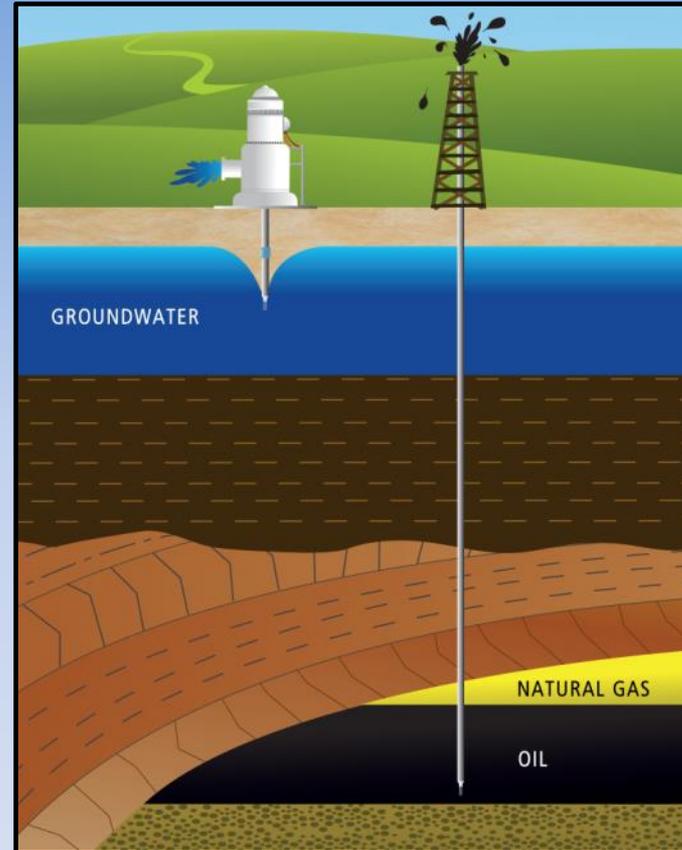
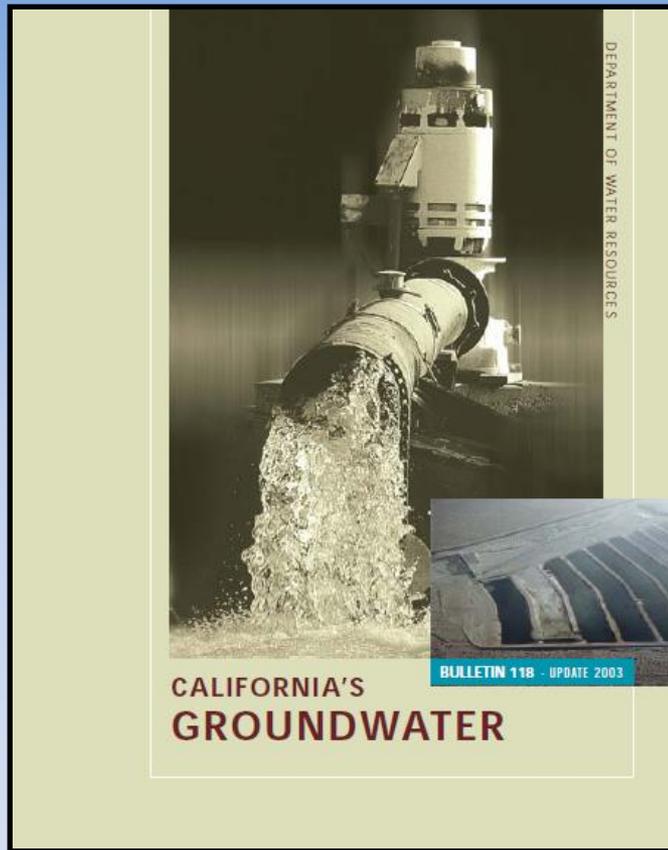


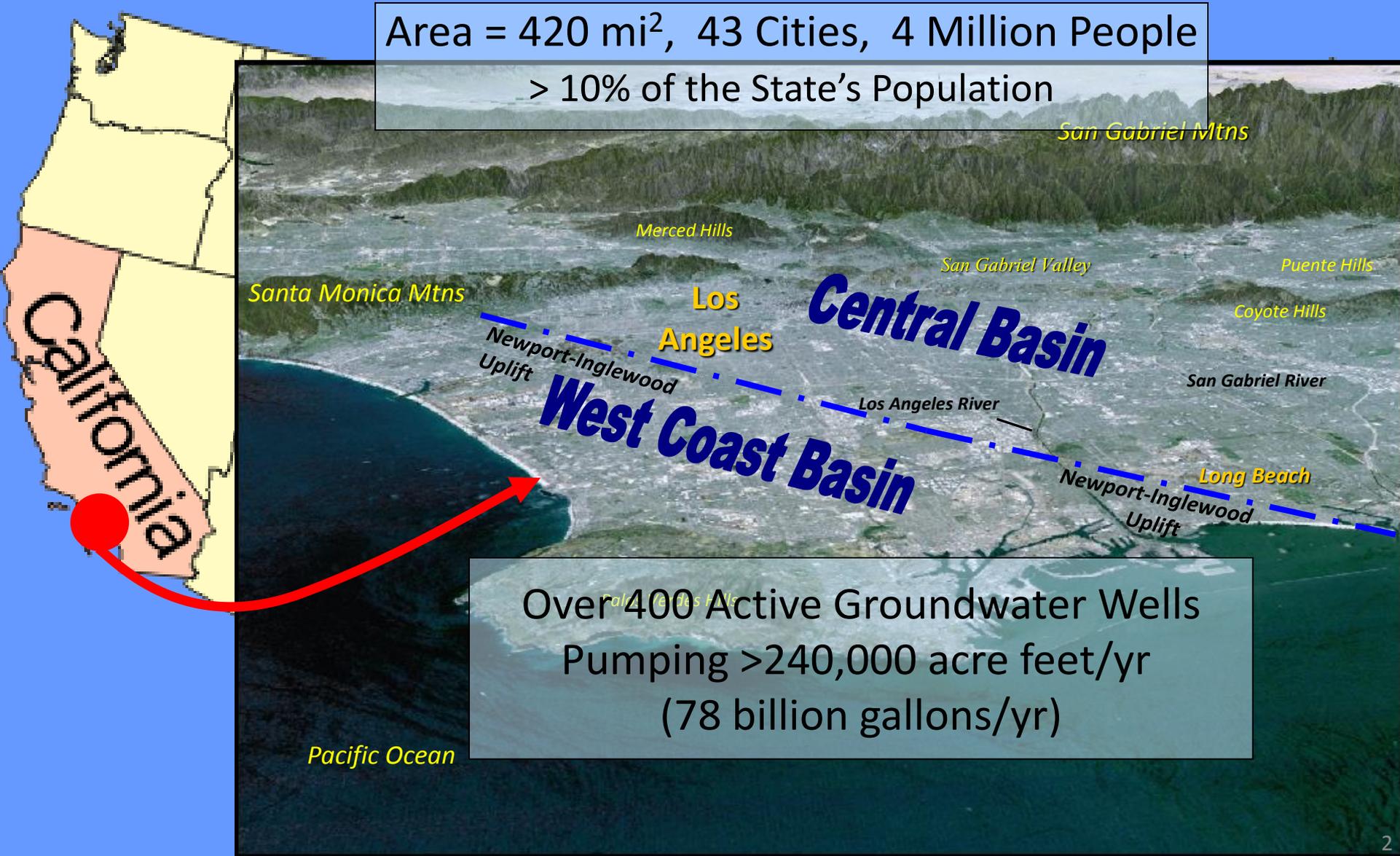
Oil, Gas and Groundwater Production in the Los Angeles Basin



By: Ted Johnson, Chief Hydrogeologist
Water Replenishment District of Southern California
August 25, 2014

Central Basin and West Coast Basin (CBWCB)

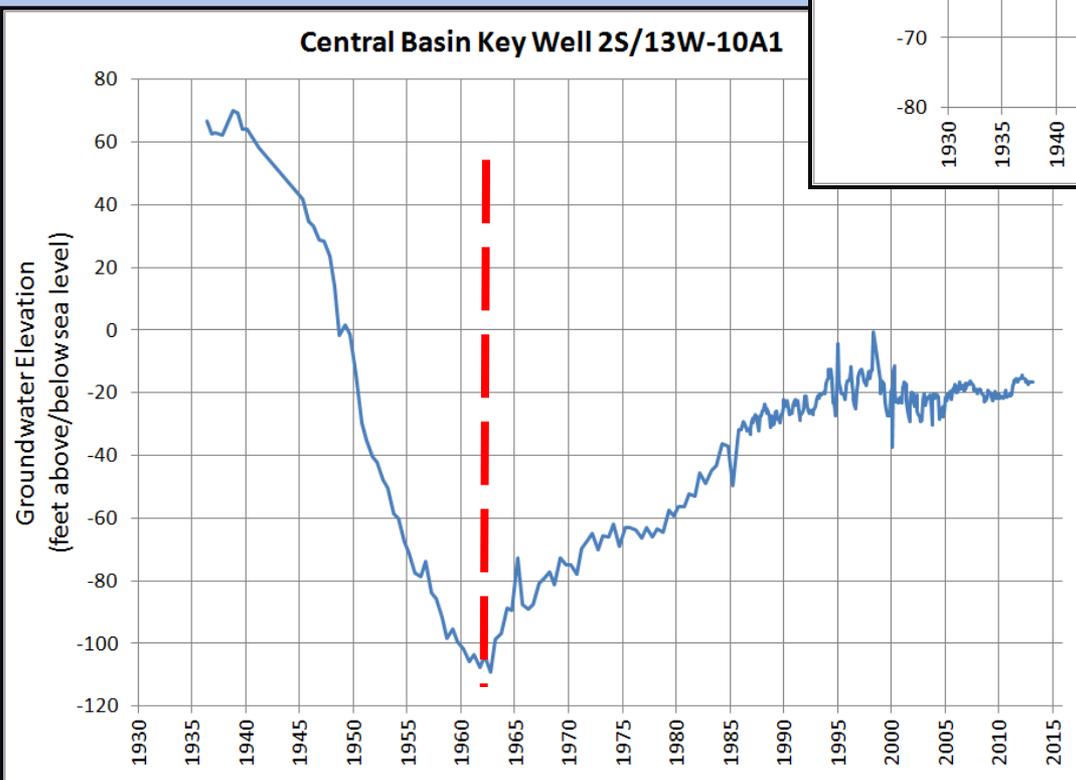
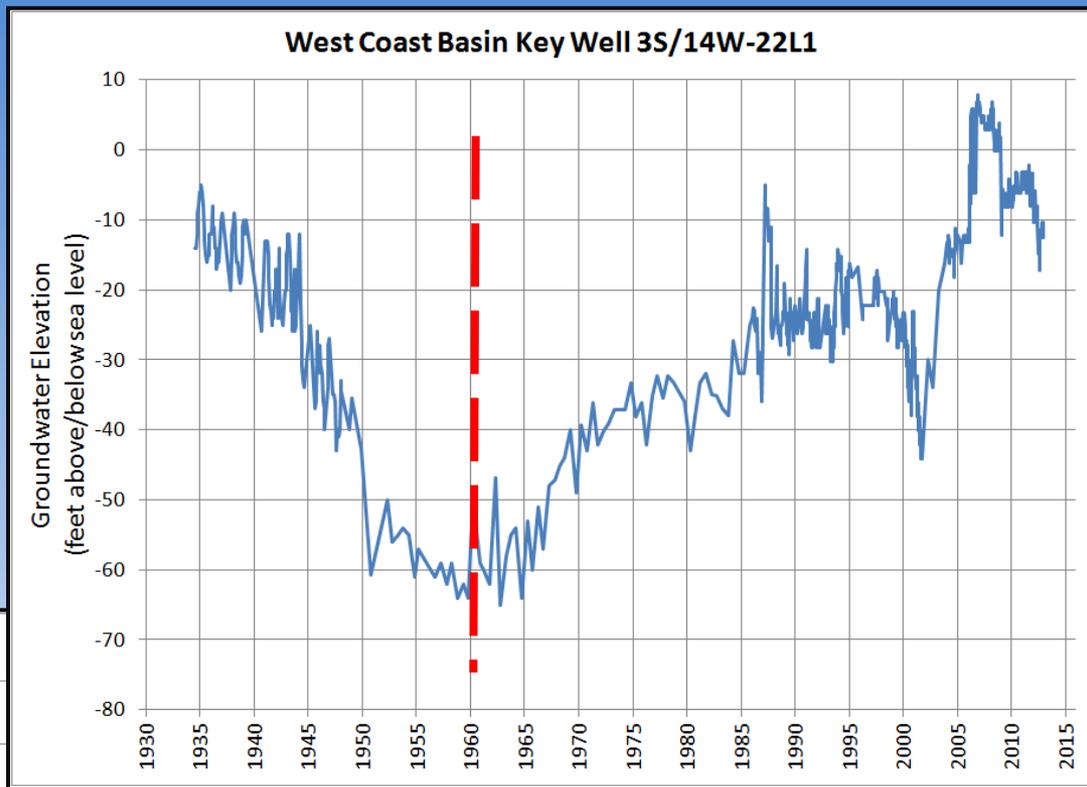
Area = 420 mi², 43 Cities, 4 Million People
> 10% of the State's Population



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

Severe Overdraft before 1960

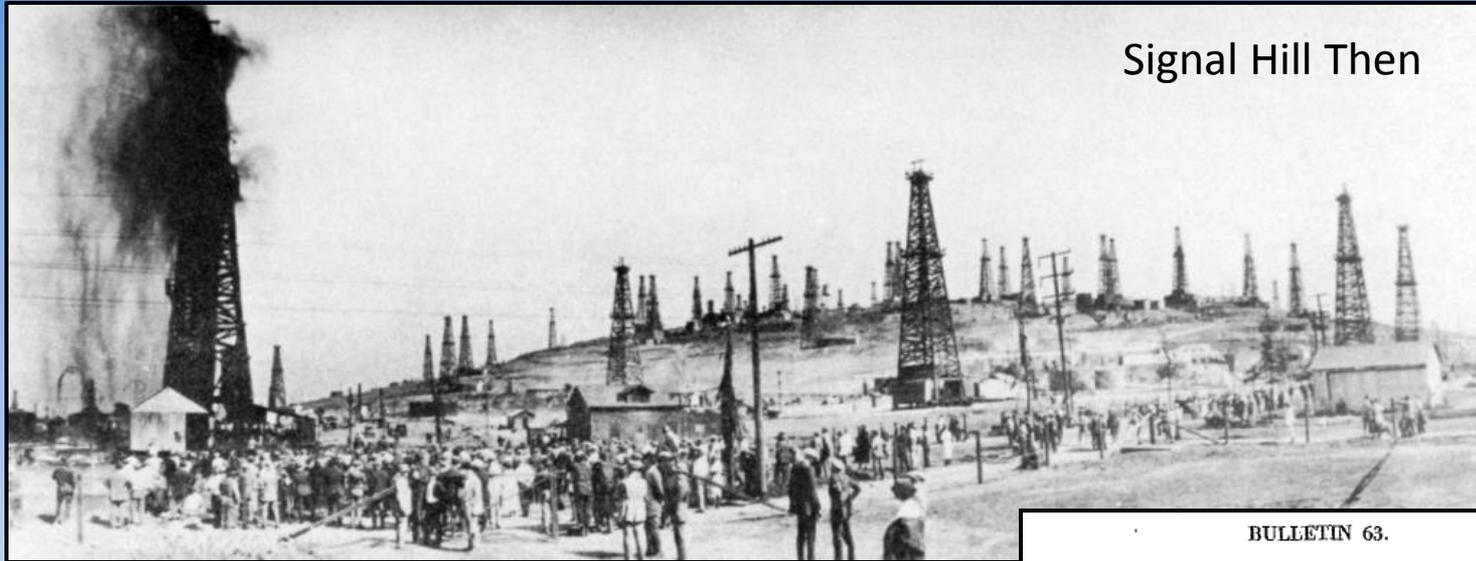
- 💧 Plunging Water Levels
- 💧 Seawater Intrusion
- 💧 Wells Went Dry
- 💧 Resource being Depleted



Recovery Due to...

- 💧 Adjudication of Basins.
- 💧 Seawater Barrier Wells.
- 💧 Formation of WRD to provide Managed Aquifer Recharge using Imported and Recycled Water. "W.I.N." program to replace imported water.

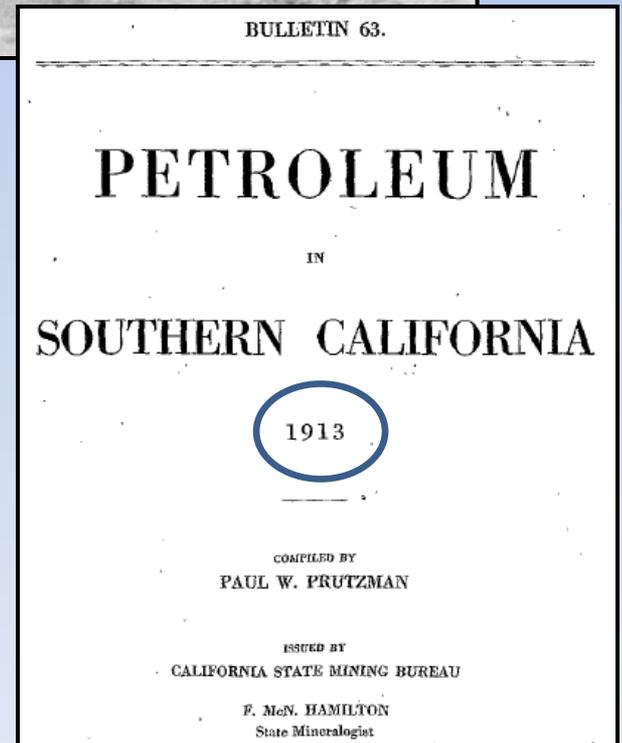
But There's Oil & Gas in the Basins too



Signal Hill Then



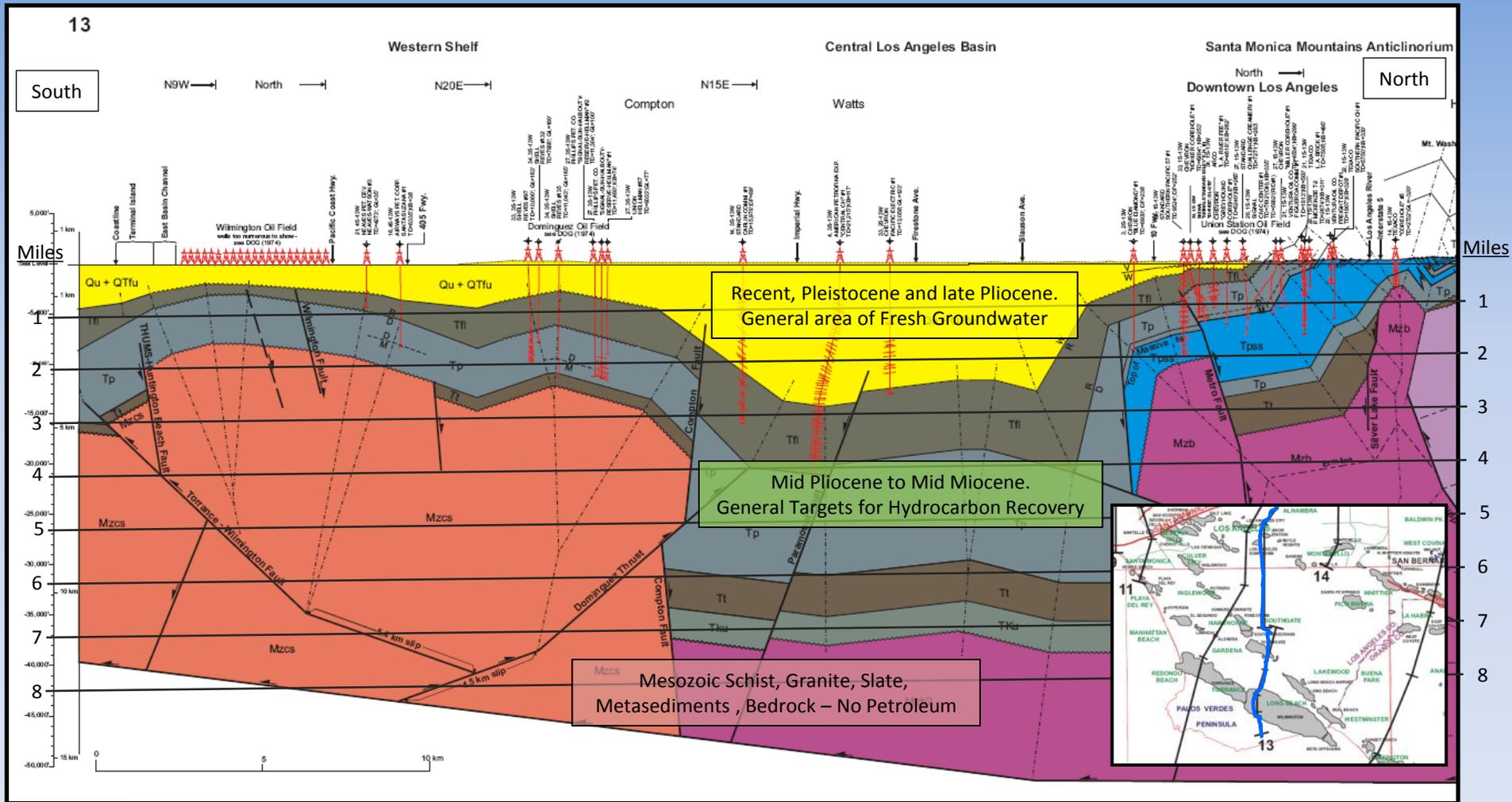
Signal Hill Now



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

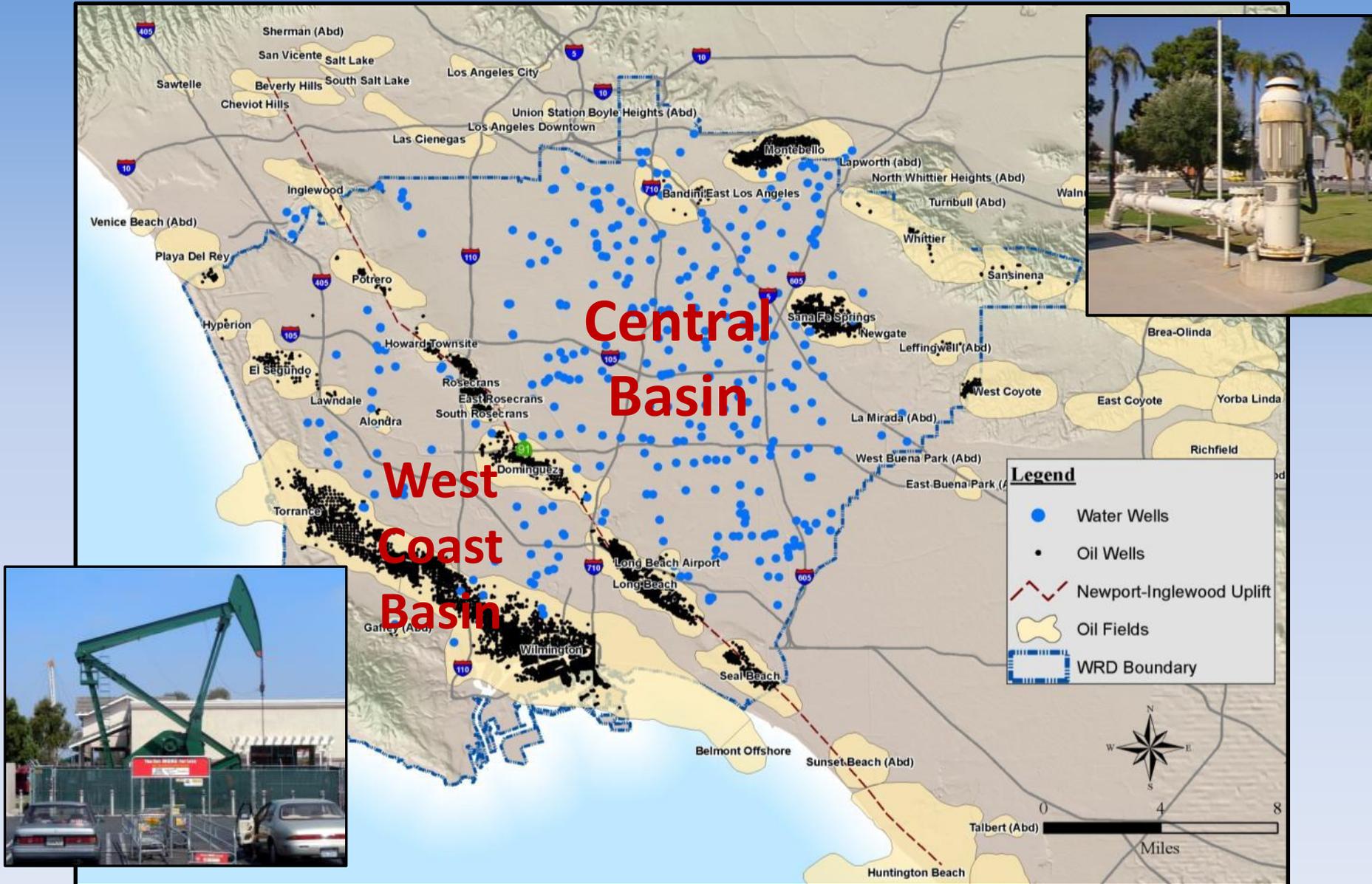


N-S Cross-Section through WRD showing Hydrocarbon and Groundwater Target Zones

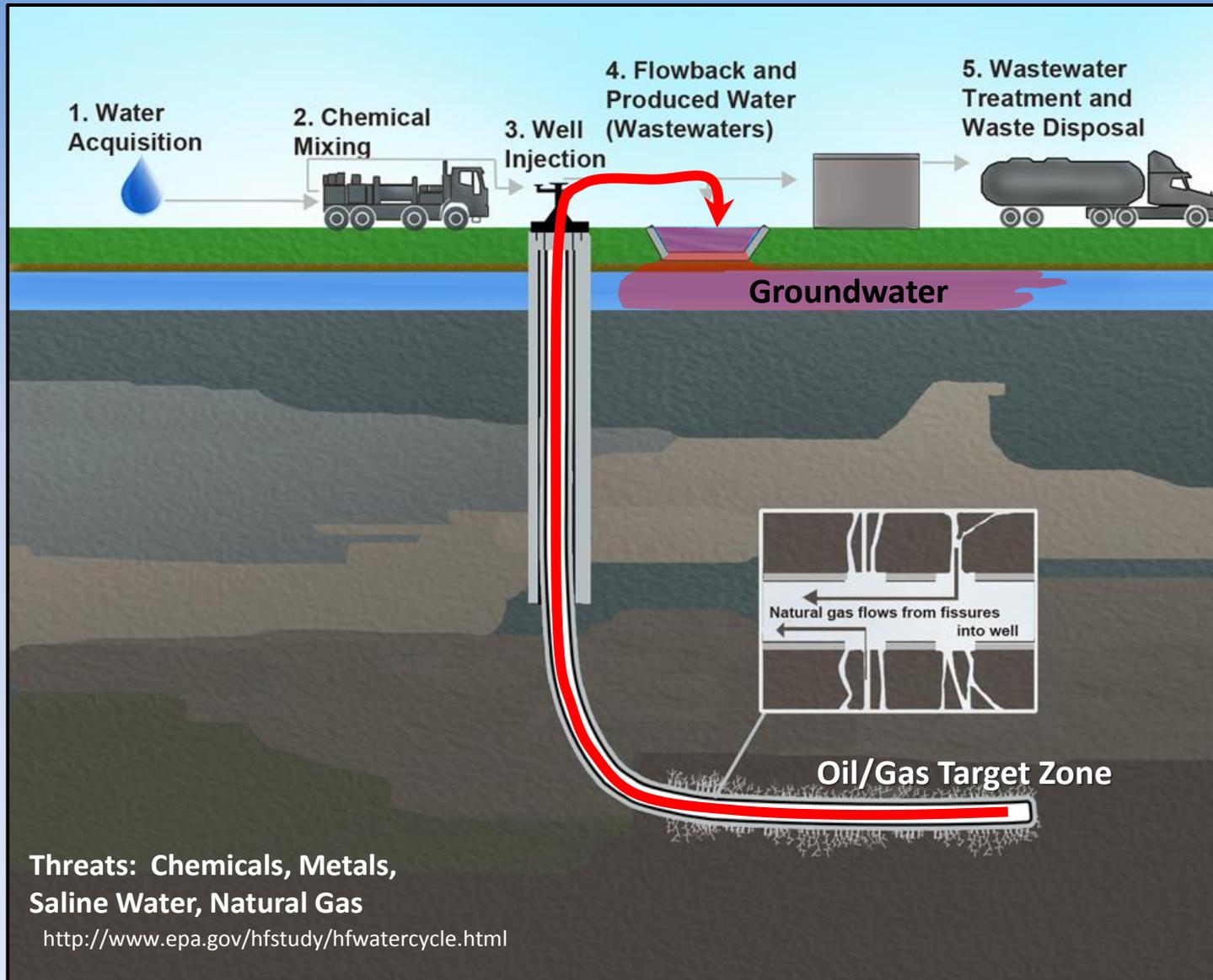


Modified from Davis – Namson, 1998
Southern California Cross Section Study

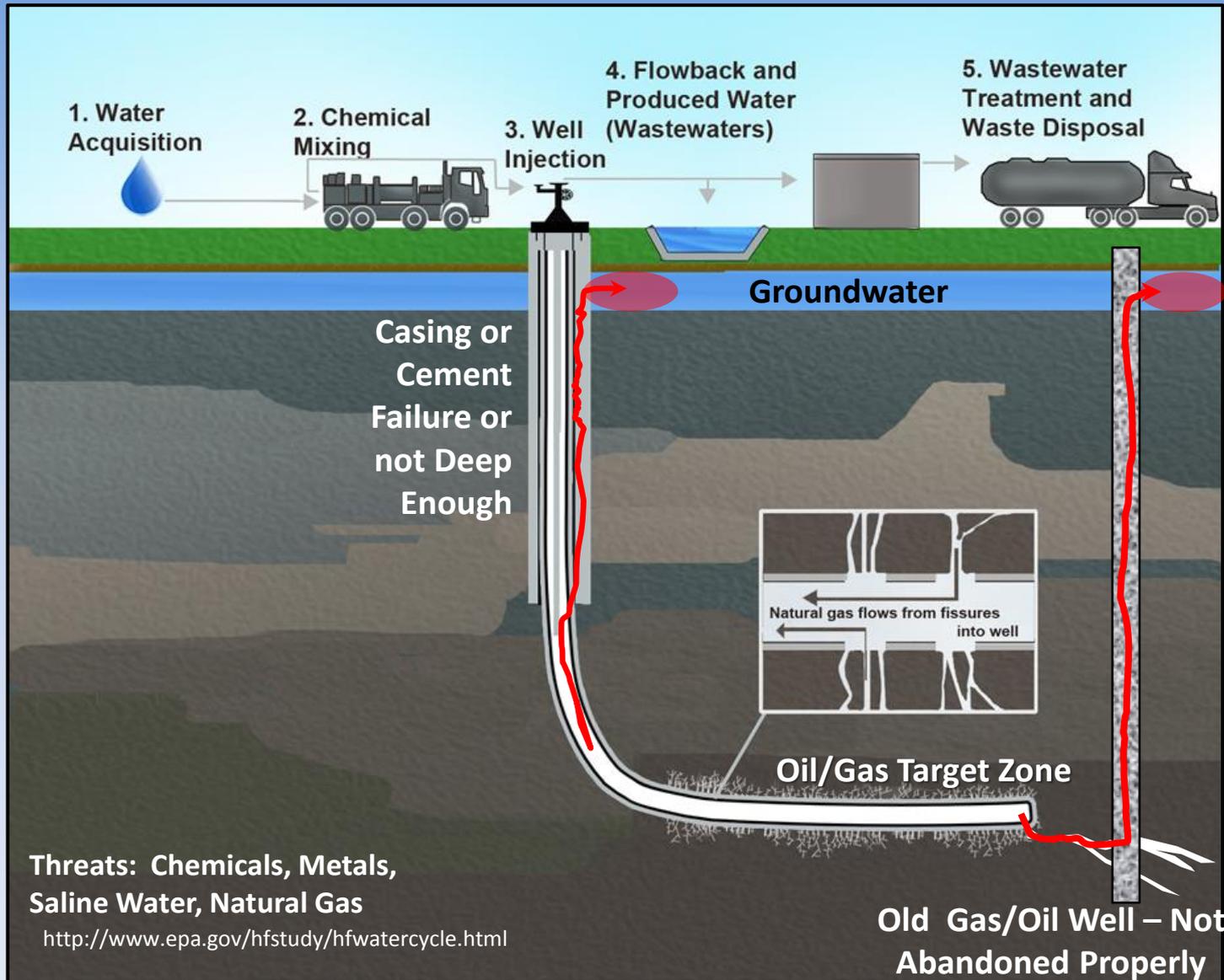
Oil Wells & Water Wells in LA Over 100 Years of Co-Existing



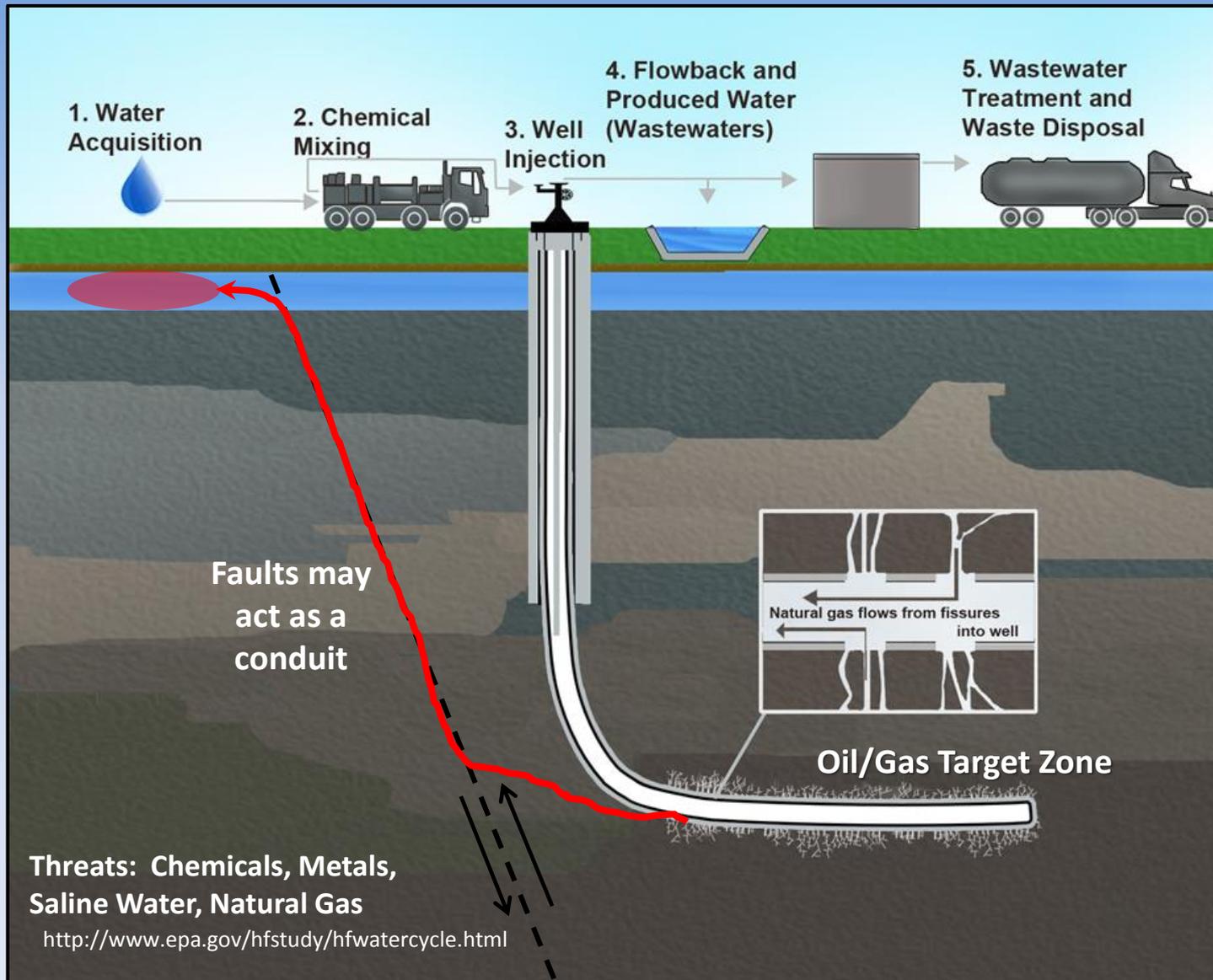
Potential Risks to Groundwater from Petroleum Operations and Well Stimulation



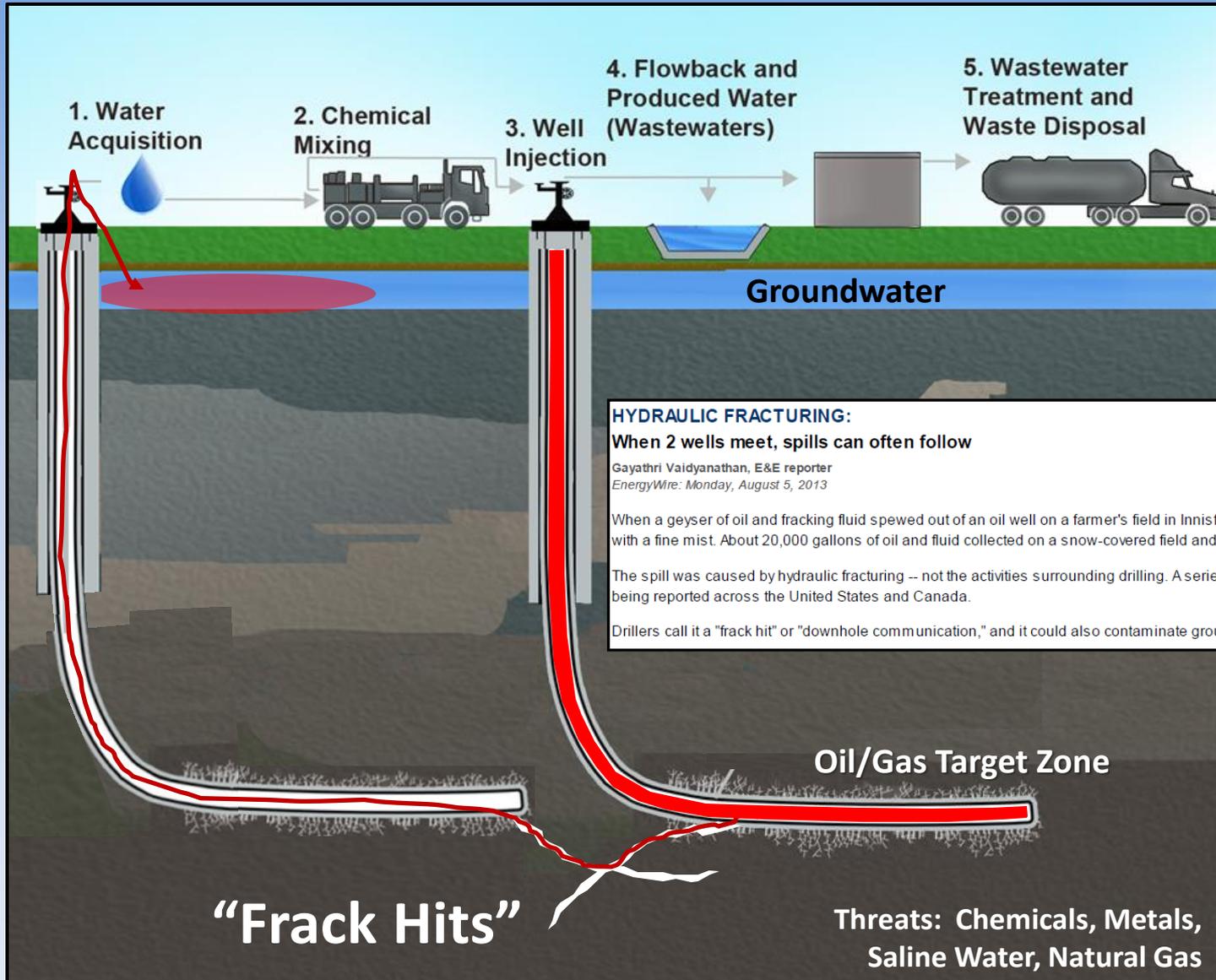
Potential Risks to Groundwater from Petroleum Operations and Well Stimulation



Potential Risks to Groundwater from Petroleum Operations and Well Stimulation

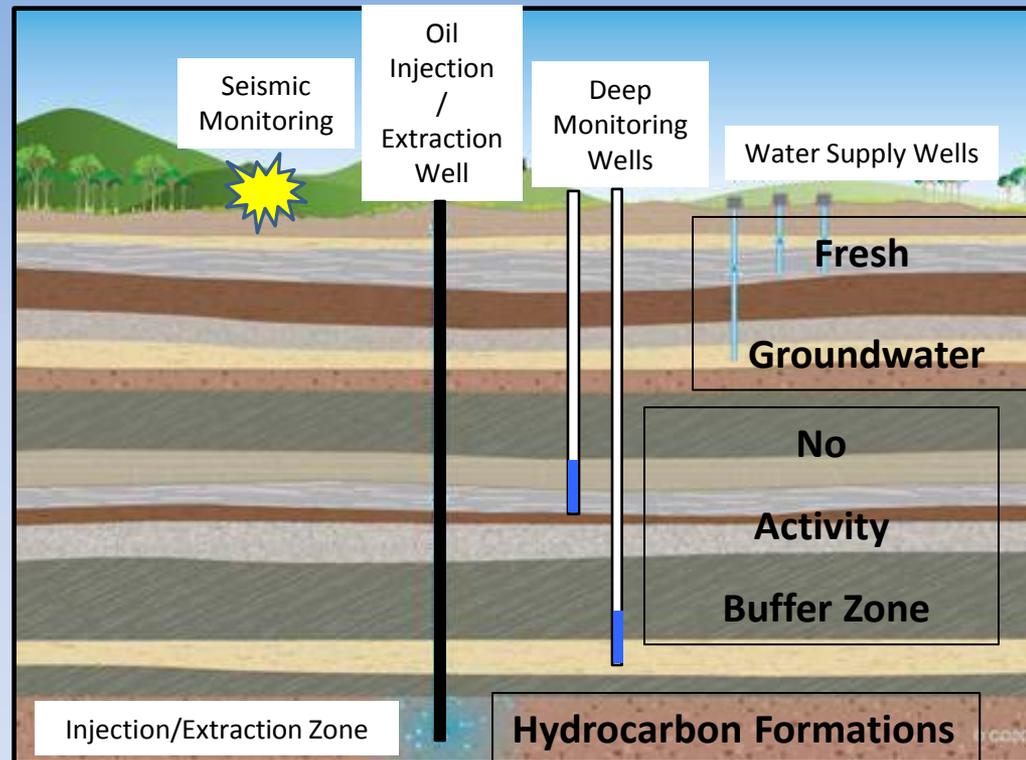


Potential Risks to Groundwater from Petroleum Operations and Well Stimulation

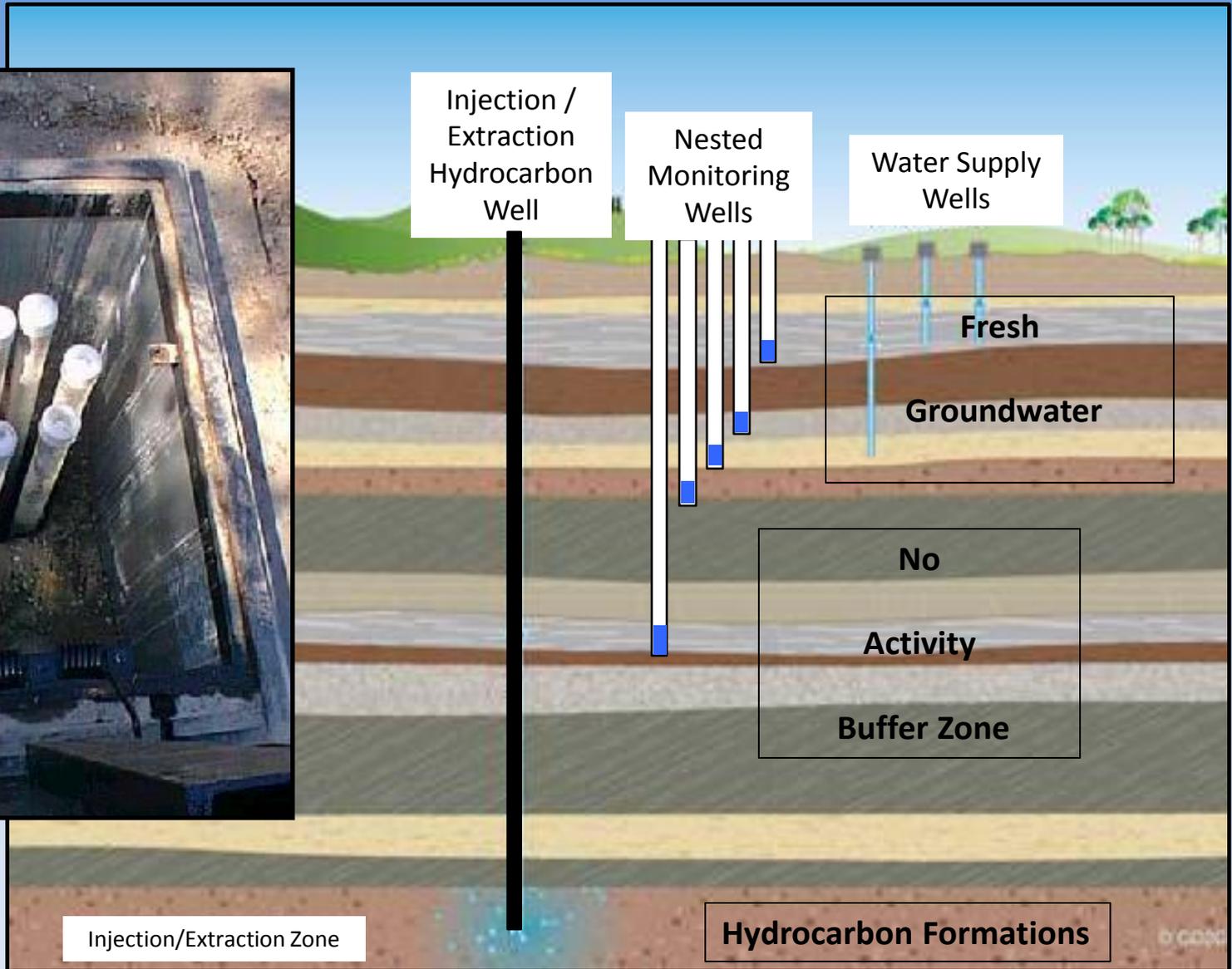


Some Ways to Minimize Risk to Groundwater

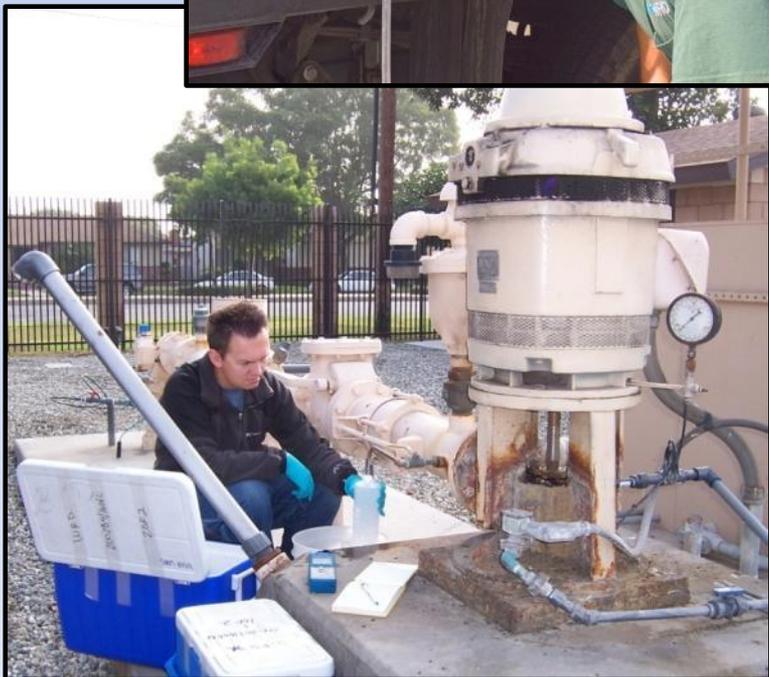
- â Baseline Monitoring.
- â Review well design to prevent leaks or fix old wells.
- â Identify artificial pathways and seal off or avoid.
- â Proper collection and disposal of wastes.
- â Know where fractures are and avoid “Frack Hits”
- â Monitor injection pressures, buffer zones, flowback ponds, fresh groundwater, seismic monitoring, groundwater basin and reservoir characterization.



WRD Nested Monitoring Wells



WRD Field Crew Samples Wells 2x/yr



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)
Manganese, 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
1,2-Dichloroethane
Fluoromethane
Carbon 113
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-Trimethylbenzene
1,2-Dichloropropane
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
o-Chlorotoluene
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 for from each sample. Over 60,000 results per year.

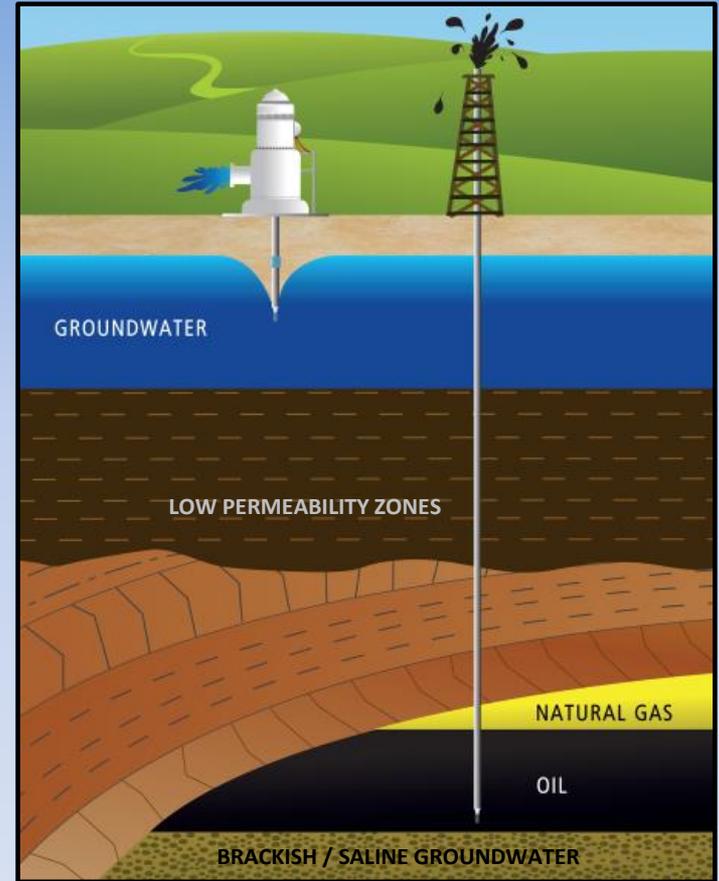
Groundwater Quality Results near Oil Fields

- Generally Good Water Quality.
- A few wells have elevated concentrations of some chemicals, such as:
 - Arsenic, Barium, Boron
 - Methane, Surfactants
 - Tert-Butyl Alcohol (TBA)
 - TDS/Chloride
 - Color/Odor
- These can be found in groundwater in non-oil production areas too.
- Either naturally occurring, or from surface releases, or from oil field operations, or from other sources. Difficult to determine.
- Additional testing / analyses may be useful to confirm results and help identify natural or human sources.



Summary

- 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 (buffer zone), so that with appropriate precaution, construction, regulation and monitoring, the activities in one should not affect the other.
- Responsible model groundwater monitoring criteria developed under SB4 will help ensure well stimulation practices are protective of fresh groundwater resources.
- WRD looks forward to continue participating in the process and assisting in any way possible.

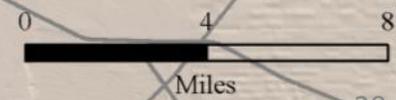


THANK YOU!



Legend

-  WRD Monitoring Wells
-  Water Wells
-  Oil Wells
-  Newport-Inglewood Uplift
-  Oil Fields
-  WRD Boundary



Contact Ted Johnson - tjohnson@wrd.org