



Water Allocation in CA: Environmental Considerations [in the Oil & Gas Industry]

**Rationalizing the Allocation of California Water Workshop
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Outline

- Environmental Uses of Water
- California's Oil and Gas Industry
 - Water Use
 - Wastewater Generation and Management
- Opportunities

Environmental Uses of Water

Environmental flows, aka *minimum flows*, are the volumes of water formally allocated for the benefit of the environment and not, for example, for economic purposes.

Lake Tahoe, Source: Christian Abend via Wikimedia



Long-billed Curlew in Marin County, Source: HarmonyOnPlanetEarth via Wikimedia

Kern River, Source: Roger Howard via Wikimedia



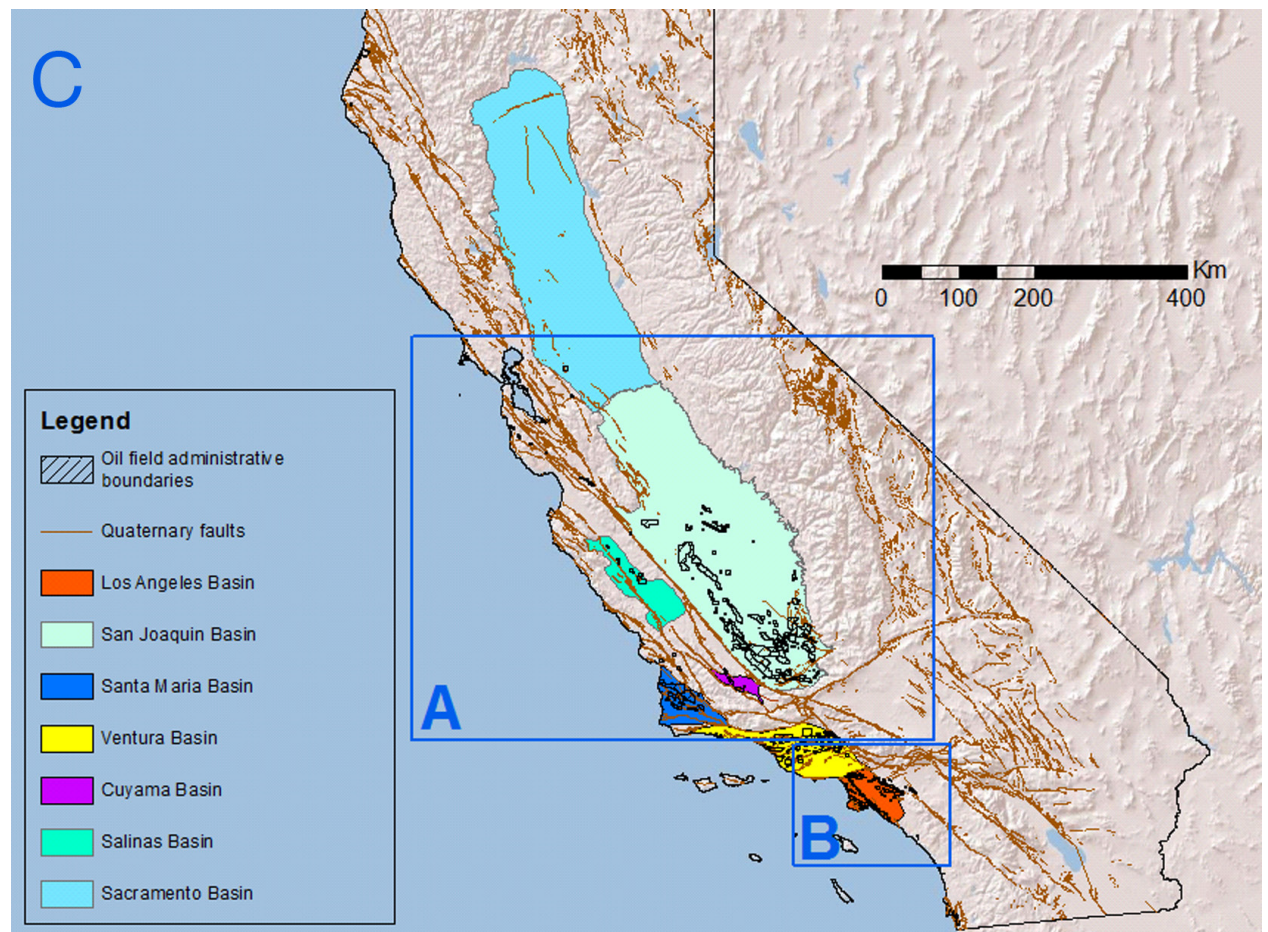
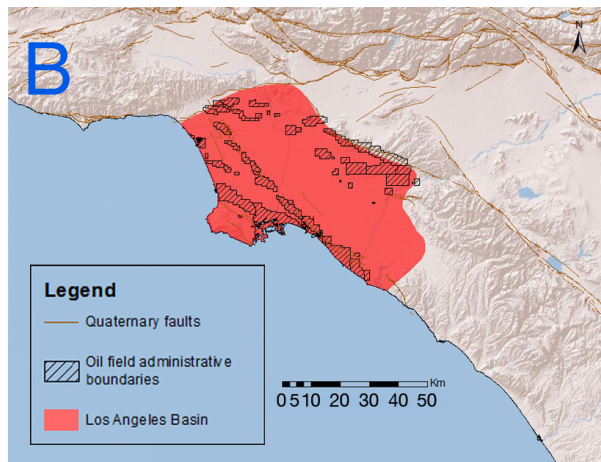
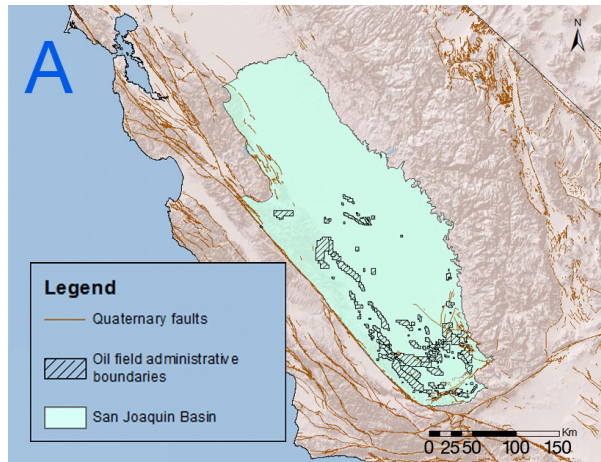
Environmental Uses of Water

- It's more than the fish ...
 - Lakes & Riparian Ecosystems & Wetlands provide
 - Spawning grounds and nurseries
 - GHG sequestration
 - Flood control
 - Water and food for terrestrial wildlife
 - Genetic diversity and medicinal compounds
- Wild and scenic landscapes → aesthetic & recreational value
- Difficult (if not impossible) to capture water's full value
- Most environmental water use is non-consumptive

But let's talk about water in oil & gas

California's Oil & Gas Industry

- Many visible oil and tar seeps
- Early exploration and production in 2nd half of 19th century
- Oil boom started around 1900 in Kern County and LA basin
- Crude oil production declining since ~1985, small uptick since 2011
- Still 3rd largest crude oil producer in 2015
 - 6% of U.S. total output
 - 3rd largest state in refining capacity
- Advances in unconventional well stimulation (primarily fracking) led to renewed focus on Monterey Shale Formation but early estimates downgraded more than 96%



Source: CCST (2014). Advanced Well Stimulation Technologies in California. An Independent Review of Scientific and Technical Information.

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Water Use – Getting the Data

- SB 1281 (2014) requires companies to submit quarterly reports to DOGGR detailing source and volume of water (freshwater, treated, or recycled) used during oil development processes, including fracking, acidization and steam injection

2015 SB 1881 Data: Water Used for Oil Production by Source

SOURCES OF WATER	TOTAL 2015 [AF]
Oil or gas well produced	274,050
Oil field water source well	4,947
Domestic fresh water system	3,082
Surface Water	1,219
Class II Industrial waste	151
Domestic recycled water	1,292
Other	569
Sale/transfer oil field produced	9,917
Recycled well stimulation treatment	3,535
Recycled other class II fluid	298
Recycled class II from well work operations	0
TOTAL	299,060*

5,593 AF
Main sources:
SWP California
Aqueduct and
the CVP Delta
Mendota Canal

* Less than total reported due to incompletely reported breakdown by source

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Produced Water Generation

- Oil to Water Ratio
 - As oil reservoirs mature, oil to brine ratio worsens
 - 1:4.5 in 1985 [256 million bbl oil, 1.1 billion bbl produced water]
 - 1:8 in 2008 [162 million bbl oil, 1.3 billion bbl produced water]
 - 1:15 in 2015 [201 million bbl oil, 3.1 billion bbl produced water]
 - Produced water composition highly variable but generally highly saline with chemicals from drilling and well stimulation processes,* temperature of 75-150 degrees F

*dispersed oil, dissolved organic compounds including aromatic hydrocarbons, organic acids, phenols, inorganic compounds, traces of chemicals added during the production /separation process, NORM.

Produced Water Generation

- ~380,000 AF [~3.1 billion barrels] in 2012

2015	Total Produced Water [AF]	Number of Reports	Completeness for Produced Water	Completeness for Injected Water
Q1	65,535	242	59%	41%
Q2	103,317	NA	>90%	NA
Q3	104,911	NA	>90%	NA
Q4	105,943	NA	>90%	NA
TOTAL	379,706			

Wastewater Management in California

- 1.8 billion bbl (61%) direct reinjection for EOR (steam and water flooding, cyclic steam stimulation)
- 831 million bbl (28%) permanent disposal in class II underground injection wells
- 150 million bbl (5%) evaporation ponds (sumps)
- 180 million bbl (6%) used for crop irrigation

Source: Circle of Blue. "Water News." May 28, 2015

Wastewater Management in California

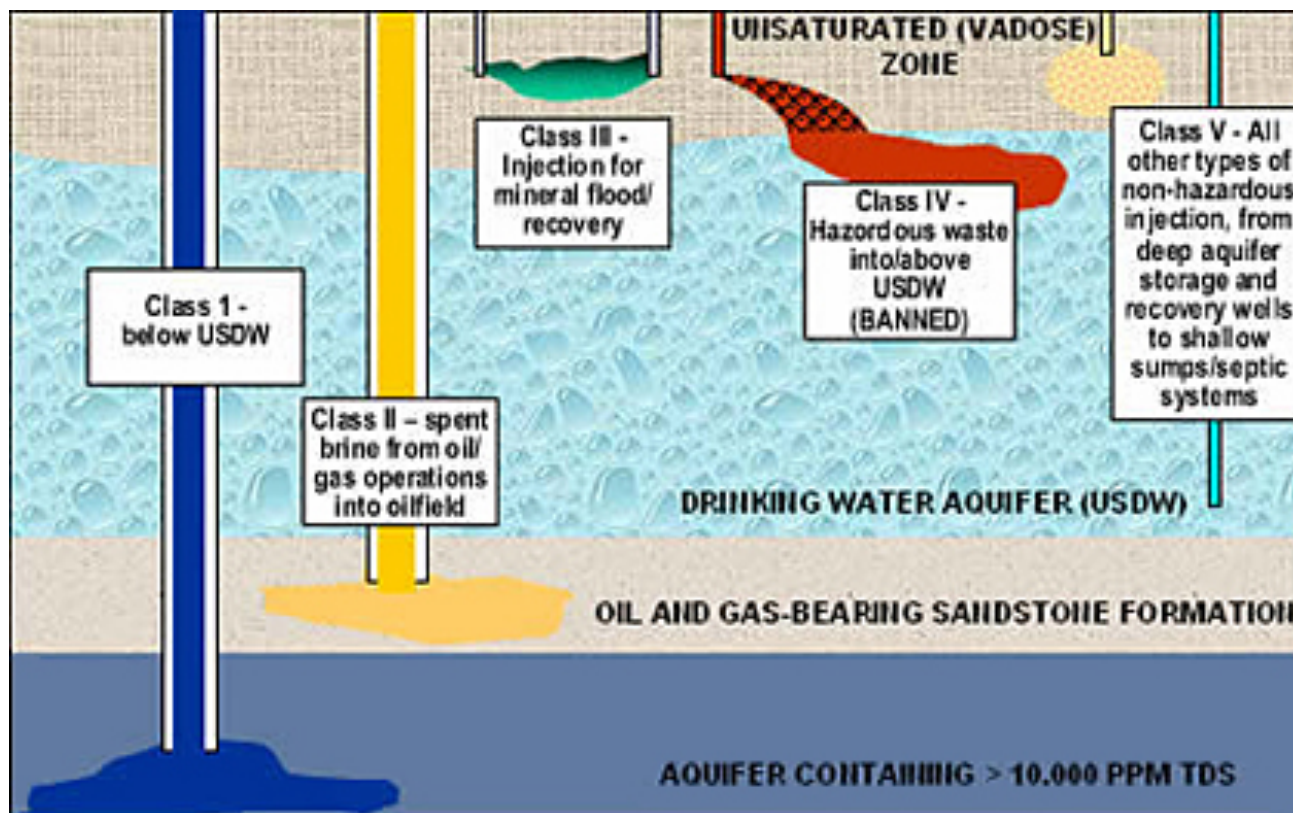
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Class II Underground Injection Wells

- 1982: CA's UIC program is operated and overseen by DOGGR based on "primacy" delegation by U.S. EPA
- 2011, 2014: Widespread irregularities and lapses in oversight found in initial EPA reviews
- 2015: shutdown of 11 class II UIC wells potentially injecting into aquifers potentially needing aquifer exemptions
- 2015: DOGGR begins full program review, adopts emergency regulations
- Ongoing review: ~2,500 wells starting with 'high risk' wells
- 2016: Emergency regulations extended

Source: [http://www.conservation.ca.gov/dog/general_information/Pages/UndergroundInjectionControl\(UIC\).aspx](http://www.conservation.ca.gov/dog/general_information/Pages/UndergroundInjectionControl(UIC).aspx)



Source: <https://archive.epa.gov/region9/water/archive/web/html/uic.html>

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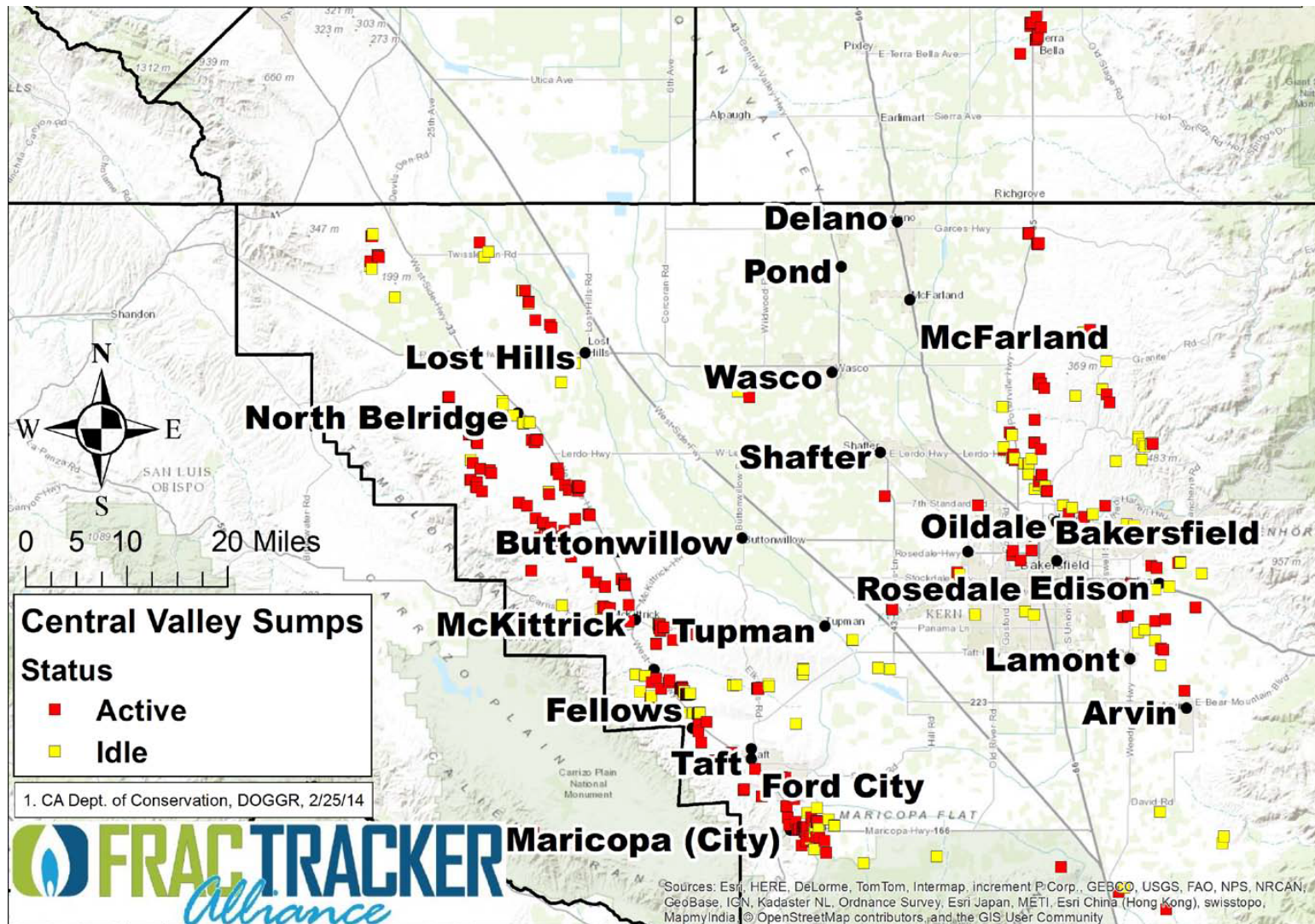
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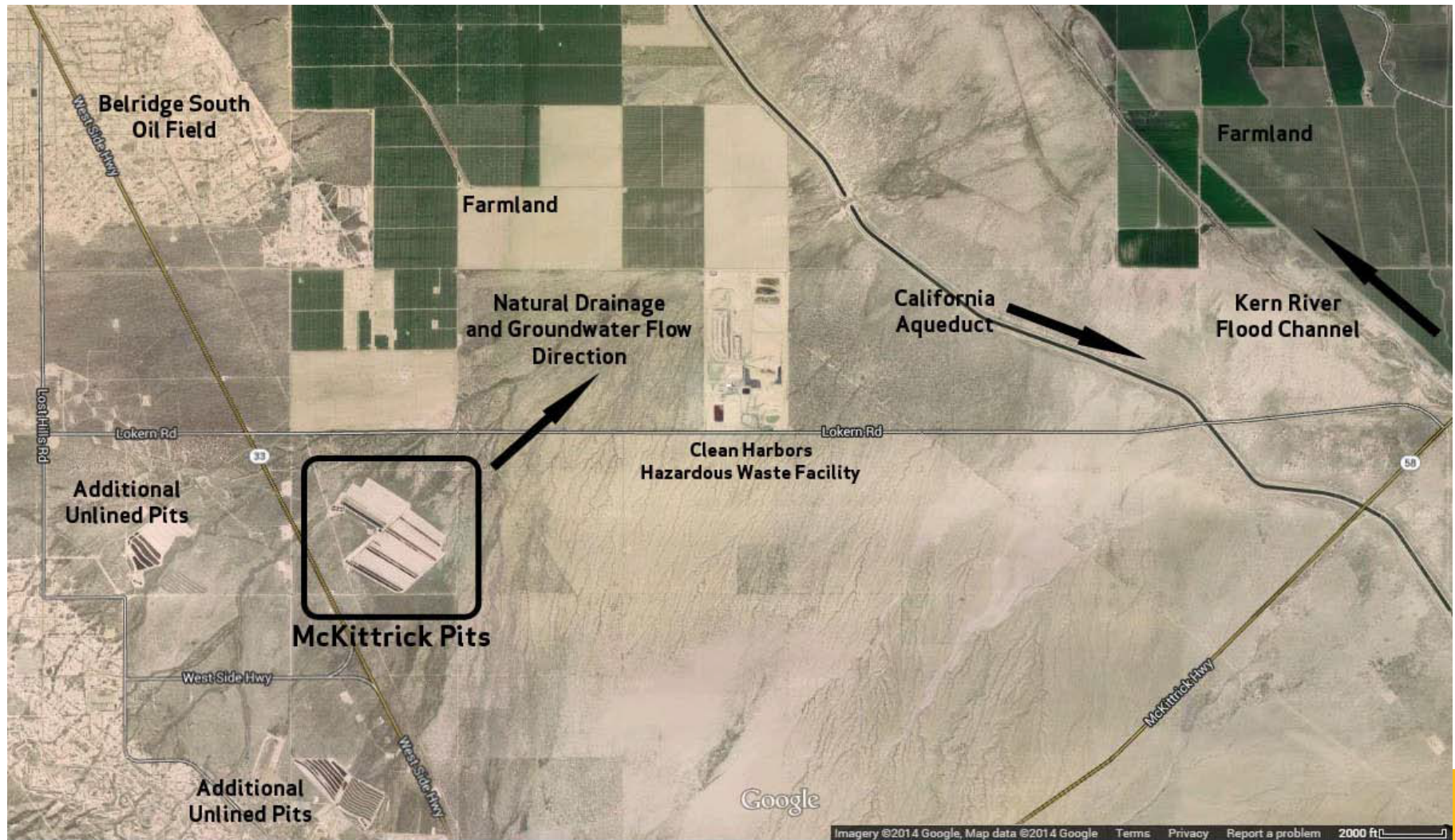
Source: Circle of Blue. "Water News." May 28, 2015

Unlined Evaporation Ponds in CA



Source: Clean Water (2014). "In the Pits."





SW

Valley Waste Disposal Company
CYM-17K1 (Phase I Well)Valley Waste Disposal Company
CYM-17N1 (Phase I Well)Valley Waste Disposal Company
CYM-17M1 (Phase II Well)Valley Waste Disposal Company
CYM-17K1 (Phase II Well)

NE

1987 FT

2197 FT

2385 FT

TD 347 FT
OL 485.1 FTTD 349 FT
OL 481.5 FTTD 351 FT
OL 430.9 FTTD 353 FT
OL 440.9 FT

Pond

Ground surface

ALLUVIUM
TULARE
FORMATION22K SAND OR
EQUIVALENT

CCE (Silty facies)

CCE

PERCHED WASTEWATER PLUME

Edge of produced
water mound

UPPER TULARE CLAY

UPPER TULARE CLAY

REGIONAL WATER TABLE

50
25
0
0 200 400
Scale (FT)

500 FT

400 FT

300 FT

200 FT

100 FT

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TABLE #2a: Results of Air Monitoring Sample Collected on May 3, 2014 and June 18, 2014
Near McKittrick 1 and 1-3 pits

Chemical	May 3 Test Results: Concentration ($\mu\text{g}/\text{m}^3$)	June 18 Test Results: Concentration ($\mu\text{g}/\text{m}^3$)	Long Term Effects Screening Level ^{*54} Concentration ($\mu\text{g}/\text{m}^3$)
Propene	1.4		n/a
CFC 12	1.9	2.0	42
Ethanol		7.1	n/a
Acetone	460	19	4800
Trichlorofluoromethane	1.0	1.0	5600
2-Propanol	23		n/a
2-Butanone (MEK)	340		1300
n-Hexane	3.5	0.69	200
Benzene**	13	1.8	4.5
Cyclohexane	24		340
n-Heptane	3.2	0.80	350
4-Methyl-2-pentanone	7.0		n/a
Toluene	21	3.0	1200
2-Hexanone**	12		4
n-Octane	2.4	0.69	350
Ethyl benzene	8.3		570
m,p-Xylene	11	1.3	180
o-Xylene	6.9	0.69	180
n-Nonane	1.8	0.71	1050
Cumene	2.2		250
n-Propylbenzene	2.3		250
4-Ethyltoluene	1.8		125
1,3,5-Trimethylbenzene	1.9		125
1,2,4-Trimethylbenzene	7.1		125
Naphthalene	7.9		50

Unlined Evaporation Ponds in CA

What we know:

- 1,165 total pits, 790 of which are active
- 1,113 total (746 active) of which are in the Central Valley
- The Central Coast Regional Water Quality Control Board identified additional 52 pits (44 active)
- 60% (475) active pits and 69% (803) of all pits are inadequately permitted

Source: Clean Water (2016). "Still in the Pits."

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Produced Water for Crop Irrigation in CA

- Example: Cawelo Water District
 - North of Bakersfield, Kern County, CA
 - ~45,000 acres
 - Serves ~34,000 acres of orchards, vineyards, other crops
 - Receives produced water from Chevron (~21 million gals per day)
 - Water pre-treated by Chevron using settling ponds, walnut shell physical filters and other means
 - Cawelo sometimes dilutes with freshwater
 - Limited testing and treatment requirements for irrigation water
 - Water testing showed elevated concentrations of several chemicals (acetone, benzene) and hydrocarbons

Produced Water for Crop Irrigation in CA

- Current research on chemical composition of wastewater in Kern County
 - With Dr. Lelia Hawkins, Isabell Lee (HMC'16) and local support in Kern County
 - Sampled 4 times b/w October 1, 2015 – March 20, 2016 from irrigation ponds and installations, Cawelo produced water canal and at well pads in orchards
 - Performed analyses of BTEX, 8 heavy metals,* Total Organic Carbon, pH

* arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver



Subset of sampling sites

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Produced Water for Crop Irrigation in CA

- BTEX below detection limit
- TOC 3ppm-11ppm (above guidelines for treated water)
- pH > 8 in some samples
- Heavy metals of concern arsenic, mercury and silver due to elevated concentrations
- Next steps: more sampling, expansion to crop and soil analysis

Summary

Environmental Considerations of Oil & Gas Production in California

- UI removes water permanently from hydrological cycle
- Evaporation ponds pose risks to
 - Groundwater (especially unlined ponds) and downslope surface water
 - Air quality
 - Wildlife
- Irrigation use w/o proper treatment and testing poses unknown risks to crops and public health

Opportunities Exist

- Reducing freshwater use in drilling, stimulation and production
 - Increased use of recycled water (from oil & gas and other suppliers)
 - Use of groundwater not suitable for drinking water and agriculture (high salinity)
- Improved wastewater management
 - On-site and commercial oil & gas wastewater recycling
 - Adoption of irrigation water quality standards, oil & gas wastewater treatment and testing rules for crop irrigation

Thanks!

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