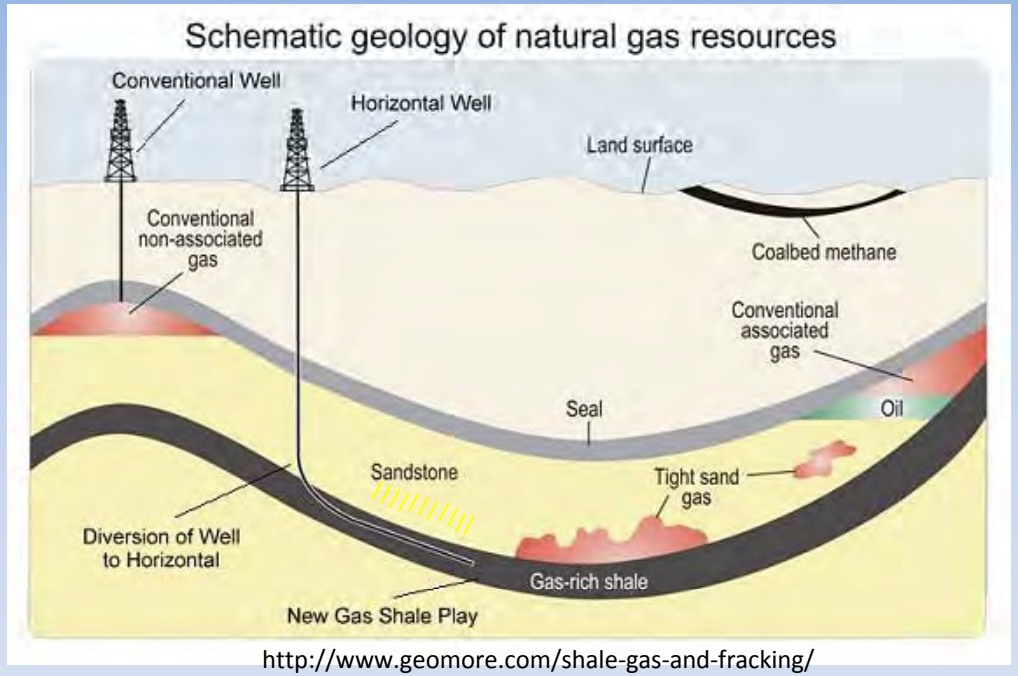
Conventional vs. Unconventional Fracking

⚒ Conventional: Fracking in permeable reservoirs like sandstone and limestone to improve oil/gas flows. Has been done by oil companies for > 50 years. Vertical or slant wells. Lower pressure and water. Common in CA and elsewhere.

⚒ Unconventional: Newer fracking in hard tight rock that is porous but not permeable (i.e. shale). Slant or horizontal wells used to expose more formation to mine. TX, PA, NY, WY, MO, CO, OH. CA next?



http://www.geomore.com/shale-gas-and-fracking/

⚒ 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).

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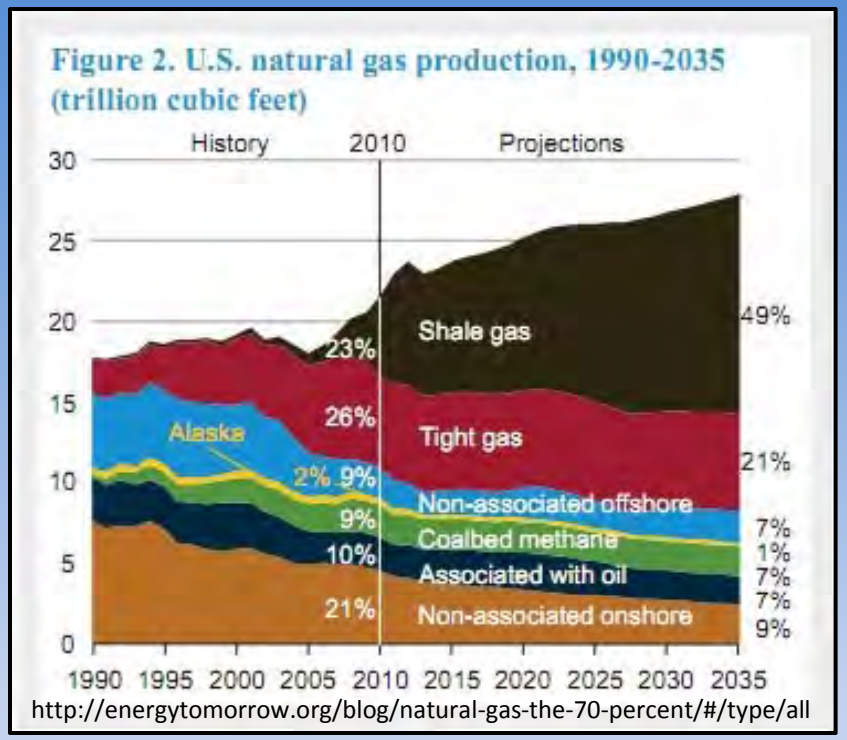
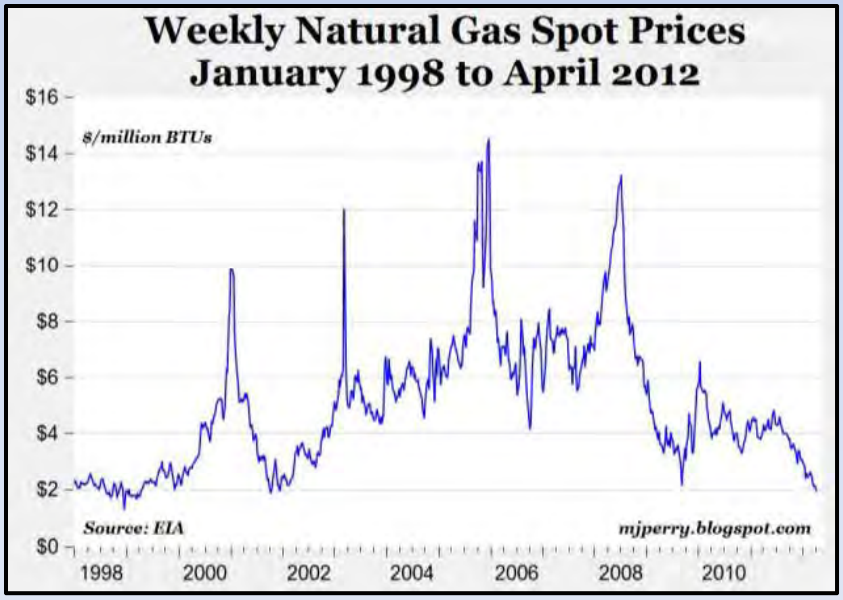
Why Frack?

- Creates a new energy resource. Unconventional drilling and fracking into now accounts for more than half the natural gas production in the U.S. Estimated 100 year supply.
- Allows extended production in older oil and gas fields.
- Allows recovery of petroleum from tight formations previously believed to be un-produceable.
- Reduced price of natural gas.
- Creates jobs in energy industry.



http://energytomorrow.org/blog/natural-gas-the-70-percent/#/type/all



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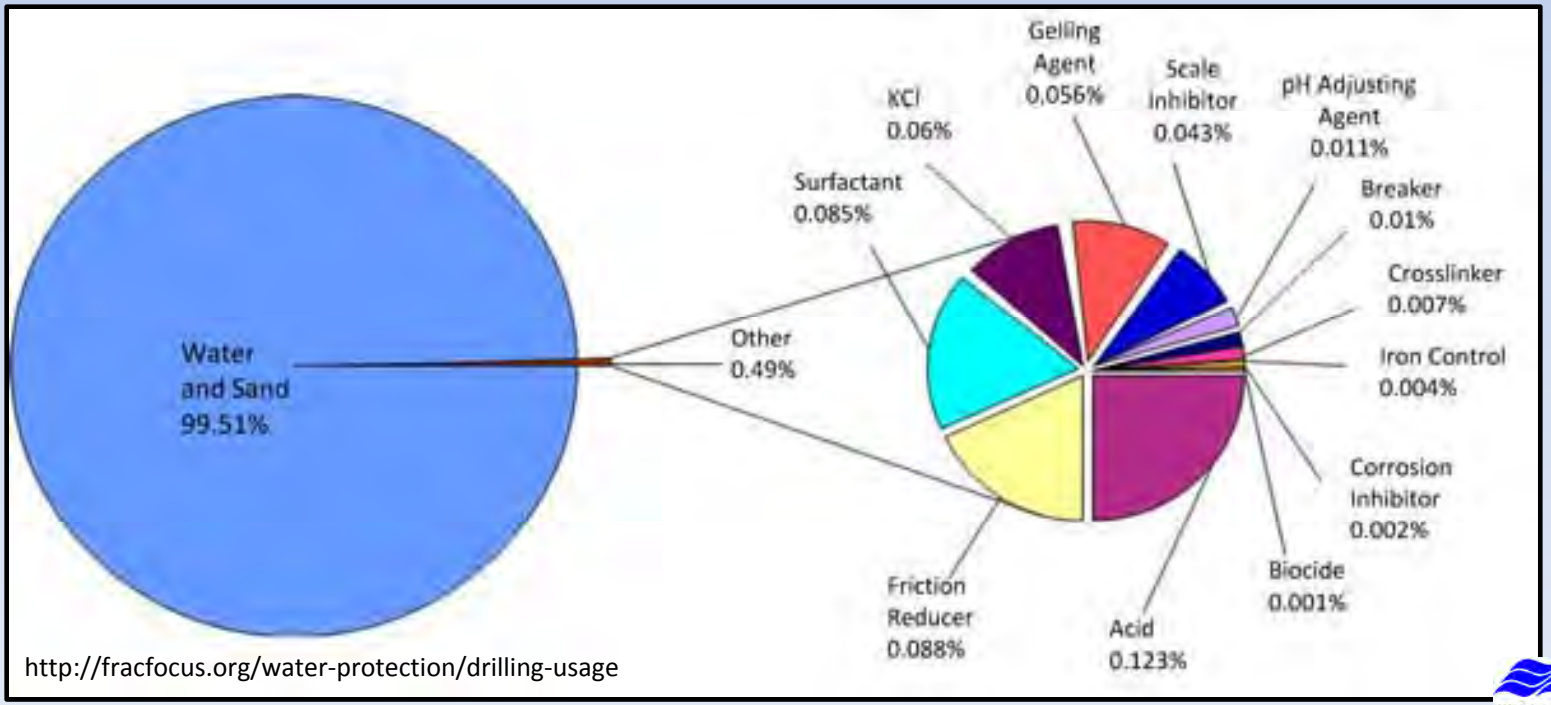
Injection Fluids

- Water is the main fluid. Average 5 million gallons per job for unconventional; < 400,000 for conventional; < 100,000 gravel pack.

- 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

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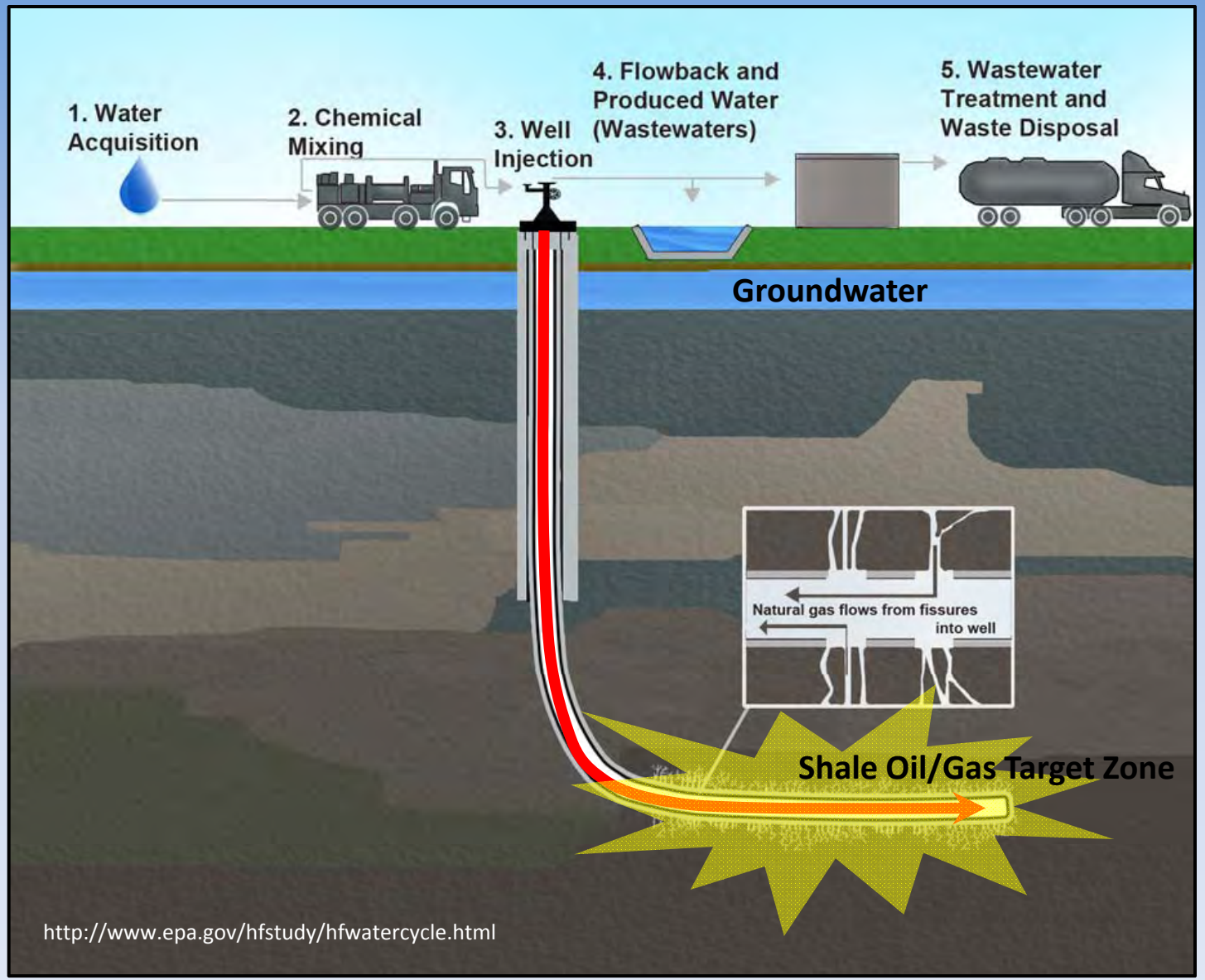
Fracking Operations



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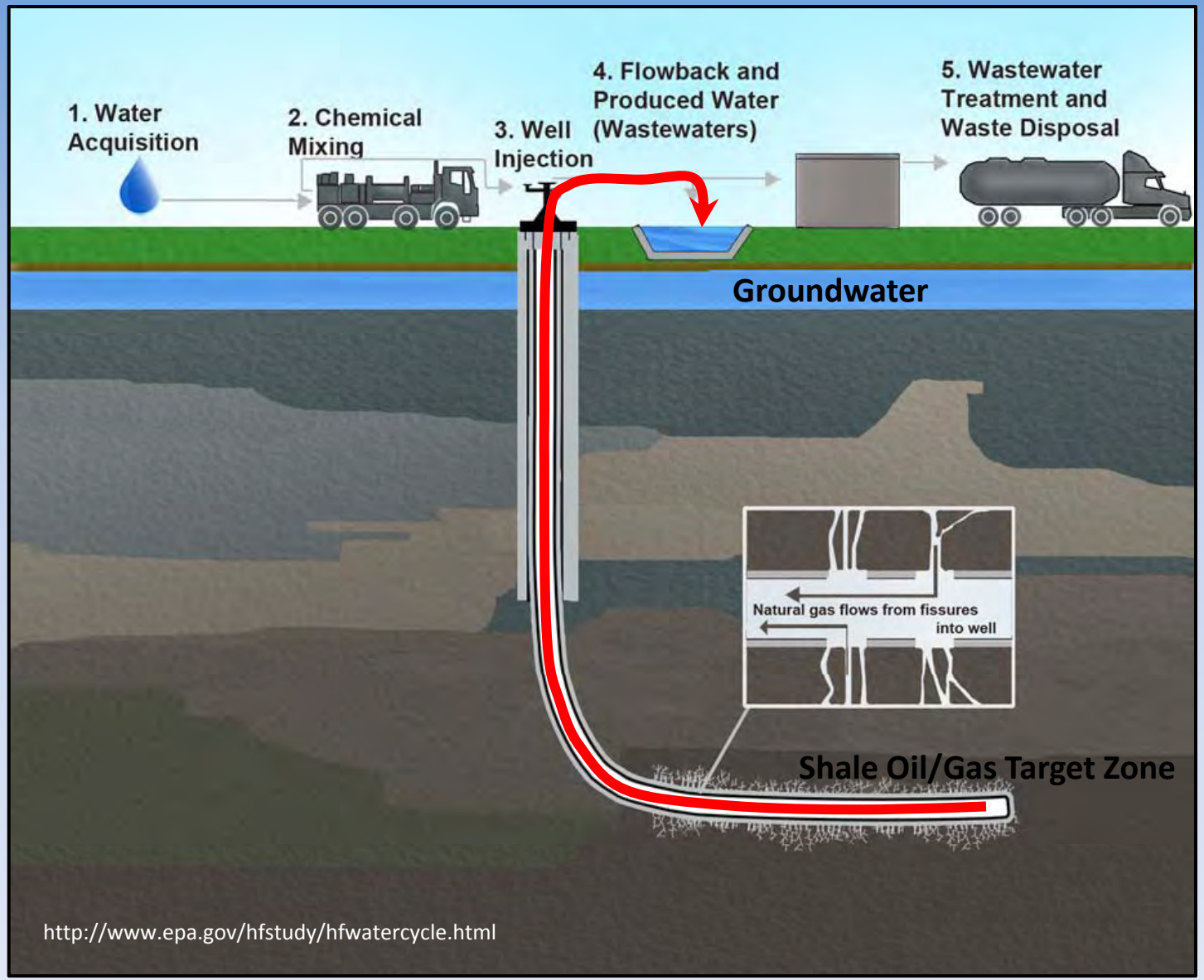
Unconventional Fracking Operations



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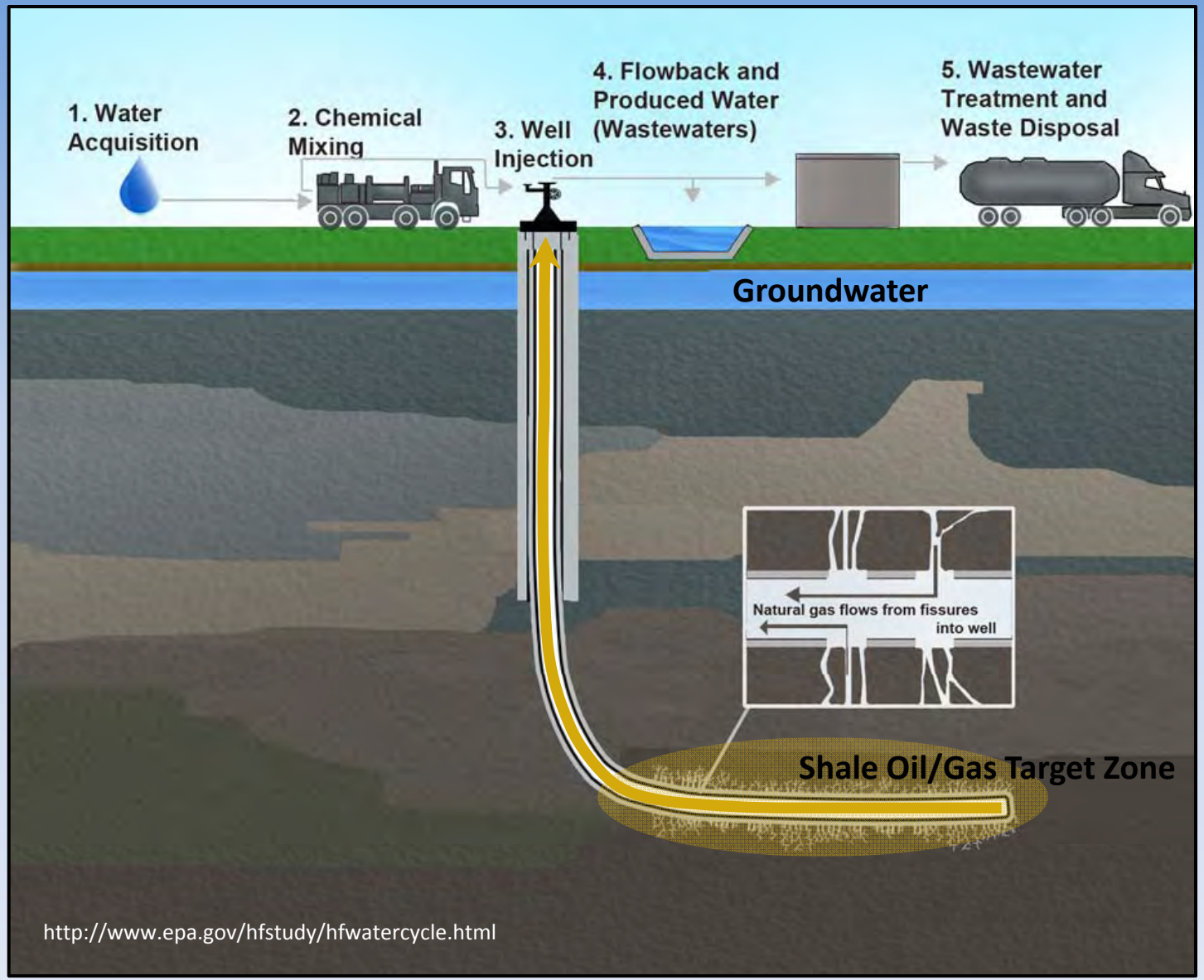
Fracking Operations



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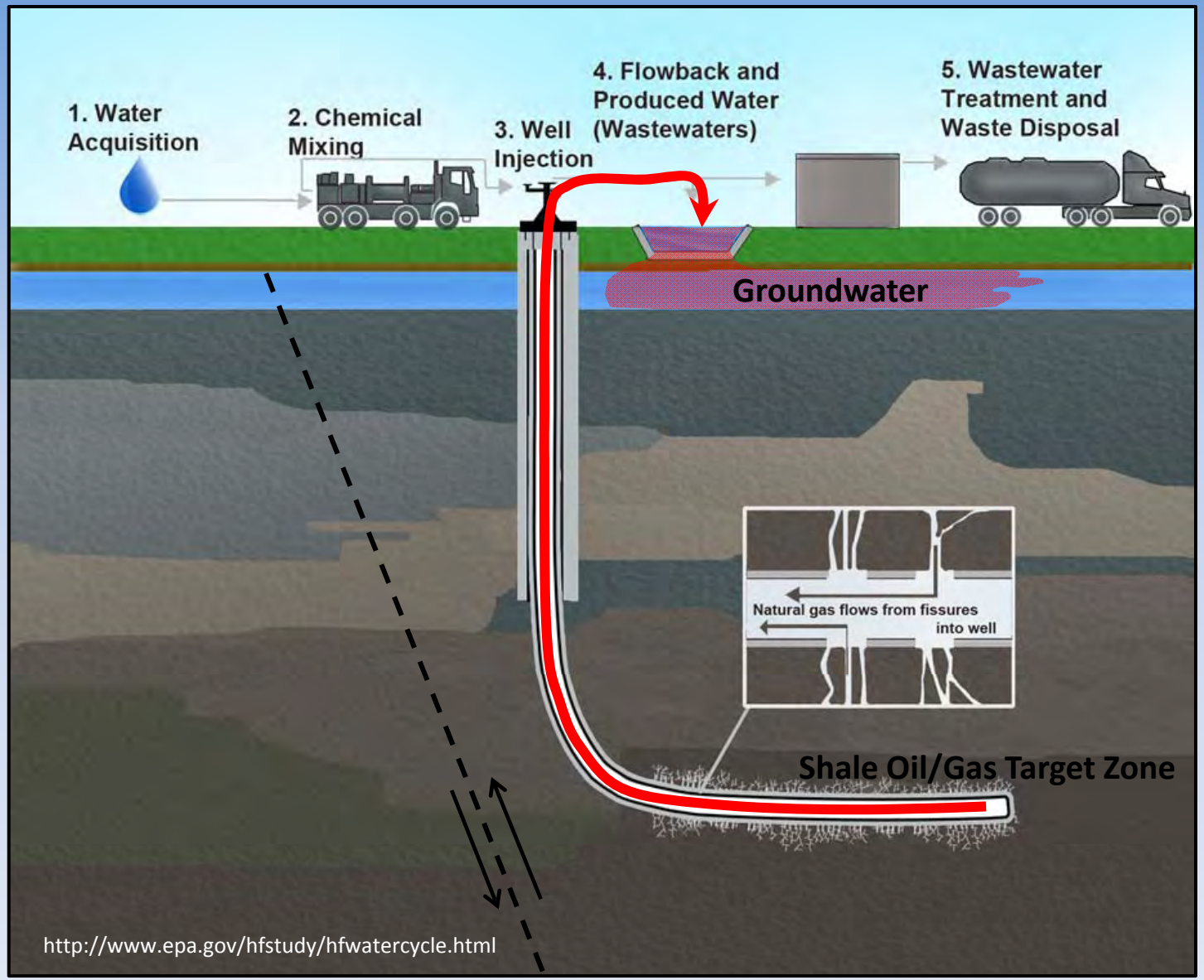
Potential Threats to Groundwater



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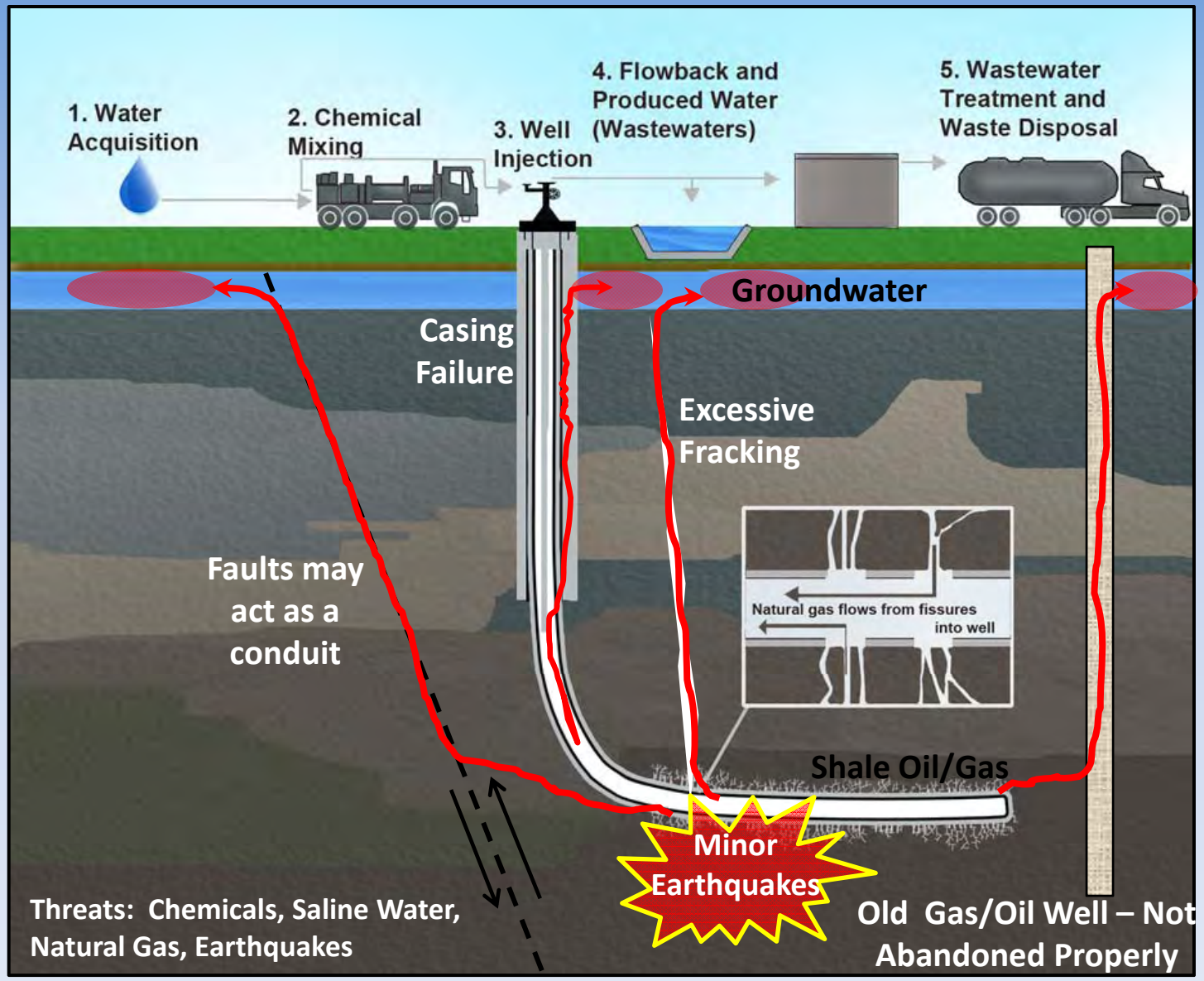
Potential Threats to Groundwater



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National Research on Fracking

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

At the request of Congress, EPA is conducting a study to better understand any potential impacts of h
fracturing on drinking water and ground water. The scope of the research includes the full lifespan of
hydraulic fracturing, from acquisition of the water, through the mixing of chemicals and actual fractur
the post-fracturing stage, including the management of flowback and produced water and its ultimate
treatment and disposal.

A first report on the study will be released for peer review in late 2012. Certain portions of the researc
released for peer review in 2014.

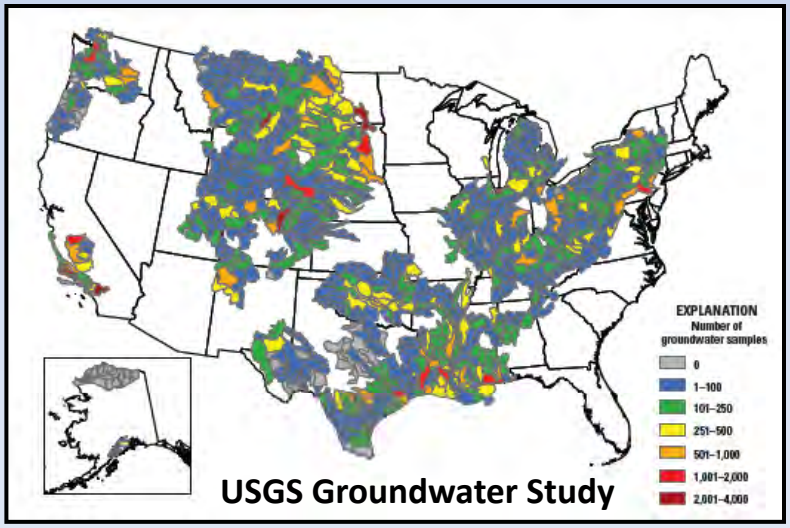
USGS
science for a changing world

U.S. Geological Survey Powell Center for Analysis and Synthesis

Water Quality Studied in Areas of Unconventional Oil and Gas Development, Including Areas Where Hydraulic Fracturing Techniques are Used, in the United States

Domestic oil and gas production and clean water are critical for economic growth, public health, and national security of the United States. As domestic oil and gas production increases in new areas and old fields are enhanced, there is increasing public concern about the effects of energy production on surface-water and groundwater quality. To a great extent, this concern arises from the hydraulic fracturing techniques being used today, including horizontal drilling, for producing unconventional oil and gas in low-permeability formations.

The U.S. Geological Survey (USGS) John Wesley Powell Center for Analysis and Synthesis is hosting an interdisciplinary working group of USGS scientists to conduct a temporal and spatial analysis of surface-water and groundwater quality in areas



USGS Groundwater Study

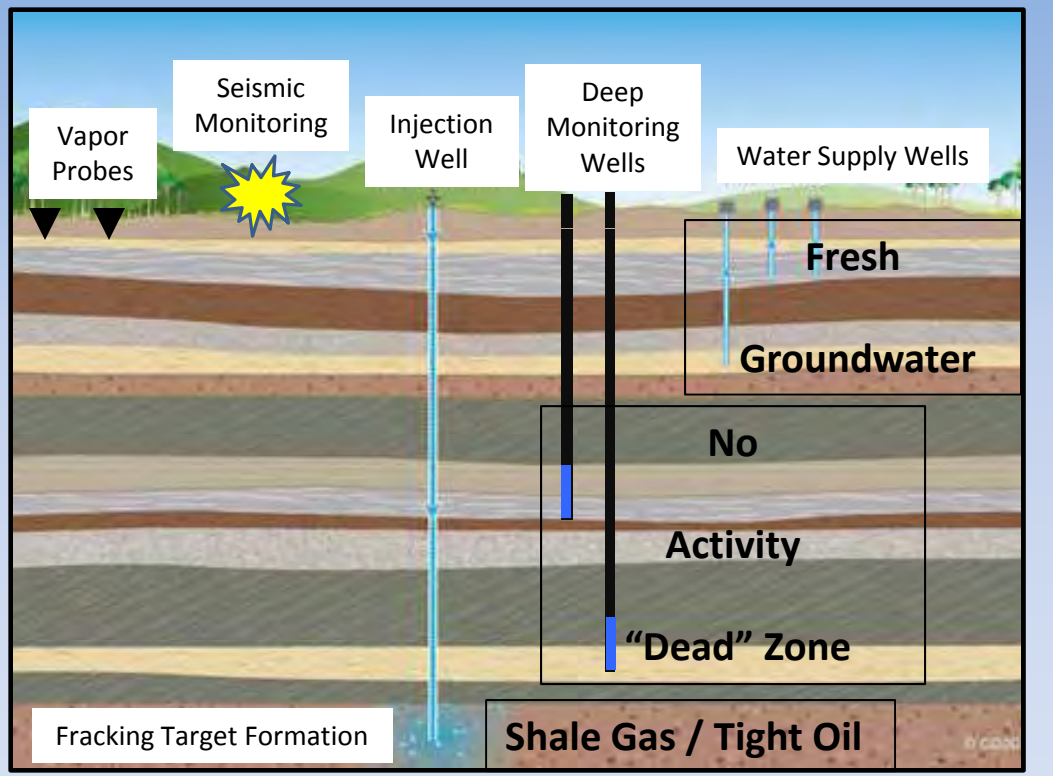
WATER RESEARCH FOUNDATION
ADVANCING THE SCIENCE OF WATER

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.
- Identify all artificial pathways and seal off.
- Proper waste collection and disposal.
- Monitor injection pressures, intervening “dead zone” aquifer, flowback ponds, deep and shallow groundwater monitoring, seismic monitoring.
- Vapor probes for soil gas monitoring at surface.



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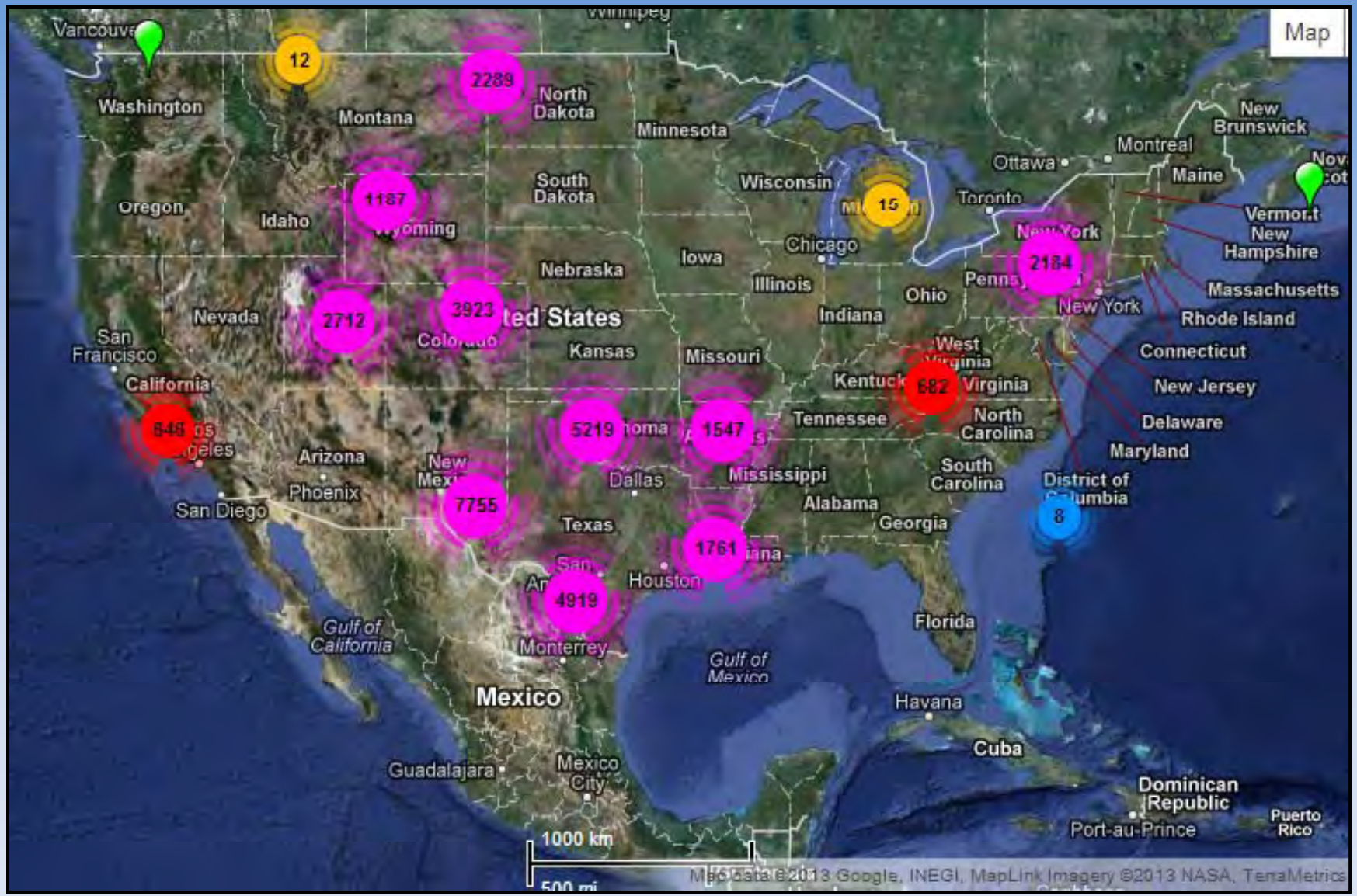
FracFocus.org – Tracks Fracking & Chemicals



http://www.hydraulicfracturingdisclosure.org/fracfocusfind/Map.aspx

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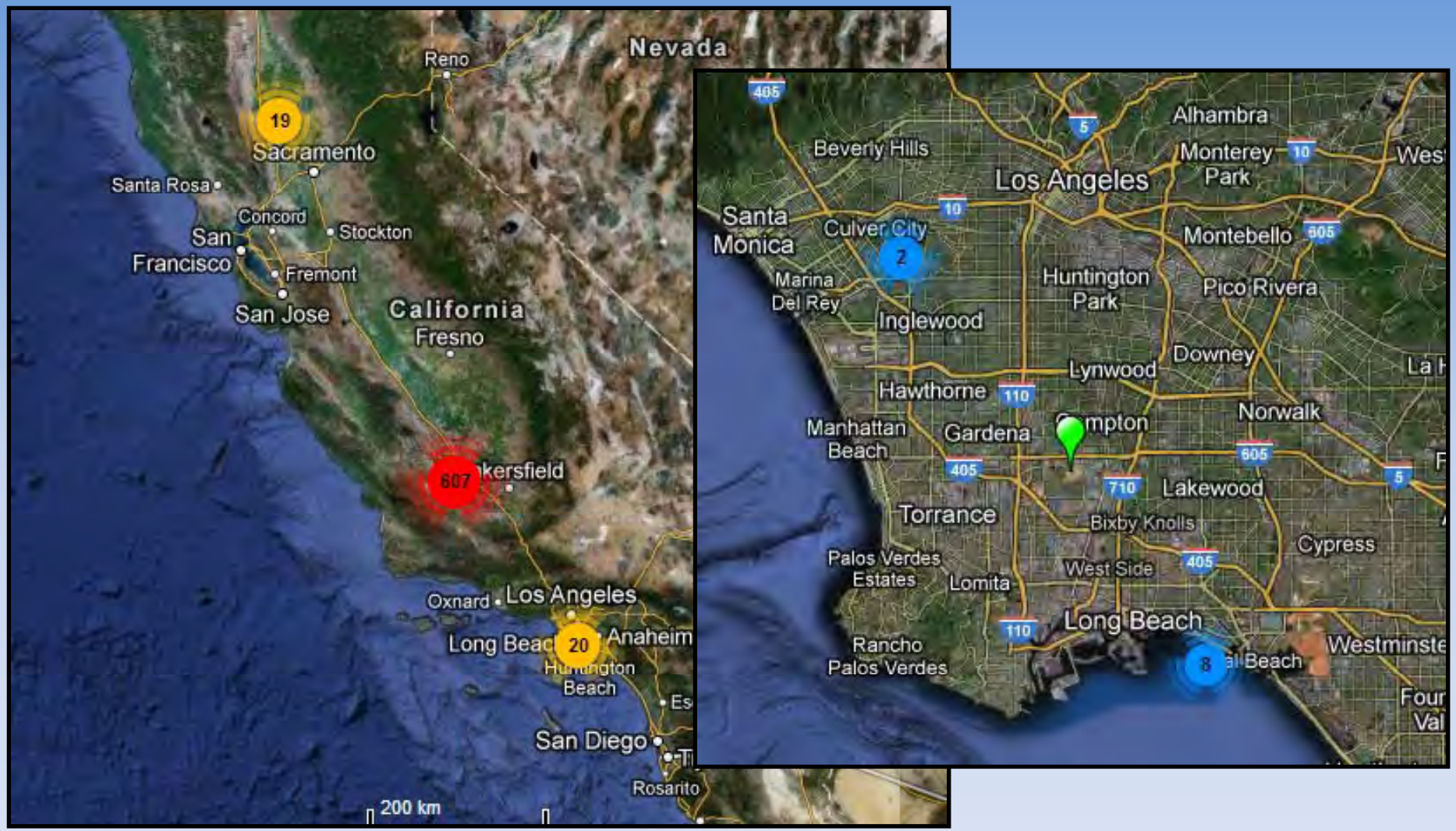
Listed California Fracking Locations



646 listed in California, 11 in the WRD area (8 offshore).
http://www.hydraulicfracturingdisclosure.org/fracfocusfind/Map.aspx

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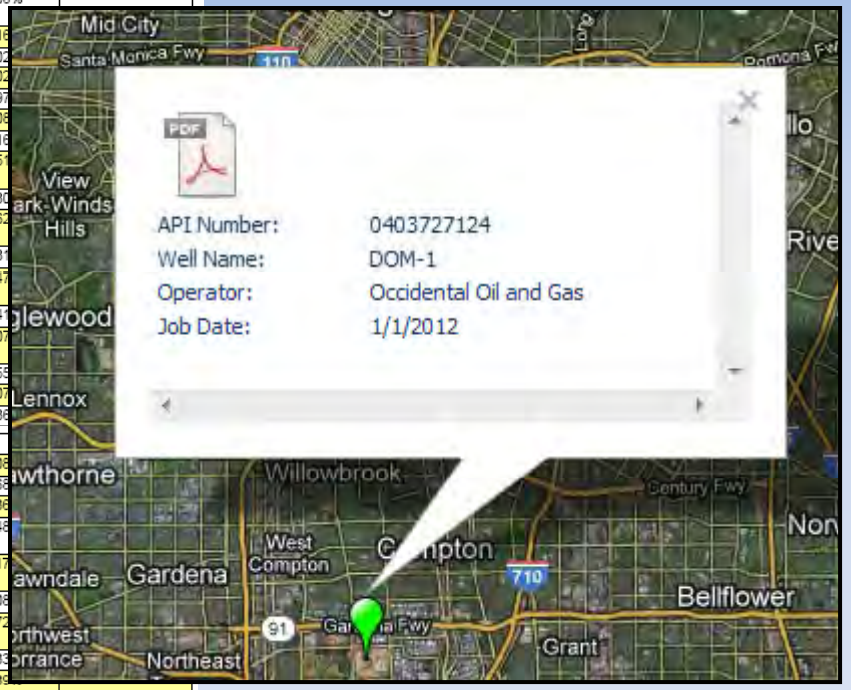
FracFocus.org Chemical Listing

Hydraulic Fracturing Fluid Product Component Information Disclosure

Last Fracture Date:	01/01/2012
State:	California
County:	Los Angeles
API Number:	403727124
Operator Name:	OXY USA Inc
Well Name and Number:	DOM-1
Longitude:	-118.243164
Latitude:	33.863524
Long/Lat Projection:	NAD27
Production Type:	Oil
True Vertical Depth (TVD):	10,885
Total Water Volume (gal)*:	143,892

Hydraulic Fracturing Fluid Composition:

Trade Name	Supplier	Purpose	Ingredients	Chemical Abstract Service Number (CAS #)	Maximum Ingredient Concentration in Additive (% by mass)**	Maximum Ingredient Concentration in HF Fluid (% by mass)**	Comments
Water	Operator	Carrier	Water	7732-18-5	100.00%	81.00754%	
X-Cide 207	Baker Hughes	Biocide	2-Methyl-4-Isothiazolin-3-One	2682-20-4	5.00%	0.00008%	
			5-Chloro-2-Methyl-4-Isothiazolin-3-One	26172-55-4	10.00%	0.00016	
			Crystalline Silica: Cristobalite	14464-46-1	1.00%	0.00002	
			Crystalline Silica: Quartz (SiO2)	14808-60-7	1.00%	0.00002	
			Diatomaceous Earth, Calcined	91053-39-3	60.00%	0.00097	
			Magnesium Chloride	7786-30-3	5.00%	0.00008	
			Magnesium Nitrate	10377-60-3	10.00%	0.00016	
Enzyme G-I	Baker Hughes	Breaker	Hemicellulase Enzyme Concentrate	9025-56-3	3.00%	0.00451	
			Water	7732-18-5	97.00%	0.14580	
High Perm CRB	Baker Hughes	Breaker	Ammonium Persulphate	7727-54-0	60.00%	0.00162	
			Crystalline Silica Quartz	14808-60-7	30.00%	0.00081	
Caustic Liquid, 25% Solution	Baker Hughes	Buffer	Sodium Hydroxide	1310-73-2	25.00%	0.02347	
			Water	7732-18-5	75.00%	0.07041	
BF-7L, Tote	Baker Hughes	Buffer	Potassium Carbonate	584-08-7	60.00%	0.69307	
			Potassium Hydroxide	1310-58-3	1.00%	0.01155	
			Water	7732-18-5	60.00%	0.69307	
XLW-56, 330 gal	Baker	Crosslinker	D-Glucitol	50-70-4	10.00%	0.06736	
tote	Hughes						
			Glyoxal	107-22-2	30.00%	0.20208	
			Sodium Hydroxide	1310-73-2	5.00%	0.03368	
			Sodium Tetraborate	1330-43-4	10.00%	0.06736	
GS-1L	Baker Hughes	Gel Stabilizer	Non-Hazardous Ingredient	Trade Secret	100.00%	0.47548	
GLFC-1B	Baker Hughes	Gelling Agent	Alkanes / Alkenes	Multiple	45.00%	0.37717	
			Guar Gum	9000-30-0	50.00%	0.41908	
Mg Light, 30/50	Baker Hughes	Proppant	Magnesium Iron Silicate	1317-71-1	10.00%	1.33772	
			Magnesium Silicate	1343-88-0	60.00%	8.02633	
			Silicon Dioxide (Amorphous As Glass)	7631-86-9	40.00%	5.35089	
SinterBlast Bauxite, 40/120, 3300#	Baker Hughes	Proppant	Alfa-Alumina	1344-28-1	100.00%	0.66846%	
			Hematite	1317-60-8	15.00%	0.10027%	
			Maghemite	1309-38-2	2.00%	0.01337%	
InFlo 75M, 330 gl tote	Baker Hughes	Surfactant	Citrus Terpenes	94266-47-4	30.00%	0.03646%	
			Isopropanol	67-63-0	30.00%	0.03646%	



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DOGGR Regulates CA Oil, Gas, Geothermal

- Permitting agency for oil and gas wells in the State. Oversee well constructions and abandonments to protect CA groundwater.

- Class II Injection Well Program to regulate injecting fluids for oil or gas operations. Strict requirements for well completion.

- No specific regulations (yet) for hydraulic fracturing. In Progress…

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Recent CA Action / Legislation

- Gov. Brown increasing DOGGR staff by 18 to step up regulation and permitting process.

- DOGGR released preliminary regulations (Discussion Draft) after holding State-wide workshops (*www.conservation.ca.gov/dog/Pages/Index.aspx*)

- 2012 SB 1054 (Pavley) – Failed. Would require notification of oil/gas drilling if the well will penetrate an underground water source.

- 2012 AB 591 (Wieckowski) – Failed. Would require disclosure of fracking chemicals and locations of fracking operations in the State.

- 2012 AB 972 (Butler) – Failed. CA moratorium on fracking .

- 2013 SB 4 (Pavley) and AB 7 (Wieckowski). Defines fracking, requires disclosure of nearby faults, requires State to develop fracking rules, requires notification of fracking jobs and chemicals.

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Local Concern over Fracking

Protesters head to Culver City meeting to decry fracking

June 12, 2012 | 10:43 pm

LA Times

Inglewood Oil Field - LAWeekly.com

Oil drilling in Carson won't use `fracking'

Press Telegram

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

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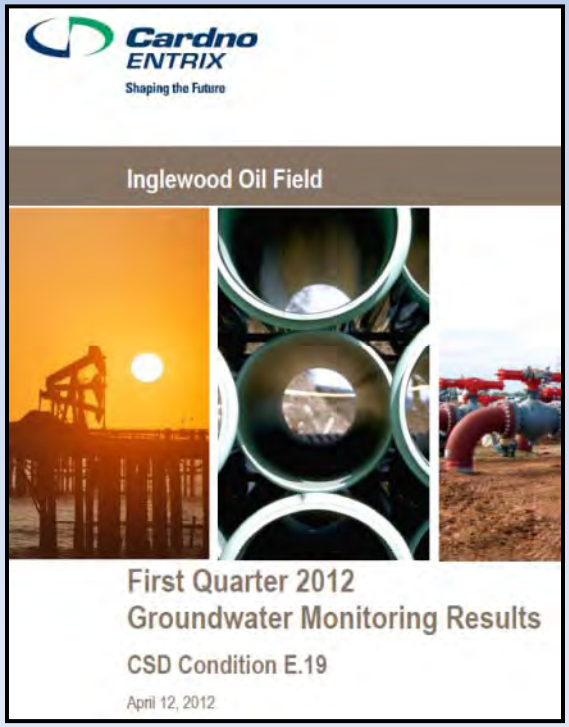
Inglewood Oil Field Fracking Controversy

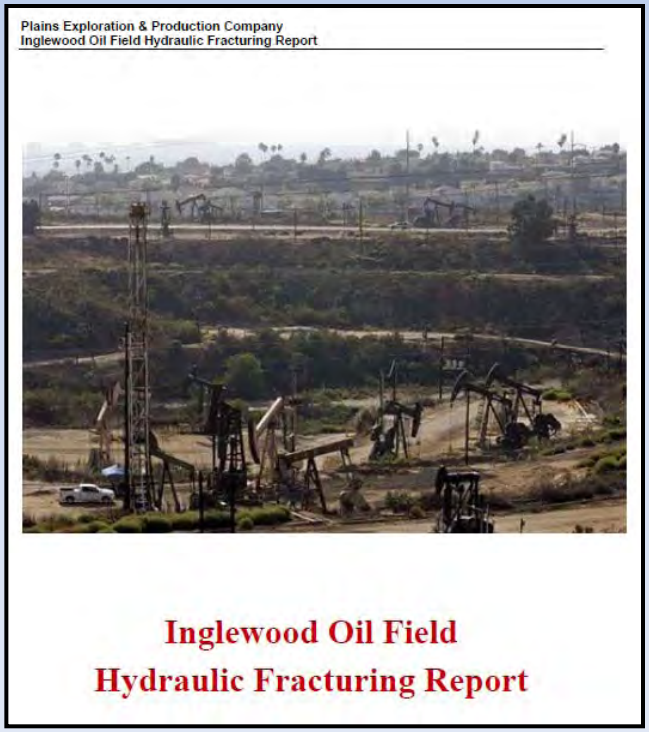
Los Angeles Times | LOCAL

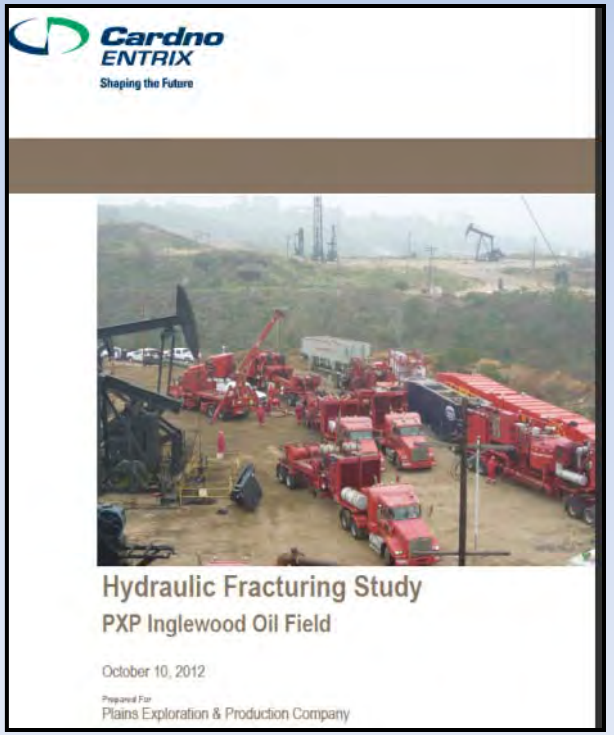
LOCAL U.S. WORLD BUSINESS SPORTS ENTERTAINMENT HEALTH LIVIN

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.







Lawsuit Filed on CA Fracking over CEQA

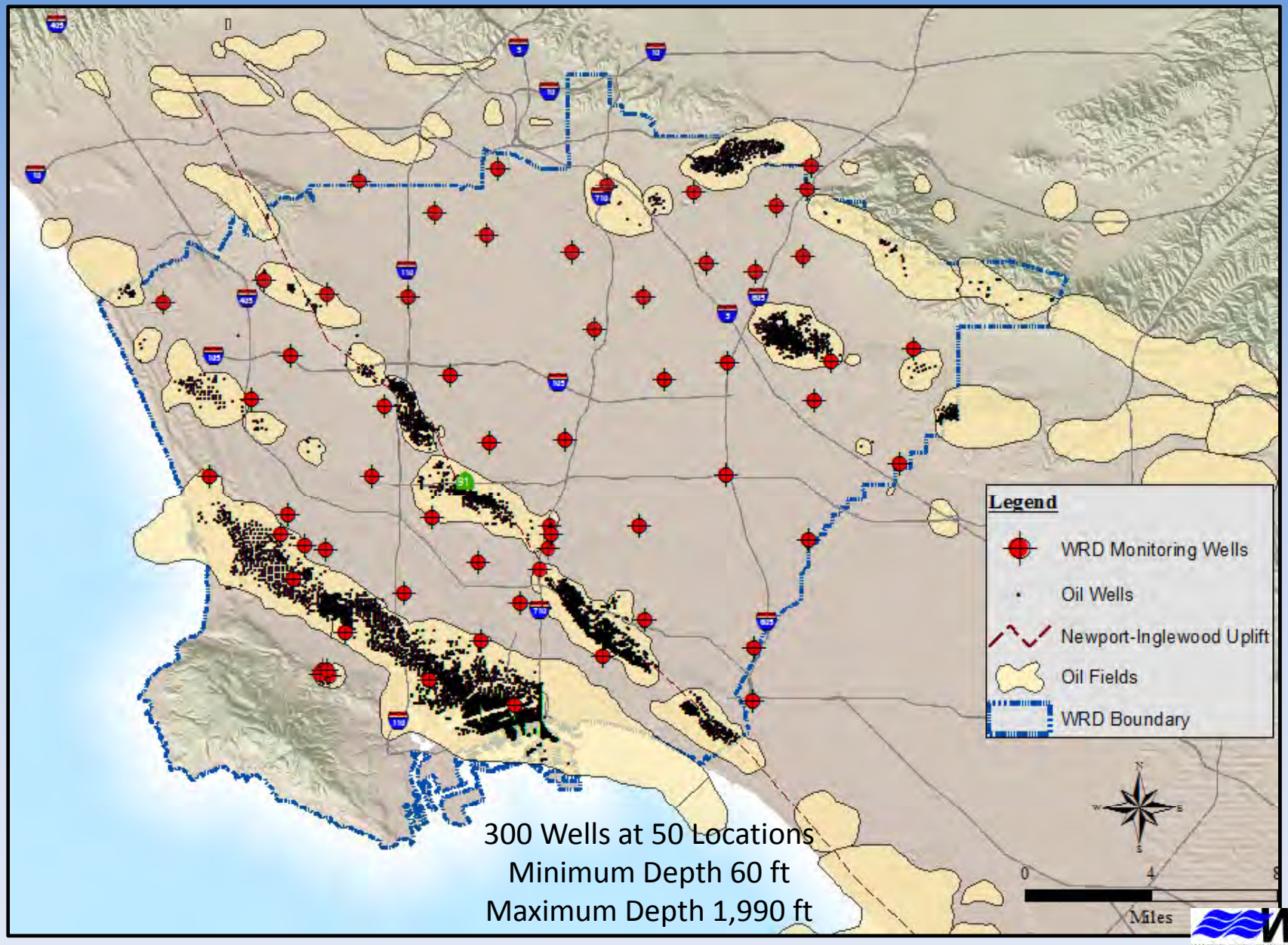
Los Angeles Times | LOCAL

Environmentalists sue California oil regulators over fracking

October 16, 2012 | 2:27 pm

A coalition of environmental advocates has filed suit against California oil regulators over the controversial method of oil extraction called hydraulic fracturing, accusing state officials of illegally "rubber-stamping" drilling permits without performing key environmental reviews.

WRD Monitoring Wells & Oil Fields



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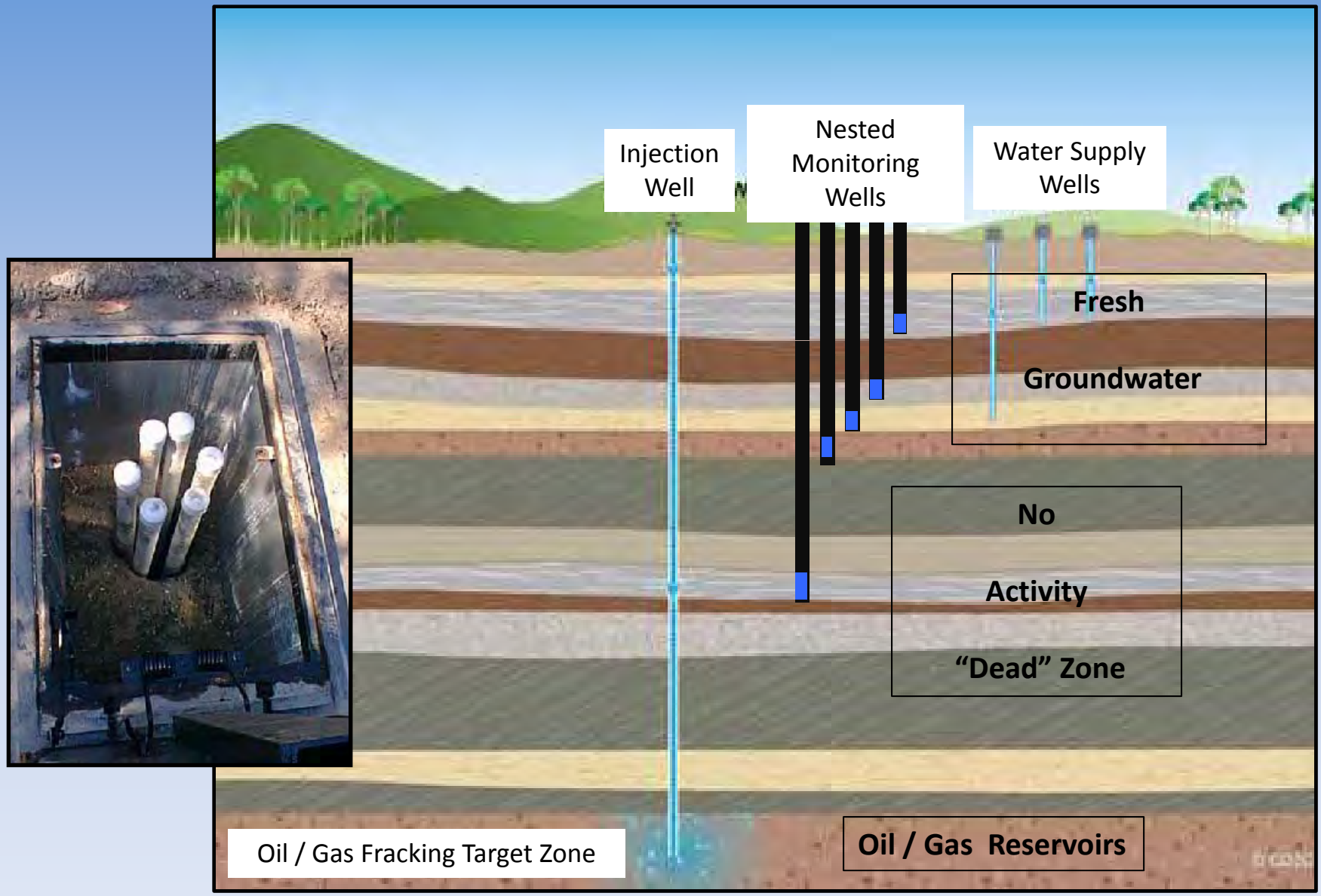
WRD Nested Monitoring Wells



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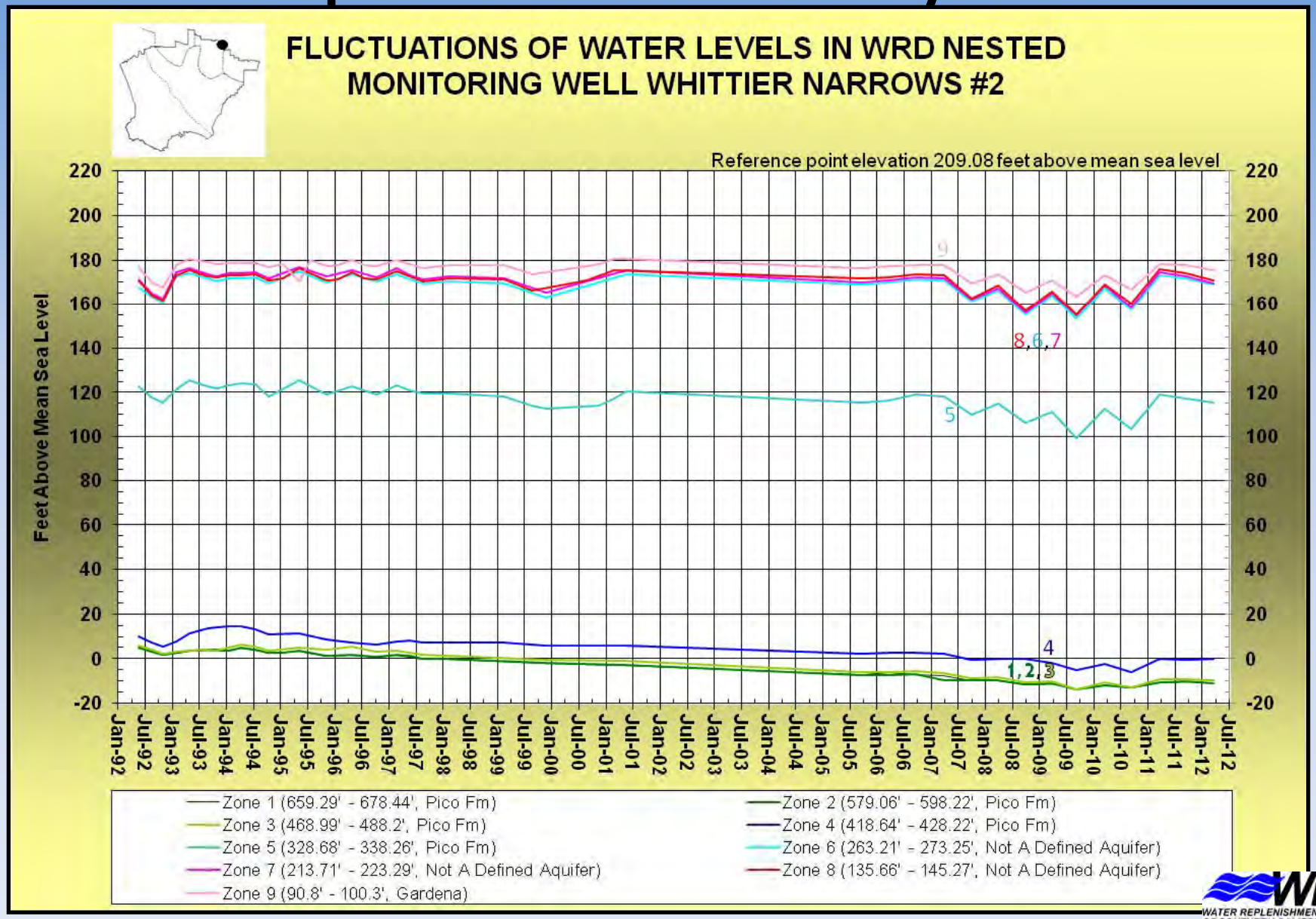
Groundwater Level Hydrograph:
Deeper Zones Anomalously Low



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GROUNDWATER QUALITY TESTING

Major Minerals

- Total Dissolved Solid (TDS)
- Cation Sum
- Anion Sum
- Iron, Total, ICAP
- Manganese, Total, ICAP/MS
- Turbidity
- Alkalinity
- Boron
- Bicarbonate as HCO3, Calculated
- Calcium, Total, ICAP
- Carbonate as CO3, Calculated
- Hardness (Total, as CaCO3)
- Chloride
- Fluoride
- Hydroxide as OH, Calculated
- Langelier Index - 25 degree
- Magnesium, Total, ICAP
- Mercury
- Nitrate-N by IC
- Nitrite, Nitrogen by IC
- Potassium, Total, ICAP
- Sodium, Total, ICAP
- Sulfate
- Surfactants
- Total Nitrate, Nitrite-N, CALC
- Total Organic Carbon

General Physical Properties

- Apparent Color
- Lab pH
- Odor
- pH of CaCO3 saturation(25C)
- pH of CaCO3 saturation(60C)
- Radon
- Specific Conductance

Metals

- Aluminum, Total, ICAP/MS
- Antimony, Total, ICAP/MS
- Arsenic, Total, ICAP/MS
- Barium, Total, ICAP/MS
- Beryllium, Total, ICAP/MS
- Chromium, Total, ICAP/MS
- Hexavalent Chromium (Cr VI)
- Cadmium, Total, ICAP/MS
- Copper, Total, ICAP/MS
- Lead, Total, ICAP/MS
- Nickel, Total, ICAP/MS
- Selenium, Total, ICAP/MS
- Silver, Total, ICAP/MS
- Thallium, Total, ICAP/MS
- Zinc, Total, ICAP/MS

Volatile Organic Compounds

- Trichloroethylene (TCE)
- Tetrachloroethylene (PCE)
- 1,1-Dichloroethylene
- cis-1,2-Dichloroethylene
- trans-1,2-Dichloroethylene
- Chloroform (Trichloromethane)
- Carbon Tetrachloride
- 1,1-Dichloroethane
- 1,1,2-Trichlorotrifluoroethane-Freon113
- Fluorotrichloromethane-Freon11
- Isopropylbenzene
- n-Propylbenzene
- m,p-Xylenes
- Methylene Chloride
- Toluene
- Dichlorodifluoromethane
- Benzene
- Ethyl benzene
- MTBE
- Perchlorate
- sec-Butylbenzene
- 1,1,1,2-Tetrachloroethane
- 1,1,1-Trichloroethane
- 1,1,2,2-Tetrachloroethane
- 1,1,2-Trichloroethane
- 1,1-Dichloropropene
- 1,2,3-Trichlorobenzene
- 1,2,3-Trichloropropane
- 1,2,4-Trichlorobenzene
- 1,2,4-Trimethylbenzene
- 1,3,5-Trimethylbenzene
- 1,3-Dichlorobenzene
- 1,3-Dichloropropane
- 2,2-Dichloropropane
- 2-Butanone (MEK)
- 4-Methyl-2-Pentanone (MIBK)
- Bromobenzene
- Bromochloromethane
- Bromodichloromethane
- Bromoform
- Bromomethane (Methyl Bromide)
- Chlorobenzene
- Chlorodibromomethane
- Chloroethane
- Chloromethane(Methyl Chloride)
- cis-1,3-Dichloropropene
- Dibromomethane
- Hexachlorobutadiene
- Naphthalene
- n-Butylbenzene
- n-Propylbenzene
- o-Dichlorobenzene (1,2-DCB)
- o-Xylene
- p-Chlorotoluene
- p-Dichlorobenzene
- p-Isopropyltoluene
- Styrene
- tert-Butylbenzene
- trans-1,3-Dichloropropene
- Vinyl chloride (VC)

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

Have not yet sampled specifically for fracking chemicals

Water Quality Results near Oil Fields

- Generally Good Water Quality or Typical of Greater Depths (color, odor, salinity).
- A few wells have elevated concentrations at depth:
  - Boron
  - Arsenic
  - TCE
  - TBA

- Sources have not yet been identified. Could be natural or may be associated with current or legacy oil field operations at surface or reservoirs. Difficult to determine.
- Additional testing for exotic compounds may help determine sources. Penn State Univ. recent study found radium and barium related to fracking flowback water in Marcellus Shale.

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Fracking 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, pollutants, 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.

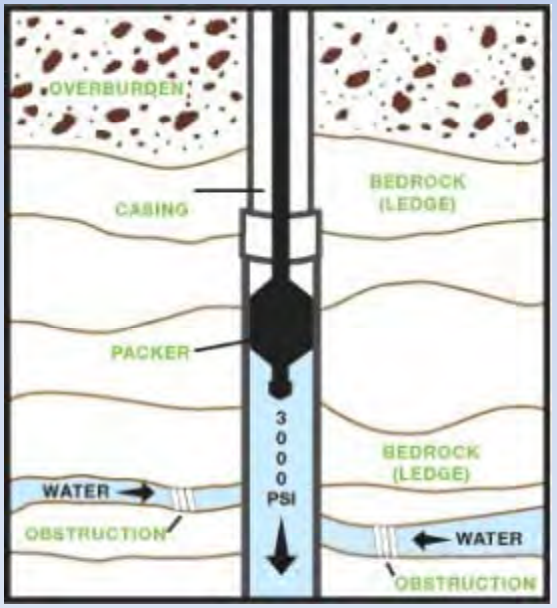
Hydraulic fracturing (hydrofracturing) is sometimes an acceptable well development and redevelopment method when properly performed. Good quality water shall be used in hydrofracturing. The water shall be disinfected prior to introduction into a well. Material used as 'propping' agents shall be free 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.

Hydrofracturing

Hydrofracturing is a water well development/rehabilitation method used to increase the yields of low-production water wells completed in rock where the fracture/joint systems are so poorly developed or so tight that little or no water can move through them.

Hydrofracturing of water wells has been used in the USA since about the late 1980s on a wide spread basis. The primary application has been in 6 inch water wells of 250 to 600 feet deep (75 to 180 meters). These wells are primarily for domestic use with some applications in 8" & 10" wells for commercial, industrial and municipal uses. The most common geology found in wells that are hydrofractured, is basement igneous type rocks such as gabbros, granites, schists, etc. There are some areas where shales and slates predominate as well as others with limestone and sandstone. Most "fracturing" occurs between 1,000 to 2,500 psi in hard rocks and 300 to 800 psi in softer rocks. The most common pumping flow rates are between 65 and 120 gallons per minute. Propants to keep fractures open; such as sand, glass beads, etc., were experimented with early on in development but now are seldom used because of their uncertain benefit, if any.

Wells can become plugged by natural sediments



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

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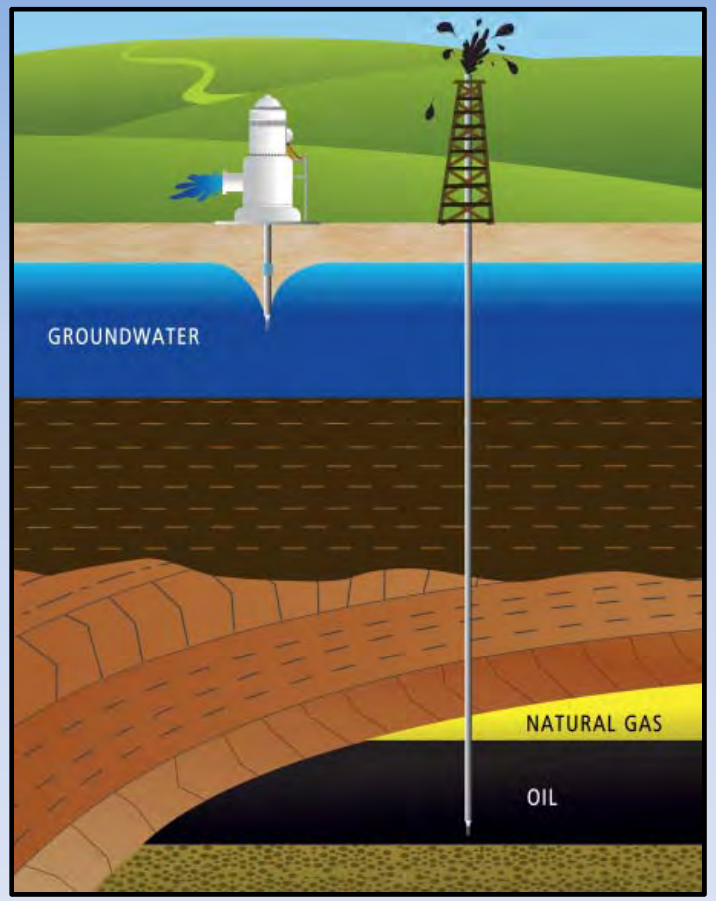
Summary

- Hydraulic Fracturing is a method used over 50 years to enhance oil and gas recovery. Newer methods are proving fruitful but controversial nationwide.

- Fresh groundwater, oil and natural gas have been successfully produced in the CBWCB 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 do not necessarily affect the other.

- WRD continues monitoring and working with regulatory agencies for responsible fracking rules. We don't want to unnecessarily hamper the energy industry, we just want to protect the groundwater quality in our service area.



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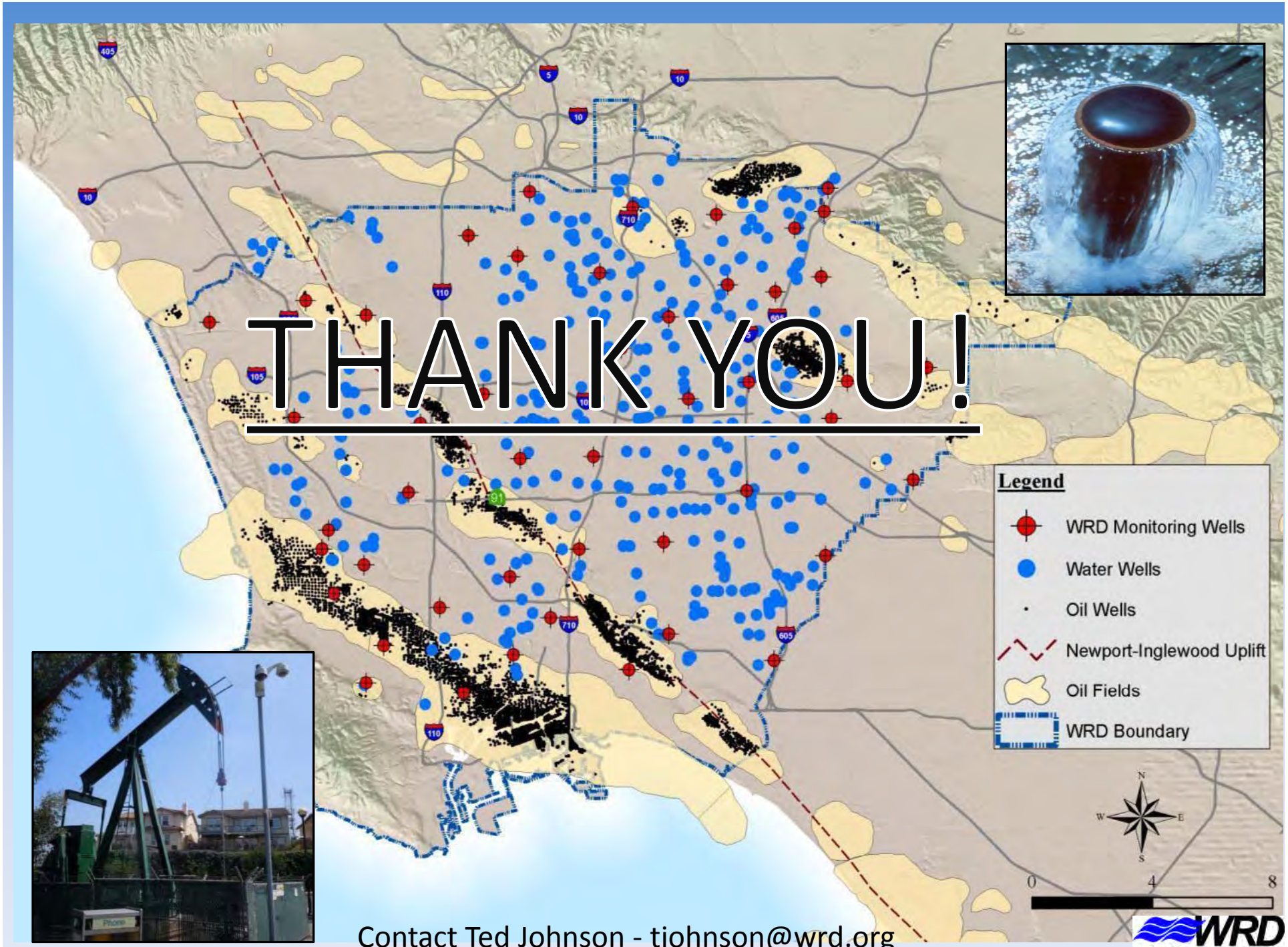
THANK YOU!
Legend
WRD Monitoring Wells
Water Wells
Oil Wells
Newport-Inglewood Uplift
Oil Fields
WRD Boundary
0
4
8
Contact Ted Johnson - tjohnson@wrd.org
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