Using Oil Field Chemical Analyses to Determine Salinity Gradients and the Depth to Underground Sources of Drinking Water in Kern County's Oilfields*

Janice Gillespie[1], Joshua Meyer[1], David Kong[1], and Stephen Anderson[1]

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[1]California State University, Bakersfield, CA (jgillespie@csub.edu)

Abstract

The use of well stimulation techniques such as hydraulic fracturing and acidizing to recover remaining oil reserves as well as to unlock new sources of oil and gas from shales has increased in many areas of the country. While this has caused an increase in US oil production and a consequent independence from foreign sources of oil, it has also created great public concern about its potential to negatively impact groundwater supplies. As a result of these concerns, the California legislature passed SB 4 (the so-called 'fracking bill') in September 2013. The bill requires the state to identify potable groundwater resources which require protection and develop a monitoring program to protect these resources in areas where hydraulic fracturing occurs.

In the past, oil producers set surface casing to protect the base of fresh water (BFW) which is defined as waters containing less than 3000 ppm total dissolved solids (TDS). However, the US Environmental Protection Agency (EPA) requires state agencies to protect Underground Sources of Drinking Water (USDW). Waters classified as USDW's have less than 10,000 ppm TDS and are considered to have potential for remediation for agriculture, landscaping and industrial uses. In this study we examine data from geochemical analyses in oil and water wells in order to determine the depth to USDW's in various oilfields throughout Kern County, California. The depth to the base of the USDW's is controlled by a number of factors including location, depth and stratigraphy.

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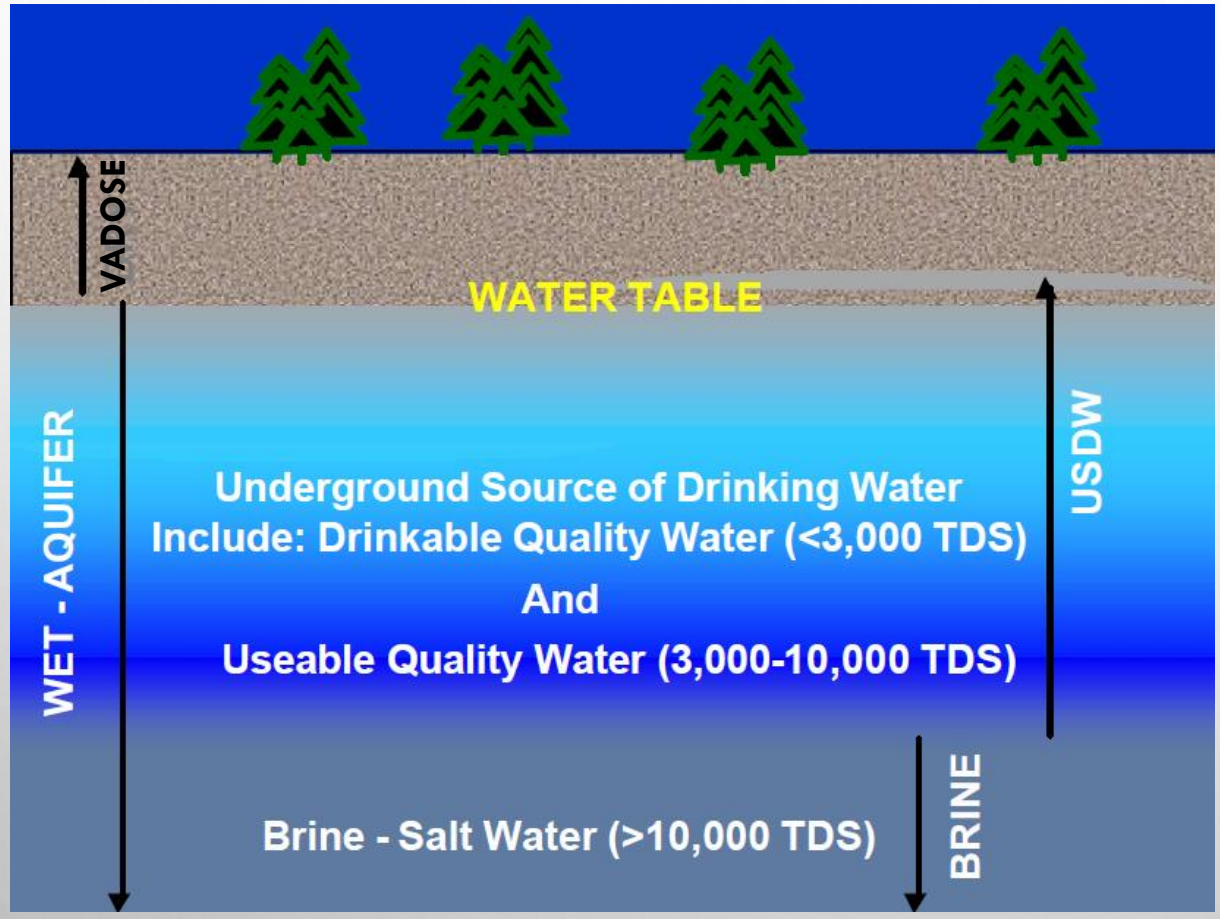
BASE OF FRESH WATER (BFW): < 3000 PPM
UNDERGROUND SOURCE OF DRINKING WATER (USDW): 3000-10,000 PPM



Very little data available for waters with TDS > 1500 ppm

GOALS

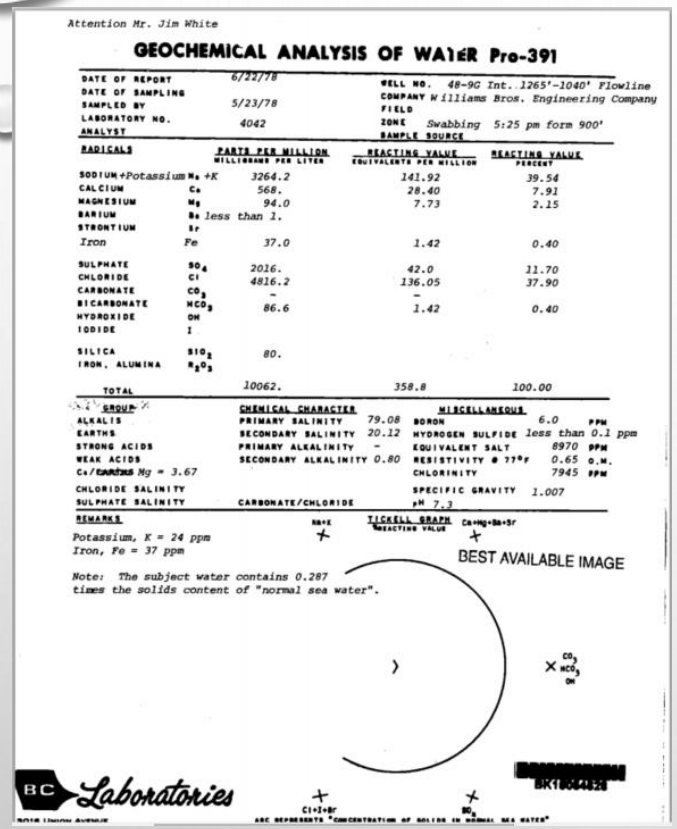
USE CHEMICAL ANALYSES TO:

A) DETERMINE THE DISTRIBUTION OF WATER SALINITY AT VARIOUS DEPTHS WITHIN THE BASIN TO IDENTIFY PROTECTED WATERS

B) DETERMINE THE DEGREE OF ACCURACY IN USING GEOPHYSICAL LOGS WHERE ANALYSES ARE UNAVAILABLE

DATA

- DOGGR GEOCHEMICAL ANALYSES—USED FOR DEEPER AQUIFER CHARACTERIZATION (JOSH MEYER)
- SWRCB, USGS, DWR AND KCWA WATER WELL ANALYSES—USED FOR SHALLOW AQUIFER CHARACTERIZATION (STEPHEN ANDERSON)
- GEOPHYSICAL LOG DATA ANALYSIS—CALIBRATED TO GEOCHEMICAL ANALYSES FOR AREAS WITH LITTLE GEOCHEMICAL DATA (DAVID KONG)



Attention Mr. Jim White

GEOCHEMICAL ANALYSIS OF WATER Pro-391

DATE OF REPORT	6/22/78	WELL NO. 48-9G Int. 1265'-1040' Flowline
DATE OF SAMPLING	5/23/78	COMPANY Williams Bros. Engineering Company
SAMPLED BY		FIELD
LABORATORY NO.	4042	ZONE Swabbing 5:25 pm form 900'
ANALYST		SAMPLE SOURCE

RADICALS		PARTS PER MILLION (MILLIGRAMS PER LITER)	REACTING VALUE (EQUIVALENTS PER MILLION)	REACTING VALUE (PERCENT)
SODIUM+Potassium	$Na+K$	3264.2	141.92	39.54
CALCIUM	Ca	568.	28.40	7.91
MAGNESIUM	Mg	94.0	7.73	2.15
BARIUM	Ba	less than 1.		
STRONTIUM	Sr			
Iron	Fe	37.0	1.42	0.40
SULPHATE	SO_4	2016.	42.0	11.70
CHLORIDE	Cl	4816.2	136.05	37.90
CARBONATE	CO_3	-	-	
BICARBONATE	HCO_3	86.6	1.42	0.40
HYDROXIDE	OH			
IODIDE	I			
SILICA	SiO_2	80.		
IRON, ALUMINA	R_2O_3			
TOTAL		10062.	358.8	100.00

GROUP	CHEMICAL CHARACTER		MISCELLANEOUS		
ALKALIS	PRIMARY SALINITY	79.08	BORON	6.0	PPM
EARTHS	SECONDARY SALINITY	20.12	HYDROGEN SULFIDE	less than 0.1	ppm
STRONG ACIDS	PRIMARY ALKALINITY	-	EQUIVALENT SALT	8970	PPM
WEAK ACIDS	SECONDARY ALKALINITY	0.80	RESISTIVITY @ 77°F	0.65	O.M.
Ca/~~CARBS~~ Mg = 3.67			CHLORINITY	7945	PPM
CHLORIDE SALINITY			SPECIFIC GRAVITY	1.007	
SULPHATE SALINITY	CARBONATE/CHLORIDE		pH 7.3		

REMARKS

Potassium, K = 24 ppm
Iron, Fe = 37 ppm

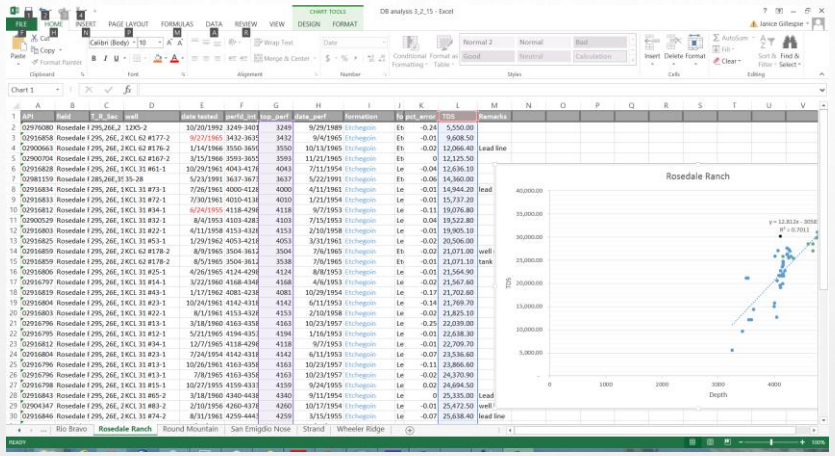
Note: The subject water contains 0.287 times the solids content of "normal sea water".

TICKELL GRAPH (REACTING VALUE)

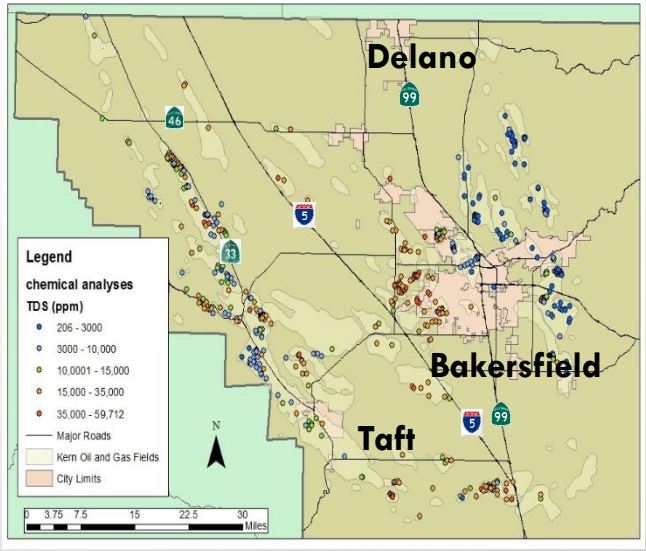
BEST AVAILABLE IMAGE

BC Laboratories

[redacted]



…entered into spreadsheet



…and GIS database

~550 scanned analyses from 1927-2014

DATABASE

- API NUMBER
- FIELD
- WELL NAME AND NUMBER
- DATE TESTED
- DATE PERFORATED
- KB
- PERF INTERVAL
- TOP PERF
- FORMATION
- PERCENT ERROR
- TDS
- REMARKS

QUALITY CONTROL

- DATE TESTED VS. DATE PERF'D: PREFER A LONG TIME PERIOD BEFORE TESTING TO BE SURE ZONE HAS CHANCE TO "CLEAN UP"

- CHARGE BALANCE-- SHOULD BE +/- 1.5% OR ANALYSIS IS CONSIDERED SUSPECT

- REMARKS—SOURCE OF SAMPLE (DST VS. PRODUCED WATER), SAMPLED BEFORE OR AFTER INJECTION COMMENCED?

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CHARGE BALANCE

ion	charge	mole wt	conc (mg/l or ppm)	meq/l	Total cations/anions
Ca	2	40.08	399	19.91017964	
K	1	39.1	23.8	0.608695652	
Mg	2	24.3	354	29.13580247	
Mn	2	54.9		0	
Na	1	22.99	5870	255.3284037	
Fe	3	55.8		0	304.9830814
F	-1	19		0	
Cl	-1	35.45	10240	-288.8575458	
CO3	-2	60		0	
HCO3	-1	61	330	-5.409836066	
NO3	-1	62		0	
SO4	-2	96.06	160	-3.331251301	
S	-2	32.06		0	
B4O7	-2	155.24		0	
I	-1	126.9		0	297.5986332
calculated TDS/chg balance			17376.8	7.38444821	
chg bal % error					1.23

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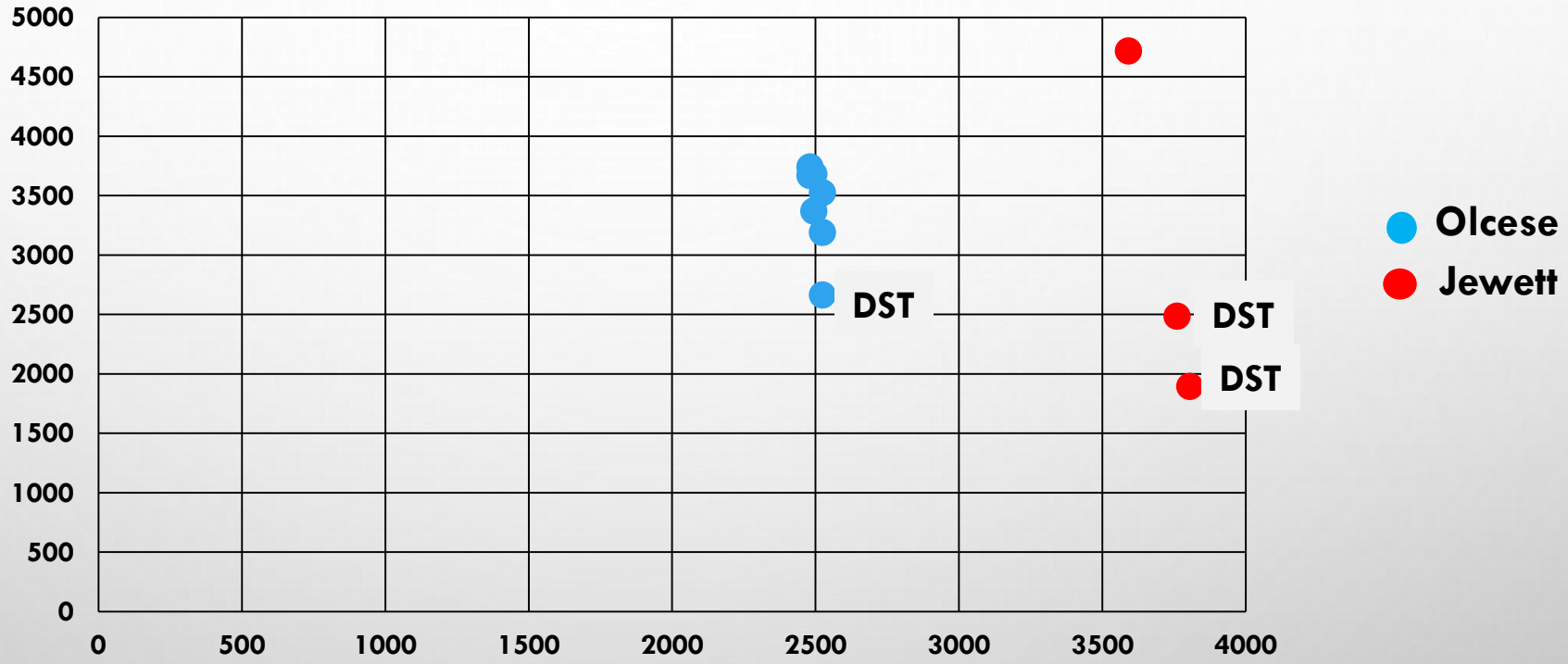
Ant Hill


5000
4500
4000
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2000
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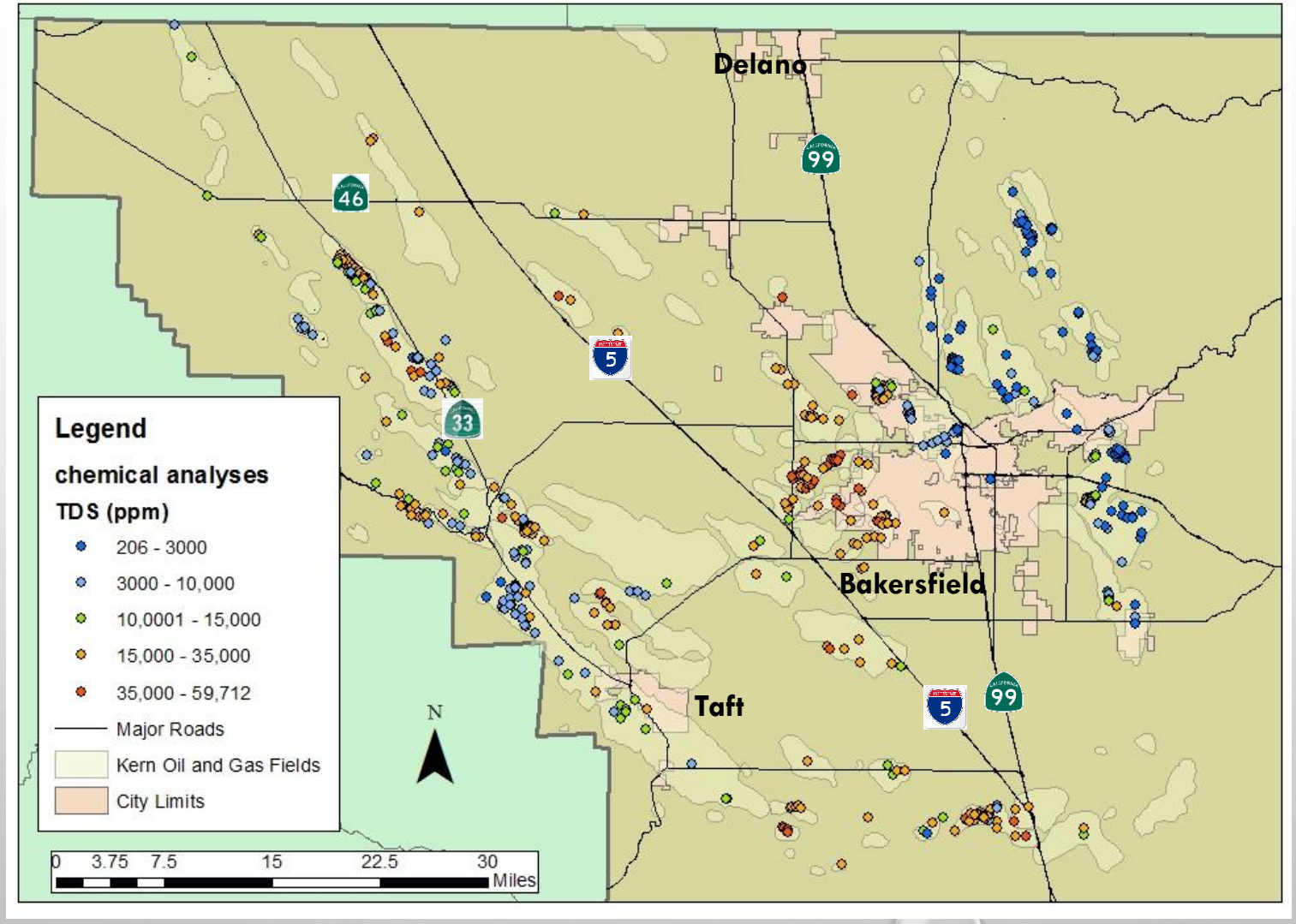
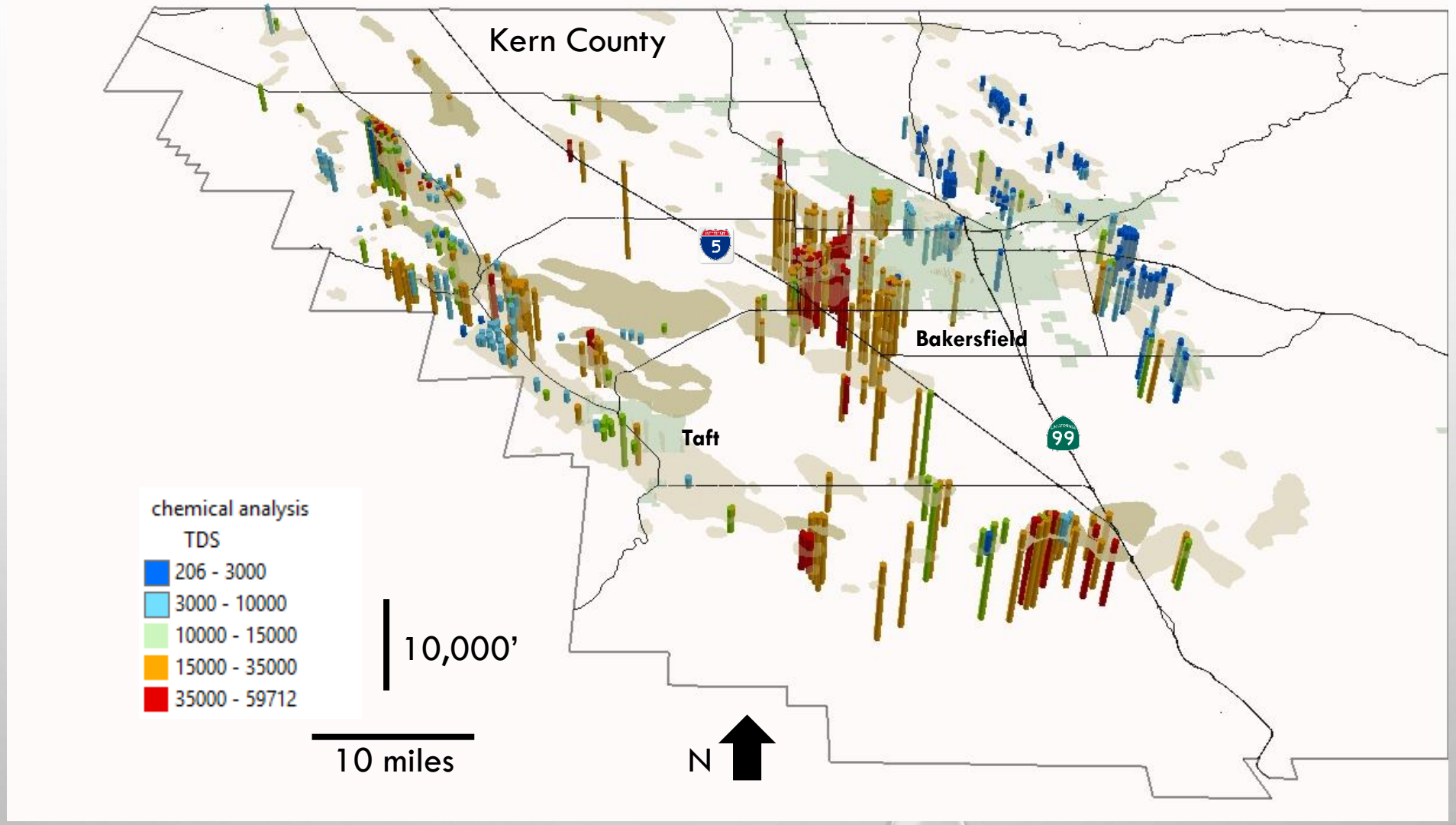
3000
3500
4000
DST
DST
DST
Olcese
Jewett

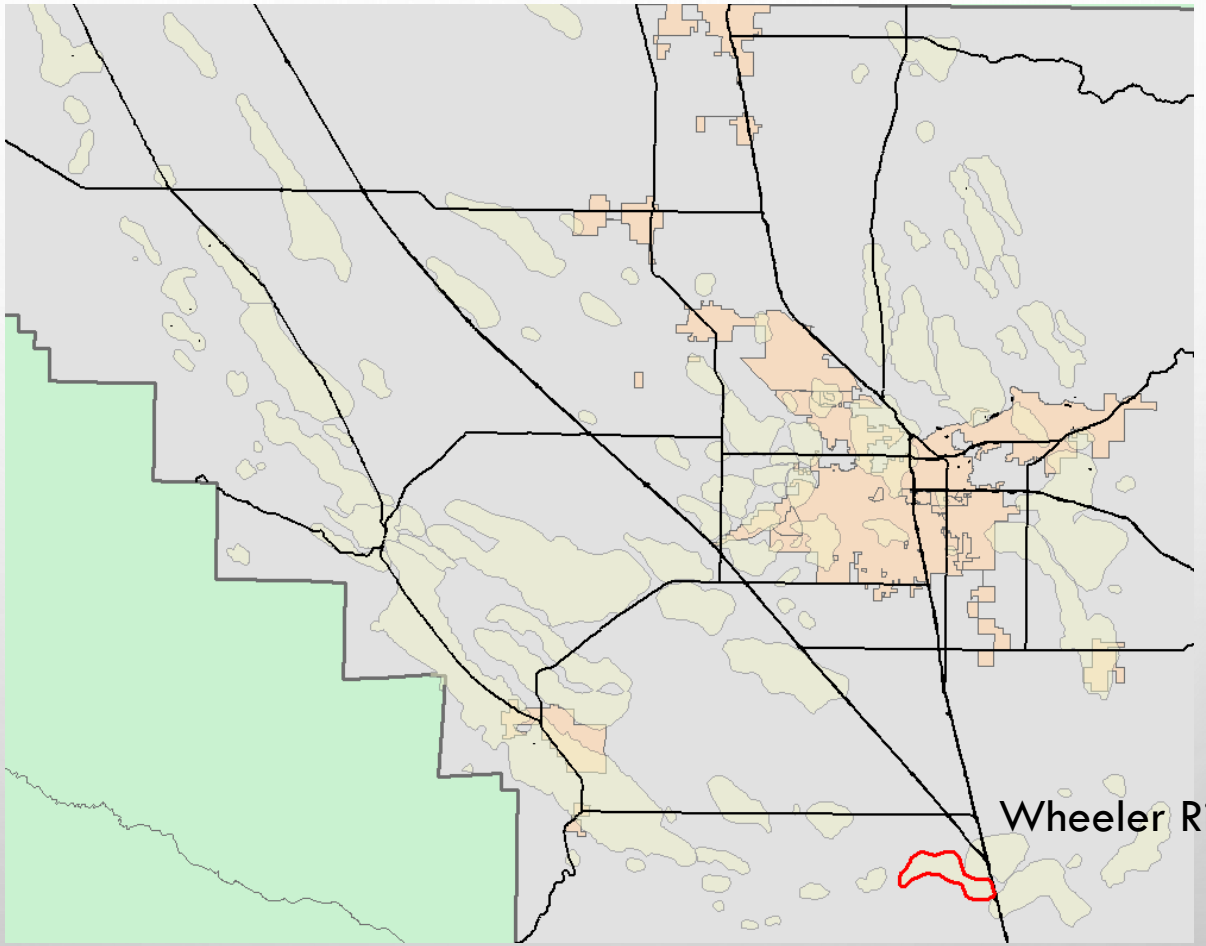
GIS DATABASE



Chemical Analysis Data 3D



LINEAR BEHAVIOR WITH DEPTH… ☺



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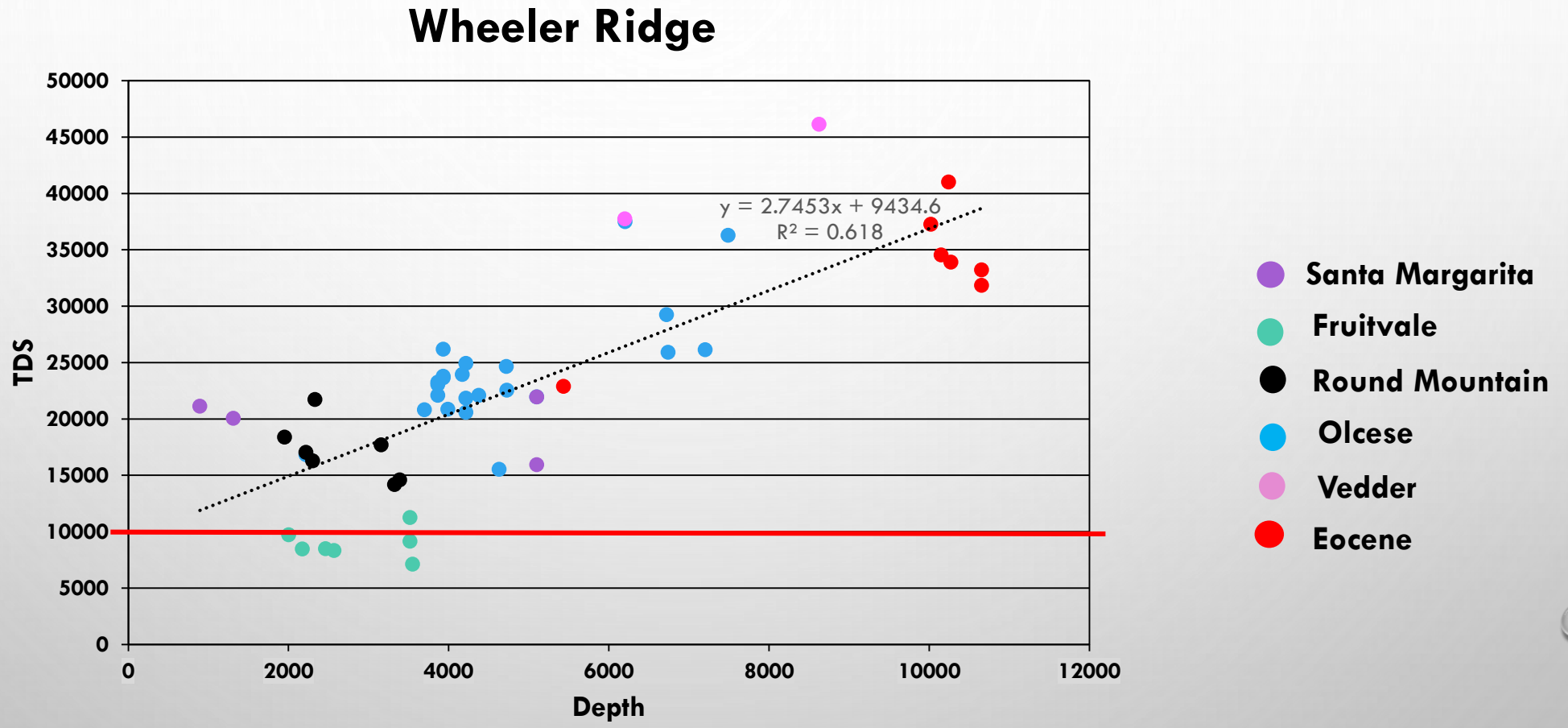
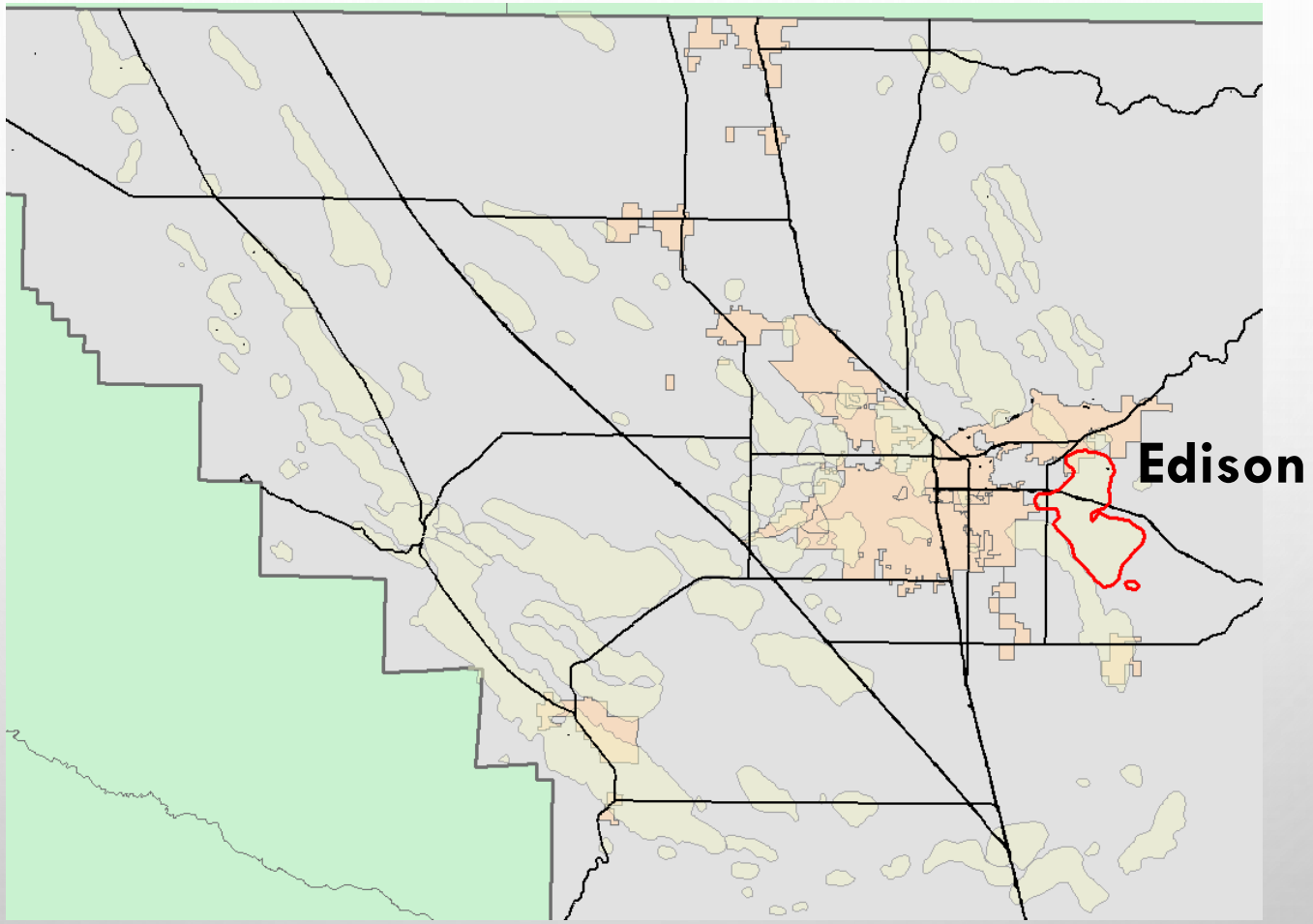


EXPONENTIAL BEHAVIOR WITH DEPTH 😐



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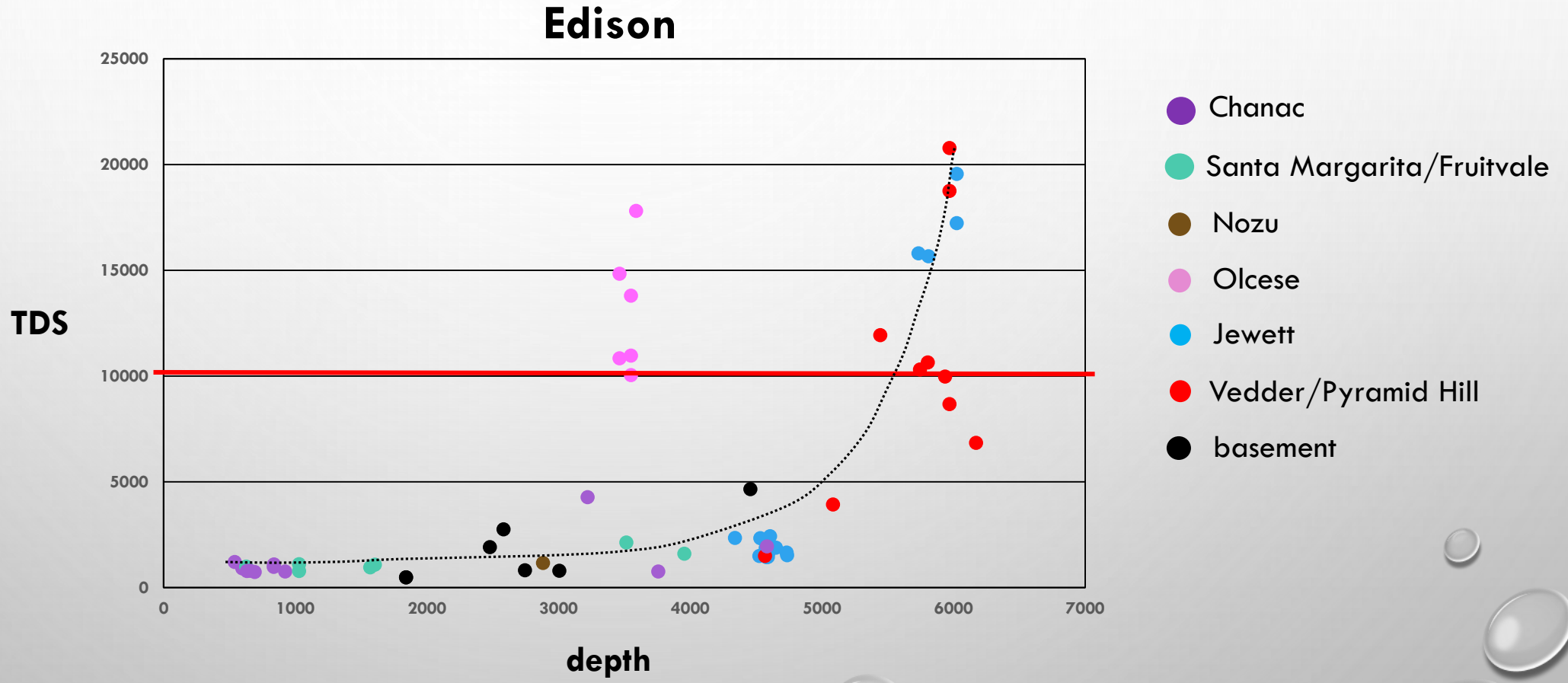
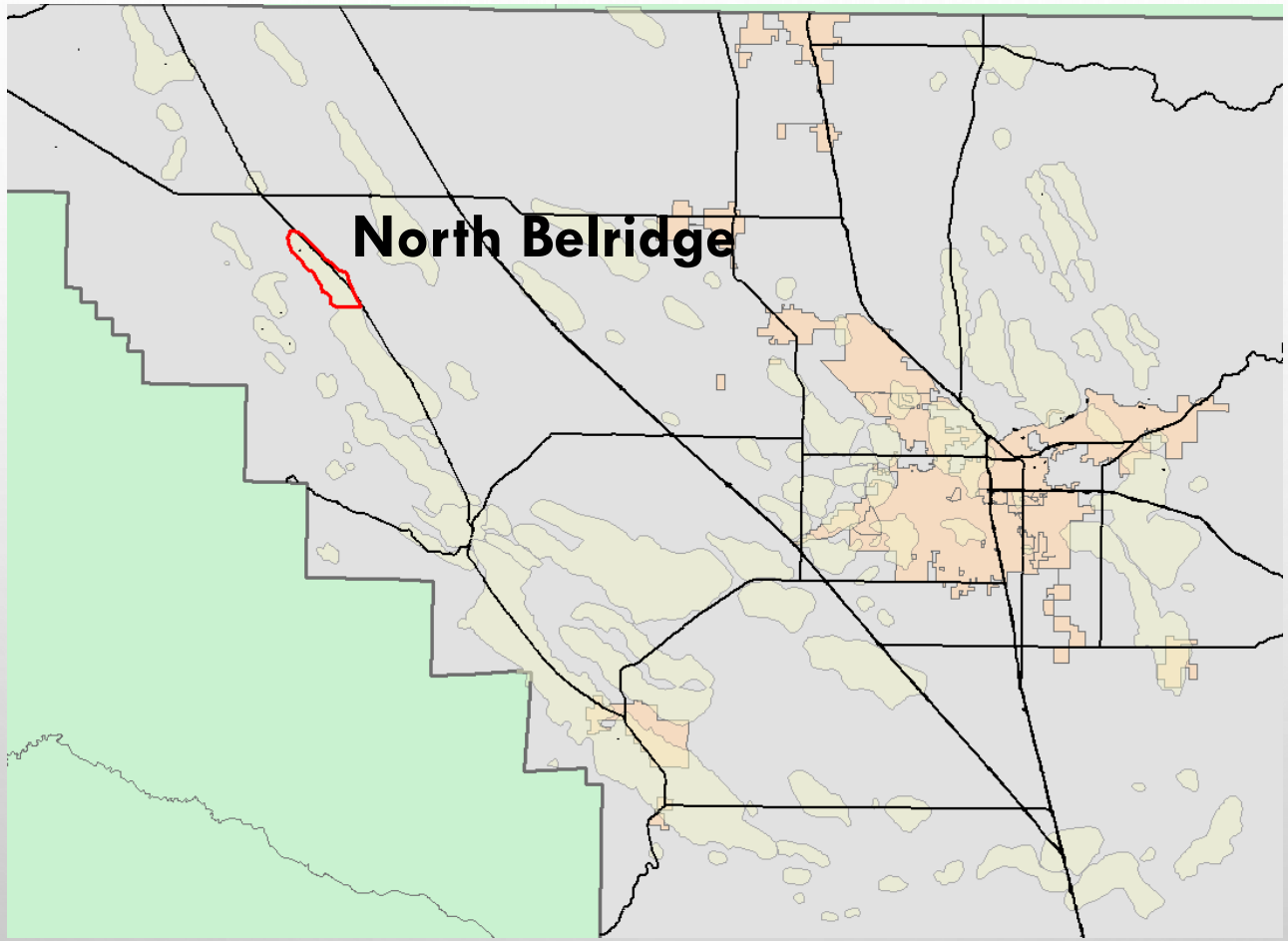
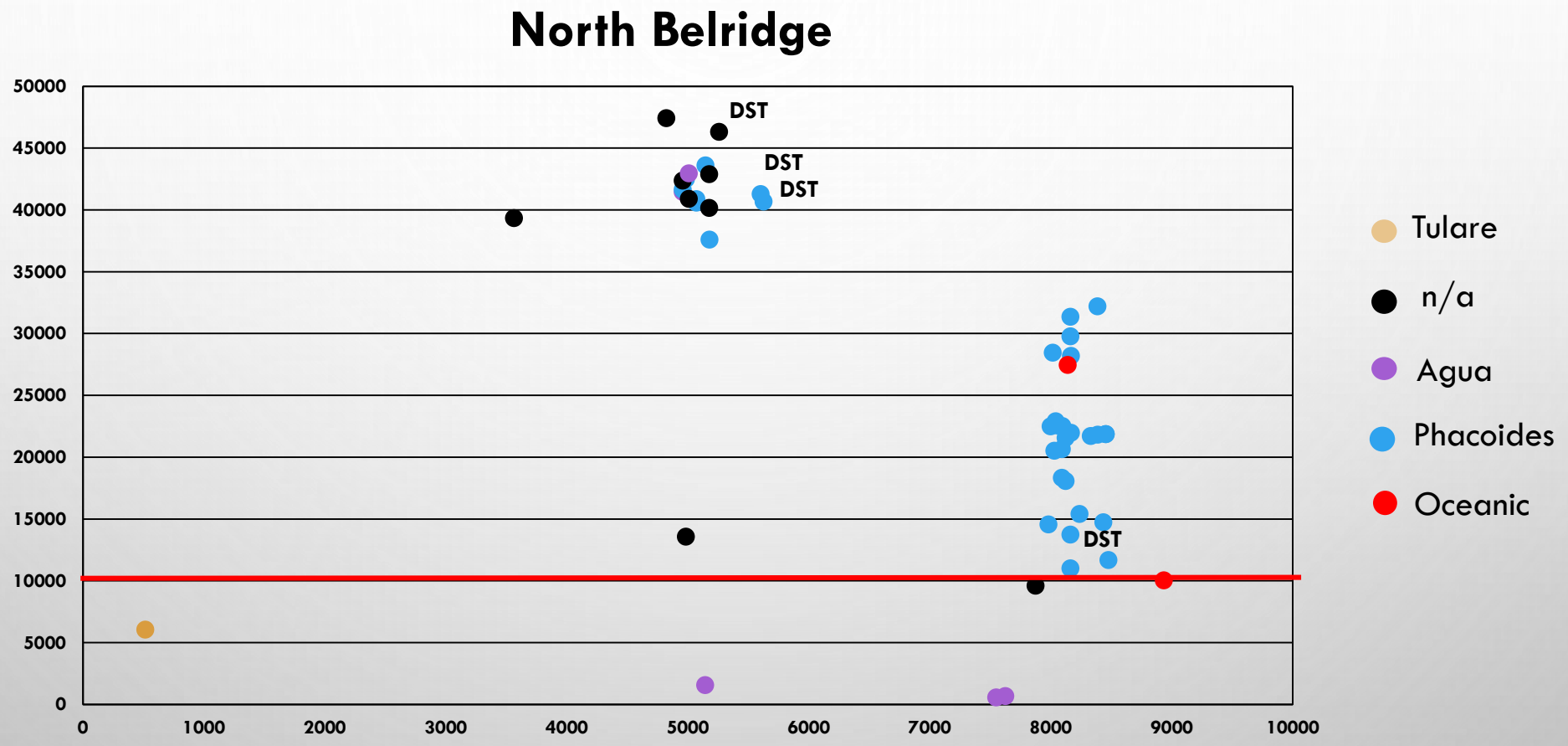


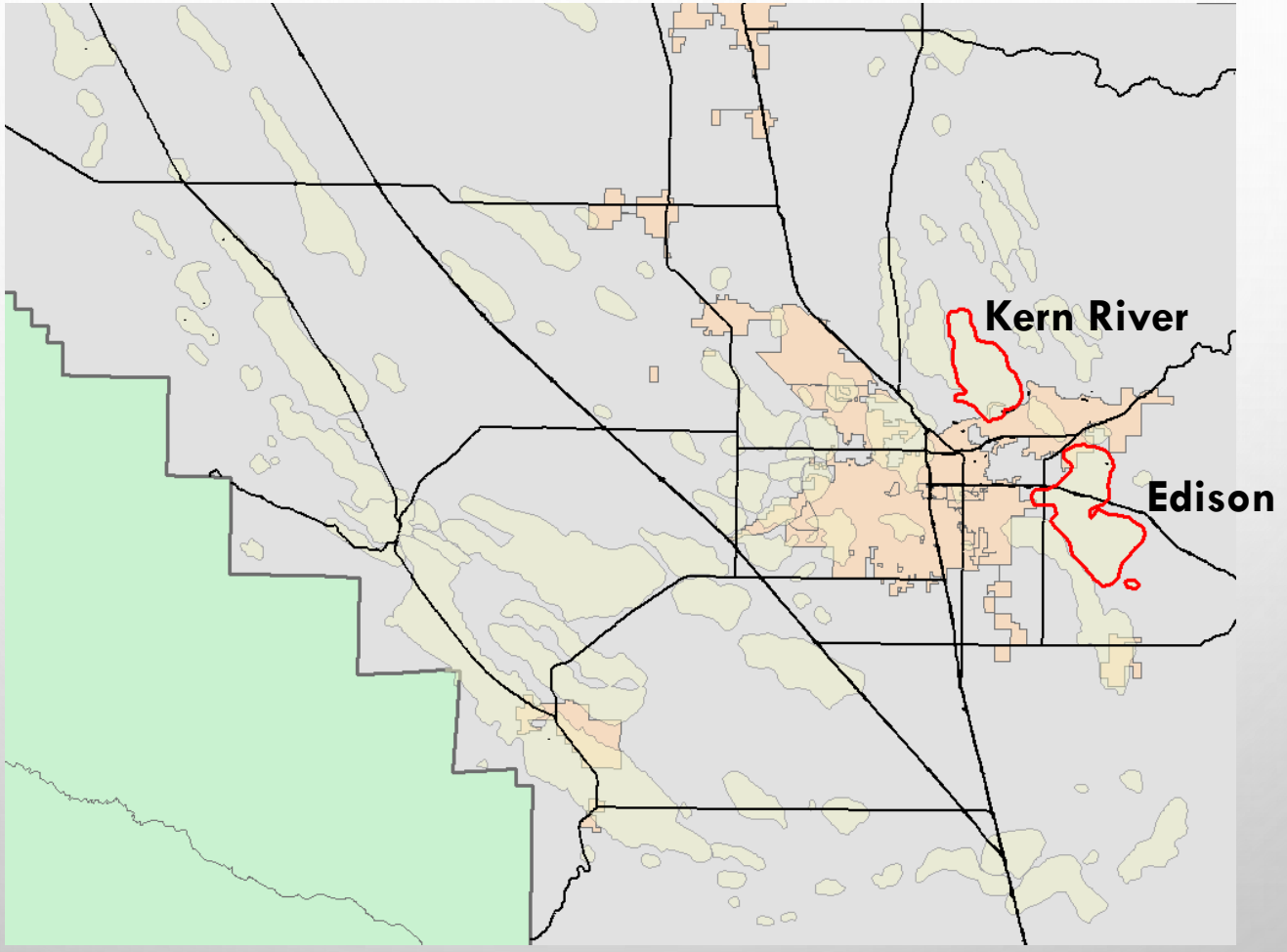
NON-BEHAVIOR WITH DEPTH…. ☹



NON-BEHAVIOR WITH DEPTH…. ☹



OLCESE OFTEN SALINE ON EAST SIDE



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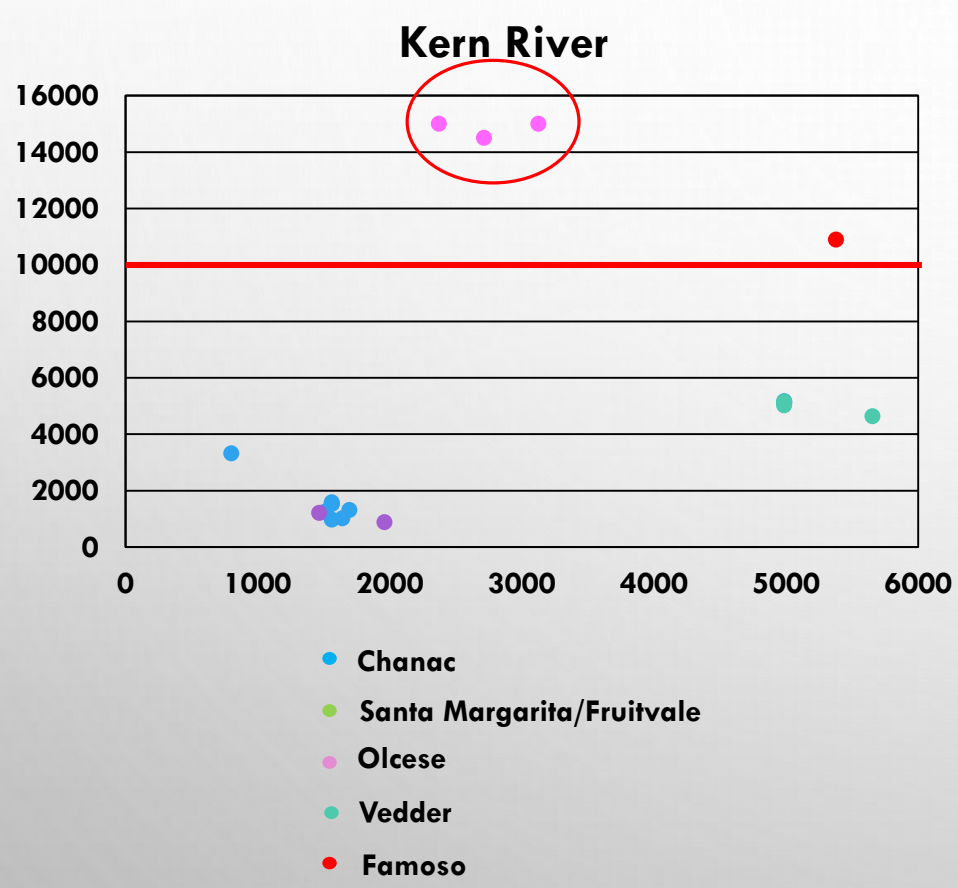
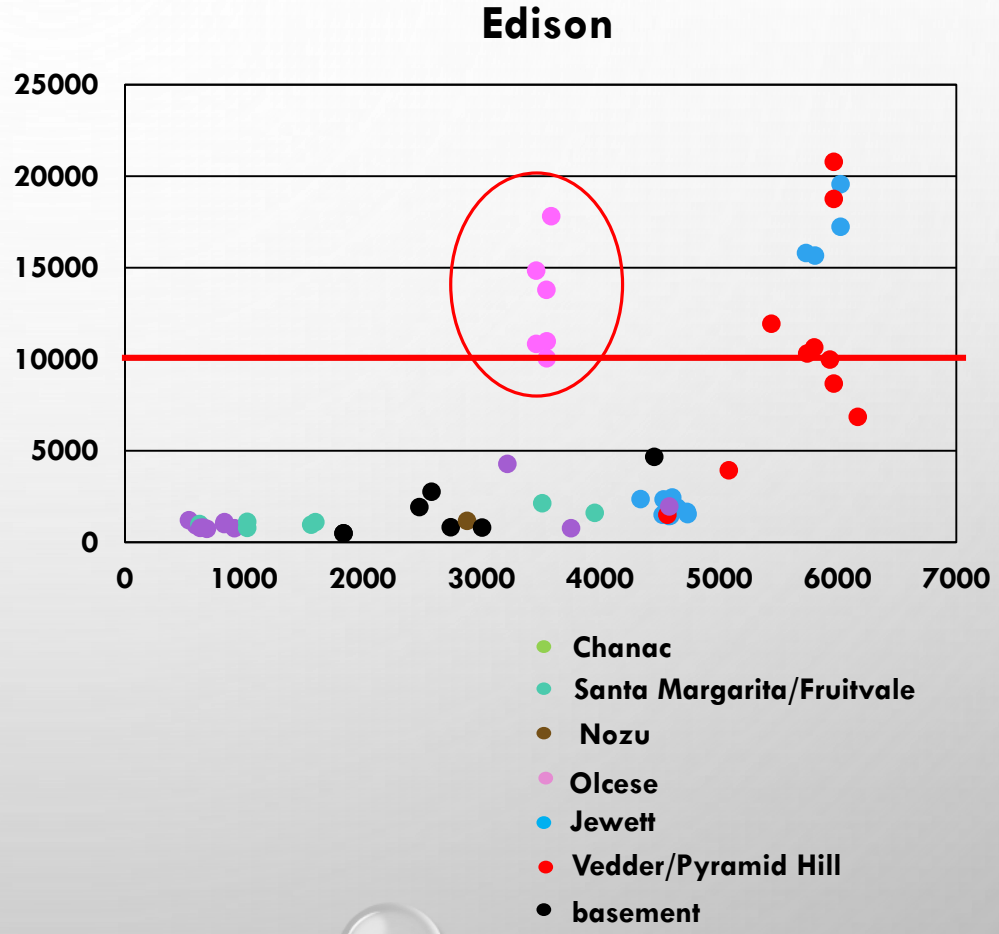
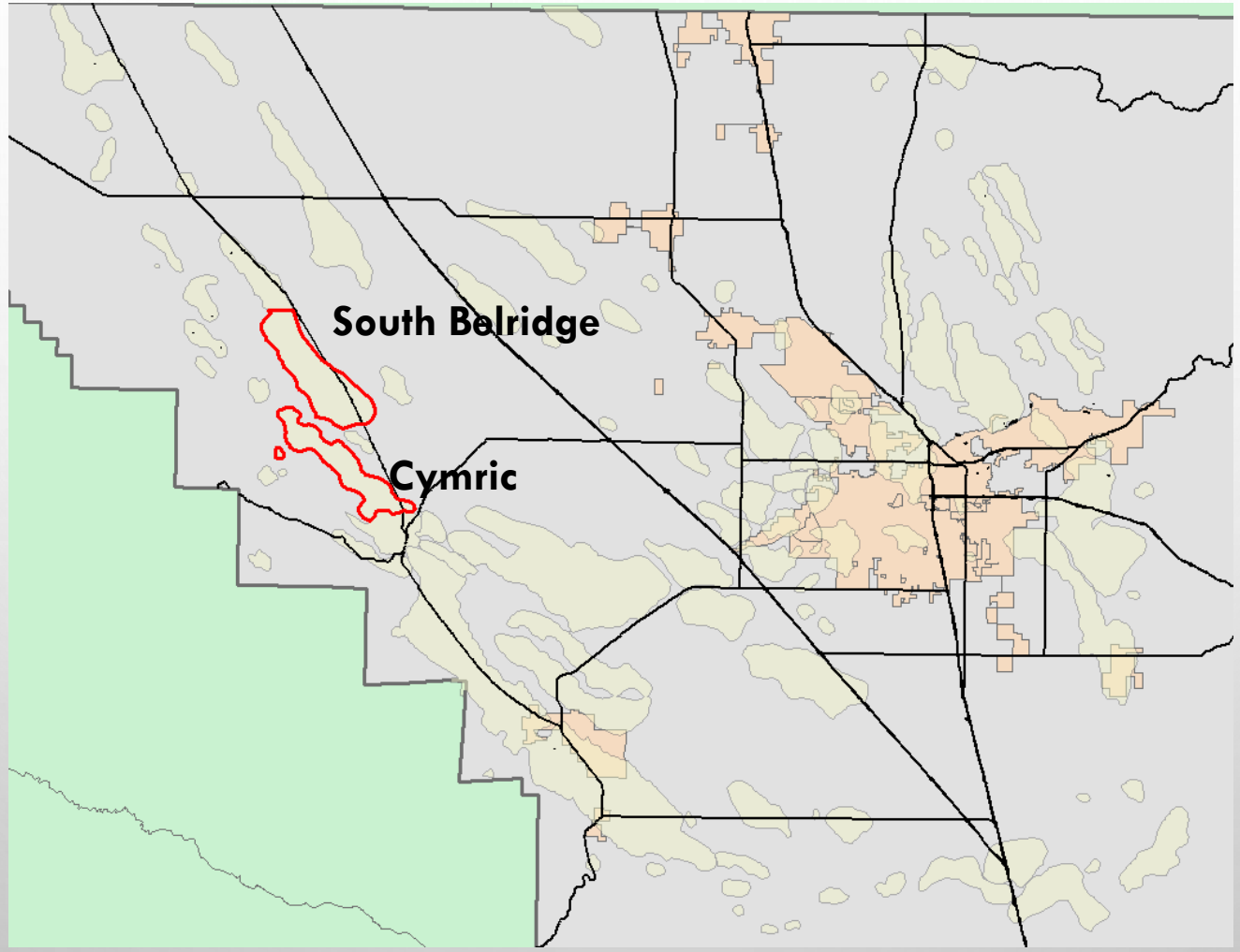




TULARE IS OF MOST CONCERN ON WEST SIDE



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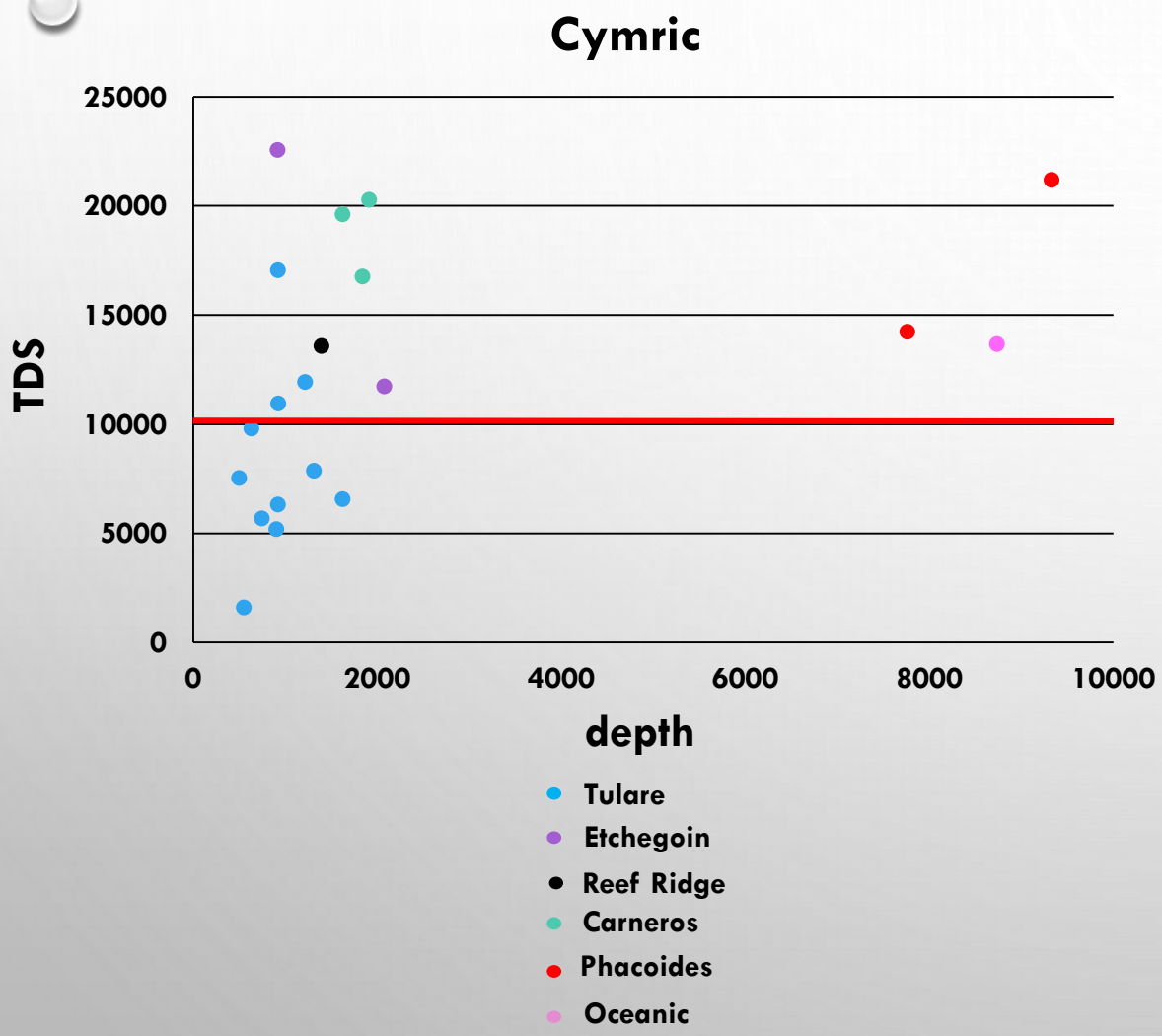
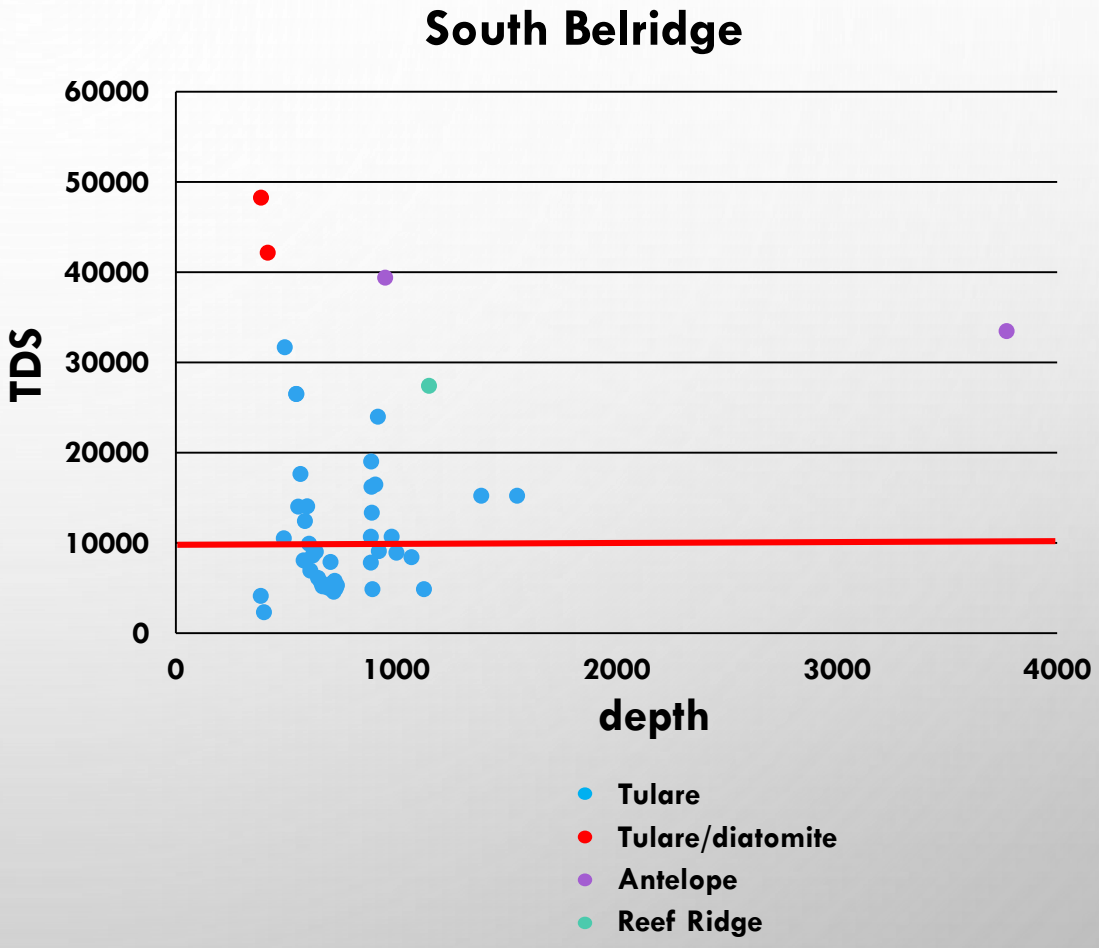
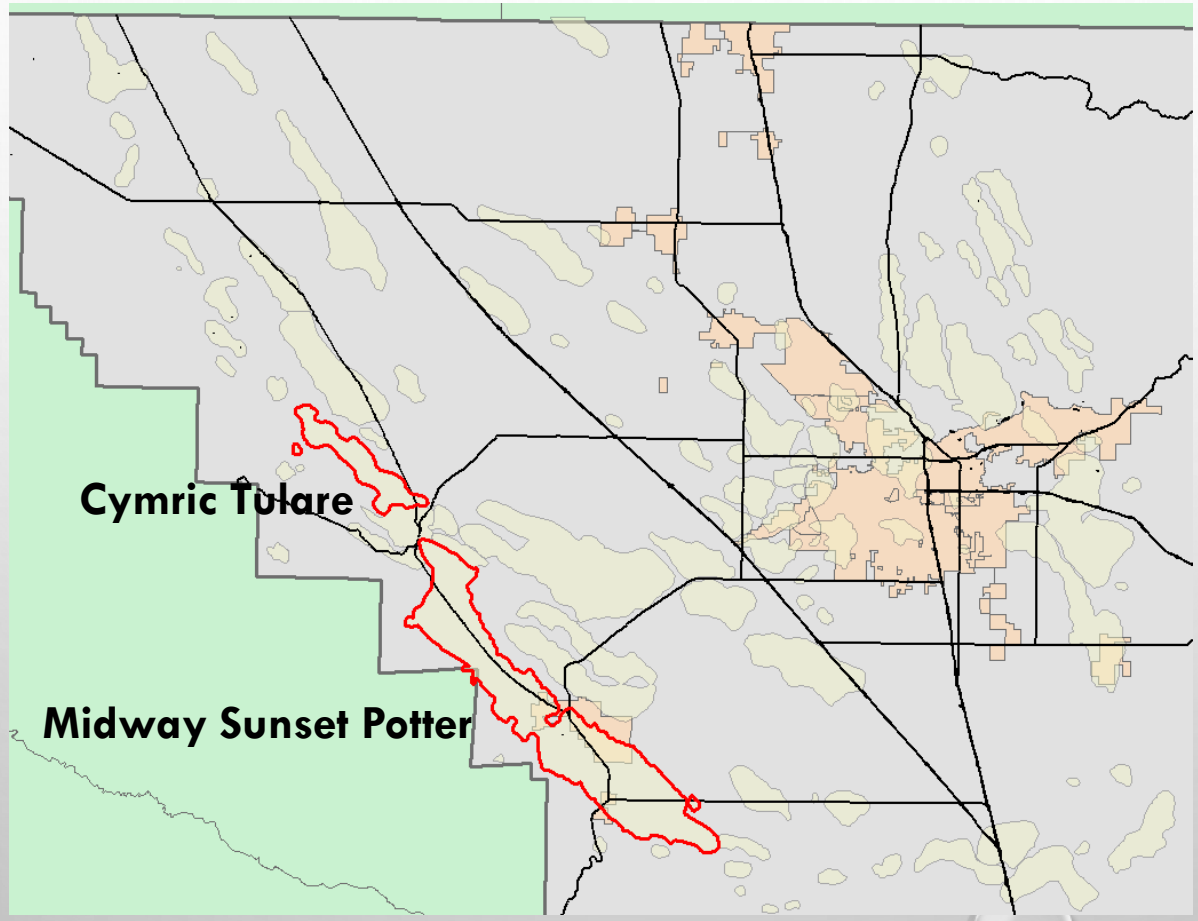




DO TDS VALUES CHANGE WITH TIME IN STEAMFLOODS?



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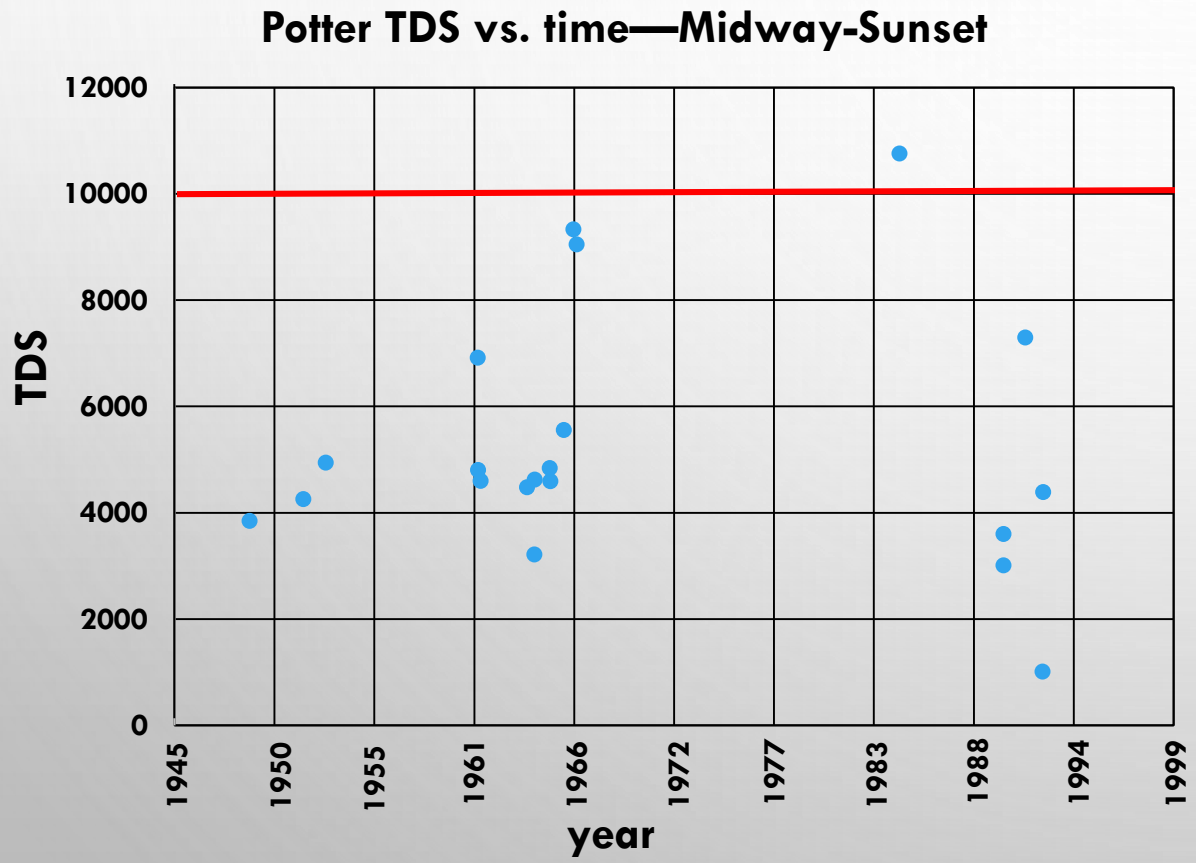
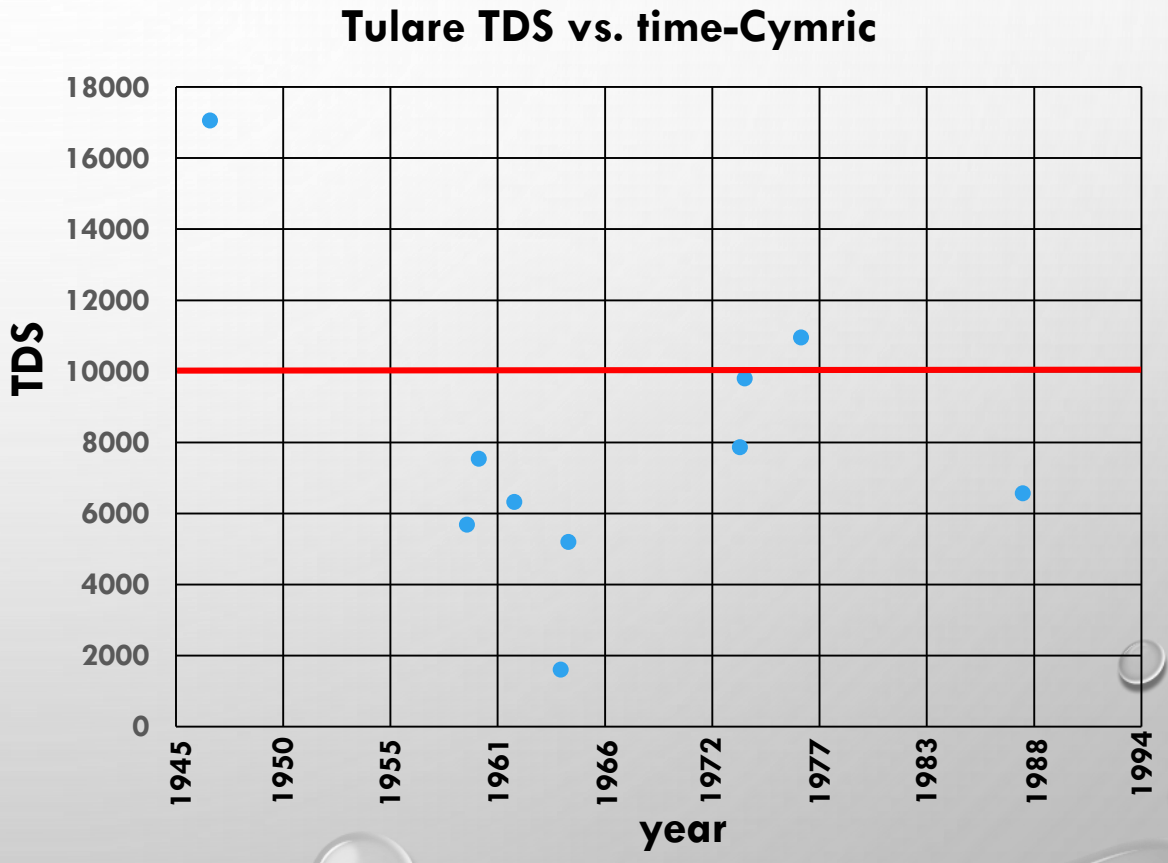
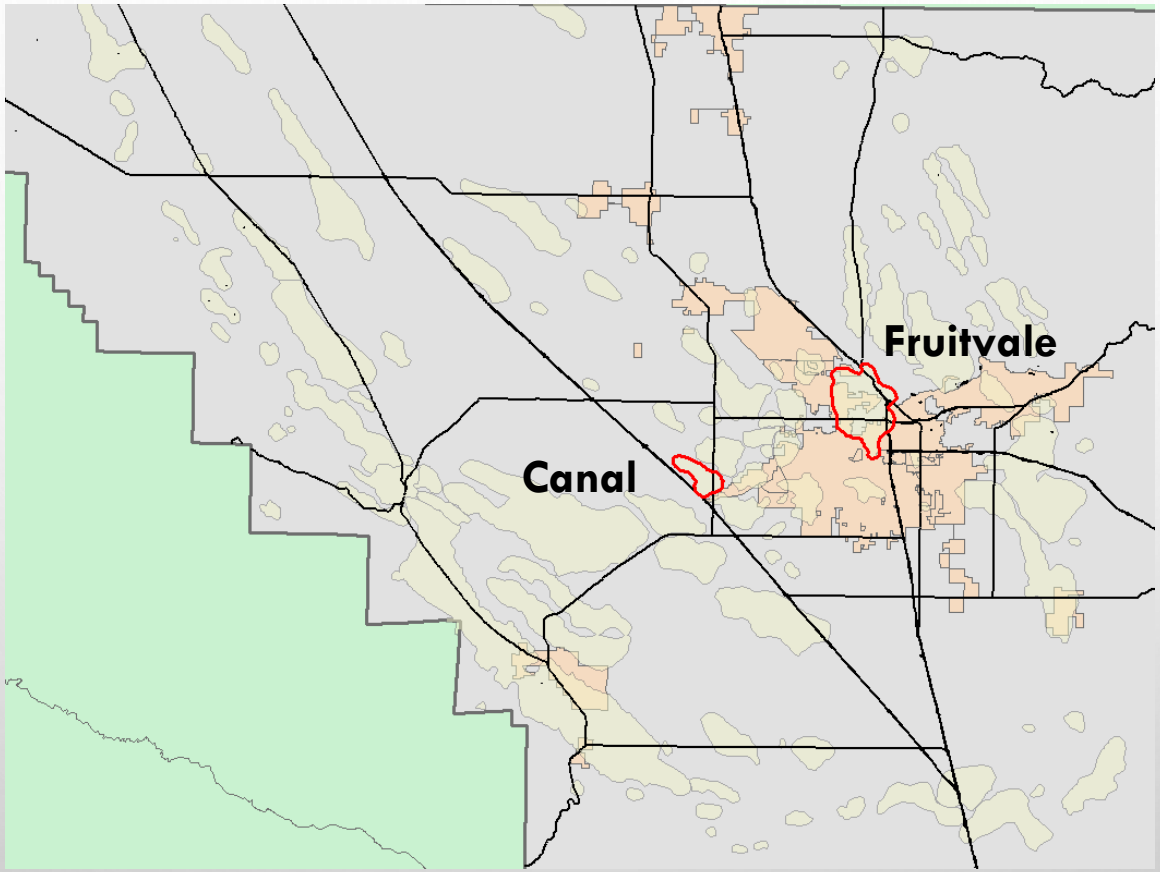


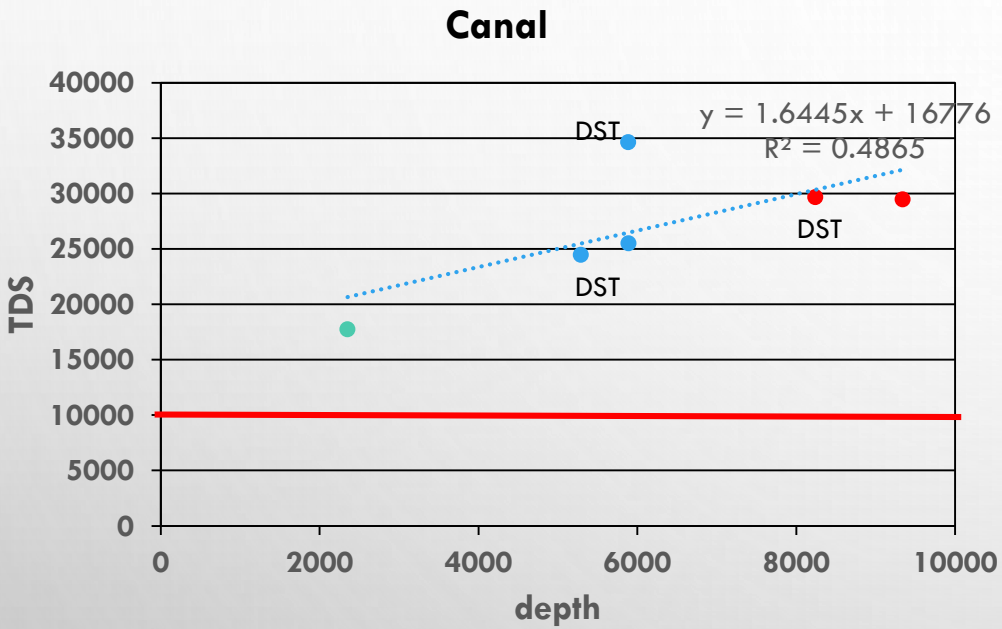


WHERE WE NEED LOG ANALYSIS…

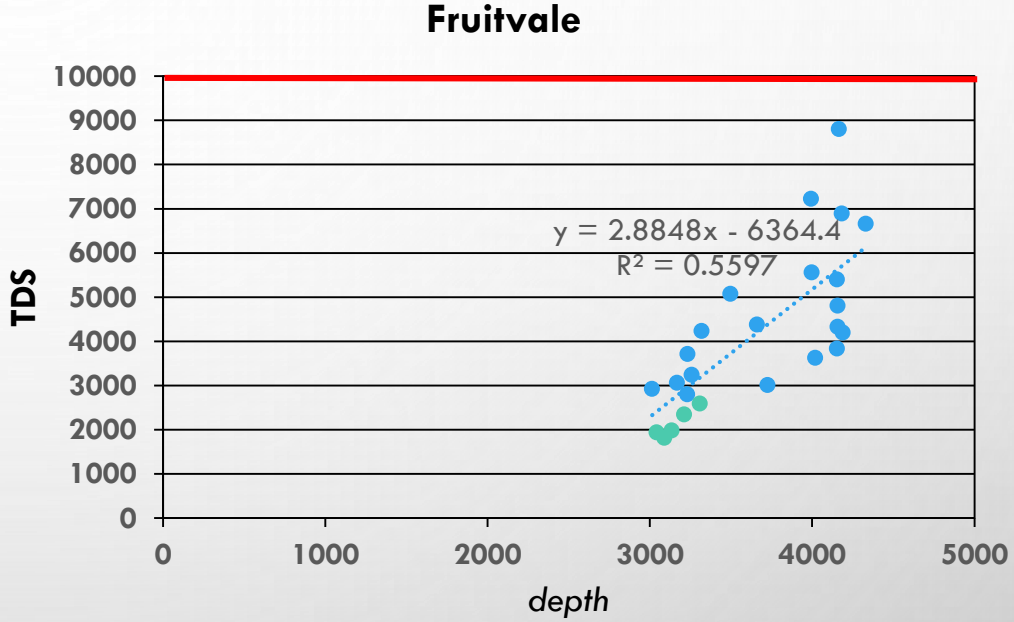


WHERE WE NEED LOG ANALYSIS…

All samples too saline

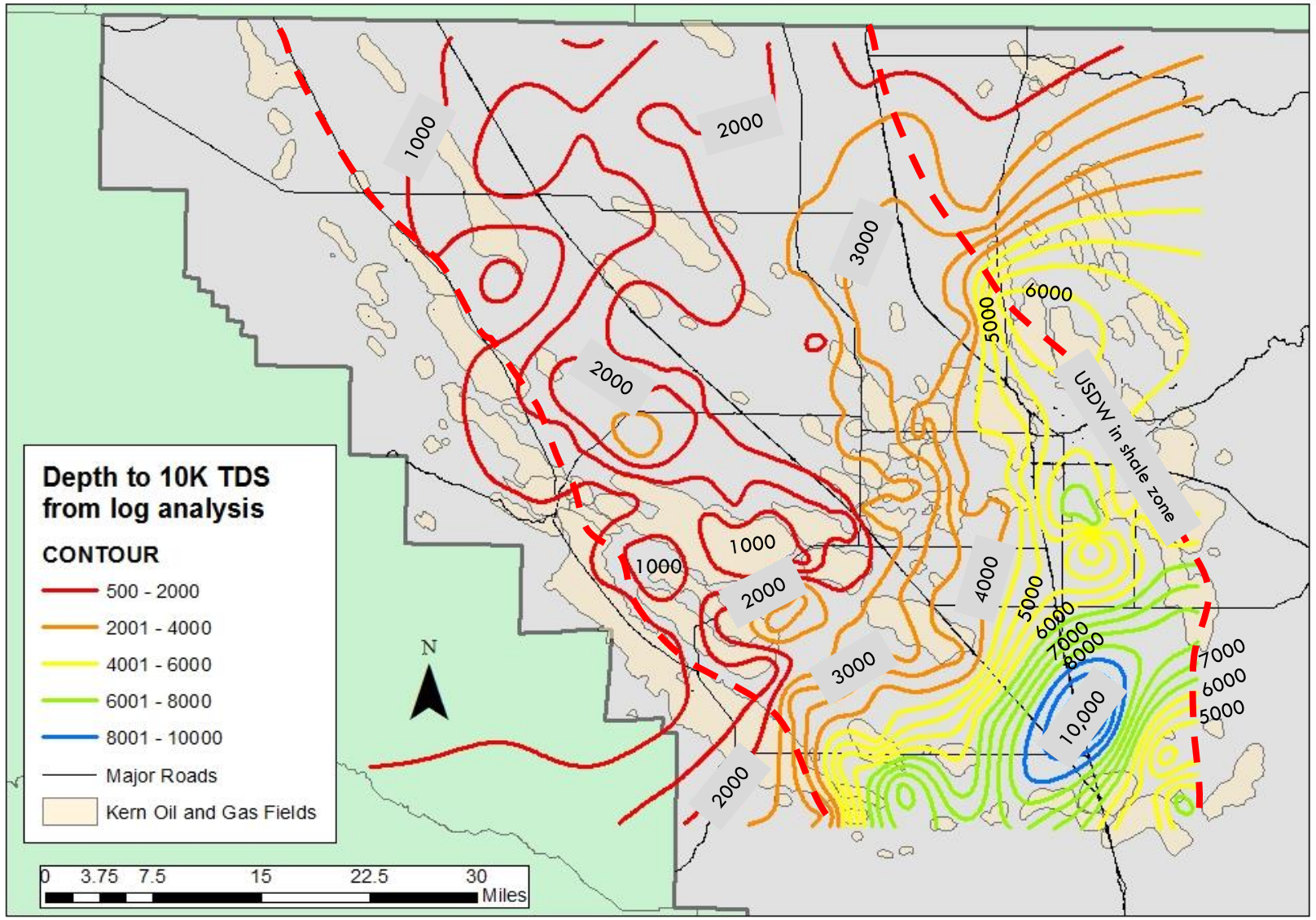


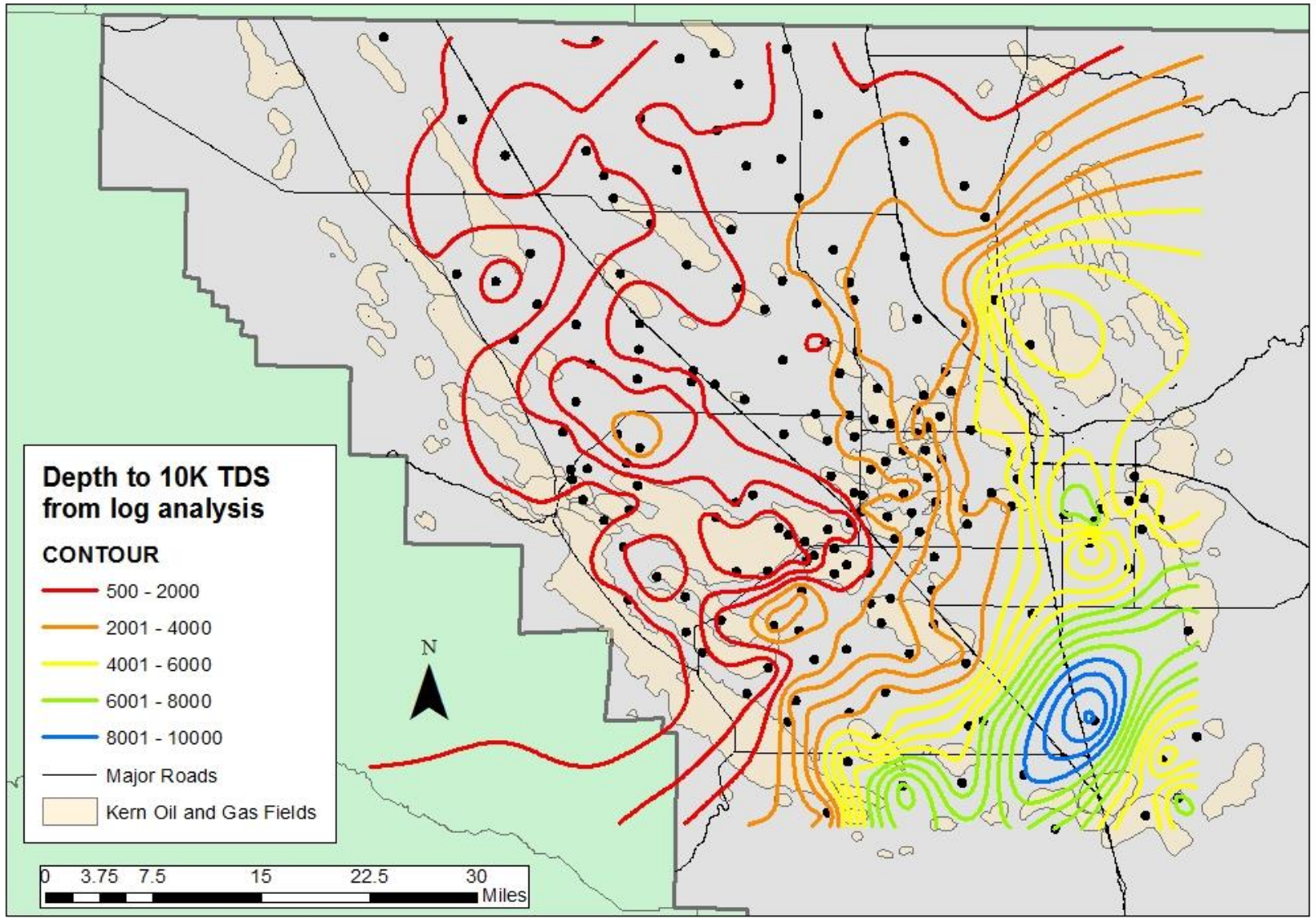
All samples too fresh



….and wherever we don't have enough chemical analyses to draw conclusions

LOG ANALYSIS


Depth to 10K TDS from log analysis
CONTOUR
500 - 2000
2001 - 4000
4001 - 6000
6001 - 8000
8001 - 10000
Major Roads
Kern Oil and Gas Fields
N
0 3.75 7.5 15 22.5 30
Miles
USDW in shale zone
1000
2000
3000
4000
5000
6000
7000
8000
10,000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Miles