Risk Posed to Groundwater Resources by the Disposal of Produced Water into Unlined Produced Water Ponds in California

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GWPC Annual Forum

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Outline of Presentation

- Background
- Tracking of Unlined Produced Water Ponds
- Groundwater Resources in the Tulare Basin of the San Joaquin Valley
- A case study

Background

Valleys and Basins

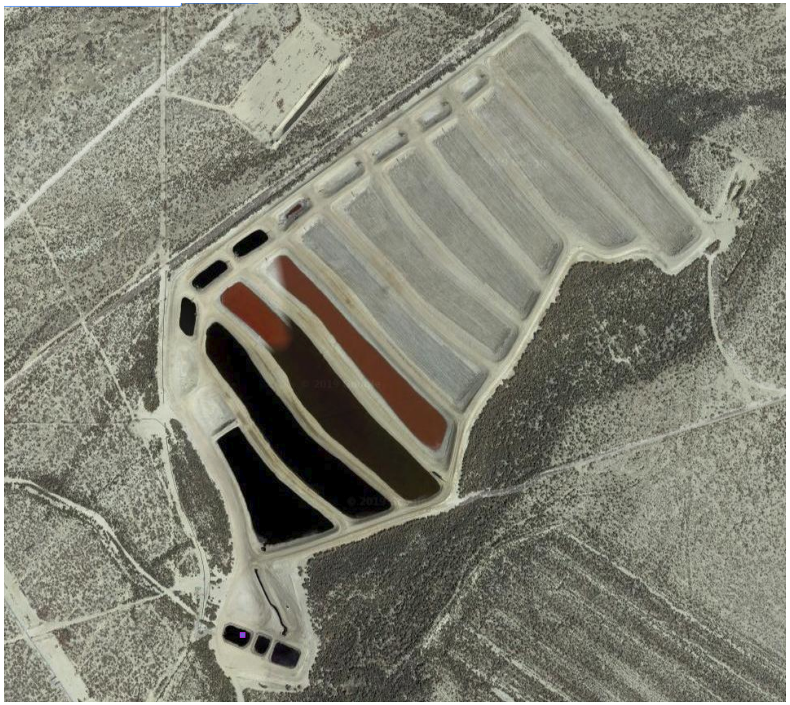
- The San Joaquin Valley occupies the southern two-thirds of the Central Valley.
- The San Joaquin Valley is separated into the San Joaquin Basin to the north and the Tulare Basin to the south.
- Nearly all unlined produced water ponds are in the Tulare Basin

Figure from USGS 2019

Produced Water Ponds

An active produced water pond is currently receiving produced water (SWRCB 2019).

An inactive produced water pond has a physical connection to a produced water source, but not currently receiving produced water (SWRCB 2019).



Aerial image of McKittrick 1-1 from Geotracker

Aerial image of McKittrick 6A, 6B from Geotracker

In large complexes, produced water enters smaller unlined ponds that provide for floatation and skimming of remaining undissolved oil prior to flowing into larger unlined ponds for evaporation and percolation (Jordon et al. 2015). Disposal of produced water into unlined pits, sumps, or ponds has been ongoing in California since at least the early 1900s (Bean and Logan 1983).

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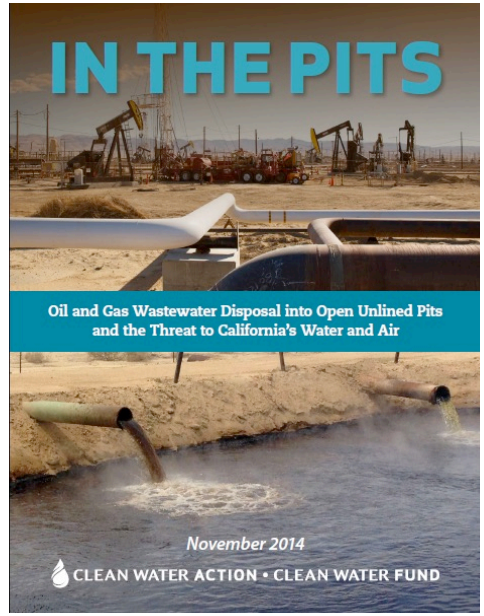
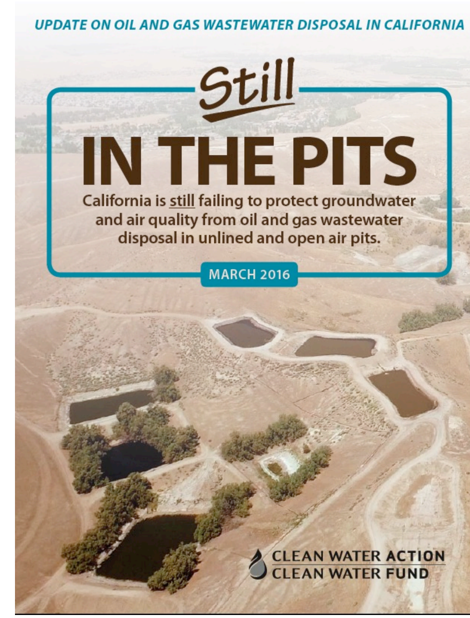
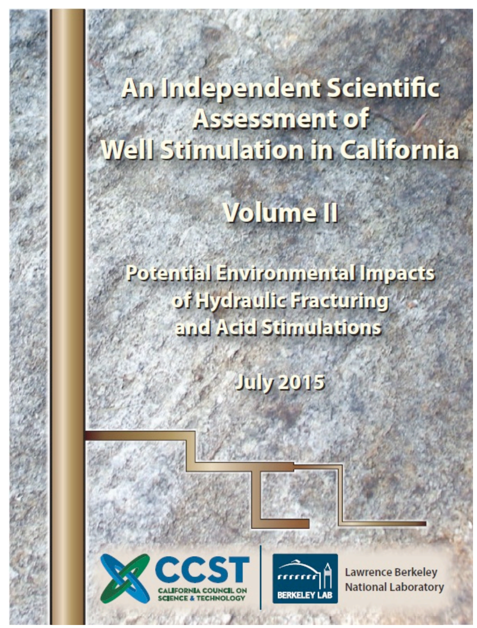
Previous Work on Unlined Produced Water Ponds in the San Joaquin Valley



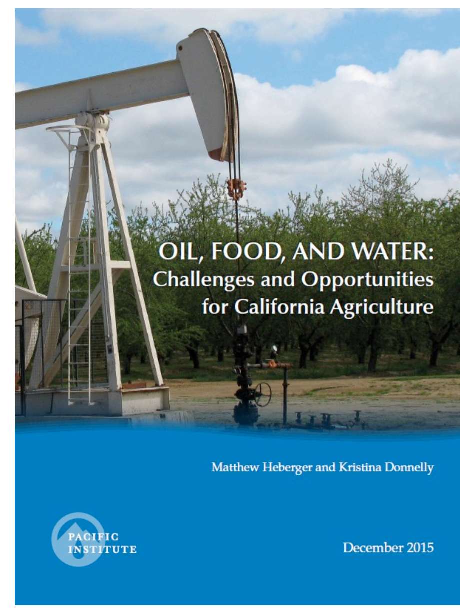
Grinberg 2014



Grinberg 2016



Jordon et al. (2015)
Stringfellow et al. (2015)



Heberger and Donnelly (2015)

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Soon to be Released Report

An Assessment of Oil and Gas Water Cycle Reporting in California:

Evaluation of Data Collected Pursuant to
California Senate Bill 1281, Phase II Report

An Independent Review of Scientific and Technical Information

CCST
CALIFORNIA COUNCIL ON SCIENCE & TECHNOLOGY

Chapter 4 (DiGiulio and Shonkoff 2019)
Potential Impact to Groundwater Resources from Disposal of Produced Water into Unlined Produced Water Ponds in the San Joaquin Valley

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Tracking of Unlined Produced Water Ponds

Tracking of Disposal Volumes by the Division of Oil, Gas, and Geothermal Resources (DOGGR)

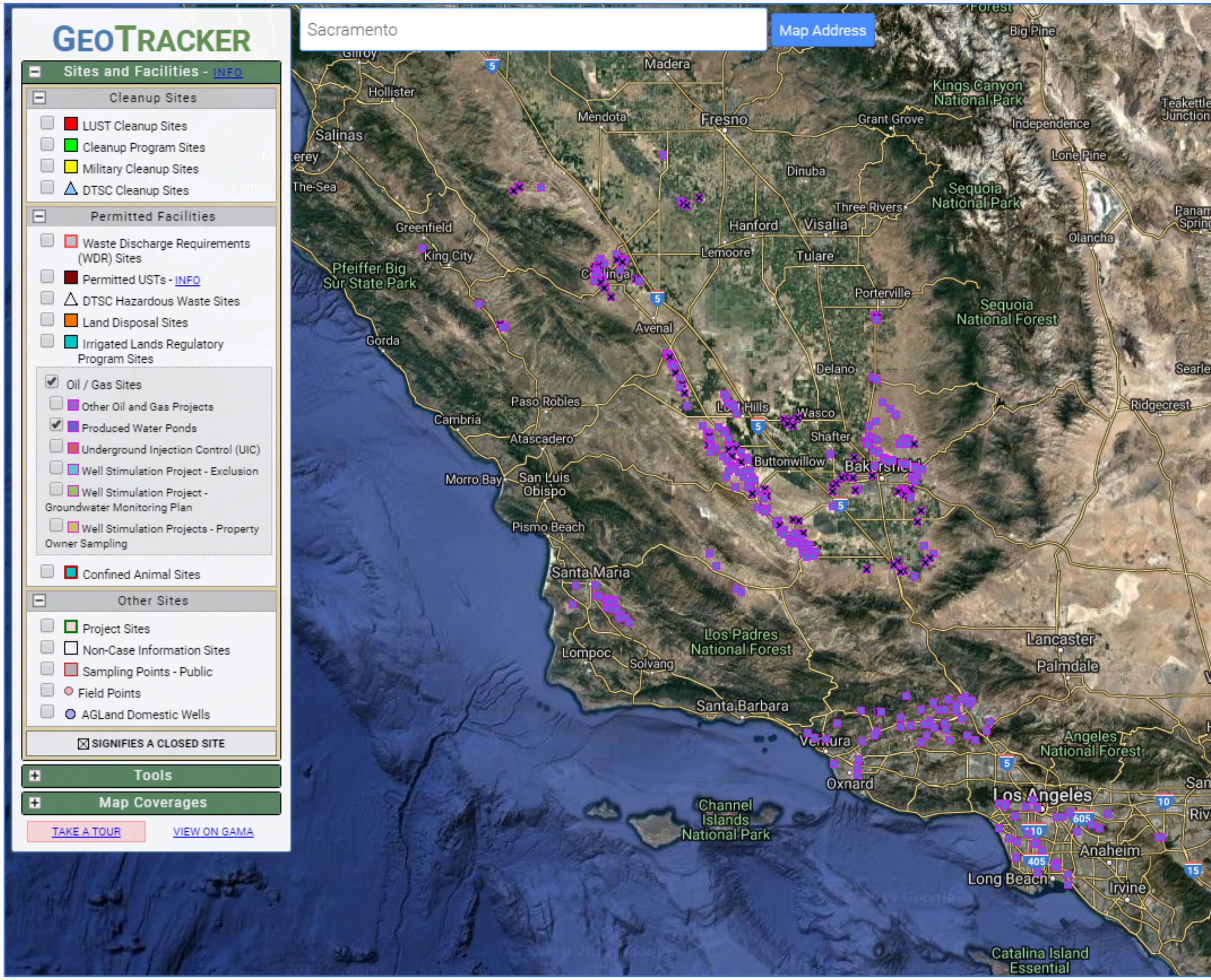
Code	Well Production and Injection Summary Reports (from 1977)	In 2014, the California Legislature passed SB 1281 (CALI 2014) which required owners of production wells to report the volume and disposition (see codes) of produced fluids from any well to DOGGR starting Q1 2015.
0	**Not Applicable**	
1	**Evaporation-Percolation**	**Sump (unlined)** - Evaporation and Percolation (infiltration): Water is placed into an unlined sump, allowed to percolate into the ground and/or evaporate into the atmosphere.
2	**Evaporation (lined sump)**	**Sump (lined)** – Evaporation: Water is placed into a lined sump, open tank, or similar container for evaporation into the atmosphere.
3	**Surface Water Body**	**Surface Water Discharge**: Water is discharged into a surface body of water such as an ocean, lake, pond, river, creek, aqueduct, canal, stream, or watercourse.
4	**Sewer System**	**Domestic Sewer System**: Water is placed into a sewage disposal or treatment system, which is generally operated by a municipality or consortium for domestic waste.
5	**Subsurface Injection**	**Subsurface Injection**: Water is injected into the subsurface of the same oil field and operator, from which it was produced.
6	**Other** (i.e. turned over to commercial water disposal)	**Other**: Water is disposed of by another method, such as commercial disposal, industrial use, non-class II wells, etc…
7		**Sale/Transfer** – To other operator or oil field: Water is sold or transferred to another operator or oil field.
8		**Surface Discharge**: Water is used on oil field land or surface for dust control, landscaping, pasture augmentation, infiltration, evaporation, etc…
9		**Operator's facilities within oil field**: Water is used for operator's facilities within the oil field (i.e., tankage, equipment operation, onsite storage, equipment/facilities cleaning and testing, etc…)
10		**Well Stimulation Treatment**: Water is used in a well stimulation treatment operation (i.e., hydraulic fracturing, acid matrix, acid fracturing, etc…)
11		**Sale/Transfer** – Domestic Use: Water is used for agriculture, irrigation, water replenishment, water banking, livestock, etc..
12		**Drilling, well work, and well abandonments**: Water is used to support well drilling, rework, and abandonment operations, for such things as well control fluid, drilling mud, cementing, etc...

State Water Resources Control Board Geotracker

SB 1281 also required DOGGR to provide the State Water Resources Control Board (SWRCB) with an annual inventory of all unlined oil and gas field produced water ponds or sumps.

California Water Boards

Produced Water Ponds Status Report: January 31, 2019



Screenshot of Lined and Unlined Produced Water Pond Facilities from the SWRCB Geotracker Graphical Interface

State Water Resources Control Board Geotracker

STATE WATER RESOURCES CONTROL BOARD
GEOTRACKER

Tools | Reports | UST Case Closures | Information

PROJECT SEARCH RESULTS

SEARCH CRITERIA: WATERPONDS

706 RECORDS FOUND — VIEW RESULTS ON MAP — EXPORT TO EXCEL — PAGE 1 OF 15

		SITE / FACILITY NAME	SITE / FACILITY TYPE	CLEANUP STATUS	OIL FIELD	OIL FIELD OPERATOR	ADDRESS (OR PARTIAL ADDRESS)	CITY	ZIP	COUNTY
[REPORT]	[MAP]	'NICHOLAS 4' WELL, VALLECITOS OIL FIELD	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT			NEW IDRIA ROAD	PANOCHE	95043	SAN BENITO
[REPORT]	[MAP]	25 HILL PROPERTIES, INC., MIDWAY-SUNSET, SHELL LEASE	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	MIDWAY - SUNSET	25 HILL PROPERTIES, INC.	7026 DARNOCH WAY	WEST HILLS	91307	KERN
[REPORT]	[MAP]	ACL LEASE	PRODUCED WATER PONDS	HISTORIC	CANADA LARGA	HAMMOND CANYON #2	SULPHUR CANYON ROAD	VENTURA	93001	VENTURA
[REPORT]	[MAP]	AERA ENERGY, NORTH BELRIDGE DISPOSAL PONDS	PRODUCED WATER PONDS	INACTIVE - PERMITTED	BELRIDGE, NORTH	AERA ENERGY LLC	HIGHWAY 33	SOUTH OF LOST HILLS		KERN
[REPORT]	[MAP]	ALISO CANYON OIL FIELD SUMP, POND, AND PIT ORDERS	PRODUCED WATER PONDS	OPEN - INACTIVE	ALISO CANYON	TERMO /CRIMSON /SO CAL GAS	0 PETER ROZE FOOTHILLS, UNNAMED ROAD	PORTER RANCH	91326	LOS ANGELES
[REPORT]	[MAP]	ANDERSON TF #1	PRODUCED WATER PONDS	HISTORIC	RUSSELL RANCH	E & B NATURAL RESOURCES MANAGEMENT CORPORATION	1848 PERKINS ROAD	NEW CUYAMA	93254	SANTA BARBARA
[REPORT]	[MAP]	ANDERSON TF #2	PRODUCED WATER PONDS	HISTORIC	RUSSELL RANCH	E & B NATURAL RESOURCES MANAGEMENT CORPORATION	1848 PERKINS ROAD	NEW CUYAMA	93254	SANTA BARBARA
[REPORT]	[MAP]	ANDERSON TF #3	PRODUCED WATER PONDS	HISTORIC	RUSSELL RANCH	E & B NATURAL RESOURCES MANAGEMENT CORPORATION	1848 PERKINS ROAD	NEW CUYAMA	93254	SANTA BARBARA
[REPORT]	[MAP]	ANT HILL, ALL LEASES	PRODUCED WATER PONDS	OPEN - INACTIVE			SEC 15,16&22,T29S,R29E,MDB&M	KERN COUNTY		KERN
[REPORT]	[MAP]	ANT HILL, SIEGFUS	PRODUCED WATER PONDS	OPEN - INACTIVE			SECTION 22, T29S, R29E, MDB&M	KERN COUNTY		KERN
[REPORT]	[MAP]	ANT HILL, SIEGFUS LEASE	PRODUCED WATER PONDS	OPEN - INACTIVE			NW1/4 NW1/4 S22,T29SR29E MDB&M	KERN COUNTY		KERN
[REPORT]	[MAP]	ANT HILL, SPA	PRODUCED WATER PONDS	OPEN - INACTIVE			NE1/4 SW1/4 S15 T29SR29E MDB&M	KERN COUNTY		KERN
[REPORT]	[MAP]	ANTELOPE HILLS OIL FIELD, HOPKINS A LEASE (AKA: EVAPORATION PONDS)	PRODUCED WATER PONDS	ACTIVE - PERMITTED	ANTELOPE HILLS	E&B NATURAL RESOURCES MANAGEMENT CORPORATION	ANTELOPE HILLS OIL FIELD	KERN COUNTY		KERN
[REPORT]	[MAP]	ANTELOPE HILLS OIL FIELD, HOPKINS A SOUTH LEASE	PRODUCED WATER PONDS	ACTIVE - PERMITTED	ANTELOPE HILLS	E&B NATURAL RESOURCES MANAGEMENT CORPORATION	ANTELOPE HILLS OIL FIELD	NORTH BELRIDGE		KERN
[REPORT]	[MAP]	ANTELOPE HILLS OIL FIELD, PHIPPEN LEASE	PRODUCED WATER PONDS	ACTIVE - PERMITTED	ANTELOPE HILLS	E&B NATURAL RESOURCES MANAGEMENT CORPORATION	ANTELOPE HILLS OIL FIELD	NORTH BELRIDGE		KERN
[REPORT]	[MAP]	ANTELOPE HILLS OIL FIELD,	PRODUCED WATER	ACTIVE - PERMITTED	ANTELOPE	E&B NATURAL RESOURCES	ANTELOPE HILLS OIL FIELD	NORTH		KERN

Screenshot of Geotracker Database

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Locations of Produced Water Ponds in California

Regional Water Board	Active Ponds		Inactive Ponds	
	Lined	Unlined	Lined	Unlined
Central Coast	32	9	15	0
Los Angeles	76	0	0	2
Central Valley	31	530	25	507
Santa Ana	0	2	0	0
Total	139	541	40	509

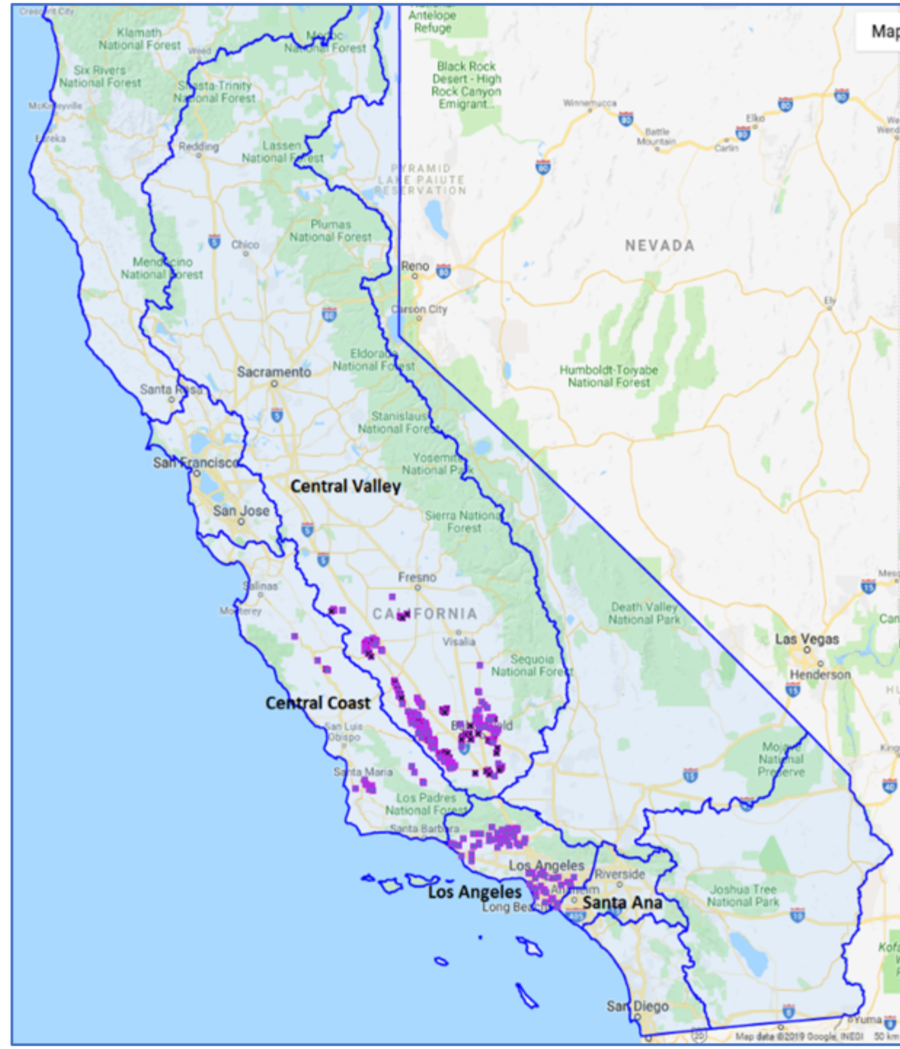
Data Source: SWRCB January 2019 Produced Water Pond Status Report (SWRCB 2019)

1,229 produced water ponds in California

1,050 of 1,229 produced water ponds (85%) are unlined

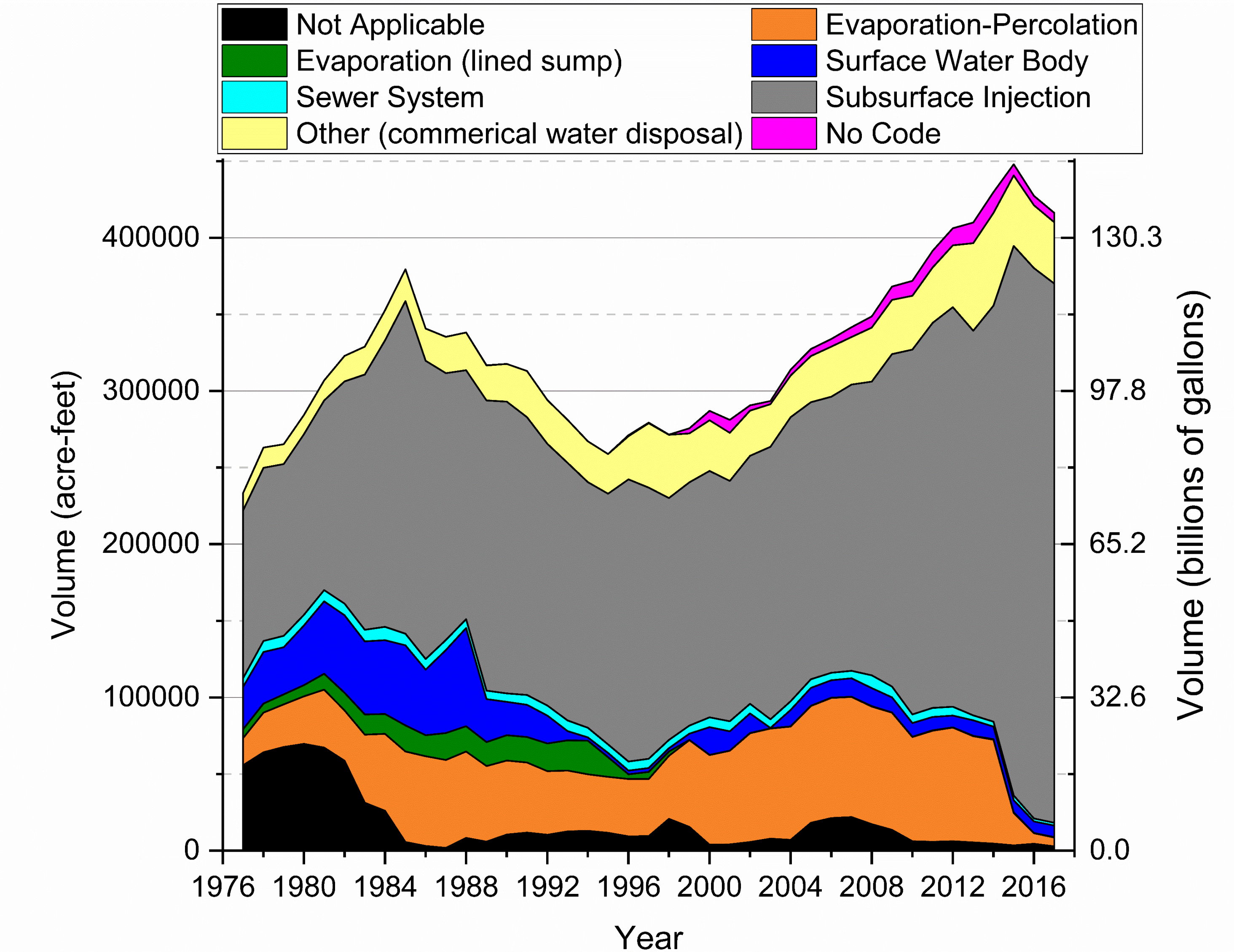
1037 of 1050 (99%) of unlined produced water ponds are in the Central Valley jurisdiction

530 of 1050 (50%) of unlined produced water ponds in the Central Valley jurisdiction are active.



Geotracker Screenshot of produced water pond facilities by state water board jurisdiction

Produced Water Disposition Between 1977 to 2017



Data from DOGGR Well Production and Injection Summary Reports

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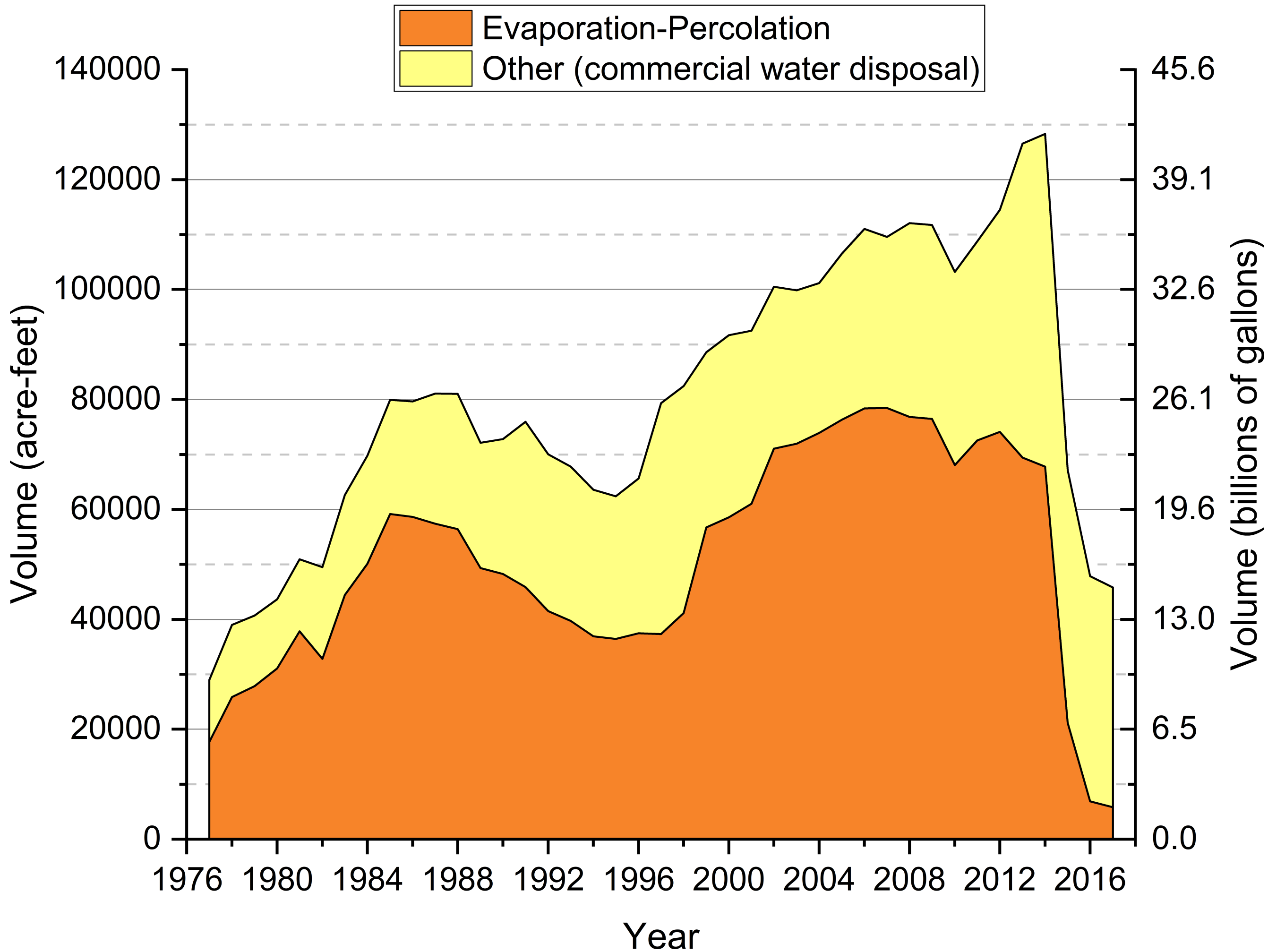
Evaporation-Percolation and "Other" Water Disposition Between 1977 to 2017

In 2007, disposal of produced water into evaporation-percolation ponds was at least 25.6 billion gallons. In 2017, disposal into evaporation percolation ponds was at least 1.9 billion gallons.

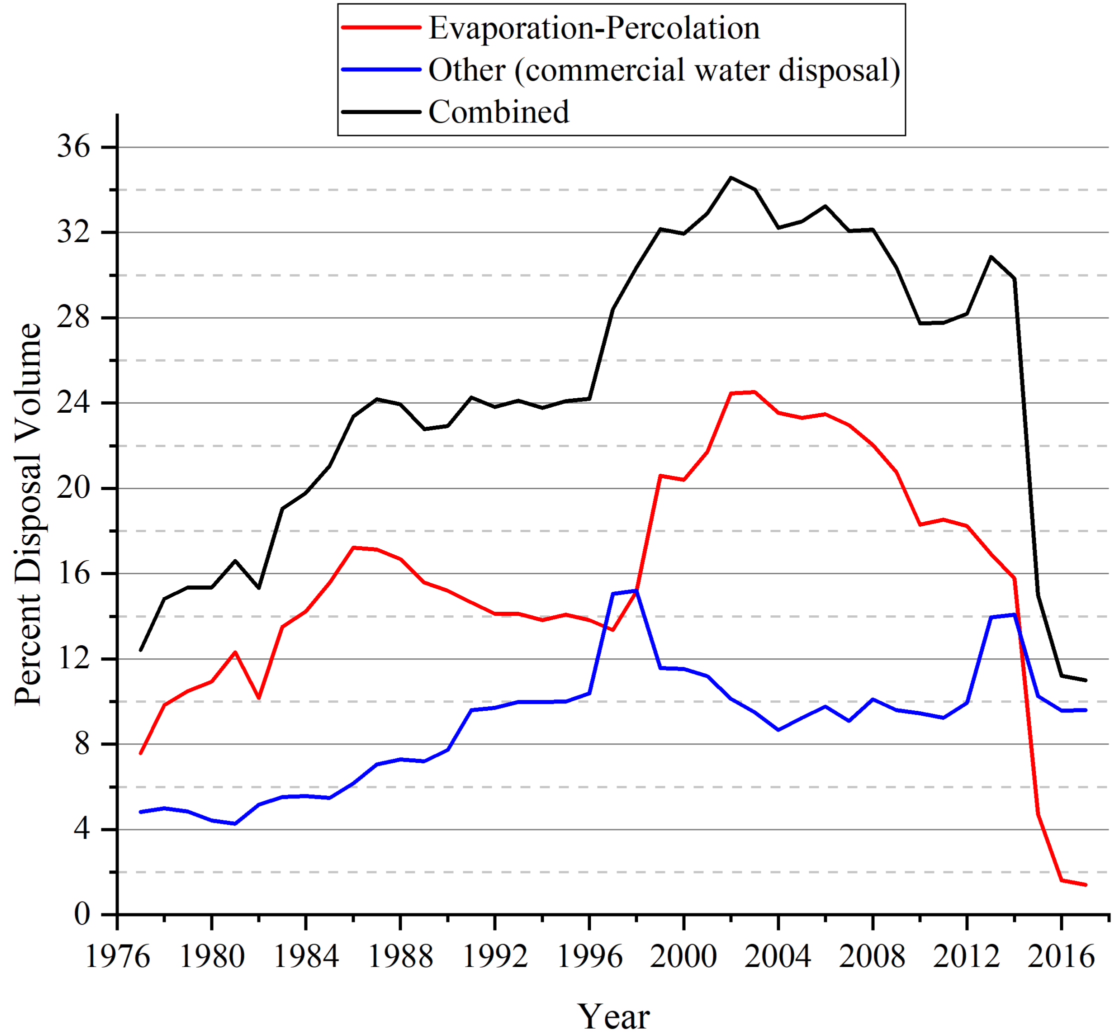


Data from DOGGR Well Production and Injection Summary Reports

PSE

Percent Disposal Volume of Produced Water Disposed in Evaporation-Percolation Ponds, "Other", and Combined

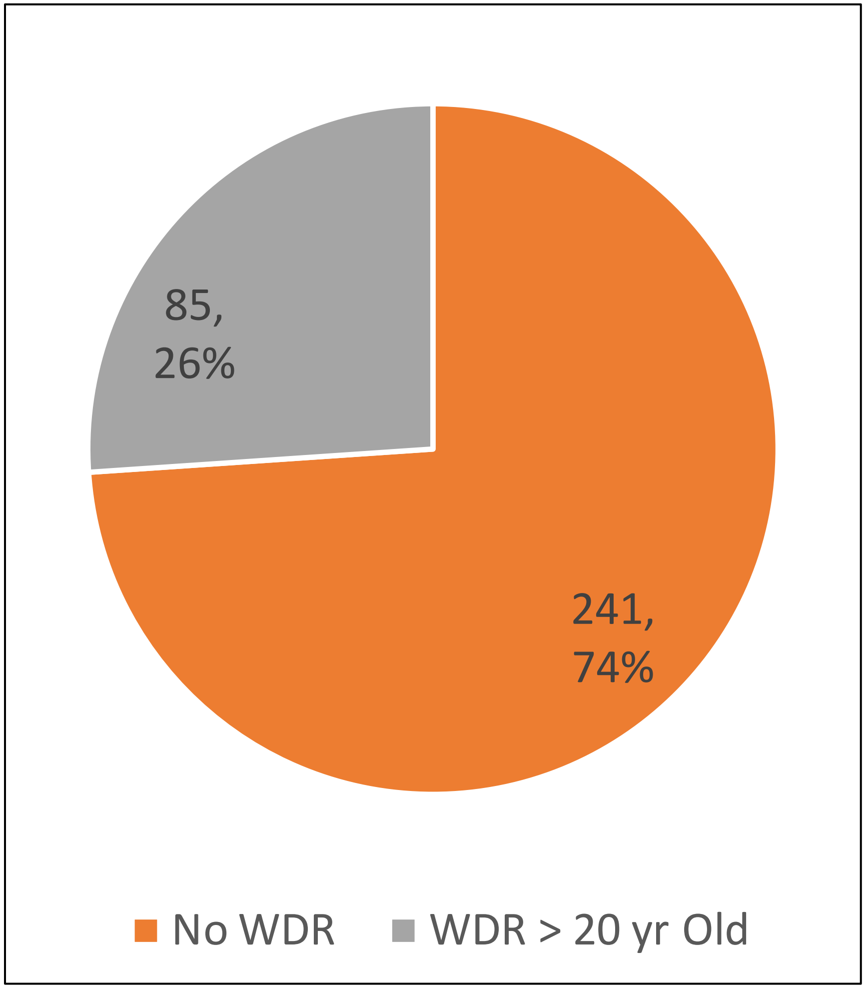
In 2003, disposal of produced water into evaporation-percolation ponds was at least 24.5% of produced water generated. In 2017, only 1.4% of produced water was reported as disposed in evaporation-percolation ponds.



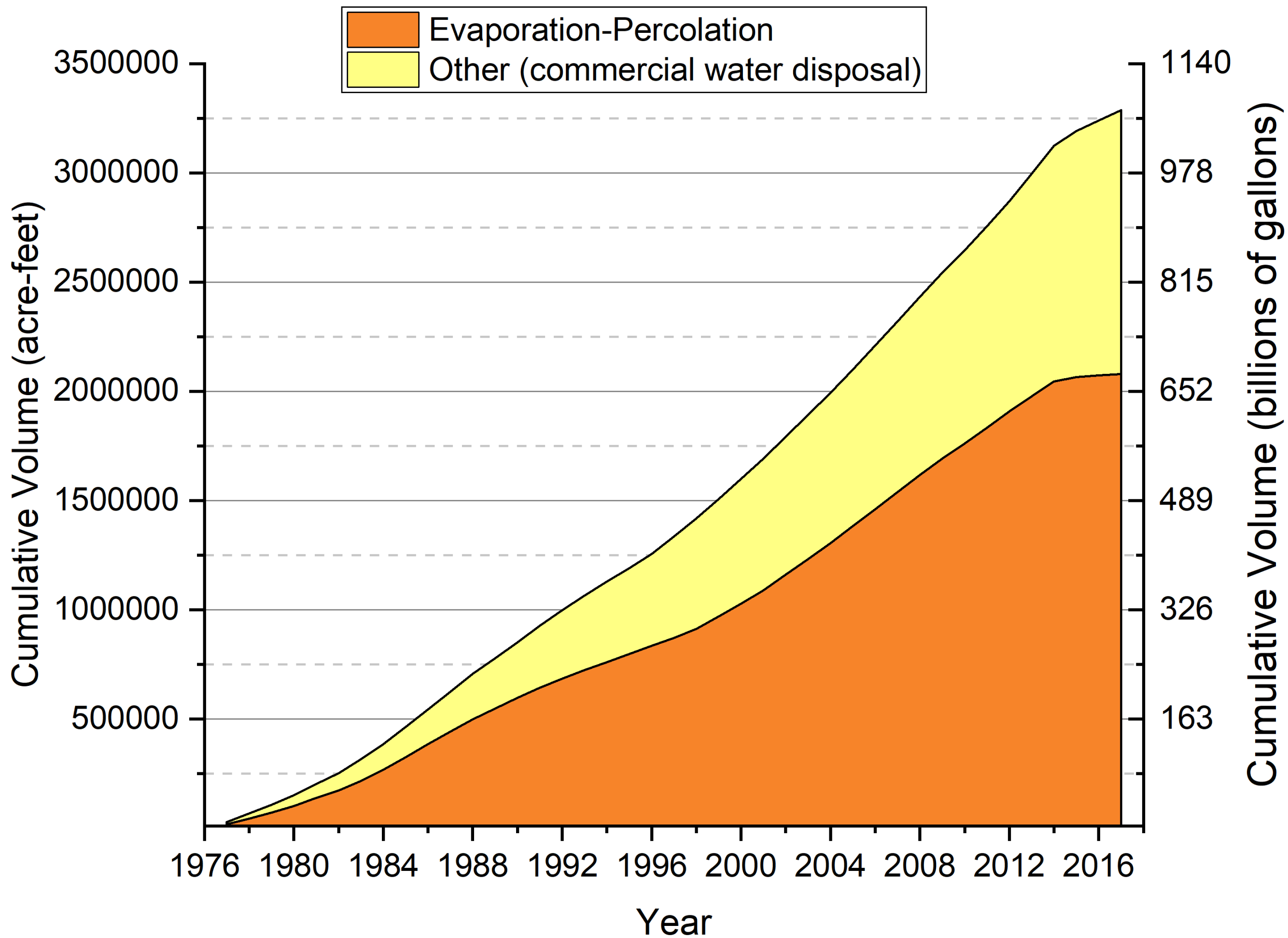
Data Source: DOGGR Well Production and Injection Summary Reports

Beginning of Regulatory Action in 2014

In May 2014, the Central Valley Regional Water Quality Control Board (CVRWQCB) located 326 facilities with 1100 produced water ponds and evaluated Waste Discharge Requirements (WDRs).



Cumulative Disposal Volumes



Data Source: DOGGR Well Production and Injection Summary Reports

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Groundwater Resources in the Tulare Basin of the San Joaquin Valley

Groundwater Resources in the Tulare Basin of the San Joaquin Valley

The Tulare Basin has 7 groundwater subbasins (locations of nearly all unlined ponds)

Salinity of Groundwater Determined in Part by:

- Origin of sediments (marine versus continental)
- Sources (stream, irrigation) and salinity of recharge water
- Evaporation and transpiration
- Geochemical processes such as ion exchange, mineral dissolution, and precipitation and associated depth and residence time
- Biological reactions that affect the oxidation/reduction state of groundwater

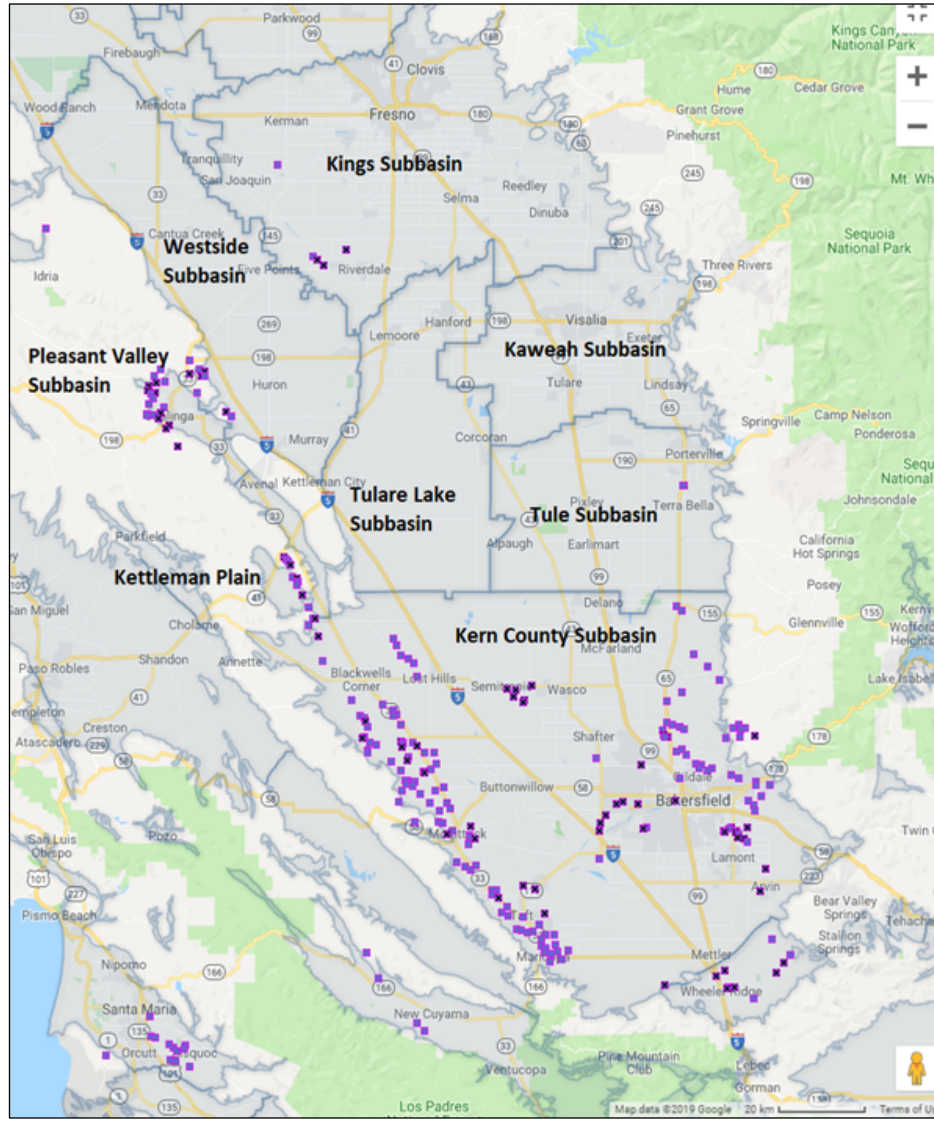

Figure from DiGiulio and Shonkoff (2019)

Hydrogeology of the Kern River Subbasin Area

- Nonmarine Kern River and Tulare Formations are the primary formations used for water supply.
- The Kern River Formation in the eastern portion contains sediment from the Sierra Nevada Mountains.
- Groundwater in the eastern portion of the Kern subbasin is primarily calcium bicarbonate waters in the shallow zones, increasing in sodium with depth.
- The Tulare Formation in the central and western portion contains sediments from Coast Range sources.
- Bicarbonate is replaced by sulfate and to a lesser degree by chloride in an east to west trend across the subbasin. West-side waters are primarily sodium sulfate to calcium-sodium sulfate type
- TDS increases from east to west.

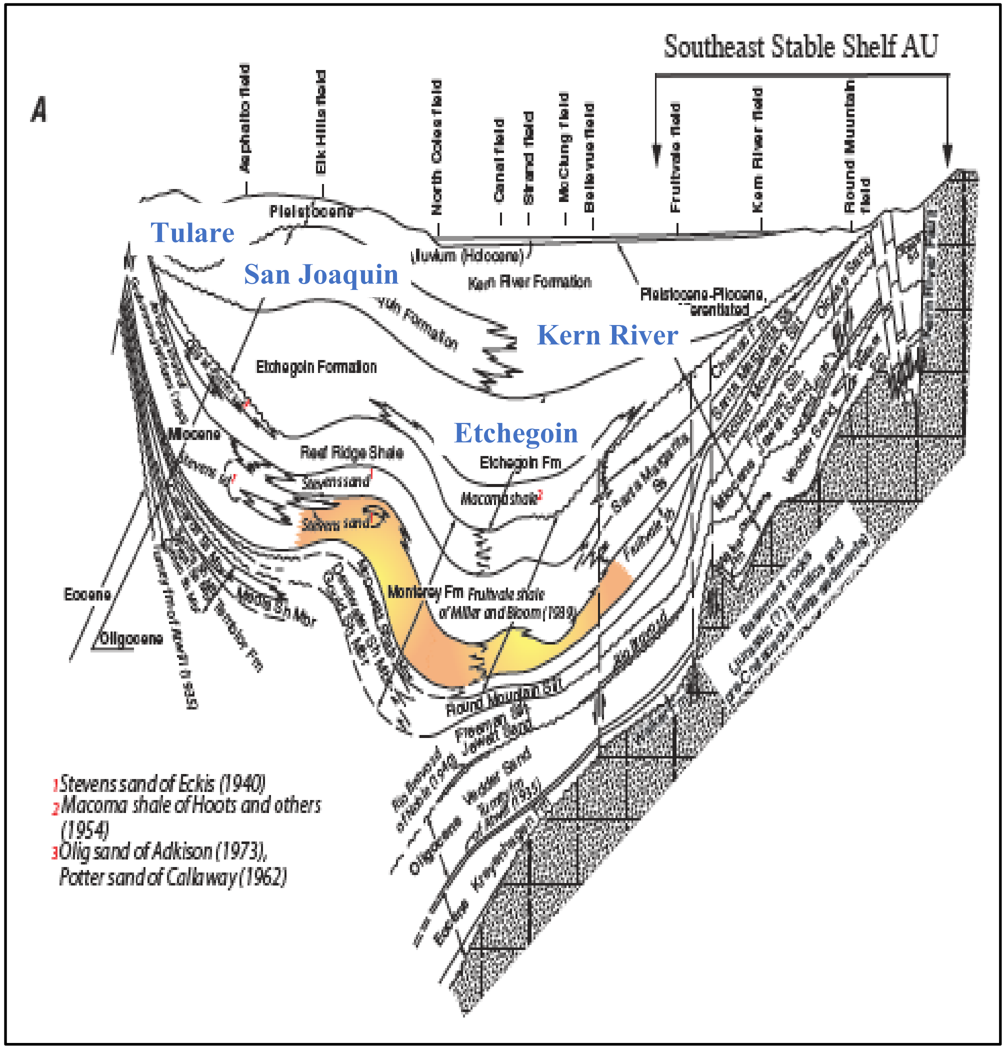

Figure from Gautier and Hosford Scheirer (2003)

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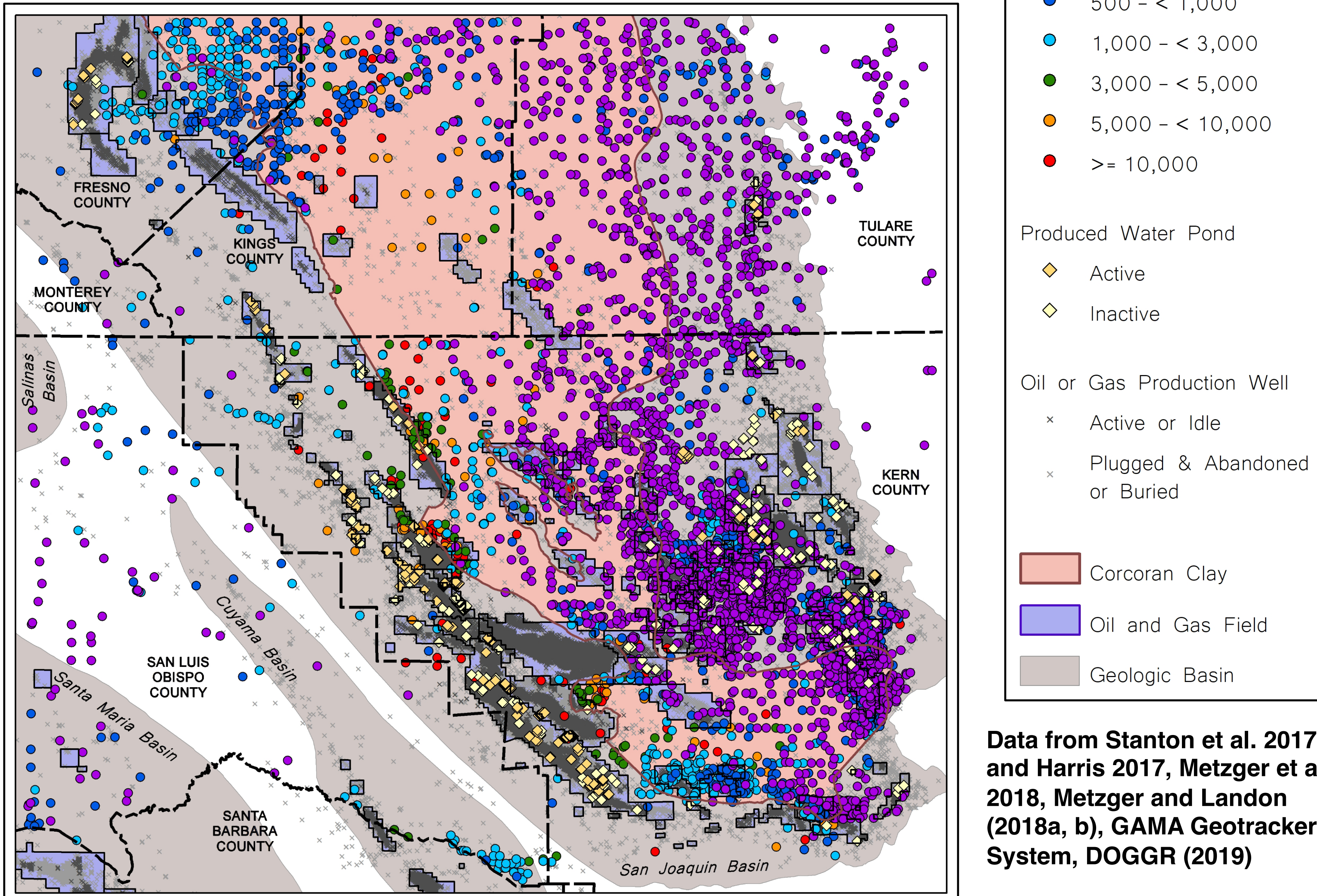
Locations of Produced Water Ponds and Concentrations of TDS in Water Wells



Data from Stanton et al. 2017, Qi and Harris 2017, Metzger et al. 2018, Metzger and Landon (2018a, b), GAMA Geotracker System, DOGGR (2019)

Figure from DiGiulio and Shonkoff (2019)

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Salinity Profiles in USGS Study Areas

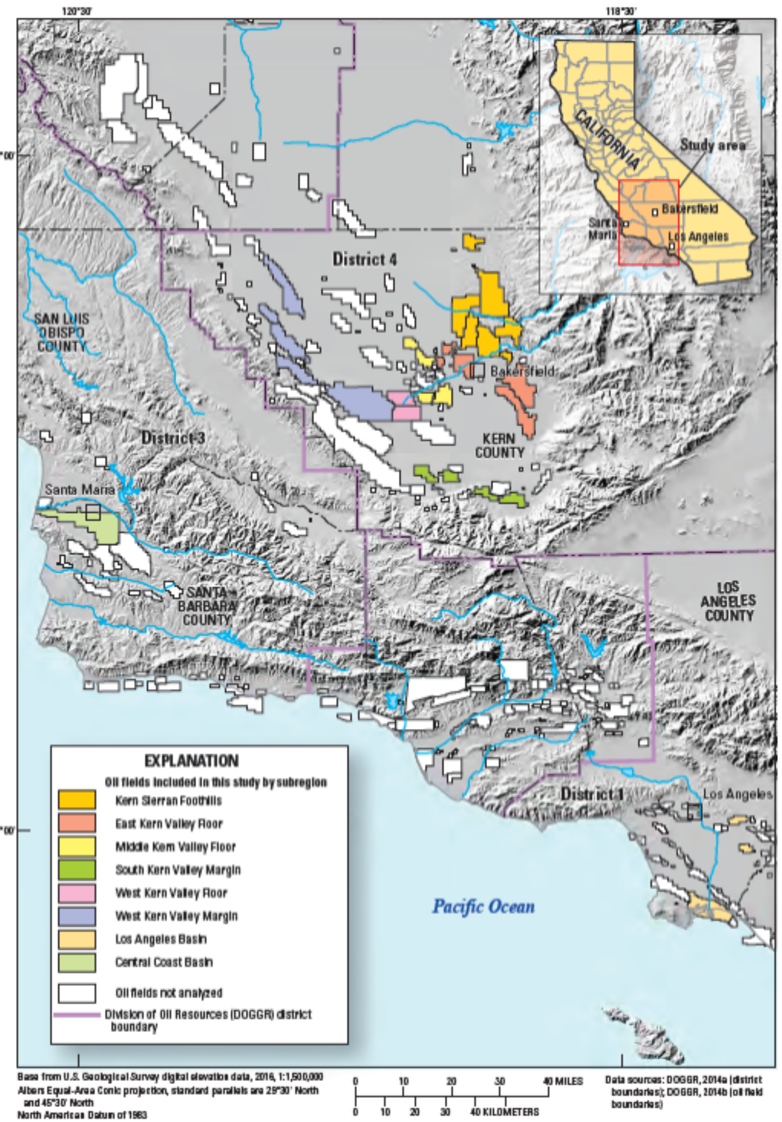
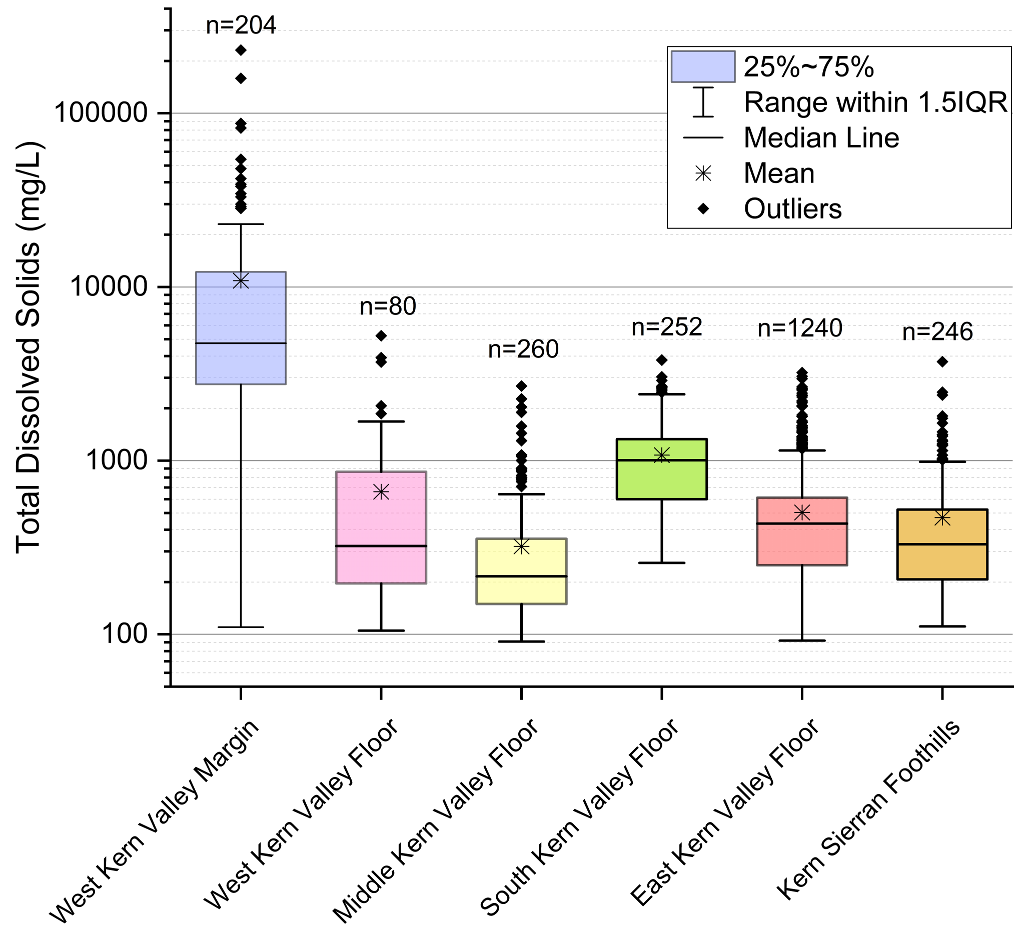
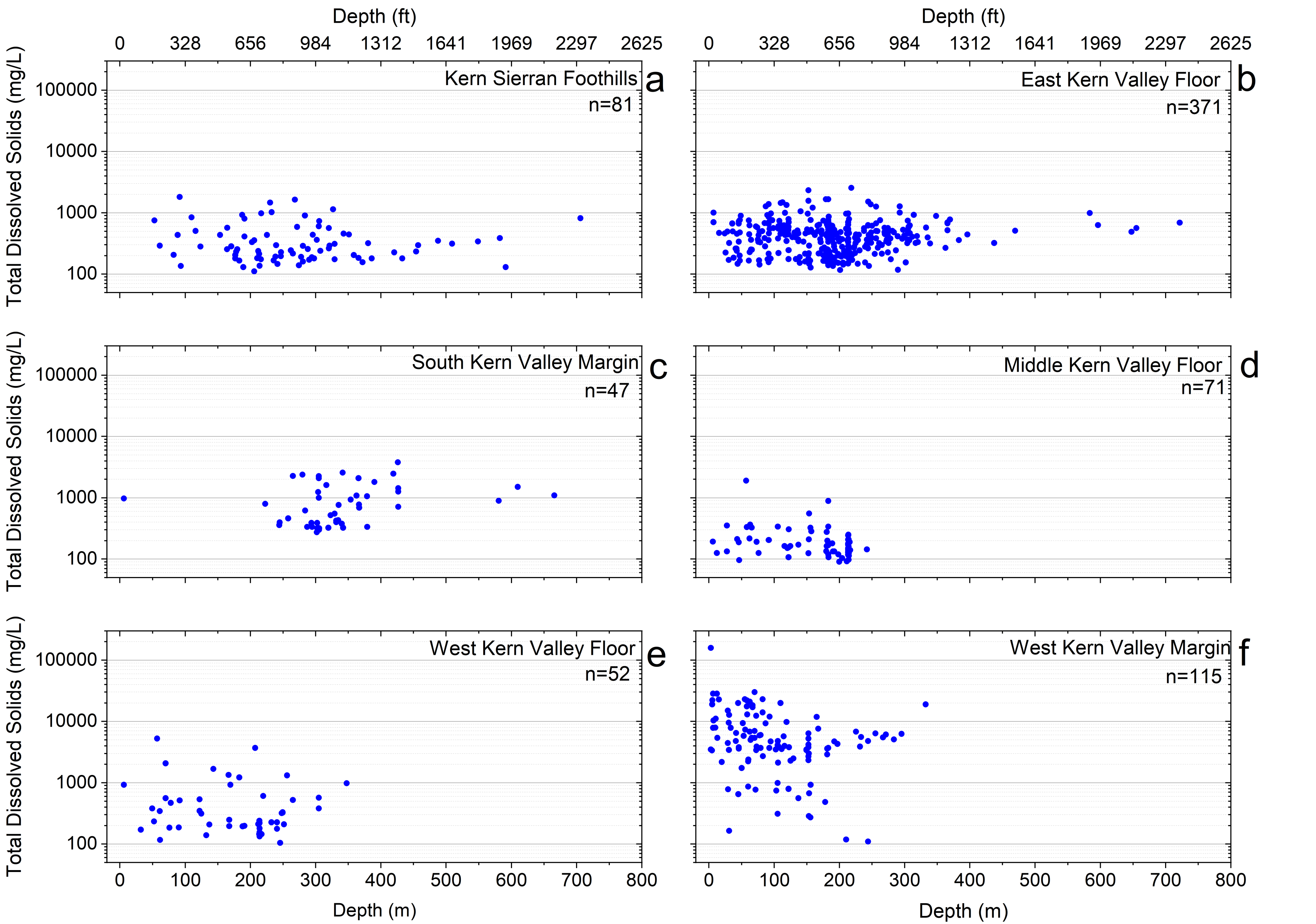


Figure from Metzger and Landon (2018a)



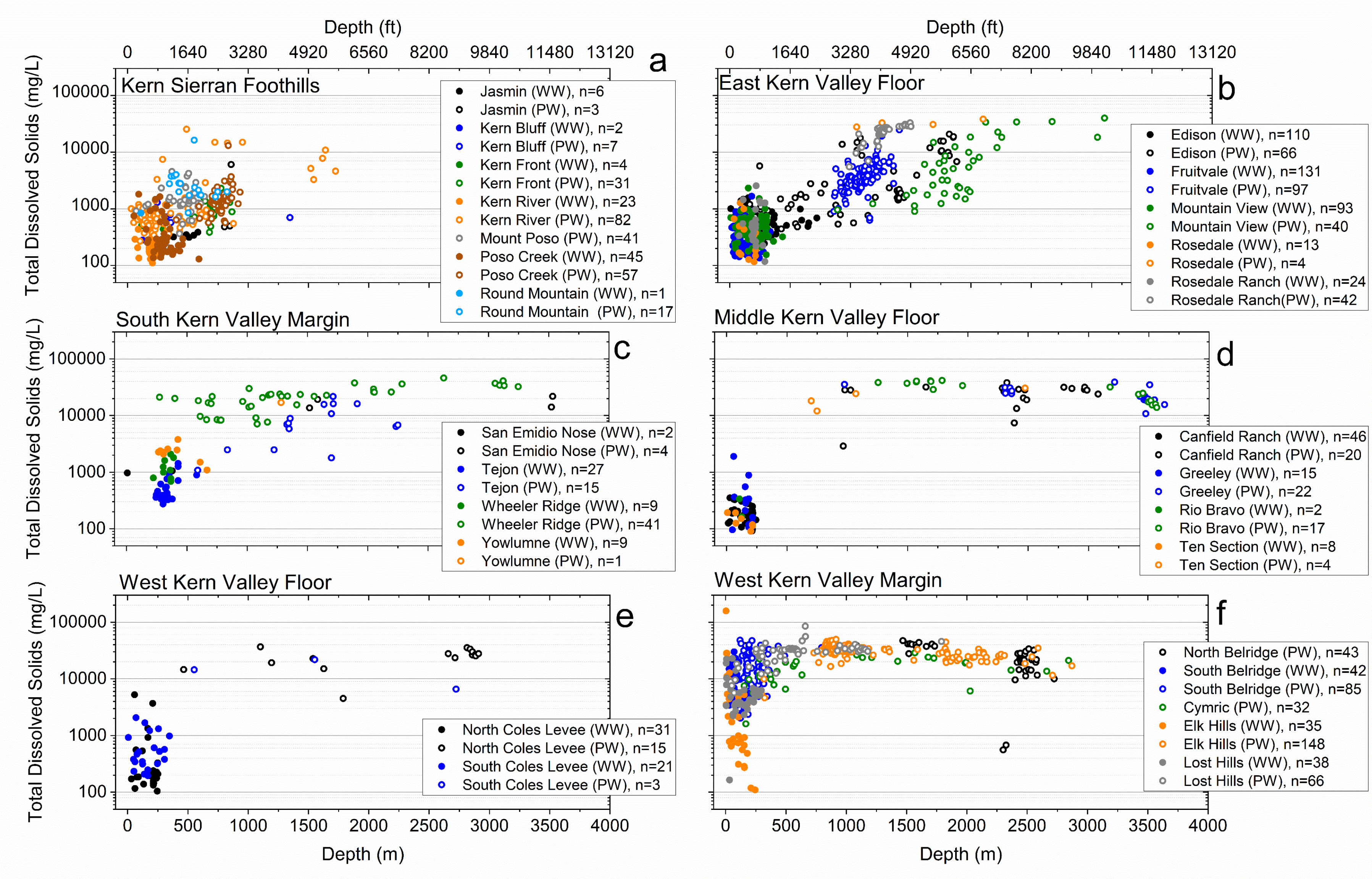
Data from Metzger et al 2018, Metzger and Landon (2018a, b)

Salinity of Groundwater in Water Wells in Kern County



Data from Metzger et al 2018, Metzger and Landon (2018a, b)

Salinity of Groundwater in Water and Production Wells in Kern County



Data from Metzger et al 2018, Metzger and Landon (2018a, b)

Effluent Limits

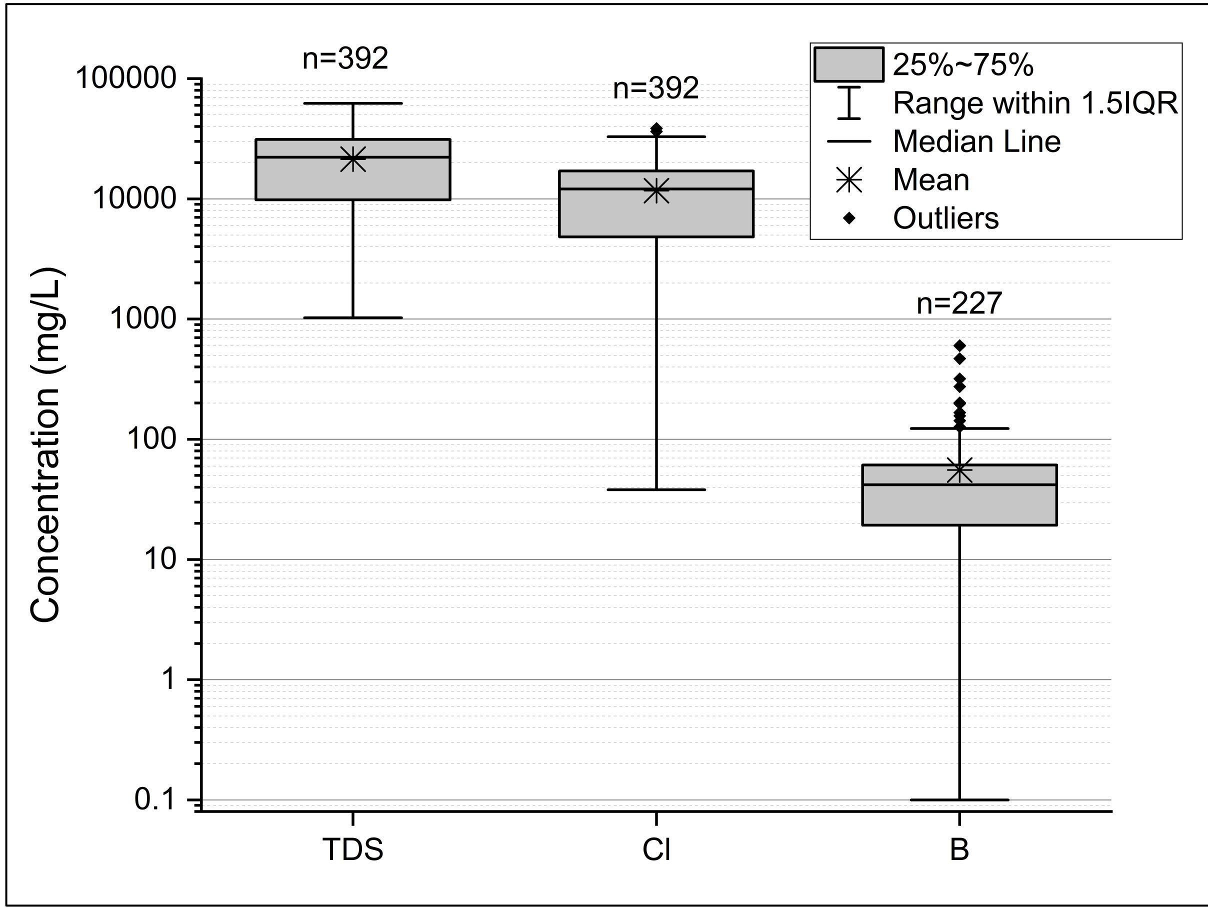
Tulare Basin Effluent Limits (CVRWQCB 2018)

- 1000 μS/cm electrical conductivity
- 200 mg/L chloride
- 1 mg/L boron

TDS (mg/L)	SJV (%)
>10,000	96.28
<10,000	3.70
Unknown	0.02

Data from DOGGR SB 1281 reporting

SJV – San Joaquin Valley



Data from USGS Produced Water Database

Treatment

Treatment	SJV (%)
Deoiling	94.87
Deoiling + Other Treatment	0.25
No Method	2.06
Membrane Treatment	0.00003
Desalination	0
Untreated	2.82

Data reported to DOGGR under SB 1281

SJV – San Joaquin Valley

Only 0.25% of produced water discharged to unlined ponds is treated beyond deoiling.

Photo credit - Clean Water Action

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Beneficial Use: Maximum Allowable TDS Levels for Protection of Groundwater Resources for Oil and Gas Development and Disposal of Produced Water in California

Maximum TDS (mg/L)	Applicability to O&G Industry	Enforceability	Overseeing Agencies
3,000 mg/L or EC < 5,000 μS/cm for municipal water supply (MUN)	Land disposal, produced water ponds	*States Sources of Drinking Water Policy* (SWRCB Res No. 88-63 (SWRCB 2006). **TDS and EC not defined for other beneficial use such as that used for agriculture (AGR).**	SWRCB
Undefined	Conventional O&G Development	PRC § 1722.22 for casing requirements	DOGGR
10,000	Well stimulation	USDW, CA Water Code § 10783(k)(2)	DOGGR, SWRCB
10,000	UIC Program	UDSW, protected unless exempted, 40 C.F.R. 144.3	EPA, DOGGR
10,000	O&G development on federal or tribal land	Onshore Oil & Gas Order No. 2, 53 Federal Register 46798	BLM, DOGGR, SWRCB

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A Case Study

Evaluation of Groundwater Contamination at the McKittrick 1 & 1-3 Facility

- The public record is extensive and easily accessible.
- The first Waste Discharge Requirement permit was issued in 1961 - an example of the long-term practice of disposal of saline (> 10,000 mg/L TDS) produced water into unlined produced water ponds.
- Discharge rates average 67,000 bbd (~ 1 billion gallons per year). Disposal volume over a 60-year operating period is estimated > 60 billion gallons.
- Complex hydrogeological and geochemical conditions that underlie and are in proximity to the facility are likely typical of numerous produced water ponds throughout the Tulare basin.
- Land utilized for agriculture with irrigation water supplied by water wells is located 457 m north of the McKittrick 1 & 1-3 Facility.

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Location on Monitoring Wells at the McKittrick 1 & 1-3 Facility

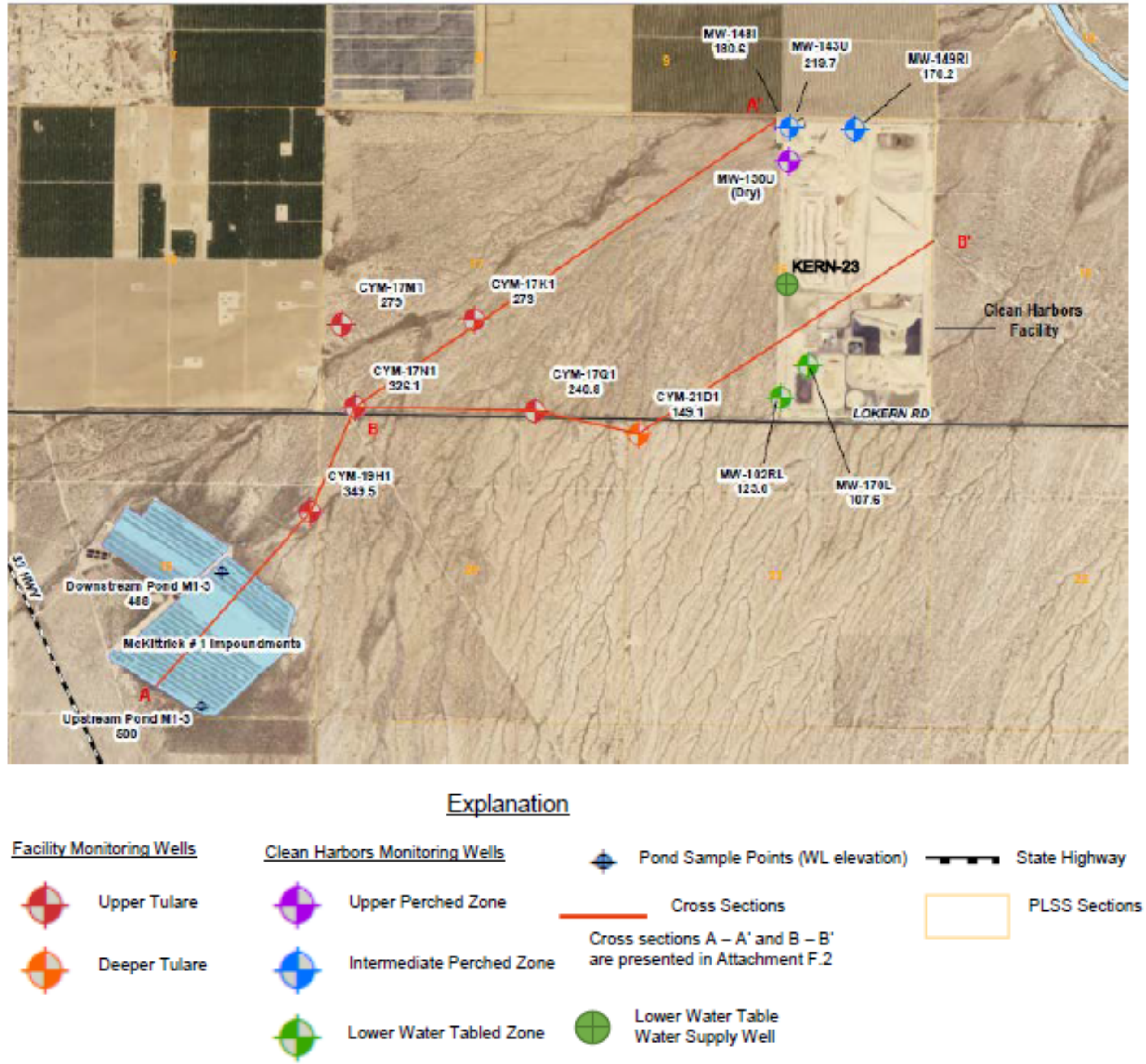

Figure from CVRWQCB (2019)

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Perched and Regional Aquifer Conditions at the McKittrick 1 & 1-3 Facility

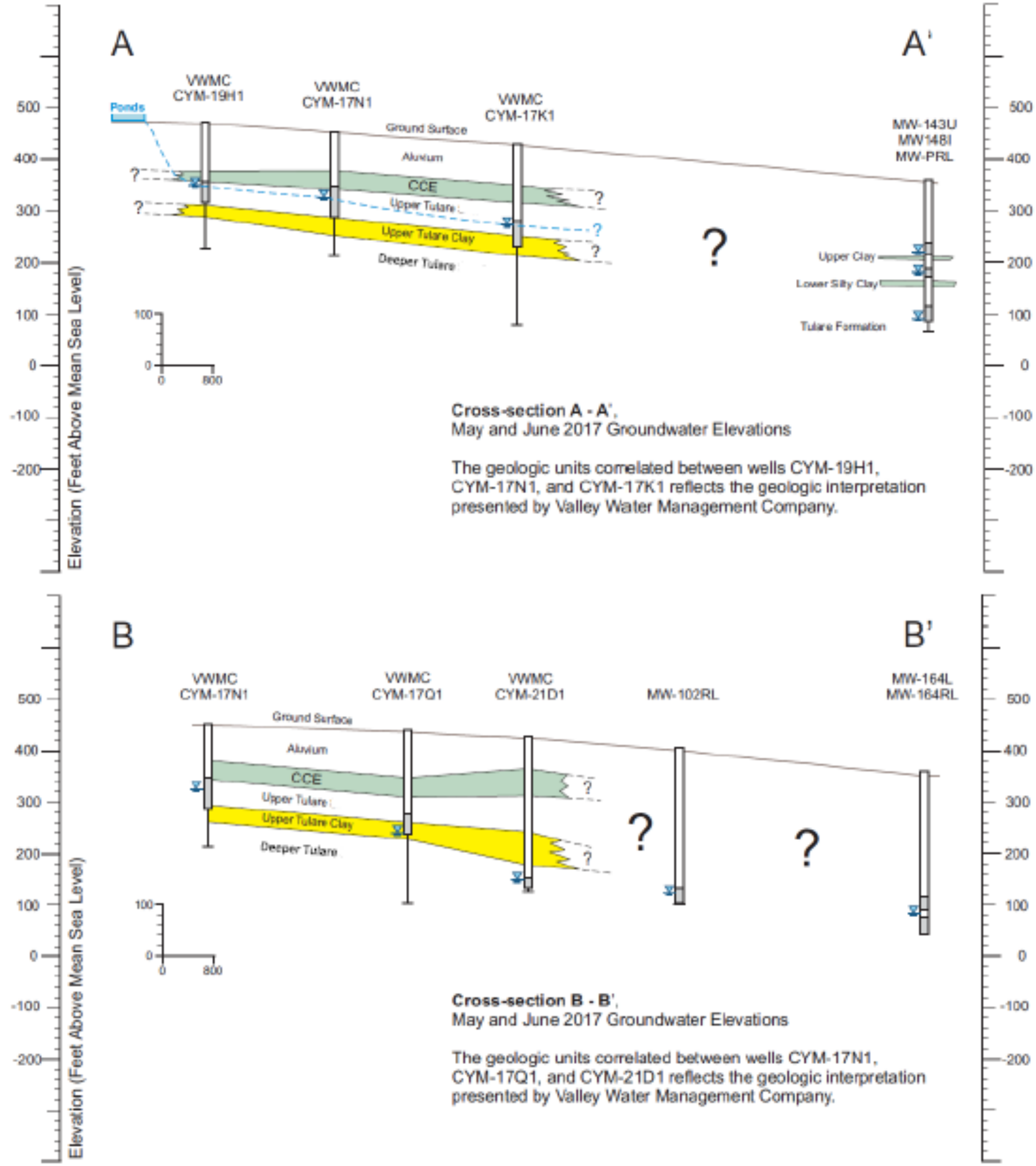

Figure from CVRWQCB (2019)

Levels of TDS, Chloride, and Boron in CYM-21D1 at the McKittrick 1 & 1-3 Facility

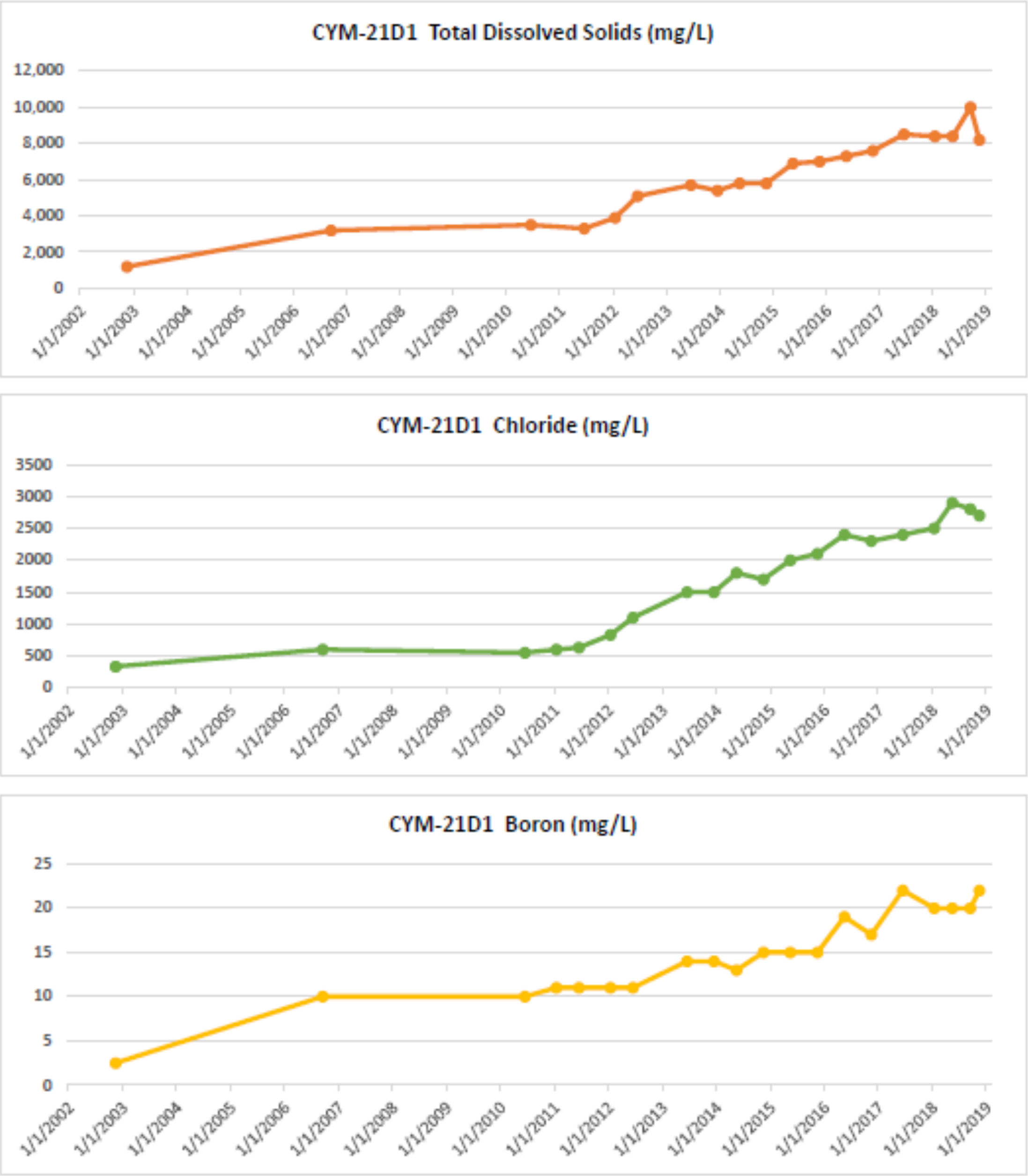

Figure from CVRWQCB (2019)

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Water Isotope Values in Monitoring Well and Pond Samples at the McKittrick 1 & 1-3 Facility

$$\delta^{18}O_{sample}\,(‰) = \left(\frac{\left(^{18}O/^{16}O\right)_{sample}}{\left(^{18}O/^{16}O\right)_{VSMOW}} - 1 \right) 1000$$

$$\delta^{2}H_{sample}\,(‰) = \left(\frac{\left(^{2}H/^{1}H\right)_{sample}}{\left(^{2}H/^{1}H\right)_{VSMOW}} - 1 \right) 1000$$

Vienna Standard Mean Ocean Water (VSMOW)

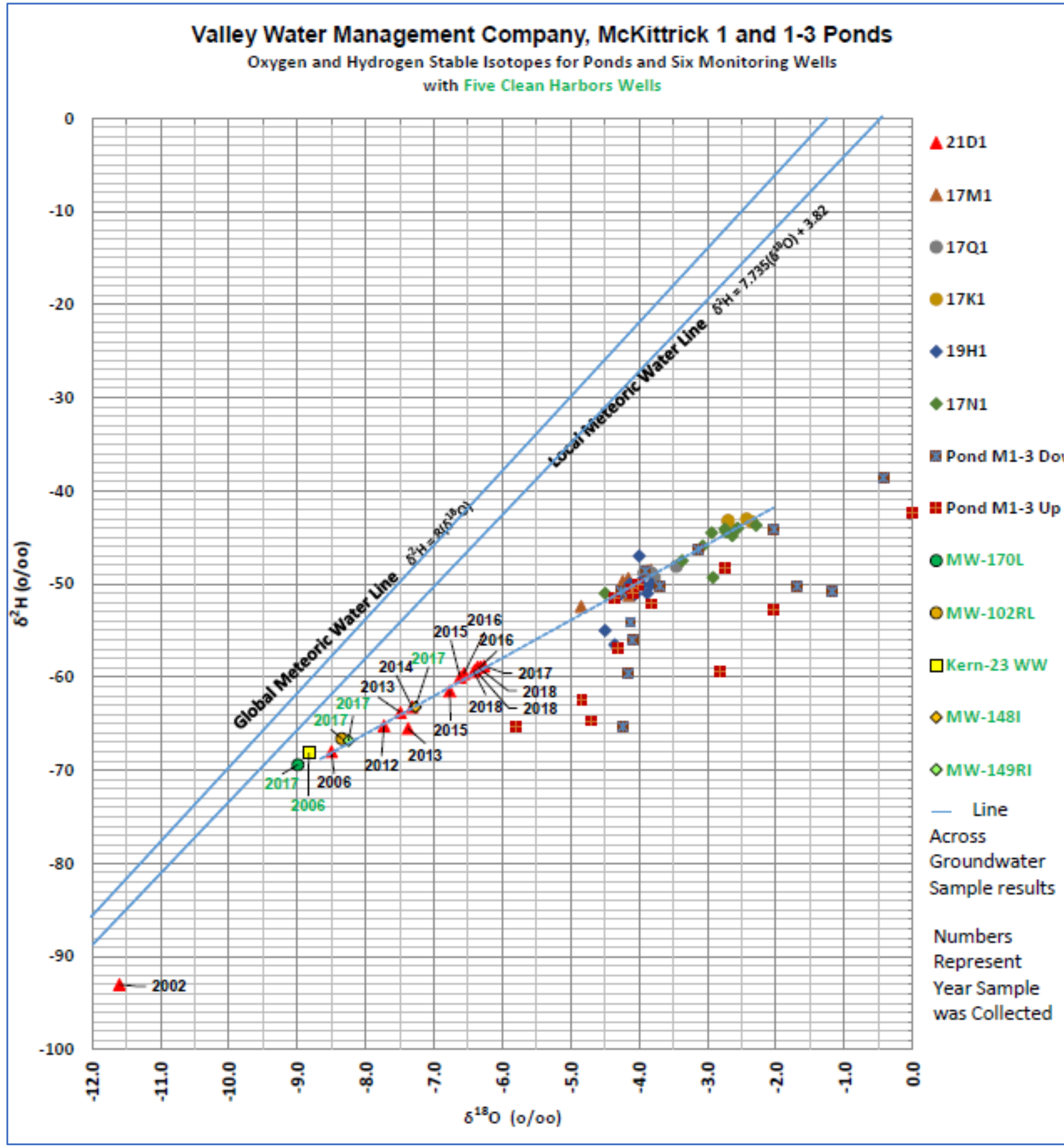
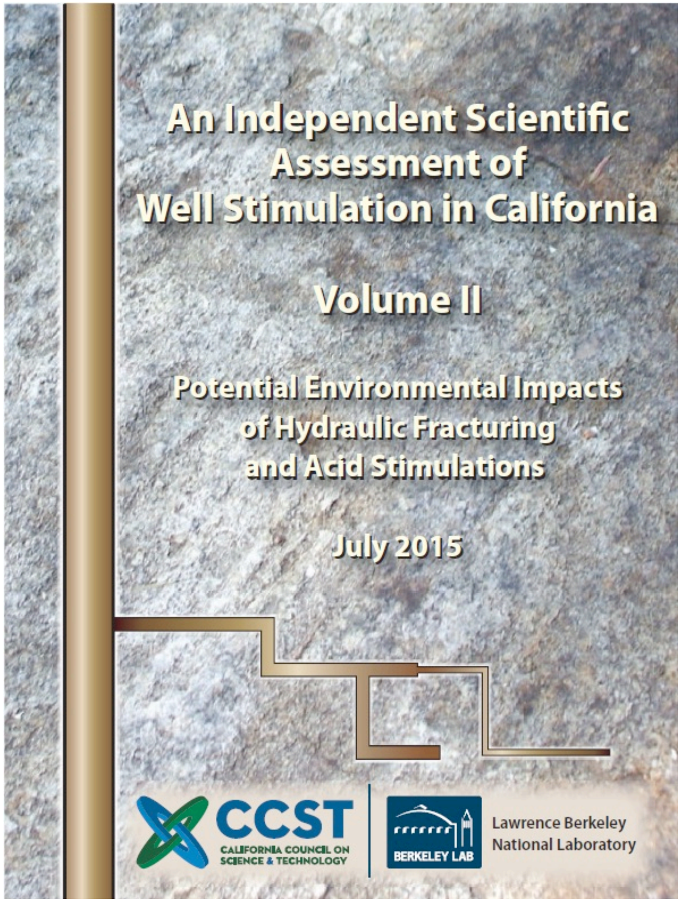


Figure from CVRWQCB (2019)

Conclusions



Jordon et al. (2015)
Stringfellow et al. (2015)

As stated by the California Council on Science & Technology and the Lawrence Berkeley National Laboratory in 2015:

- Unlined produced water ponds poses a risk to groundwater resources in California.

- If concentrations of salinity and constituents of concern cannot be reduced to levels protective of groundwater resources, this practice should be phased out.

- Groundwater investigations should be expanded to determine the extent of groundwater impact from past disposal.

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Thank You!

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