Investigation of Surface Expressions in the Midway Sunset Oil Field

Ahinoam Pollack (Noe)

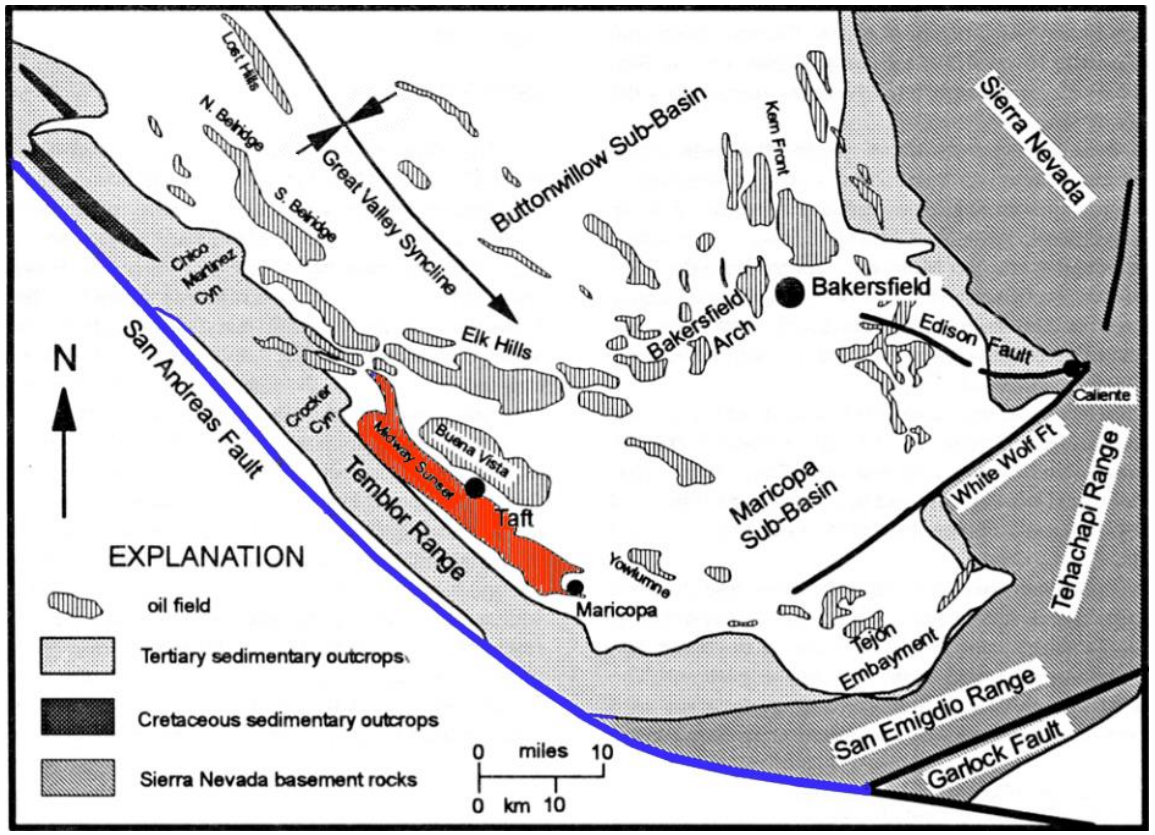
November 9, 2017

Flight Itinerary

1. Where is the study area? What are surface expressions? What is the history of surface expressions in the study area?
2. What is the aim of the study?
3. Spatial statistical analyses.
4. Temporal correlations between surface expressions and injection data.
5. Preliminary flow simulations results.

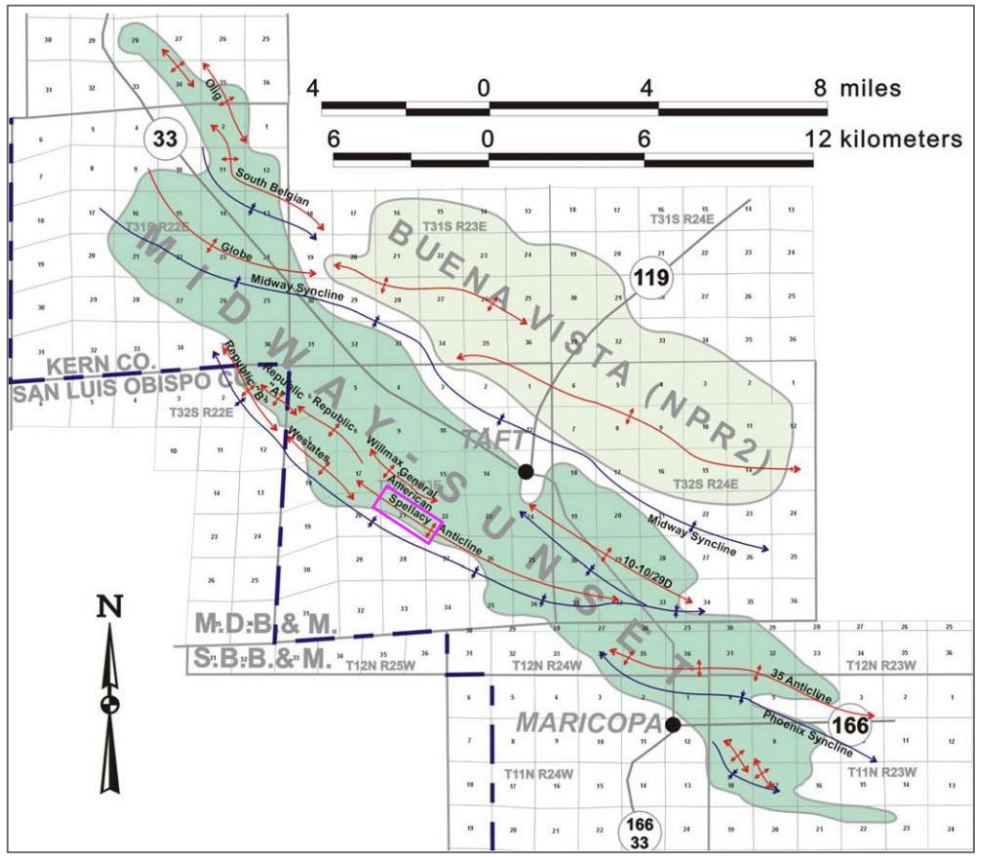
- Structural, Petrophysical and Geological Background of the Area.

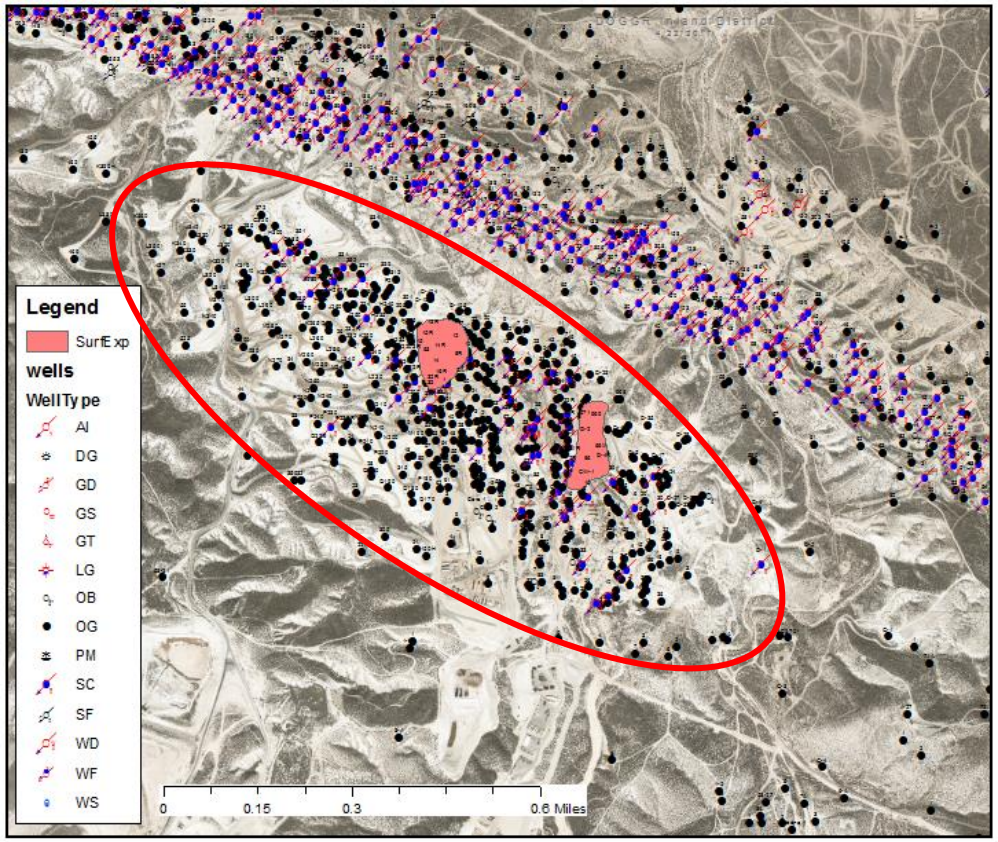
Where Is The Study Area?



Reid, 1995

Where Is The Study Area?





738 wells in an area of half a square mile

What are Surface Expressions?

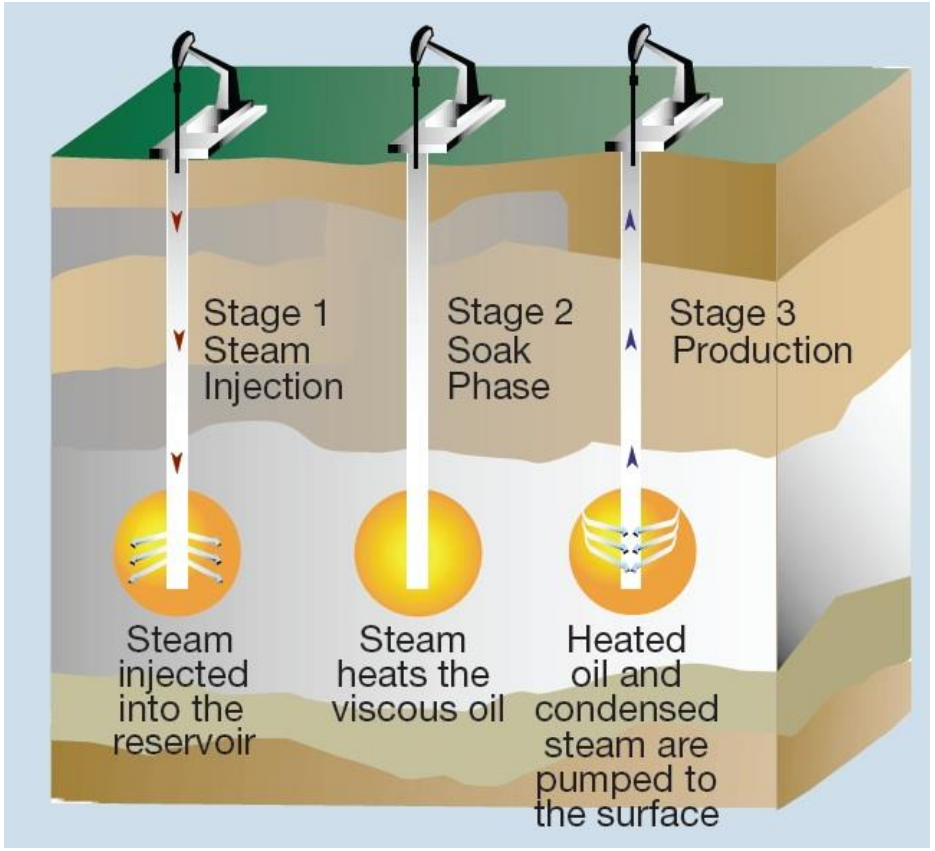
DOGGR, 2011
http://psbweb.co.kern.ca.us/UtilityPages/Planning/EIRS/mckittrick_landfill/Vol5/CA%20DOC%20DOGGR%20Well%2020%20--Report%20re%20Chevron%20Fatality%206-21-11%20(5-4-2012).pdf

What are Surface Expressions (cont.)?

Recorded by Pengcheng Fu, 2016

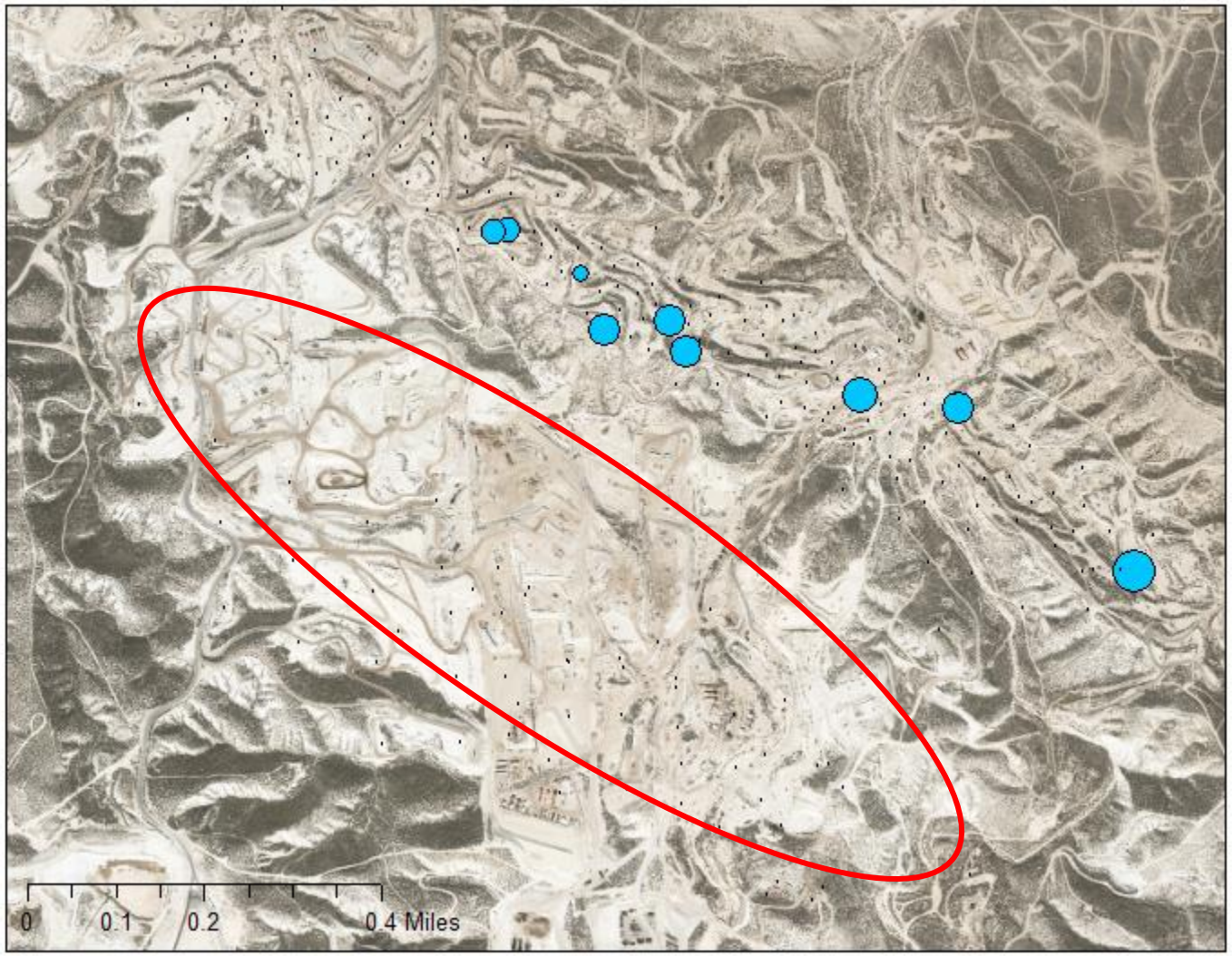
What Is The History of Surface Expressions?

Cyclic Steaming – Since 1993



Canadian Association of Petroleum Producers

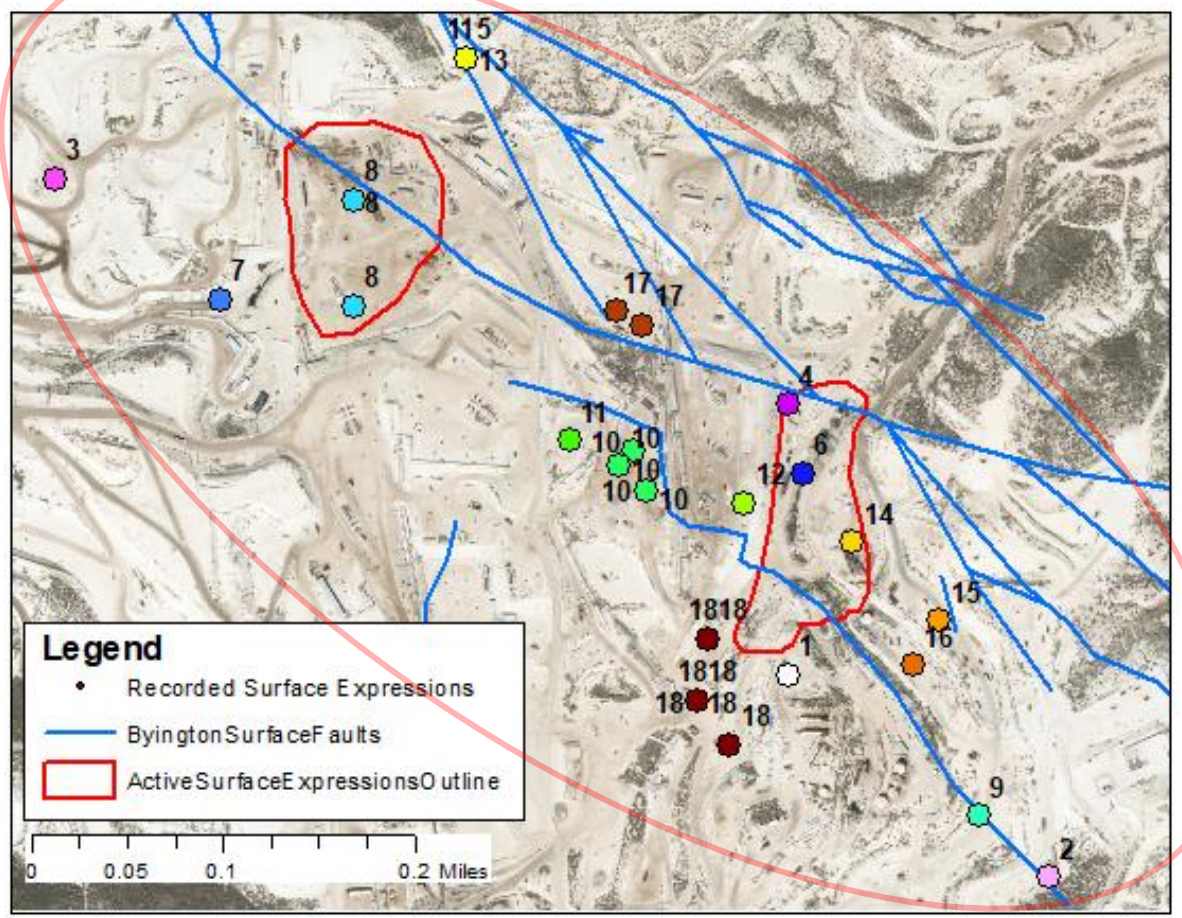
Steam Injection History



1/1/1977

What is The History of Surface Expressions?

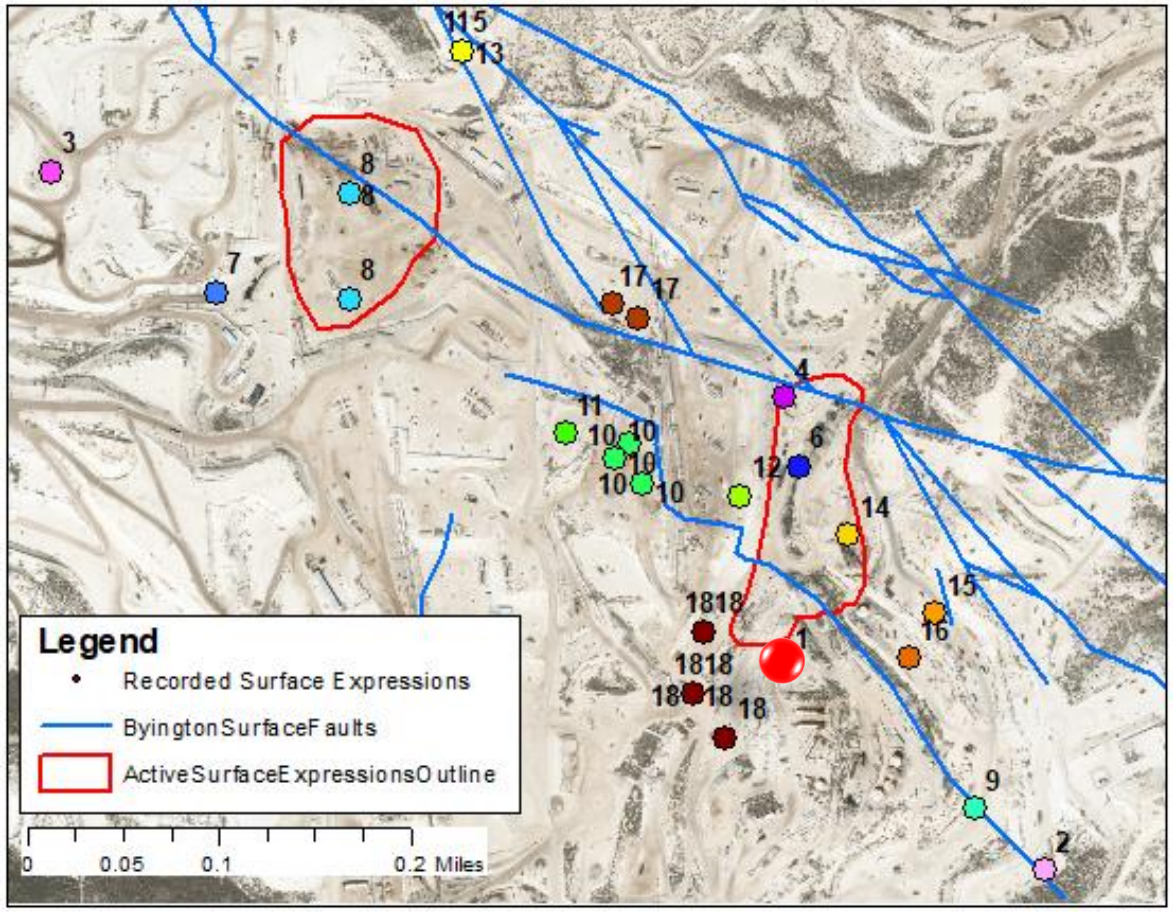
	Date	Event Name
1	3/19/1998	Williams 8
2	10/13/1998	McKeon 1
3	11/22/1999	Well 26
4	7/30/2009	DM1 Buena Fe
5	2/10/2010	Unknown location Buena Fe
6	12/20/2010	Sandy Creek
7	6/21/2011	Well 20
8	6/22/2011	Bull-Birch Series
9	10/16/2011	South Cerritos 11
10	8/15/2013	Keene 53
11	9/18/2013	Keene 66
12	8/1/2014	Cypress 15
13	5/22/2015	Buena Fe Hillside SE
14	10/30/2015	Buena Fe 66M
15	11/8/2015	South Cerritos 28
16	2/12/2016	Keene 55
17	2/12/2016	Kelly 11
18	3/20/2016	Williams High Energy



1: Williams 8

Time: 3/19/1998

Report Description: During steaming operations, had breakthrough on well 8. The well flowed steam, mud, oil and produced water to surface along fractures - approximately 50 bbl water and 10 bbl oil.

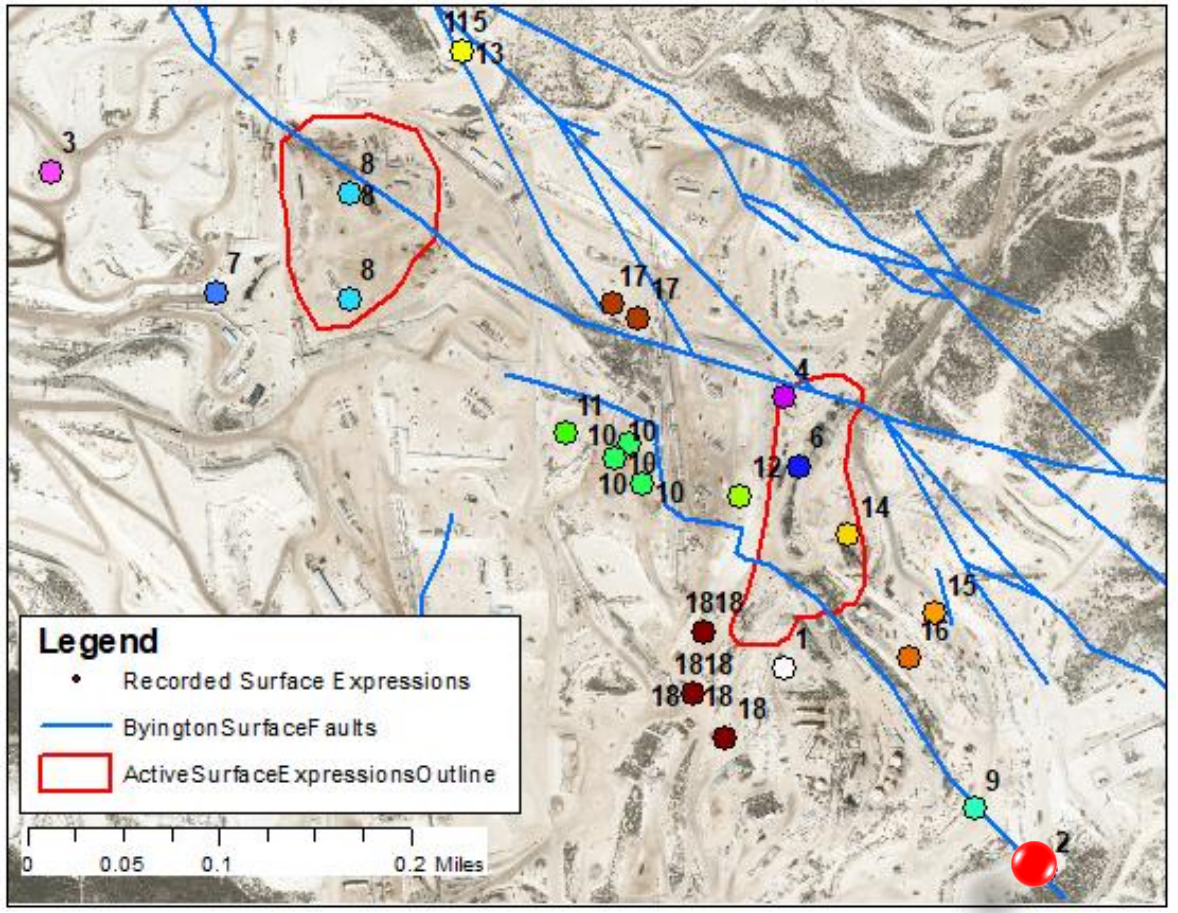


#2: McKeon 1

As I discussed with Mark Gamache, AERA is requesting verbal approval of our Permit to Abandon McKeon Fee #1. The well flowed to surface behind pipe on October 12, 1997. At that time, Nuevo stopped their offset steam injection and the flow to surface stopped. In the interim, AERA ran logs and reviewed the well construction in order to determine whether to plug or recomplete. As we finished the logs on October 27, 1997, the well again began to flow to surface. Texaco was steaming an offset well and at our request turned off the steam late October 27,1997. Again, the well has stopped flowing to surface.

Time: 10/13/1998

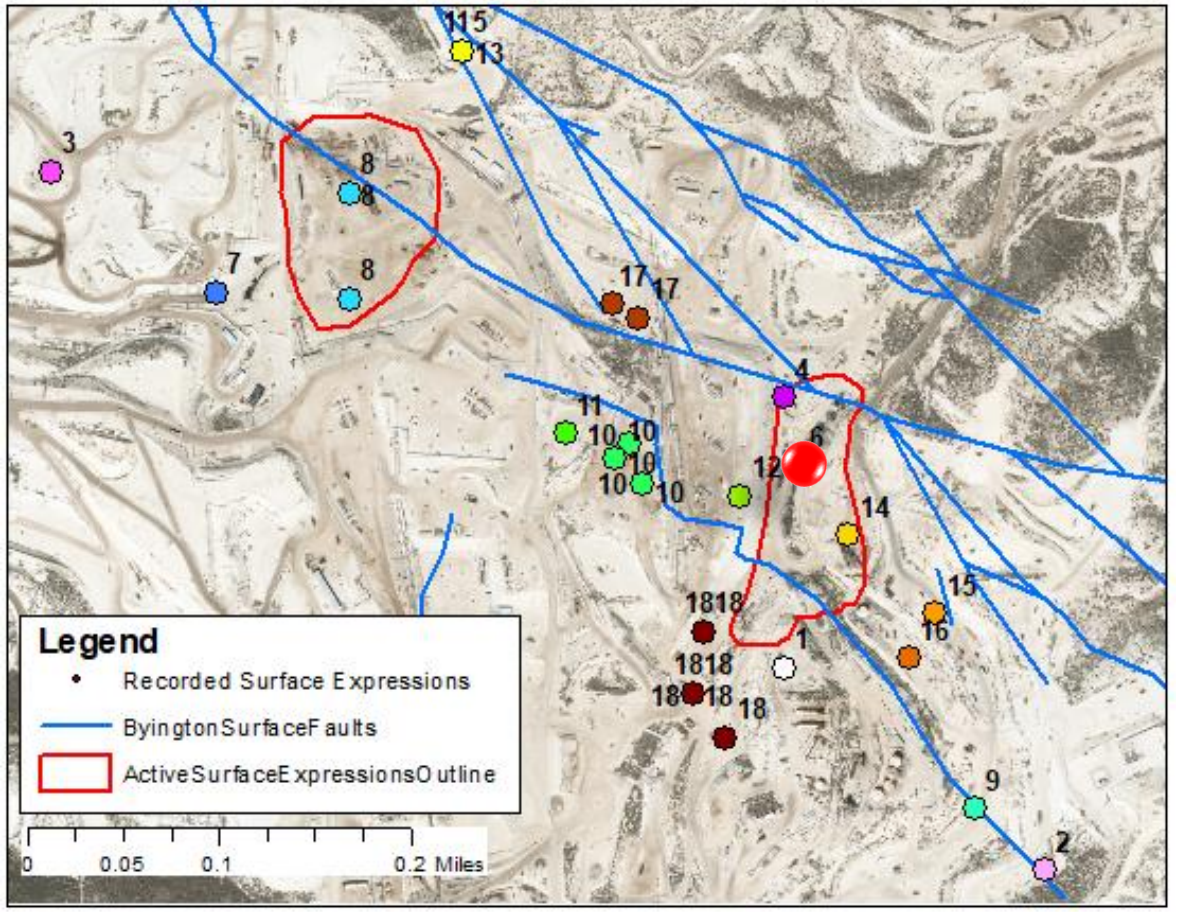
Report Description: McKeon 1 Oil and water breaking through to surface near abandoned well # 1, probably from steaming operations at Cerritos 13. Well 13 shut in steaming operations. Approximately 18 bbl of oil and 72 of water.



#6: Sandy Creek

Time: 12/20/2010

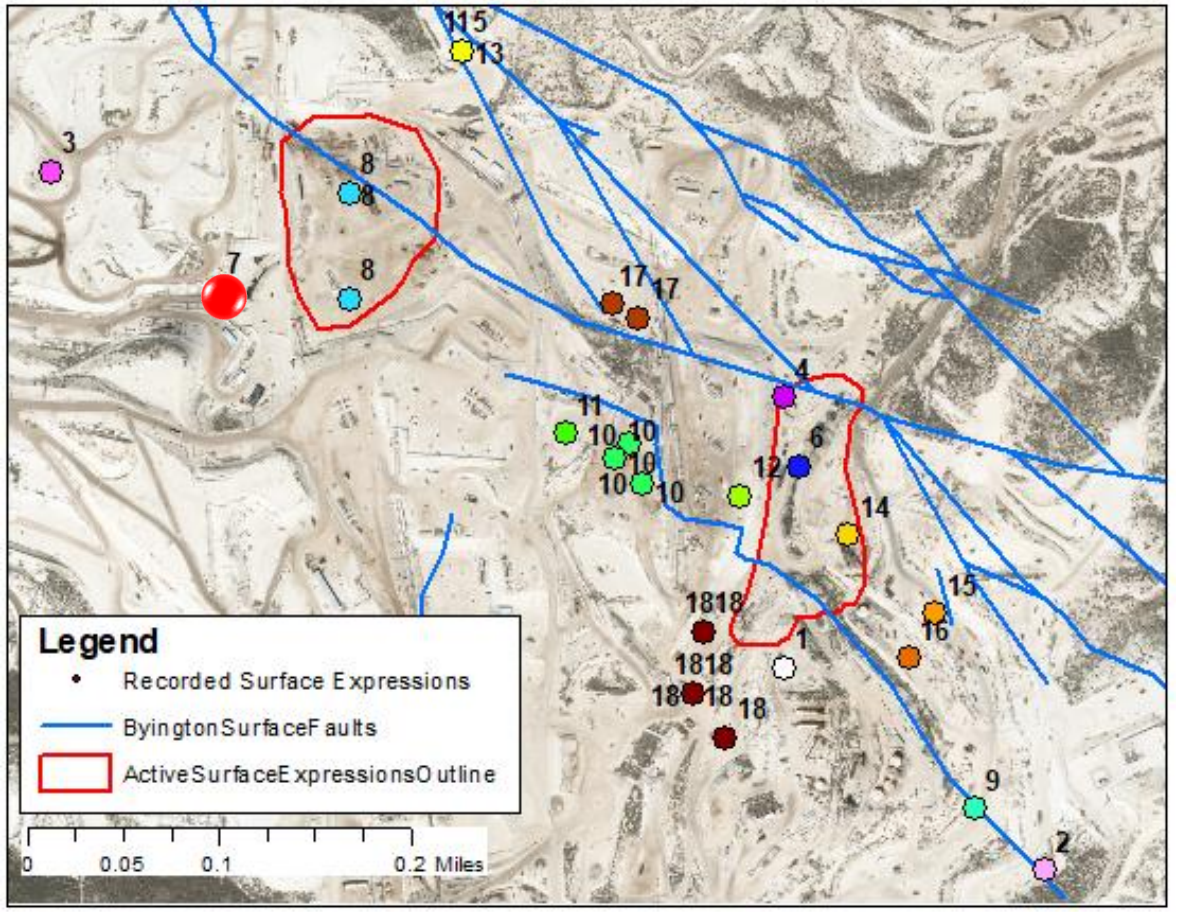
Report Description: Heavy rains flooded area overflowing cellars and surface expression pits, sending oily water down Sandy Creek for a distance of approximately 4 miles.



#7: Well 20

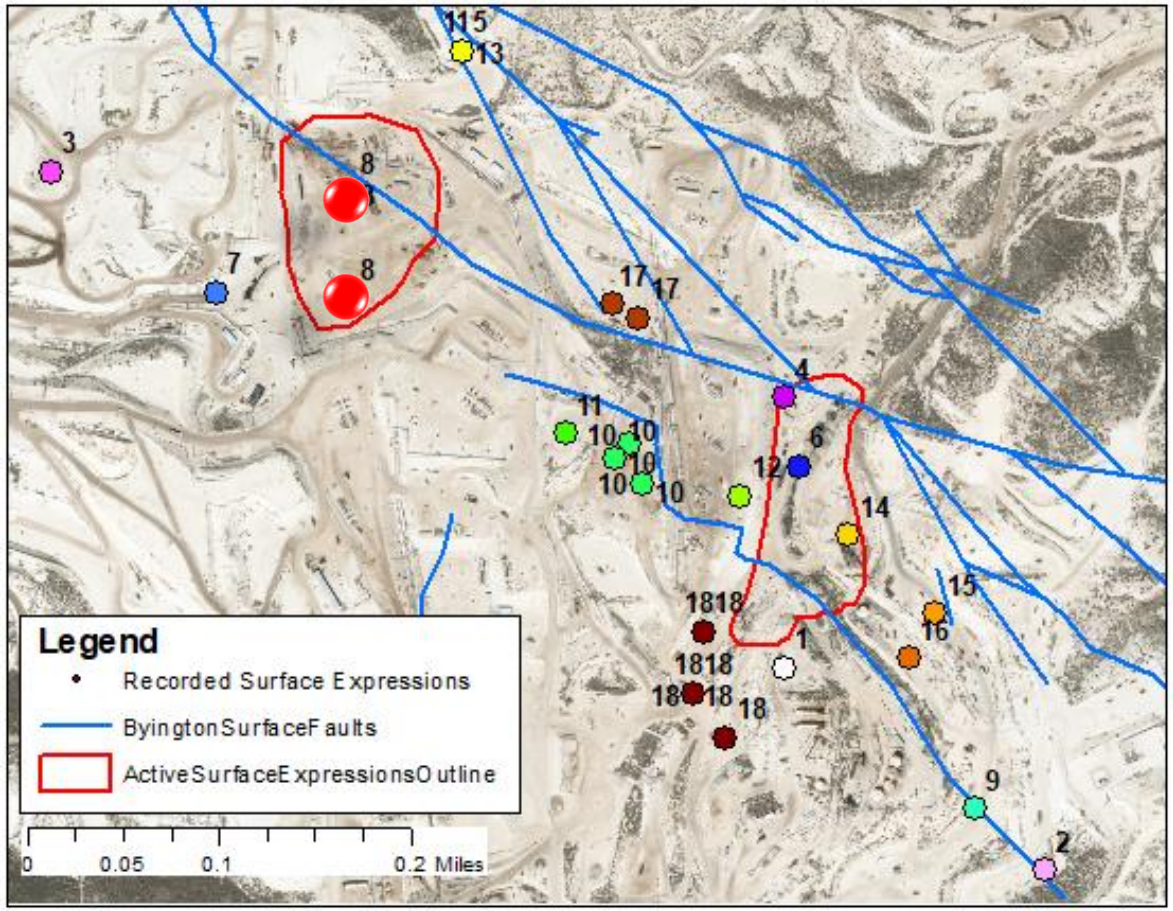
Time: 6/21/2011

Report Description: Fatality near a known and previously active surface expression location. Steam outlet, ~350 bbl/day. Again in 2014, released over 1200 bbl/day.



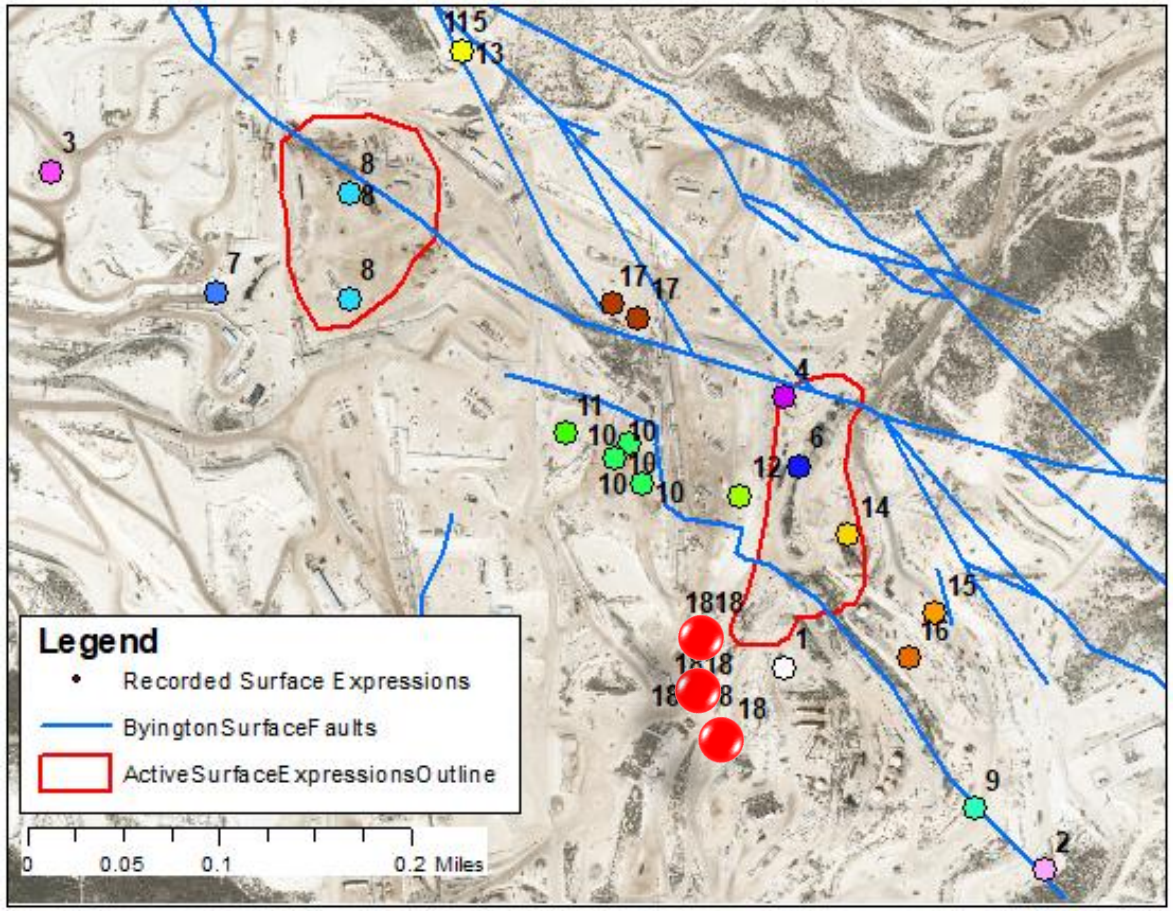
#8: Bull-Birch Series

Date	Report
6/22/2011	Fluid expression covered two areas on separate terraces. The actual surface expression near 'Bull' 9 covered an area approx. 20'x30'. Fluid flowed down to lower terrace and covered an area approx. 40'x50', near "Birch" 10R.Berms placed around areas on both terraces. Vacuum trucks removing fluid as needed. The 1st 24 hours approx. 500 bbls of fluid removed. 2nd 24 hours approx. 150 bbls removed. Approx.. 1000 bbls of fluid removed after 1st week. Estimated 5 to 10% of fluid is oil. This surface expression is located in the middle of 14 cyclic steam injection wells. It was reported that the surface expression surfaced and spread within a few minutes.
6/27/2011	This surface expression is a reactivation. Approximately 30 bbls of fluid had been removed from the location. Water cut is around 90 to 95%.
8/22/2011	10 bbls fluid released onto slump of slope of terrace into containment basin due to overflow of fluid outside of berm. Containment basin in place to hold fluid from “Bull’ 9 surface expression, which continues to flow at approx. 30 to 40 bbls/day.



17: Williams High Energy

Date	Report
4/13/2016	SE activity is relatively stagnant, still steaming and bubbling, steaming may have subsided slightly. Rainwater is still contained behind berms, water trucks were brought in to start pumping the water out.
4/14/2016	Since the initial high energy occurrence of the surface expression on March 20. 2016, the expression has migrated four times. The first three creating craters with high energy releases of steam and fluid. The fourth migration on April 15 is a 1/2 bbl low energy release of fluid.
4/15/2016	SE has migrated ~20ft SE of current 10x10' crater. Smaller 4x4', low volatility SE, with ~1/2bbl of oil at surface.
5/1/2016	The current location appears to be #5 in this sequence. Current expression has been at location about 4 weeks. Water injection into nearby SC well was started Thursday Apr 28. SE activity quiets as water is injected, and begins to pick up again when water is shut off [cold water or injected steam from CSS?]. #4 is closely adjacent to a mud-covered pump jack. This expression was throwing mud up to 70 feet. #3 can be seen with a pipeline crossing it. #2, the one I saw, appears to be but a shallow bowl. #1 is also visible to the rear of the video and image I took.
7/19/2016	The activity on the SE do not change for the last 3 weeks. Very calm, not steam.
4/19/2017	Surface Expression: Low energy SE. No Fluid. No steam in injecting within 250' from the SE. Near Well 12W (030-29571). Close to 2016 SE area. Steam 3'X4' area is taped off.

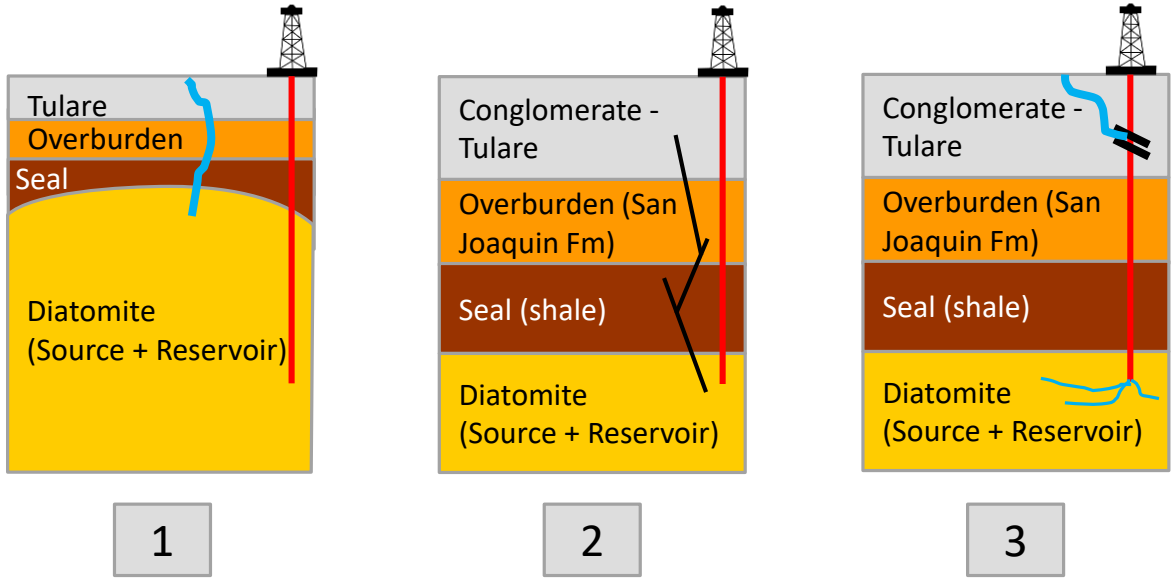


What Is the Aim of the study?

- Optimize oil production while ensuring safety, mitigating surface expressions.

To Mitigate the Seeps, We Must Understand Them: Hypotheses of Possible Flow Mechanisms

1. Structure/Geology
2. Fractures
3. Damaged wells



Possible Catalysts

1. Large injection volume
2. Large pressure gradient
3. High ratio of injected steam to produced fluids
4. High number of steam cycles

Methodology

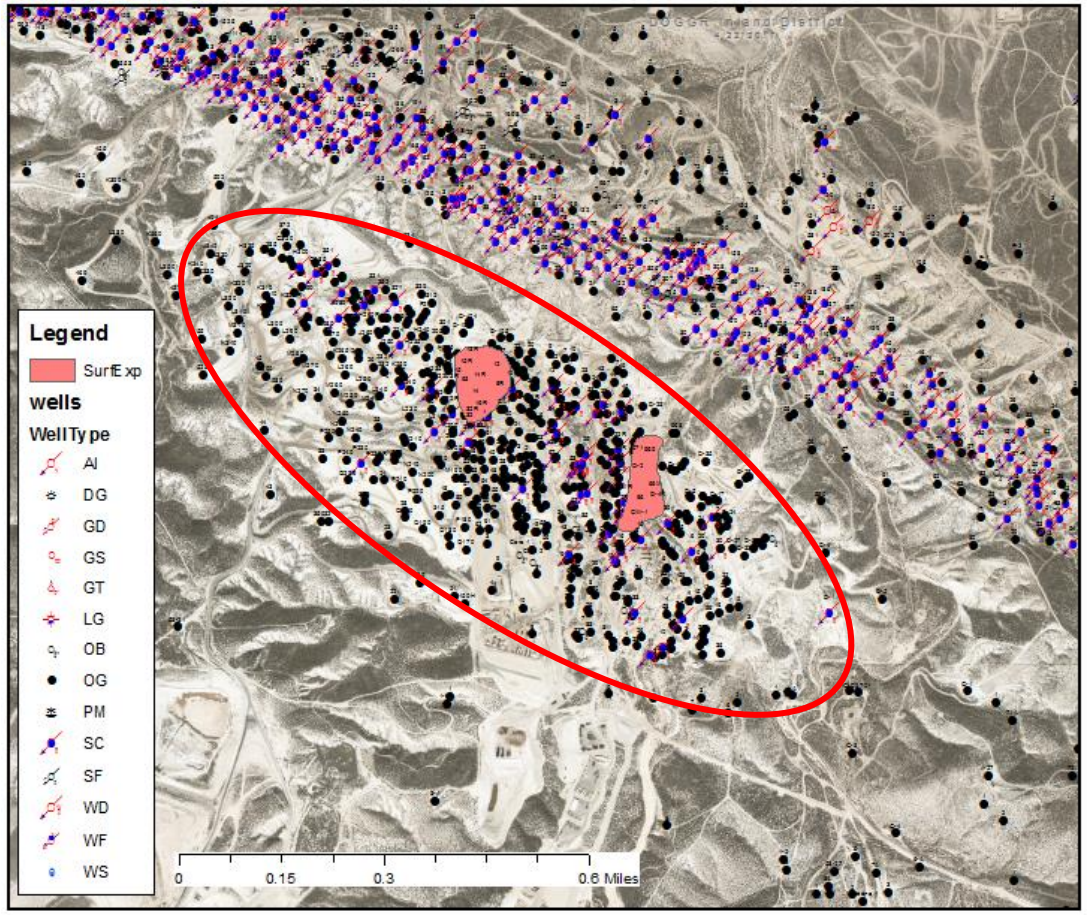
1. Spatial Analysis
2. Temporal Analysis
3. Flow simulation

The Aim of Spatial Analysis

Explore spatial relationships between surface expressions and **geological**, **production** and **engineering** properties.

Why Spatial Analysis?

- Cyclic steaming is common.
- Seeps are **localized** in two zones.
- What is different about the zones with the surface expressions?

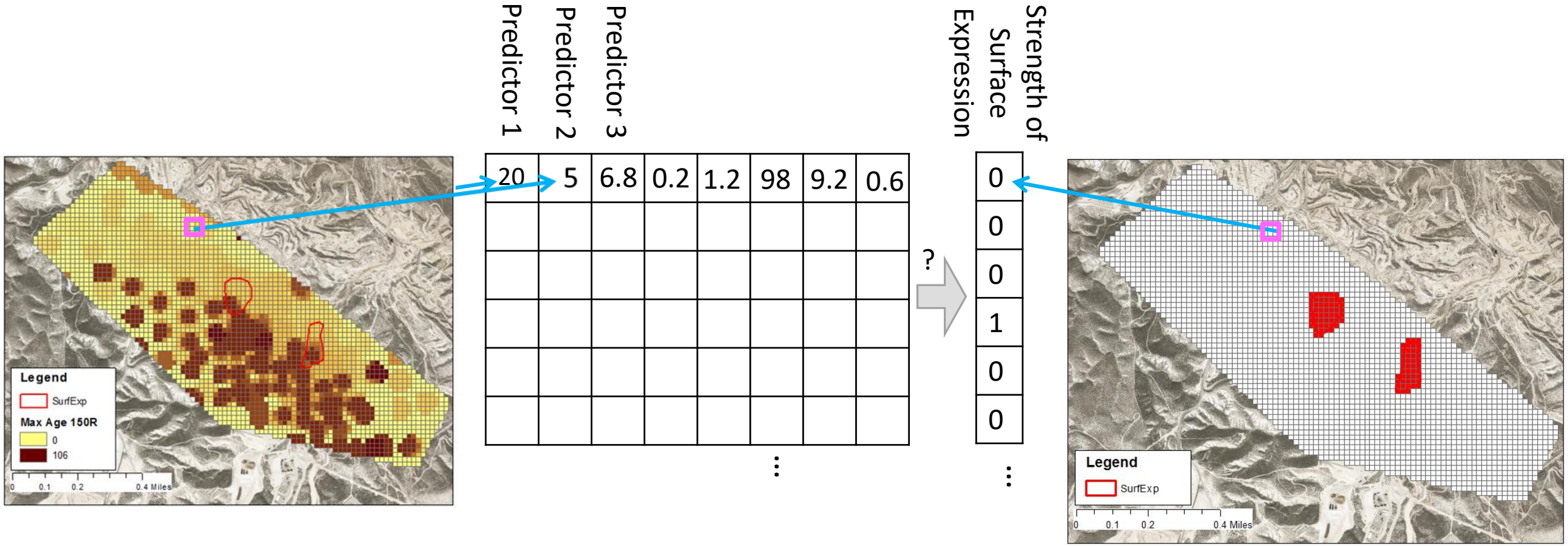


How Do We Analyze a Spatial Relationship?

Machine Learning algorithms on Gridded Spatial Data:

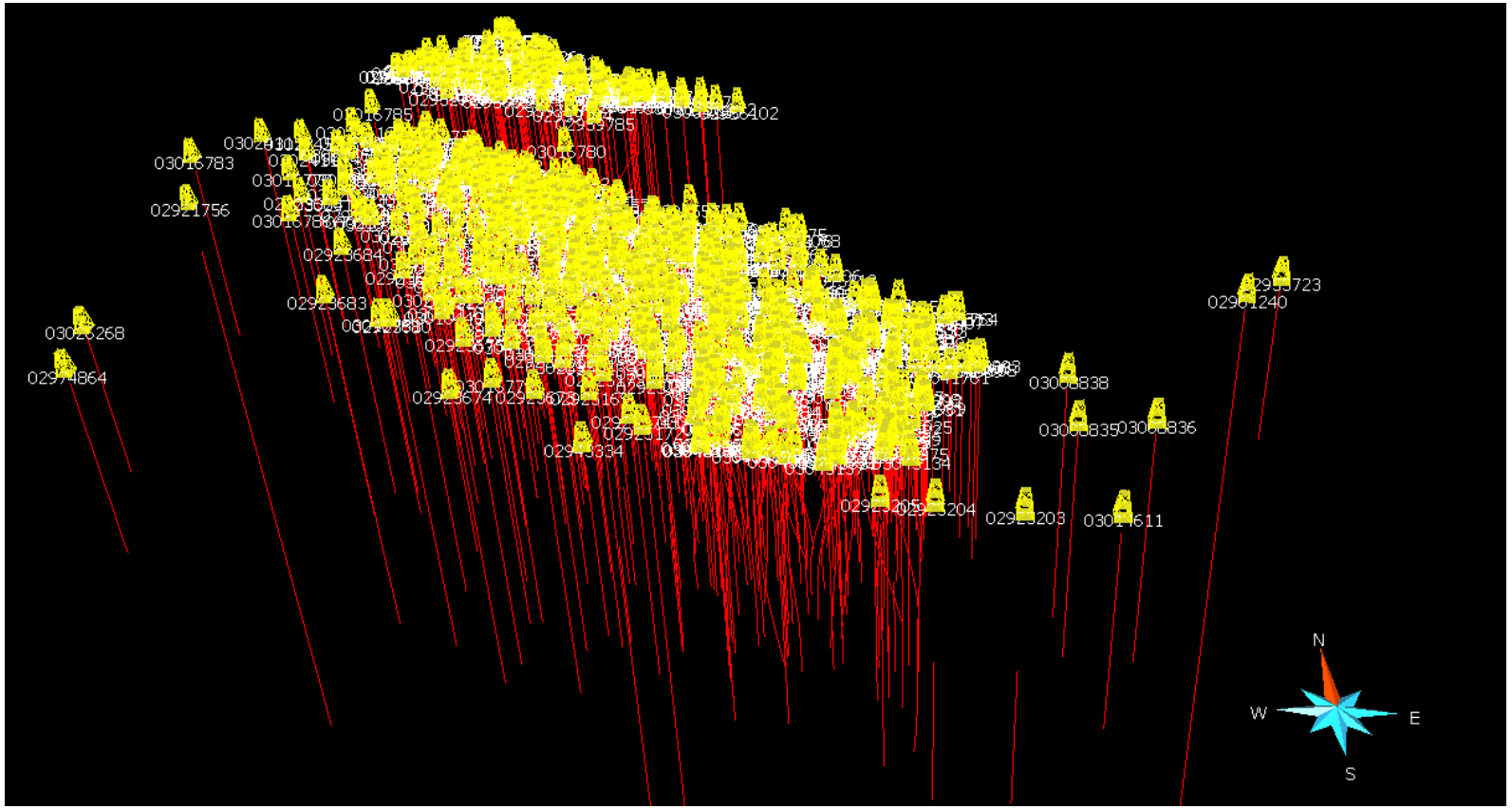
1. Logistic Regression
2. Classification Tree

How Do We Analyze a Spatial Relationship?



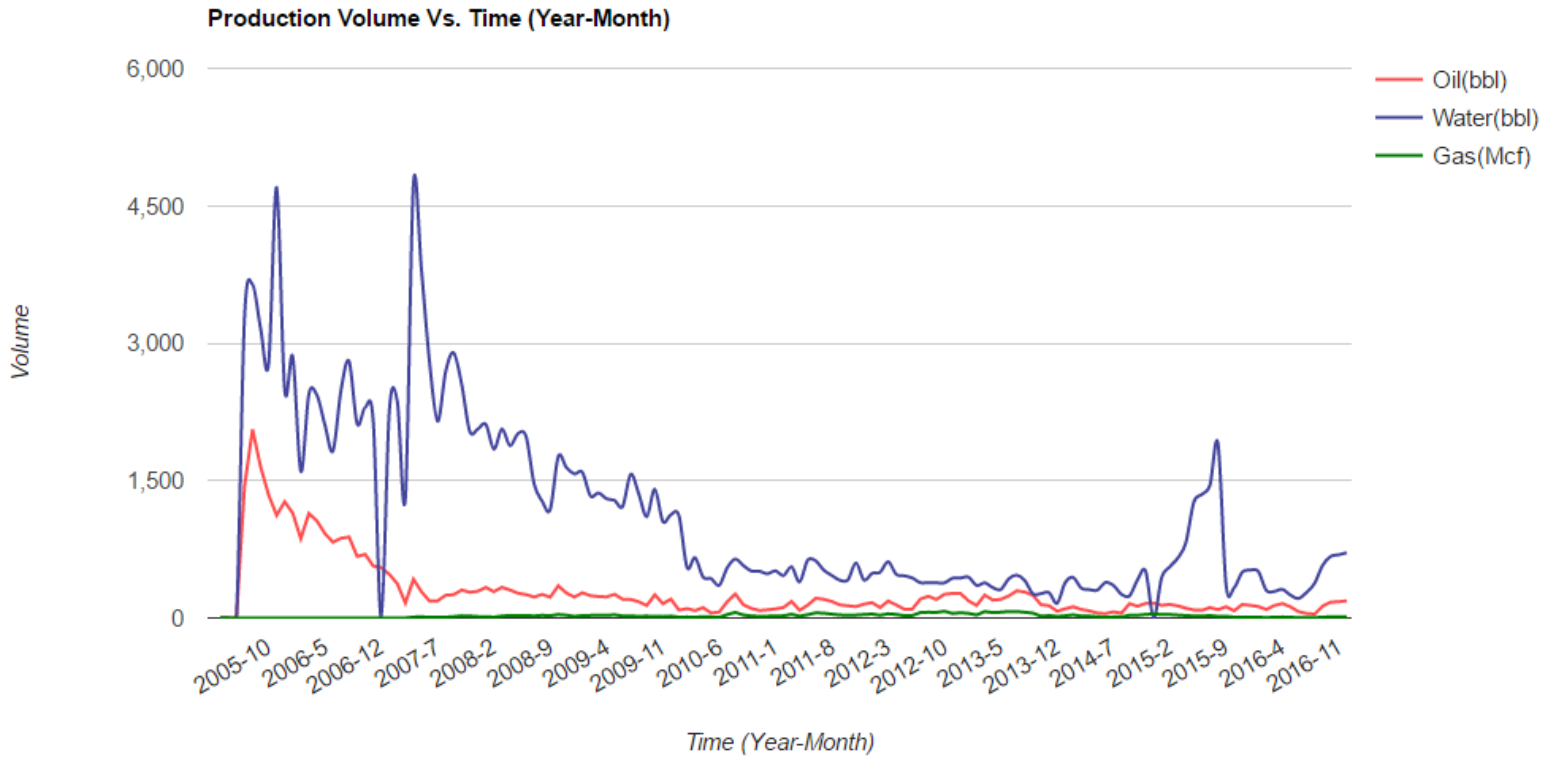
What Data Do We Have to Use for Predictors?

What Data Do We Have? Well Logs



- ~700 well logs

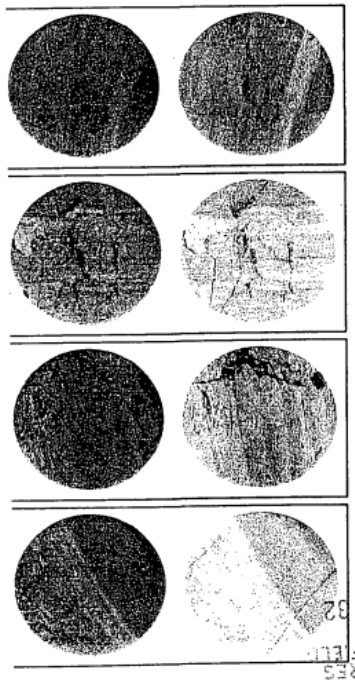
What Data Do We Have? Production and Injection Data



- Production and Injection Data – 1024 wells

What Data Do We Have? Core Data

- 78 wells with Core Data



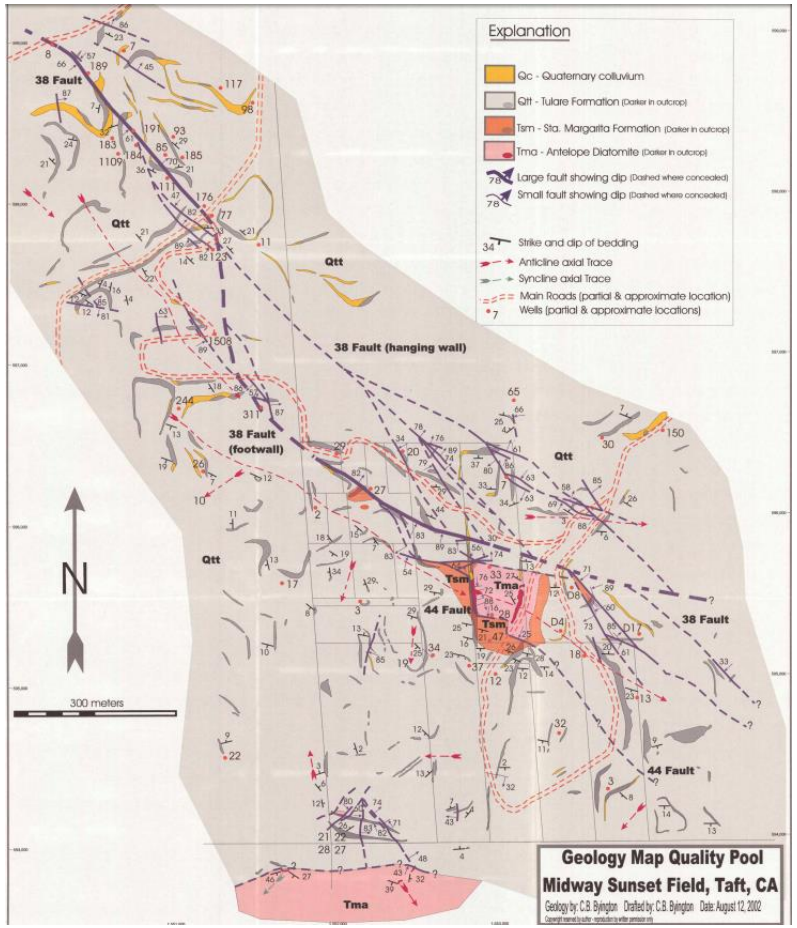
Sidewall Core Analysis Results

Sample Number	Depth ft	Rec in	Perm. Kair md	Porosity %	Fluid Saturation			
					Oil %	Water %	O/W Ratio	Total %
5	495.0	1.6	2.1	59.5	38.0	57.6	0.66	95.7
Diat brn vslty scly m stn gld flor								
6	505.0	1.7	3.1	65.7	31.0	63.4	0.49	94.4
Diat brn vslty d-m stn bgld flor								
7	515.0	1.7	3.2	62.3	30.7	65.6	0.47	96.2
Diat brn vslty scly carb d-m stn gld flor								
8	541.0	1.8	3.8	63.0	42.0	50.9	0.83	92.9
Diat brn vslty d stn bgld flor								

2010 SEP -3 PM 12:32
RECEIVED-BAKERSFIELD
OIL-GAS-GEOTH RES

F/ Indicates Visible Fracture(s) Present

What Data Do We Have? Surface Data



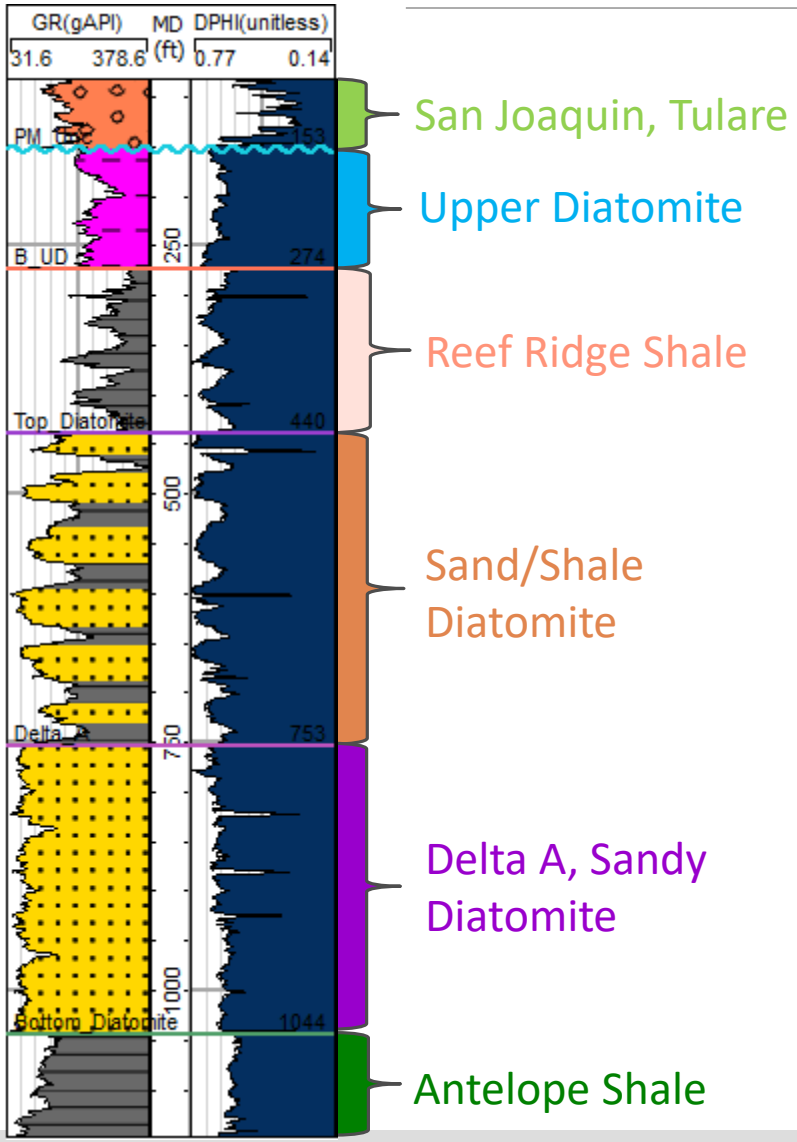
- Geology map + surface fault lines

Byington, C. B. (2003)

How to Construct Predictors?
Predictor Engineering

- **Geological/Structural**
  - Depth to formations
  - Thickness of formations
  - Faulting
  - Reservoir Properties: Porosity/Permeability of different formations
- **Production Data**
  - Injection – production
  - Max Injection pressure
- **Well Engineering**
  - Well status (plugged/active)
  - Age of wells

Geological Predictors



San Joaquin, Tulare

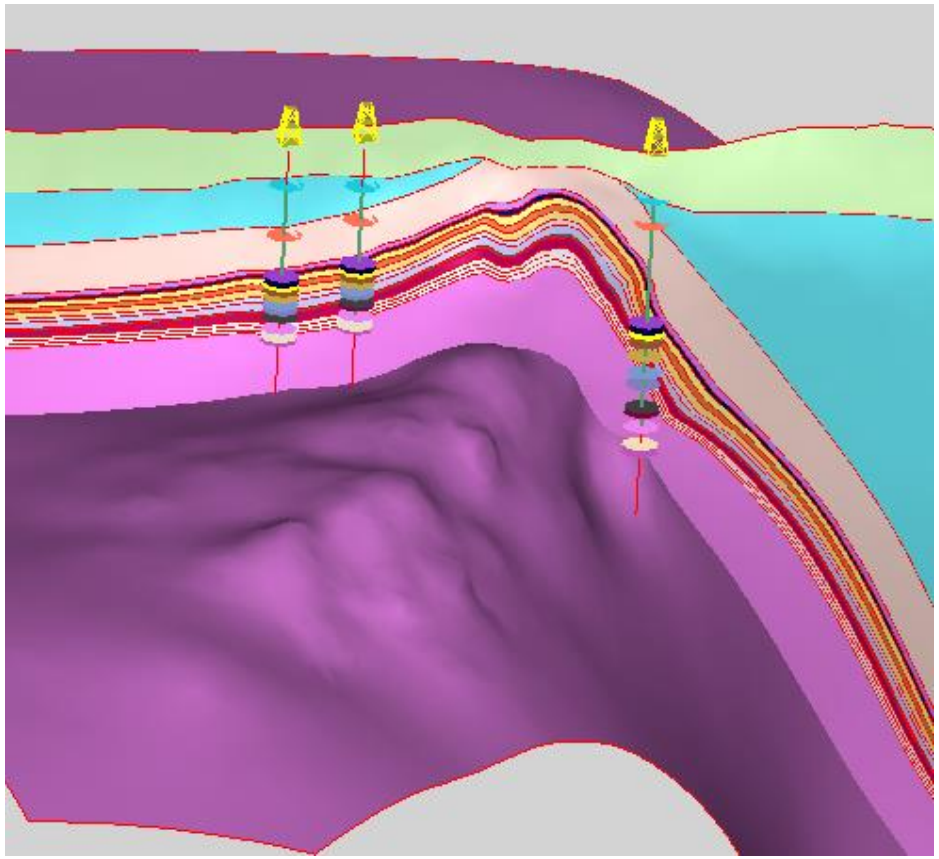
Upper Diatomite

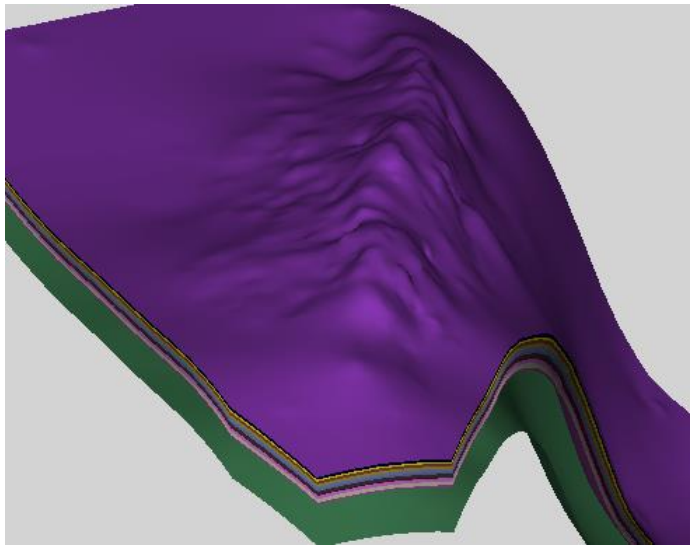
Reef Ridge Shale

Sand/Shale Diatomite

Delta A, Sandy Diatomite

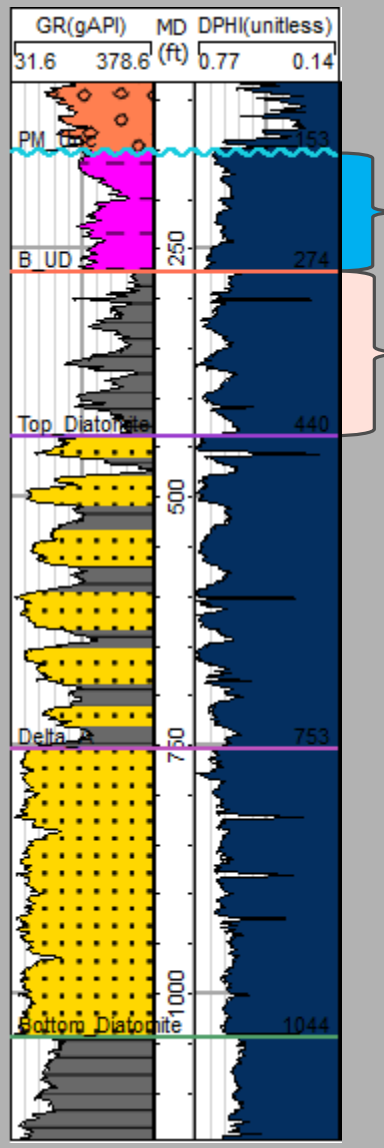
Antelope Shale





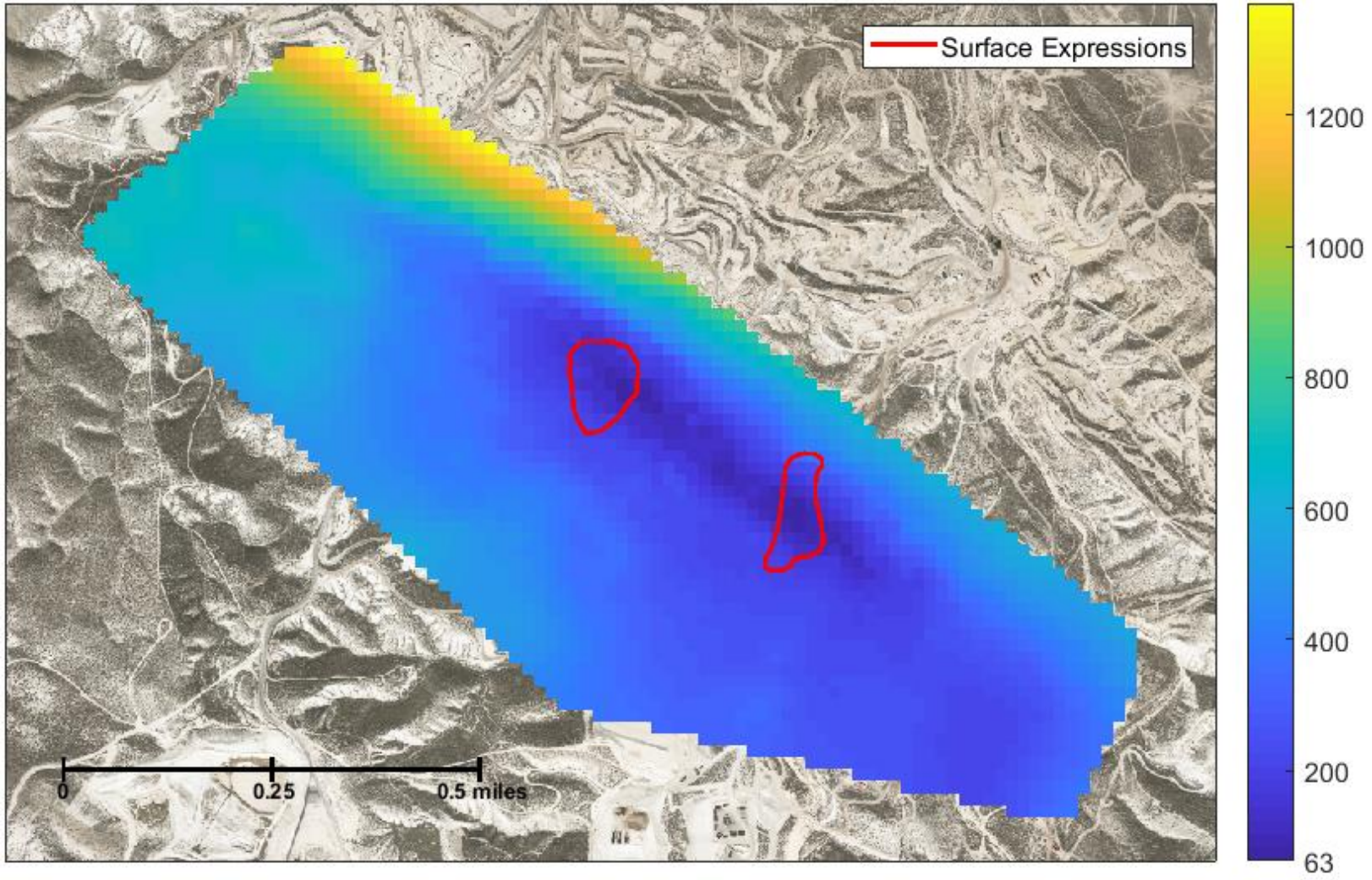
Gregory, G. J. (1996), Reid (1995)

Thickness Seal (ft)

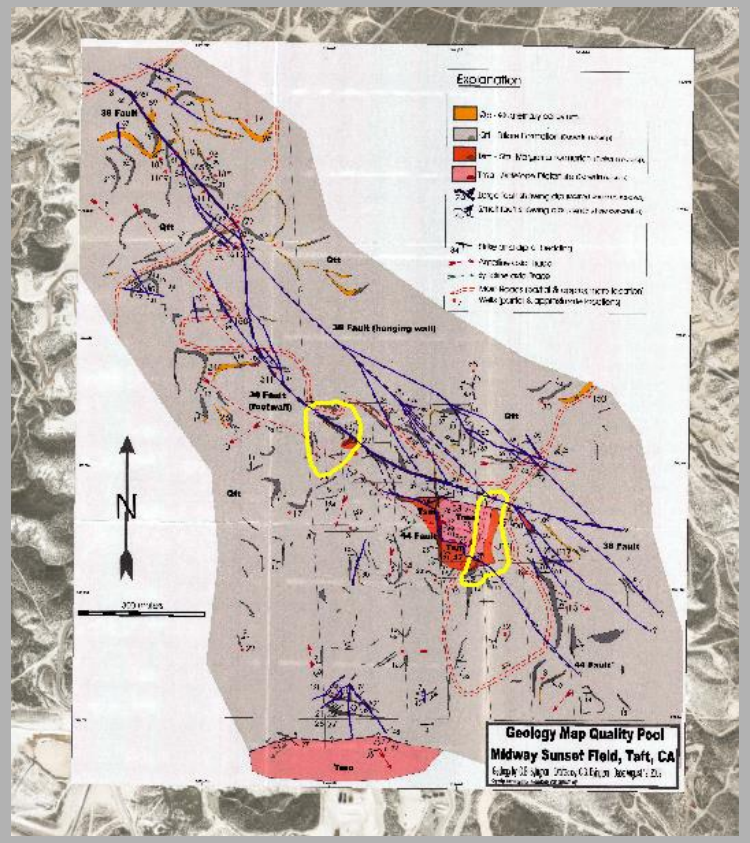


Upper Diatomite

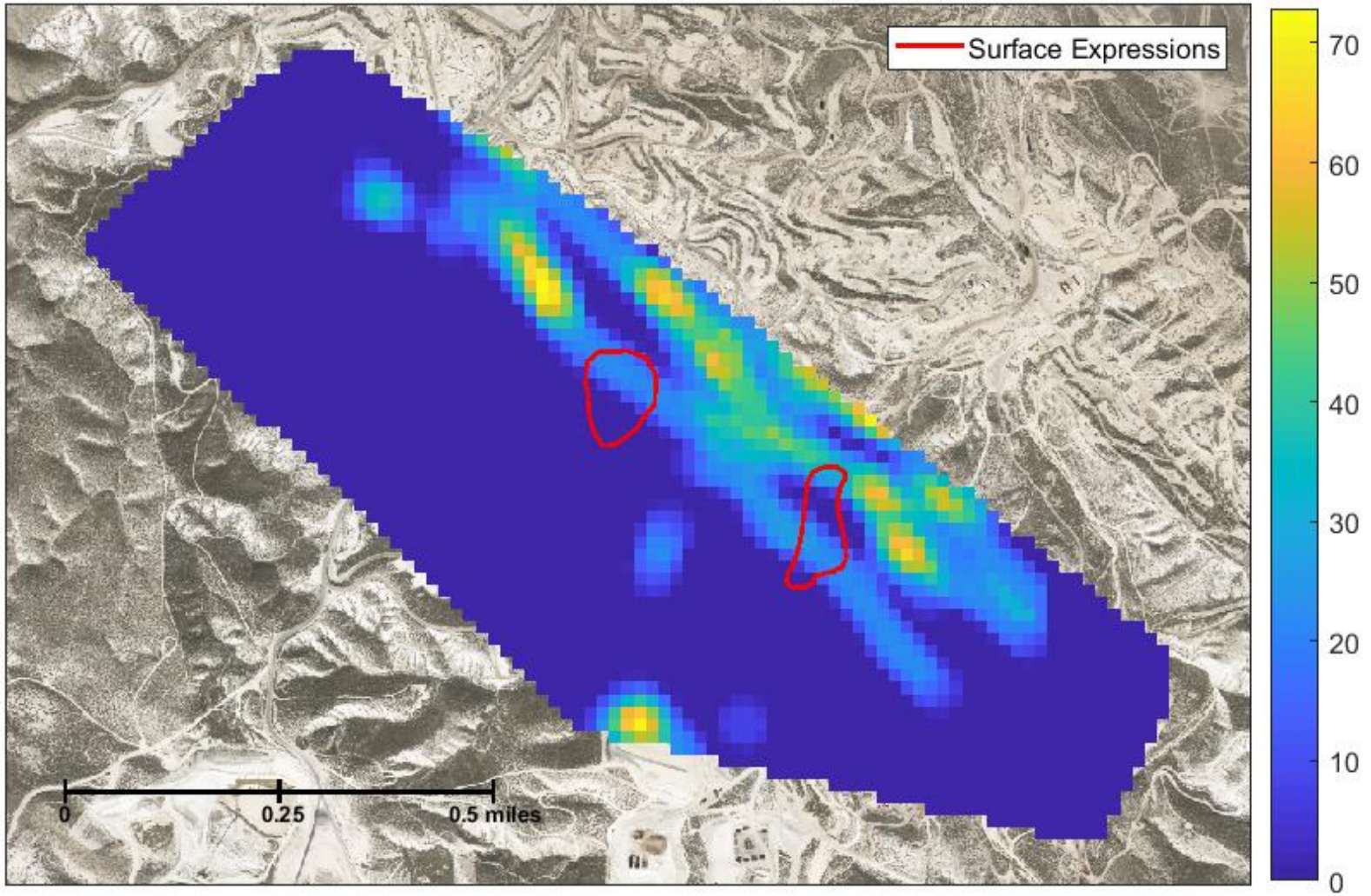
Reef Ridge Shale



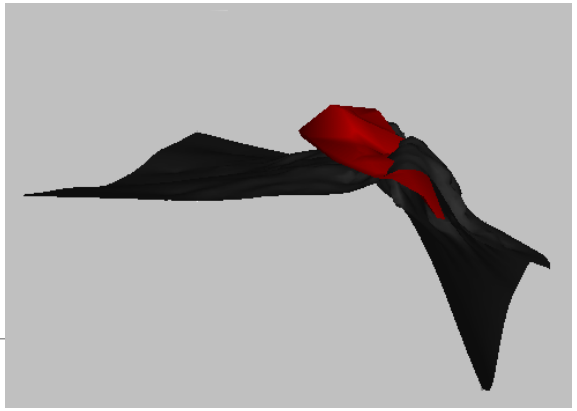
Fracture Density

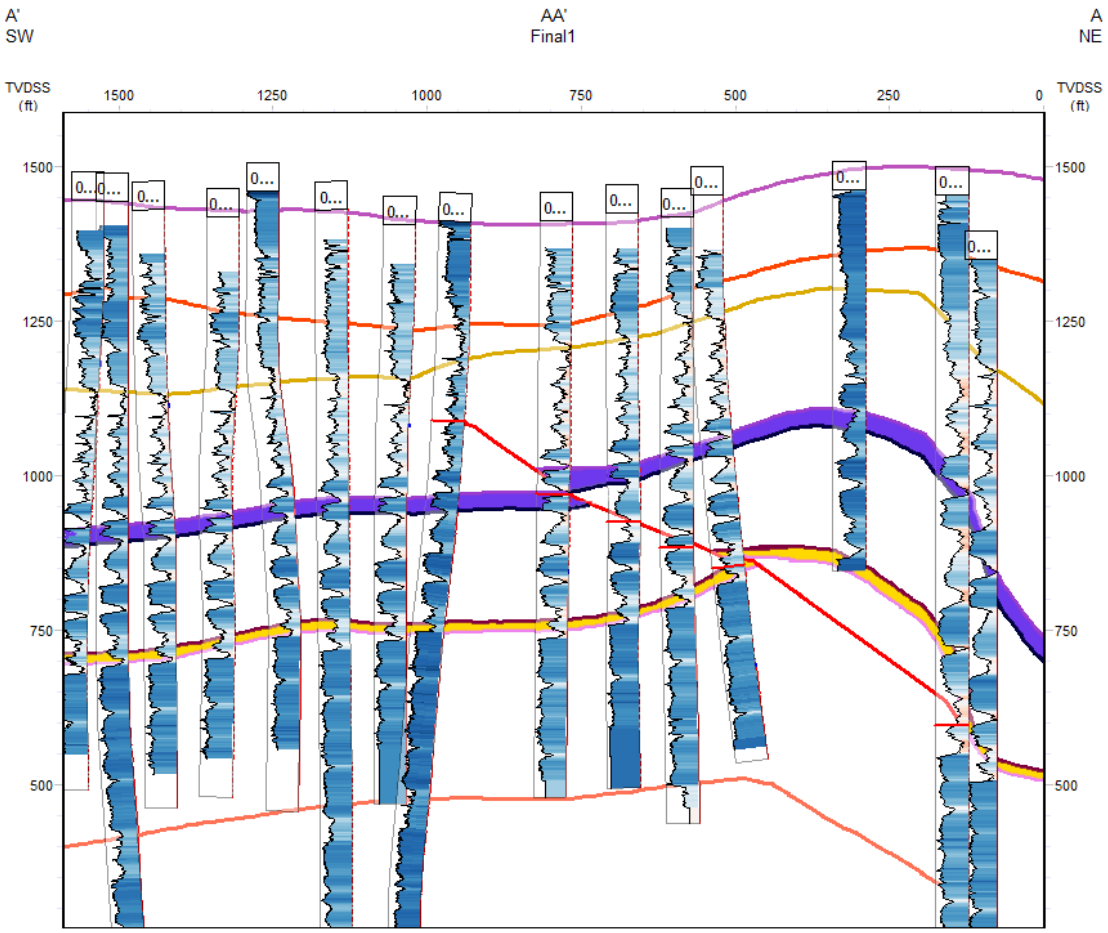


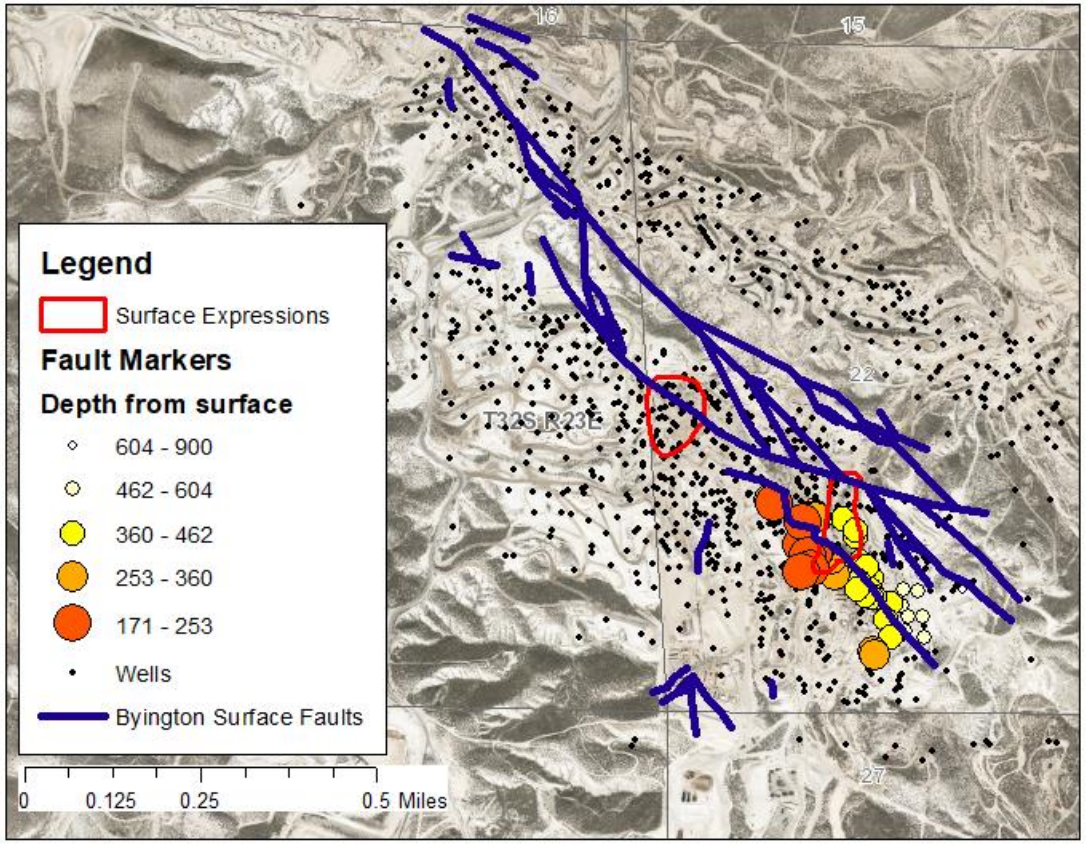
Byington (2003)

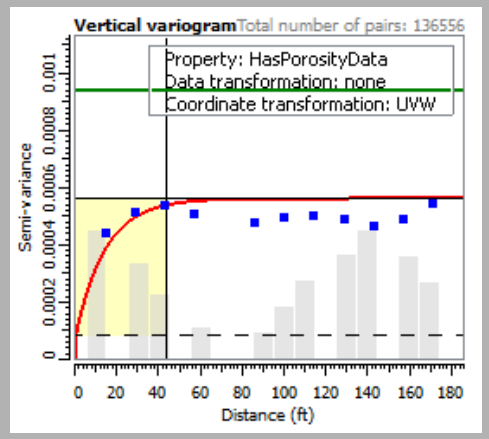


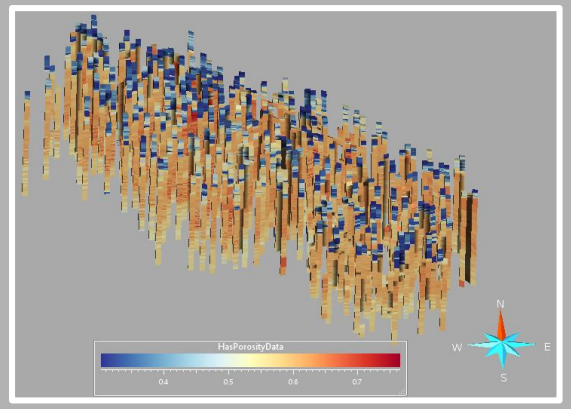
Large Reverse Fault

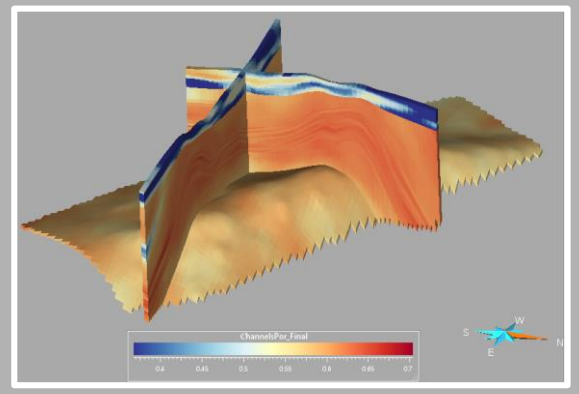




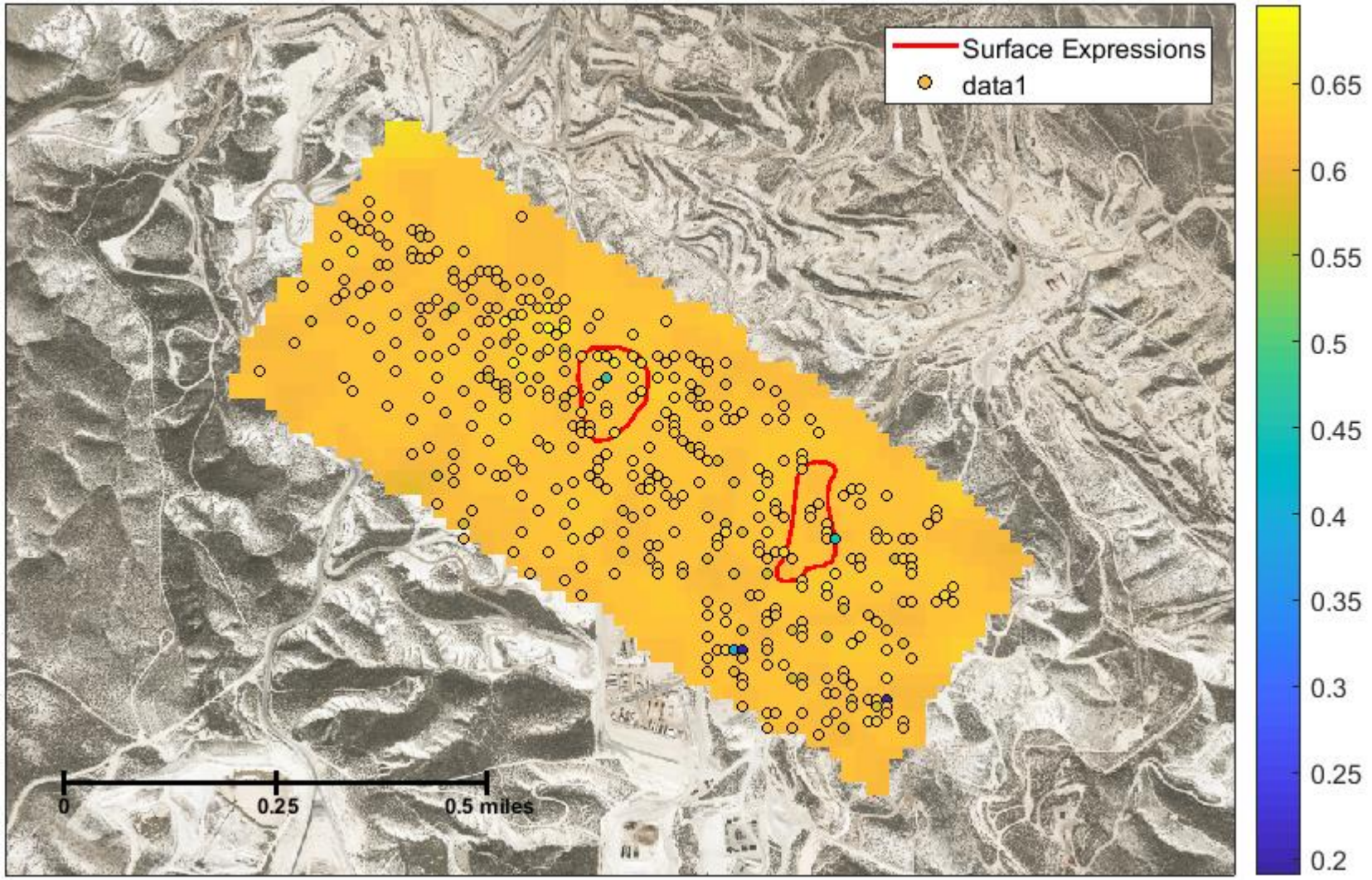






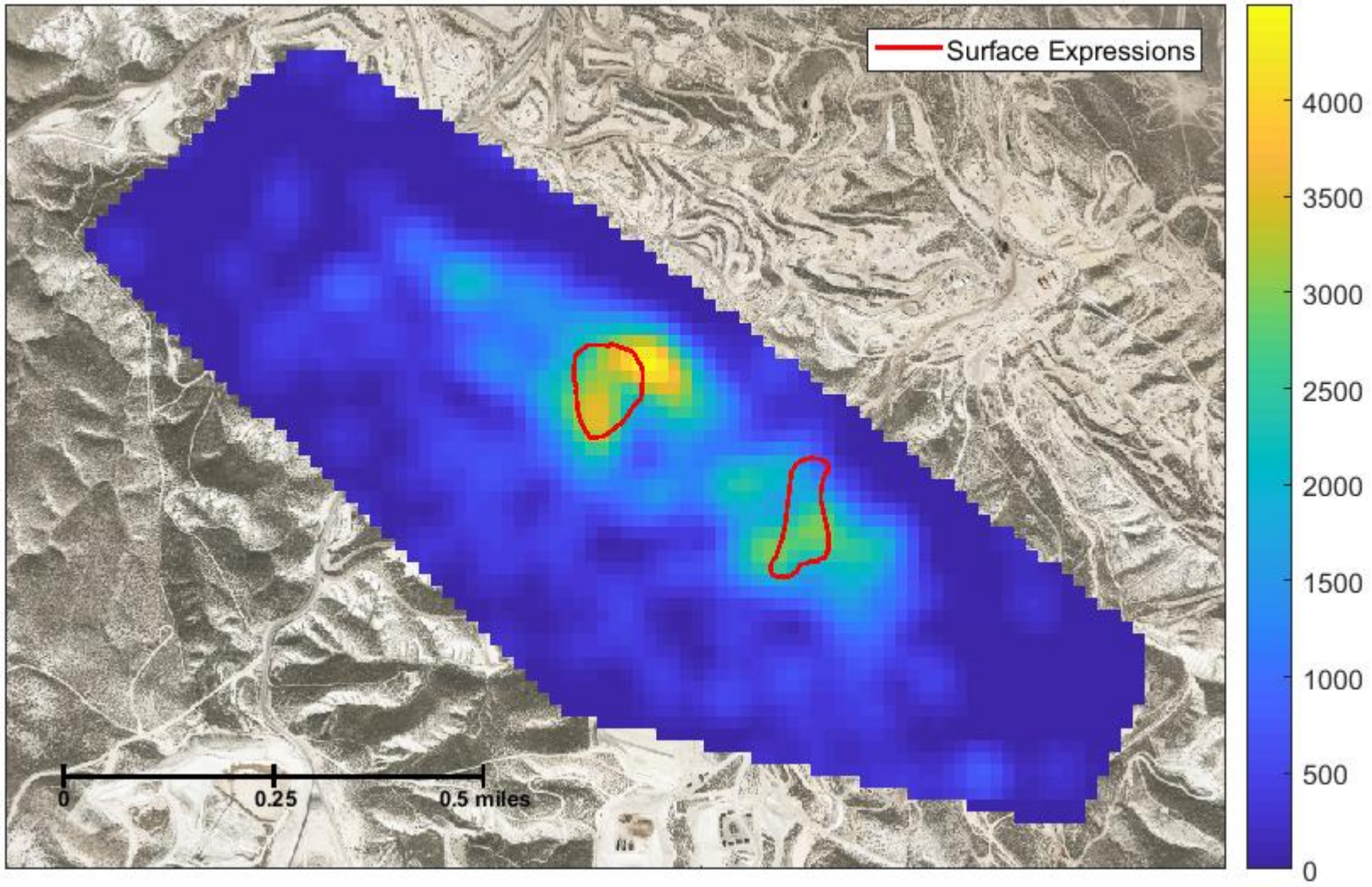


Porosity Seal

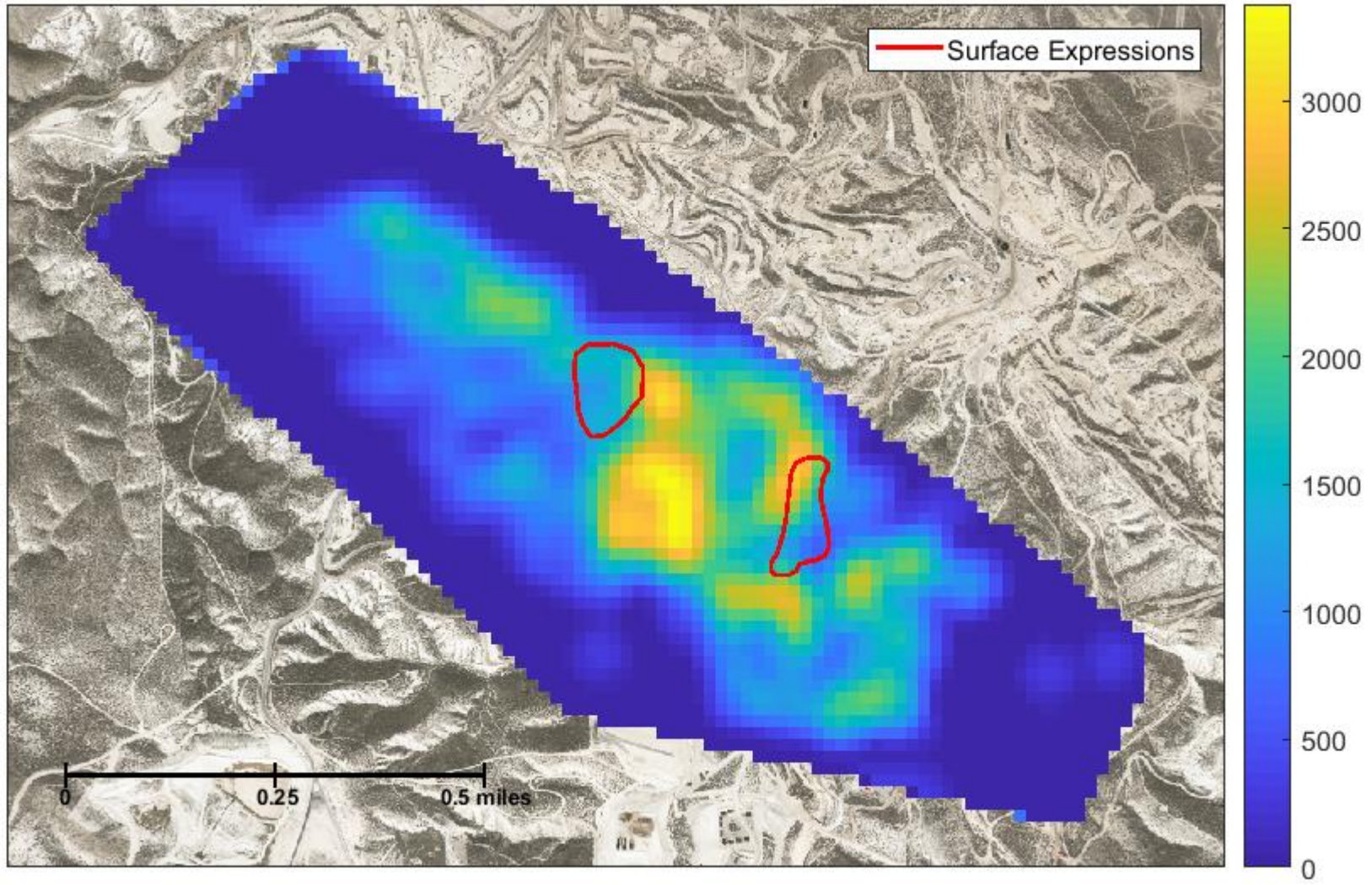


Well Engineering Predictors

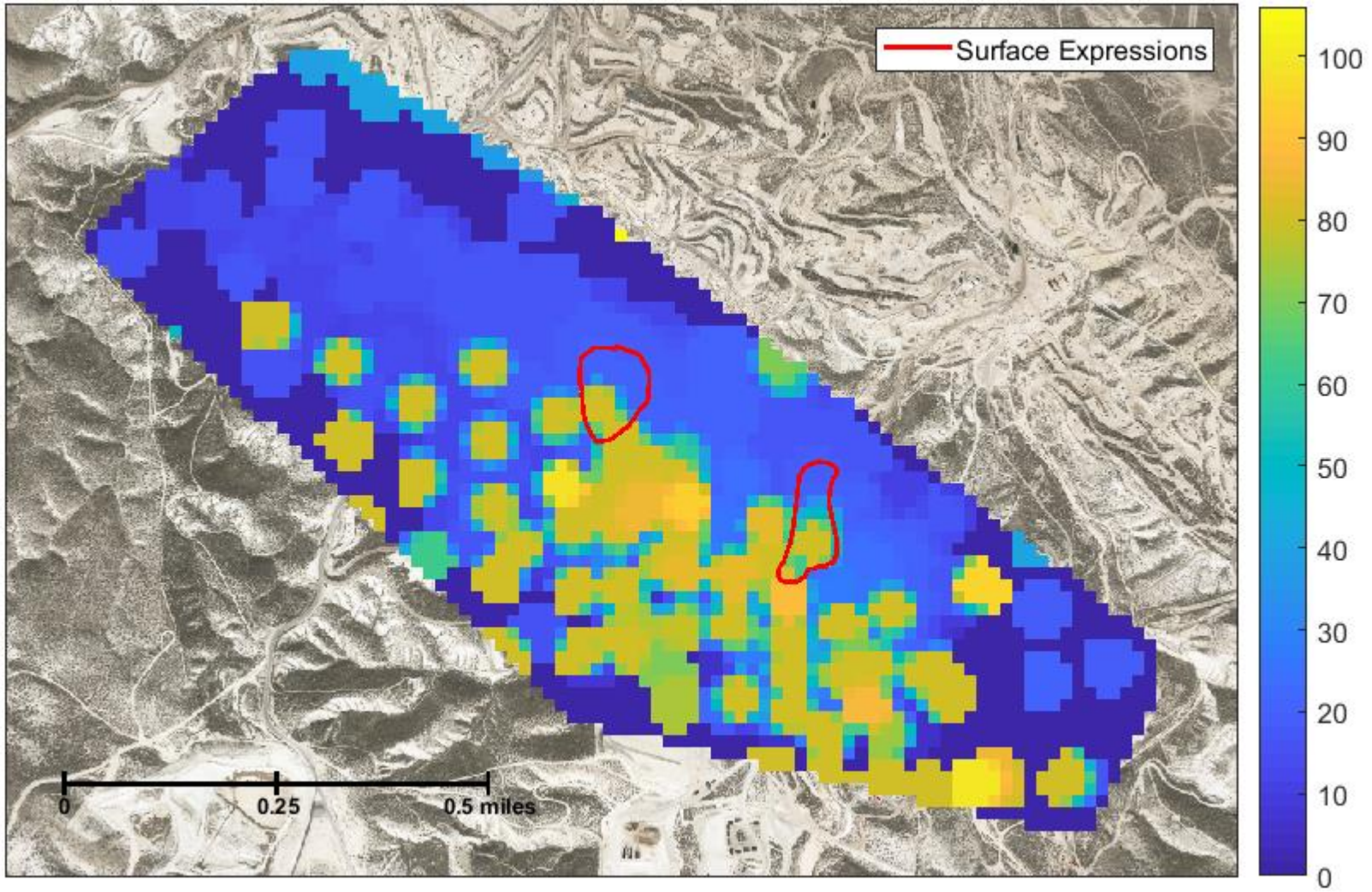
Plugged Wells Density (wells/mi^2)



Active Wells Density (wells/mi^2)

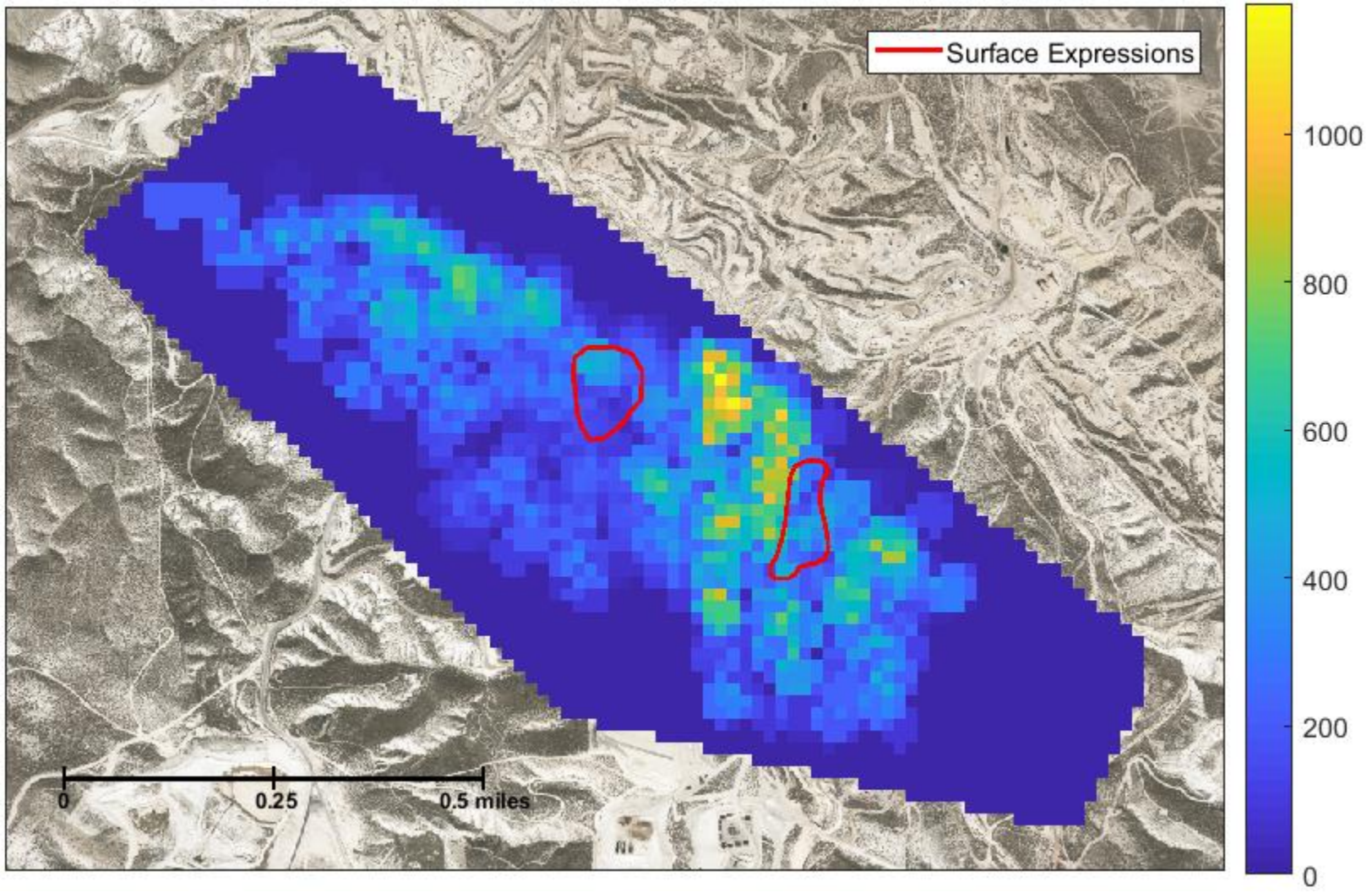


Maximum Age of Wells

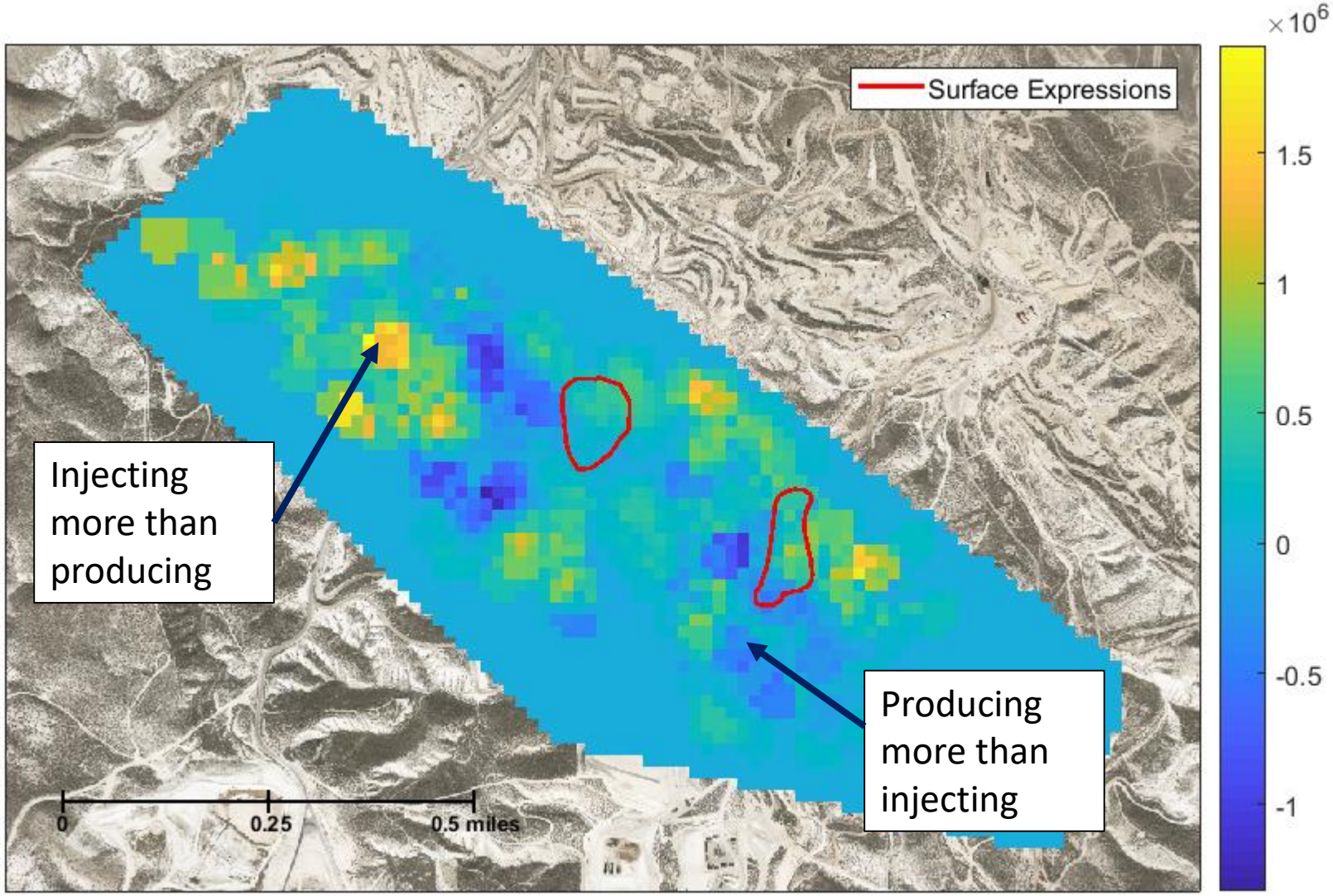


Production Data Predictors

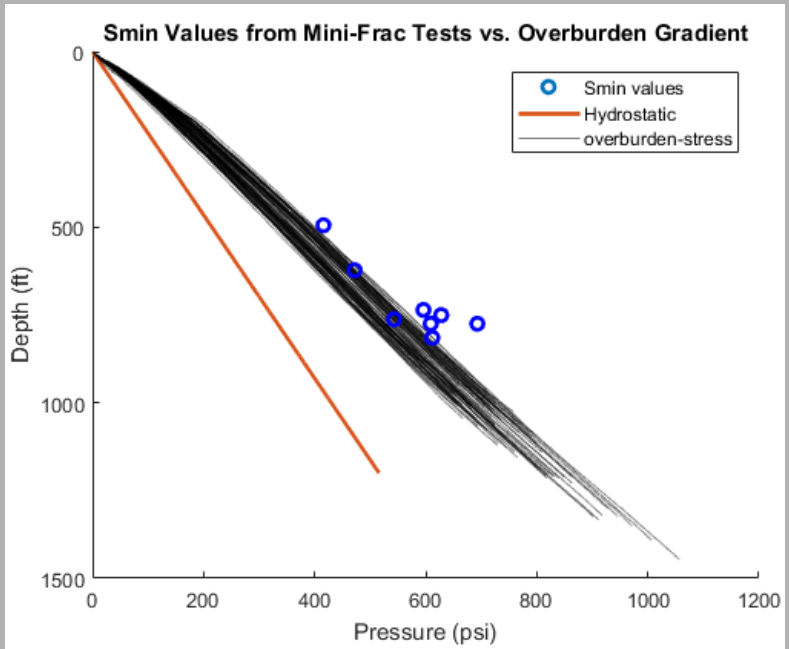
Cumulative Number of Cycles



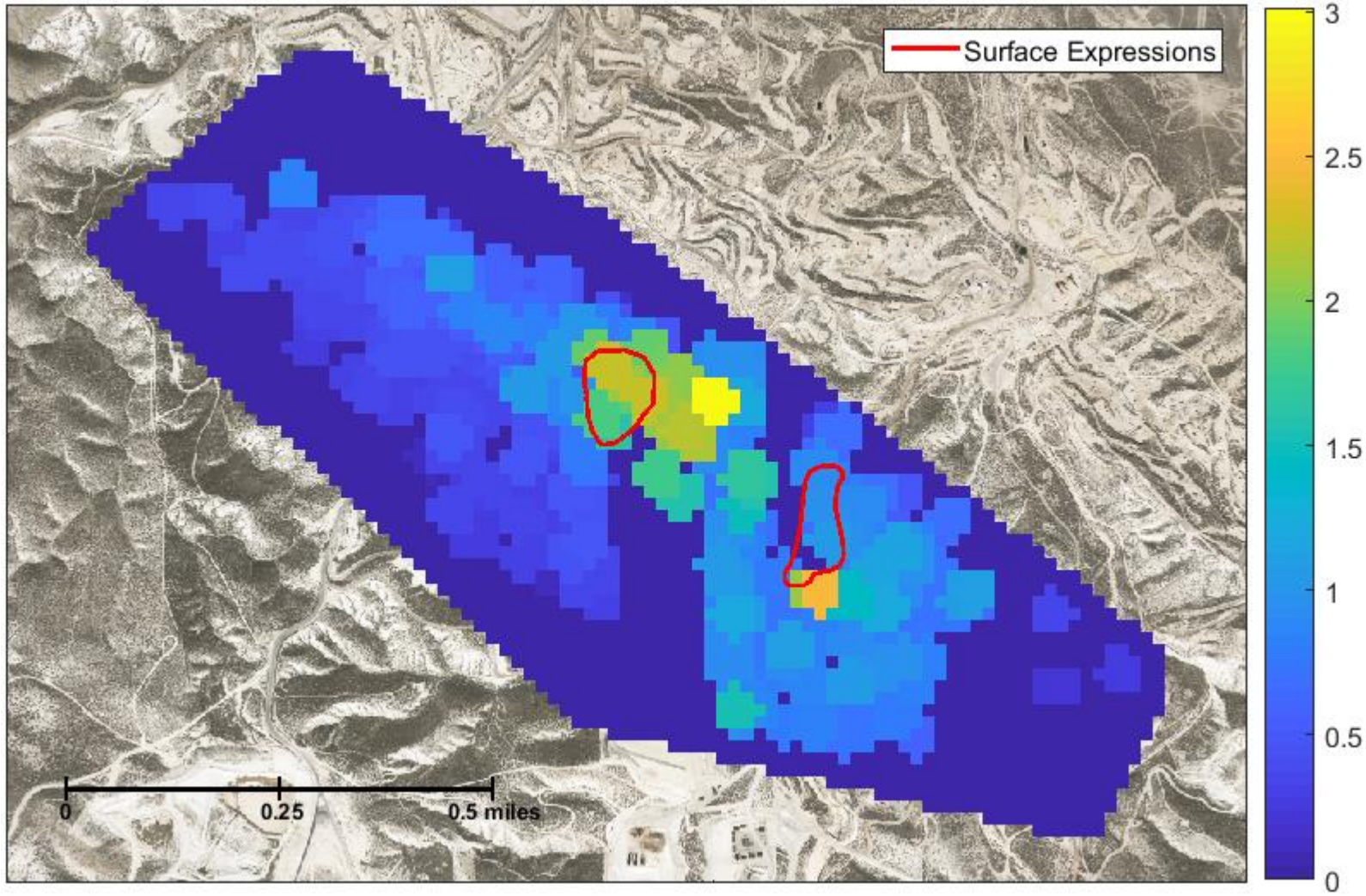
Water Injection – Water Production (bbl)



Maximum Pressure (psi/ft)



Fracture gradient ≈ 0.72 psi/ft



Input Into Classification Algorithm of Choice

1. Logistic Regression
2. Classification Tree

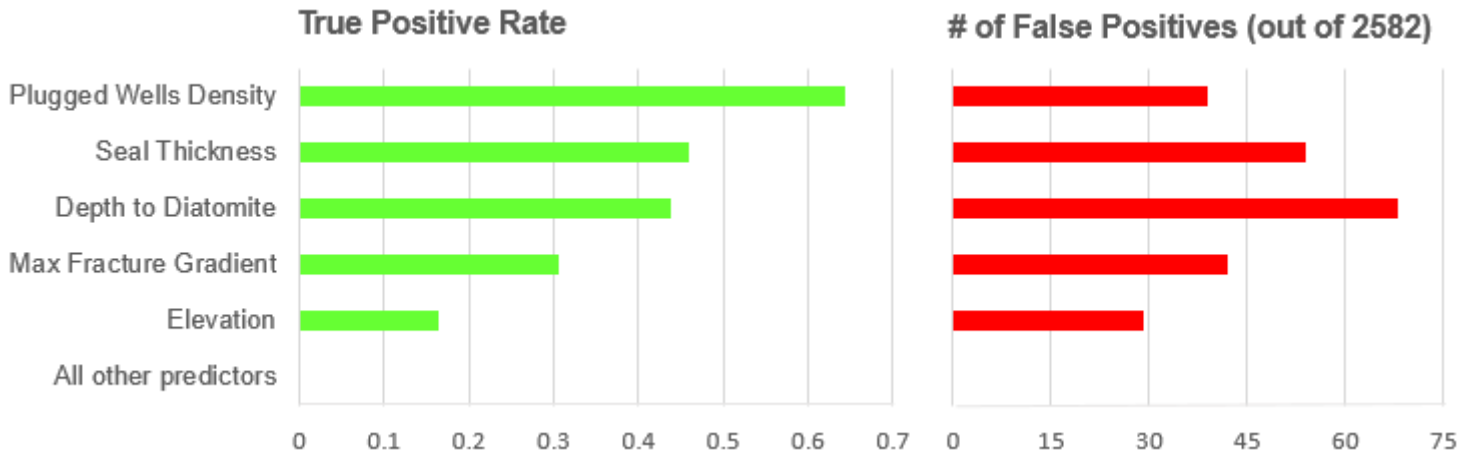
Logistic Regression

$$p(Seep) = \frac{e^{\beta_0+\beta_1 X_1+\cdots+\beta_p X_p}}{1+e^{\beta_0+\beta_1 X_1+\cdots+\beta_p X_p}}$$

$\beta_1, \beta_2, \beta_3 .. \beta_n \rightarrow coefficients$
$X_1, X_2, X_3 \ldots X_n \rightarrow Predictors/Attributes$

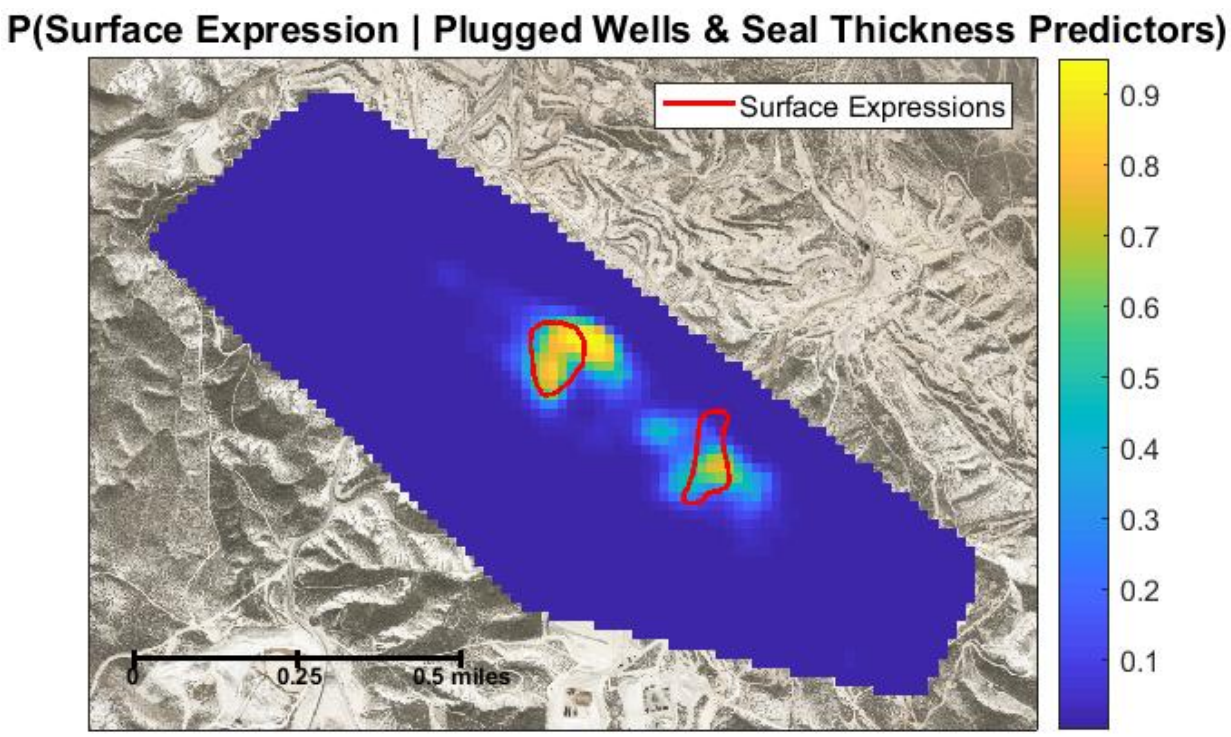
Logistic Regression - Screening

1. Seal Thickness
2. Depth to the Top of the Diatomite
3. Concentration of faulting
4. Elevation
5. Cumulative steam injection minus water production
6. Maximum pressure gradient
7. Number of steam cycles
8. Density of active wells
9. Density of plugged wells
10. Age of wells

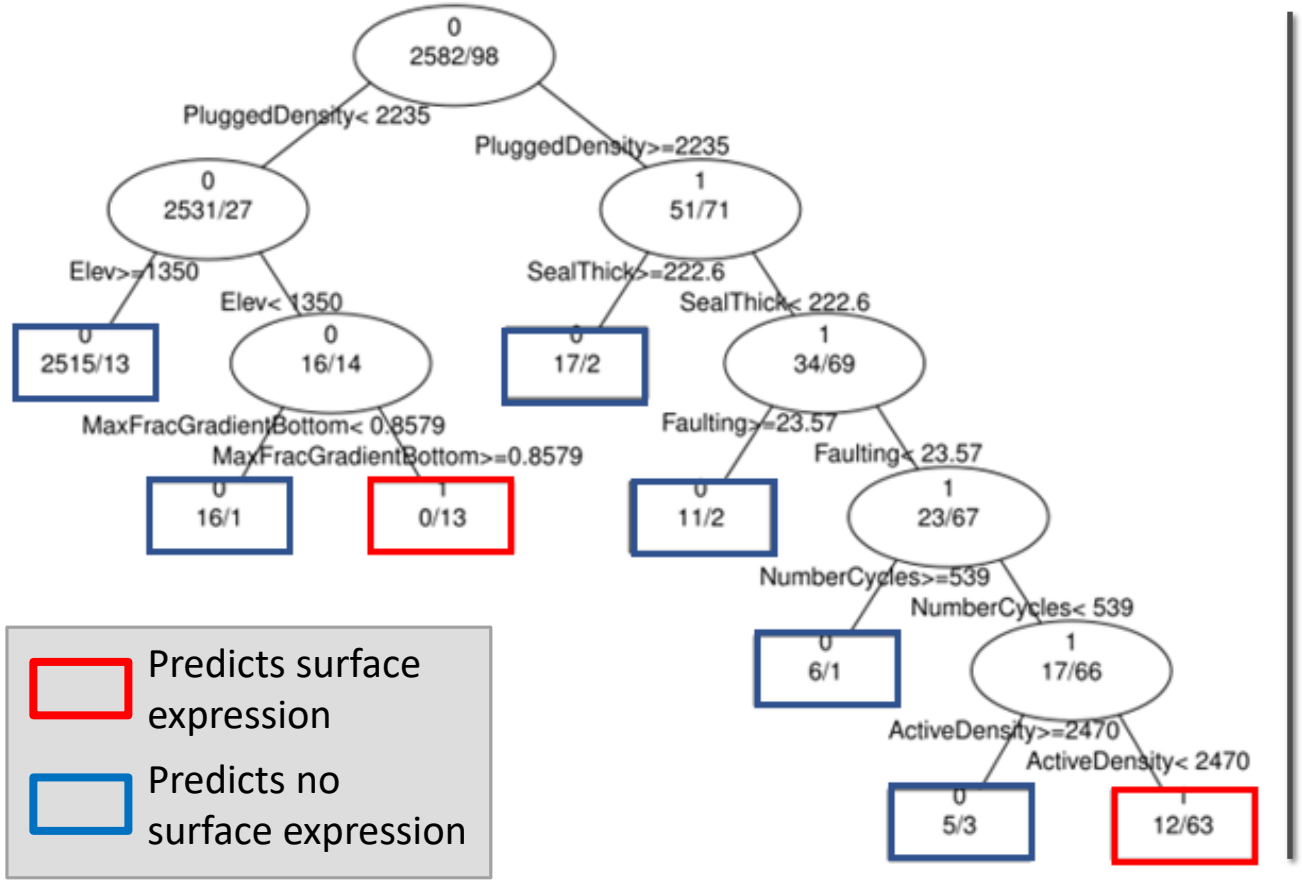


Logistic Regression: Concentration of plugged wells + Seal Thickness

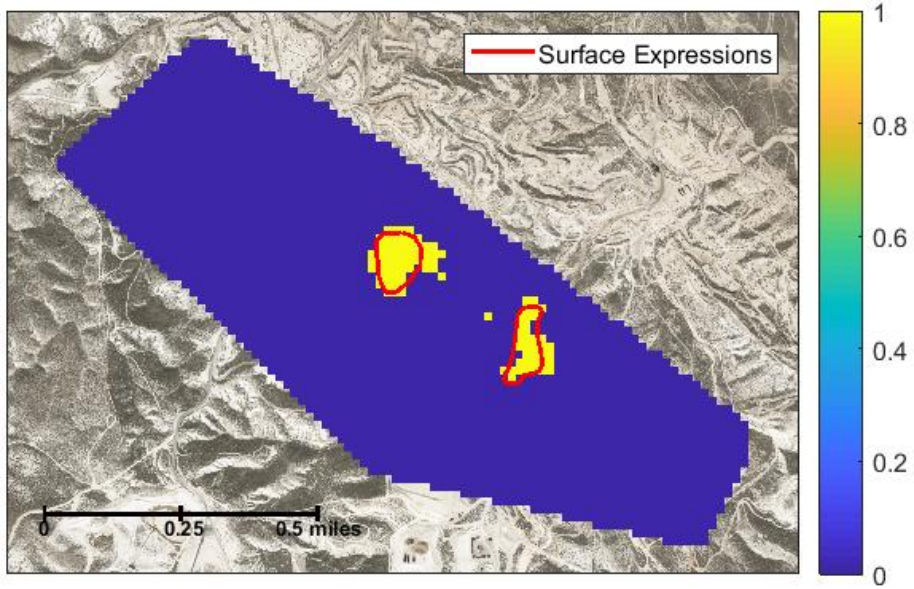
	Predicted no surface expression	Predicted a surface expression
No surface expression	**2536**/2582 98% Specificity	**46**/2582 2% False Positives
Surface expression	**26**/98 26.5% Missed Alarms	**72**/98 73% Success



Classification Tree



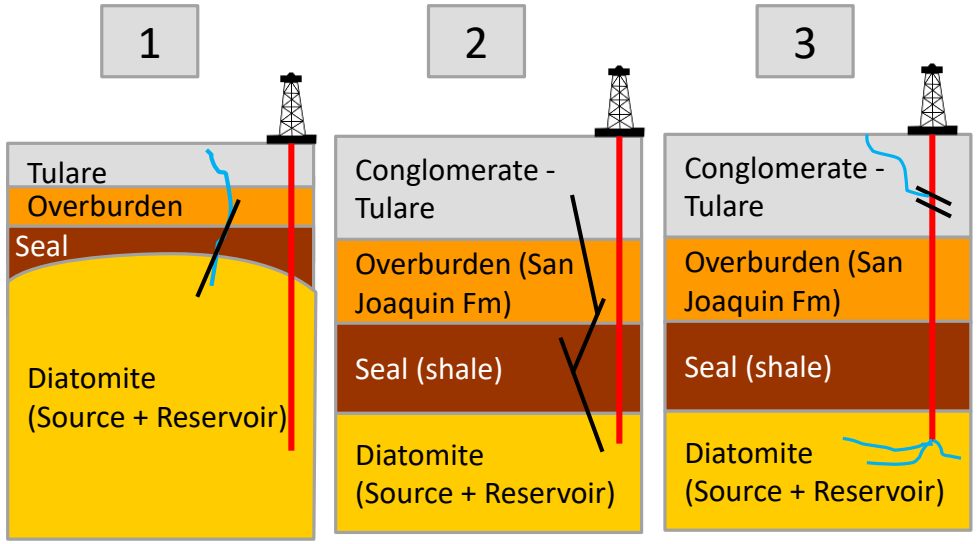
	Predicted no surface expression	Predicted a surface expression
No surface expression	**2565**/2582 99% Specificity	**17**/2582 1% False Positives
Surface expression	**19**/98 19% Missed Alarms	**79**/98 81% Success



Spatial Analysis Conclusions

1. Structural hypothesis –correlation found with seal thickness/depth to producing formation.
2. Plugged wells show a high spatial correlation to surface expressions.

1,2,3. Combination

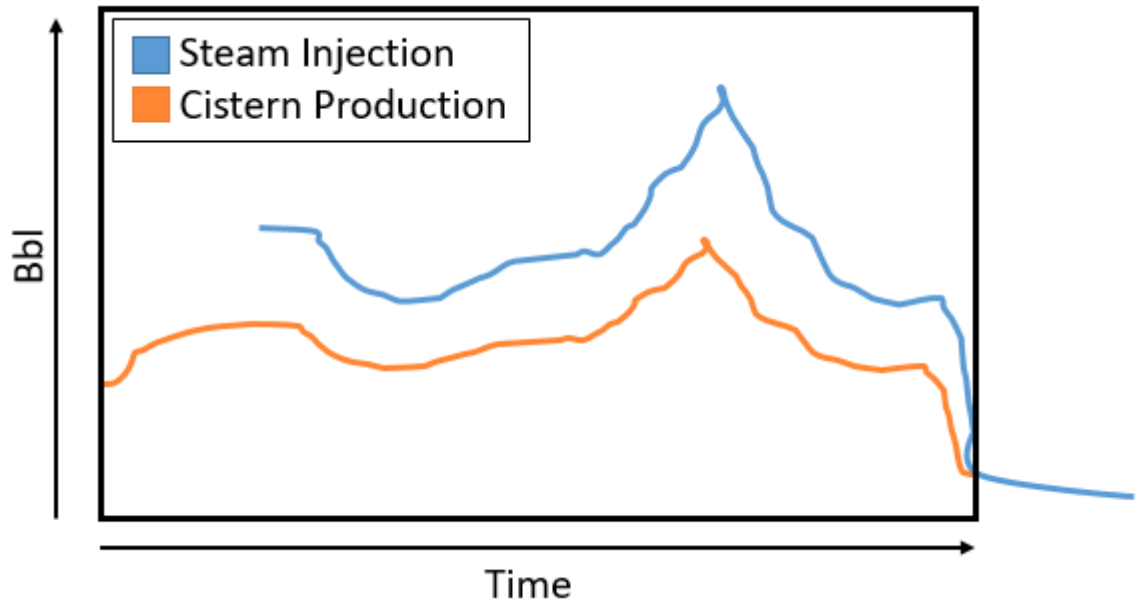


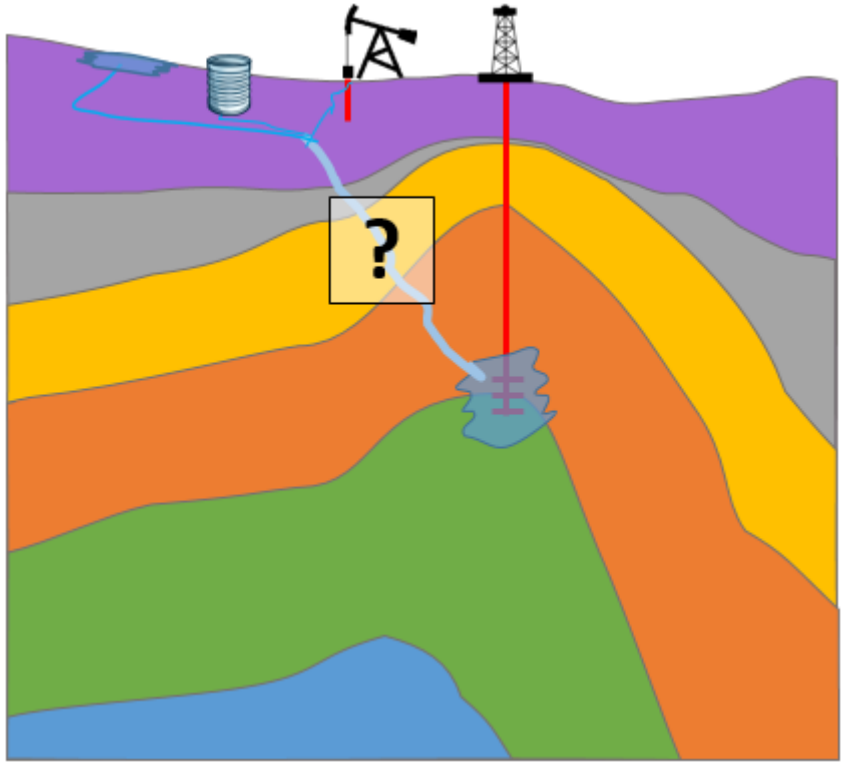
The Aim of Temporal Analysis

Explore similarity between the temporal signal of surface expressions and the temporal signal of steam injection.

What is the Assumption?

If the steam injection rate is similar to the cisterns' fluid production rate then there is a likelihood that they are related.



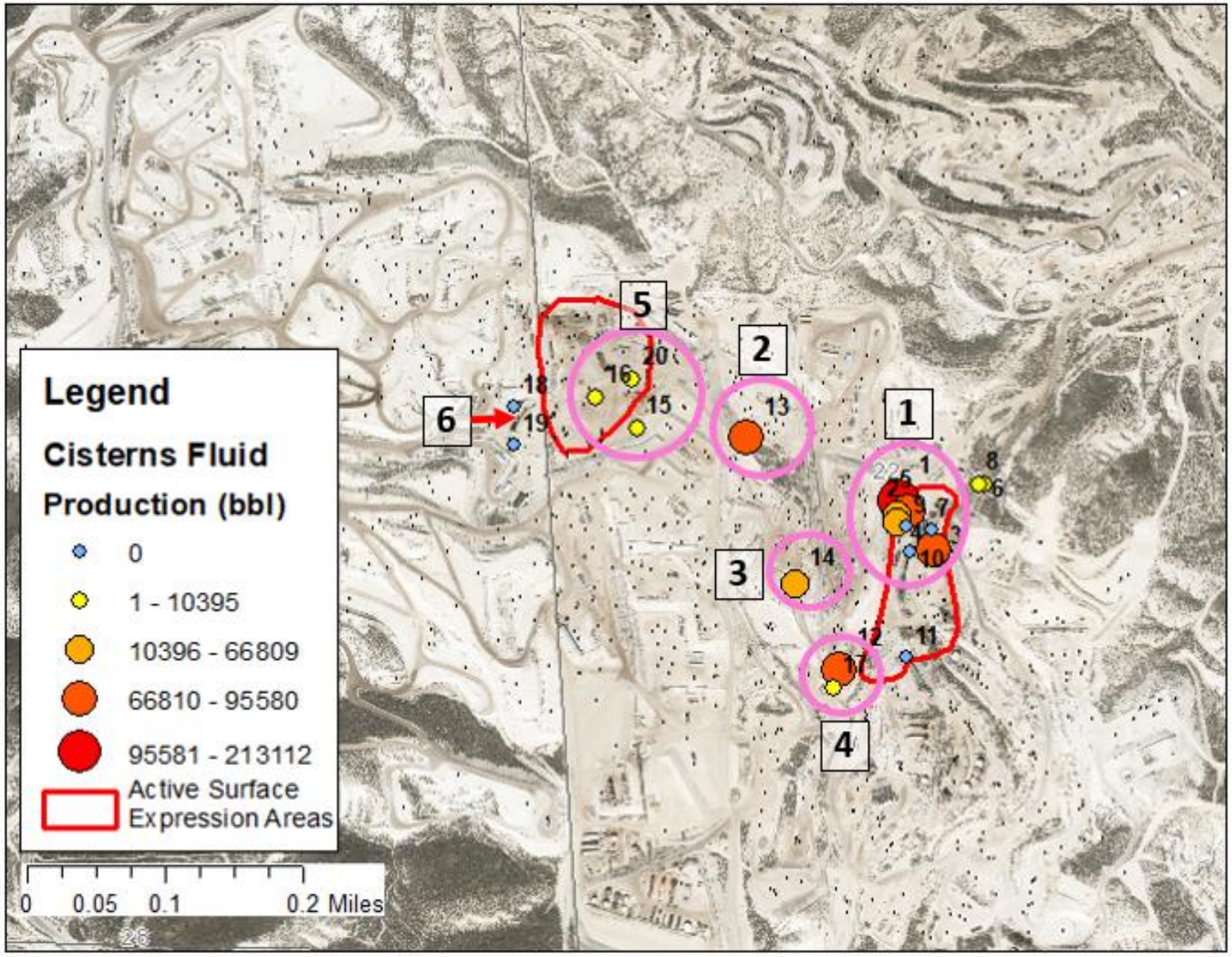


What Data Do We Have?

1. Cisterns with API numbers
2. Pull volumes from Well 20

Investigate Six Areas

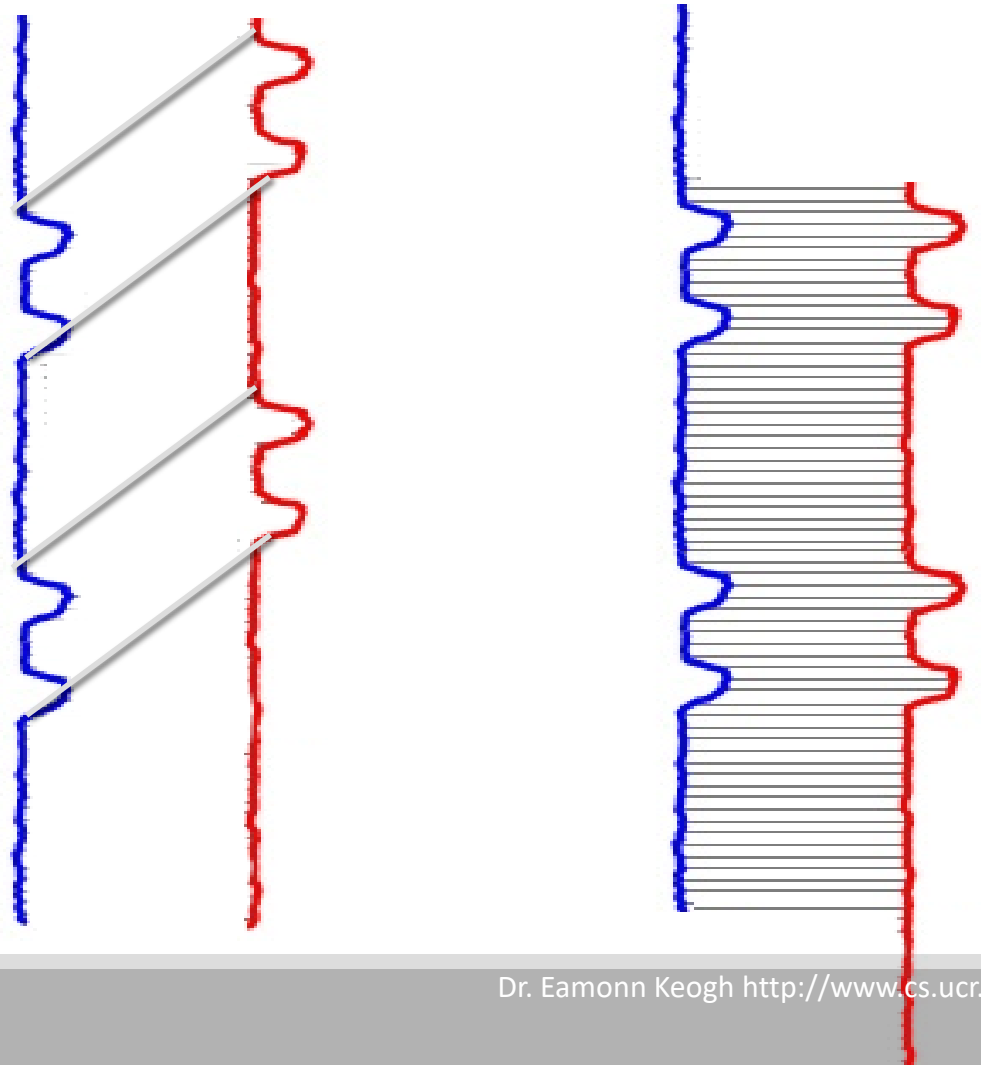
1,374,224 Bbl fluid!



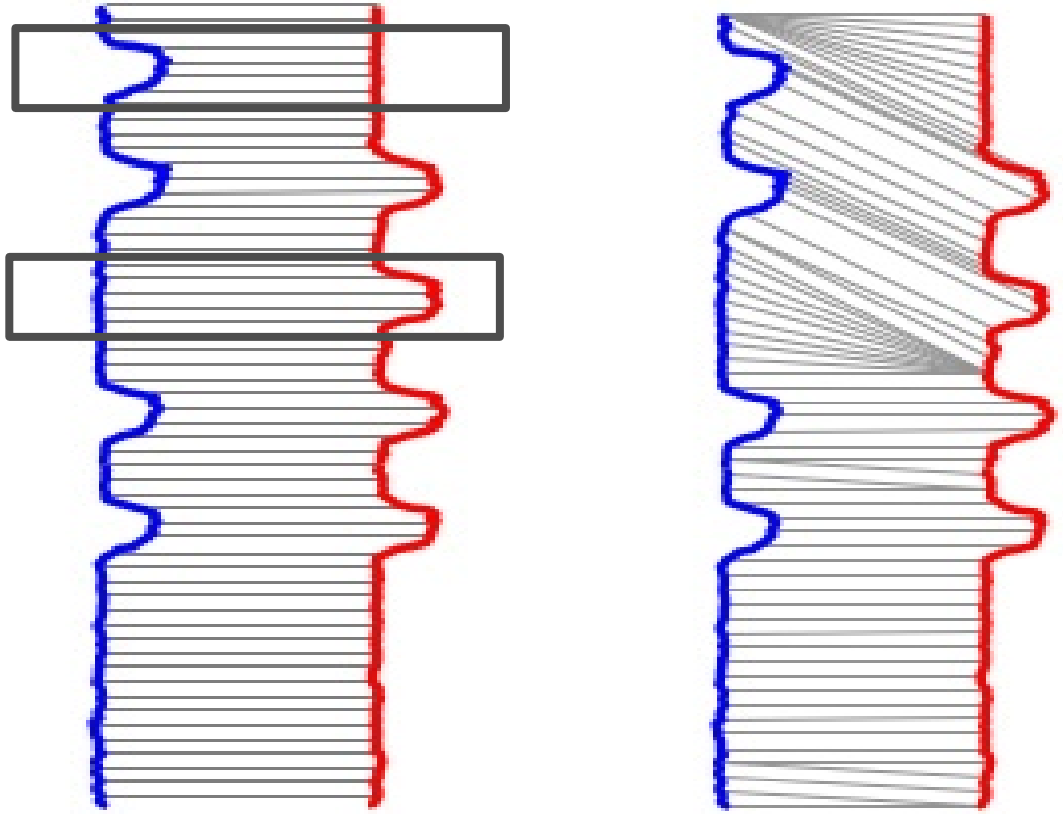
How Will We Measure Similarity?

1. Cross Correlation
2. Dynamic Time Warping

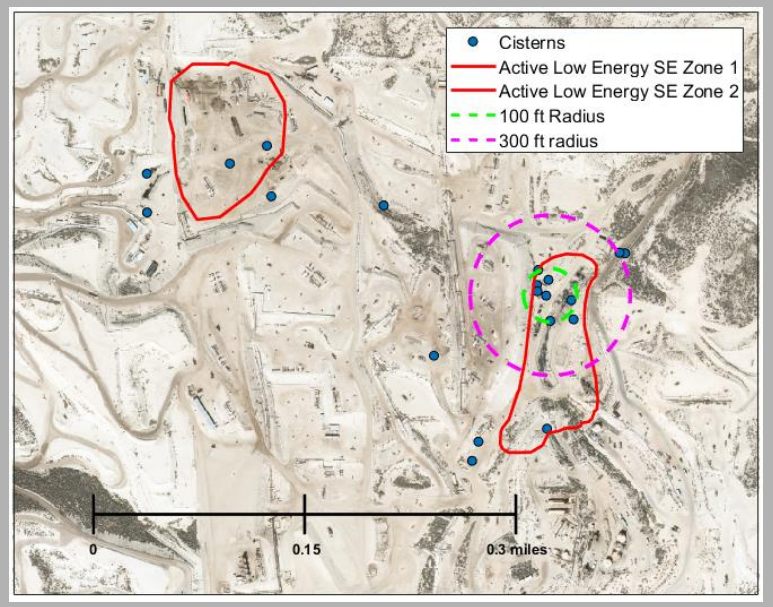
Cross Correlation – Handles Lags

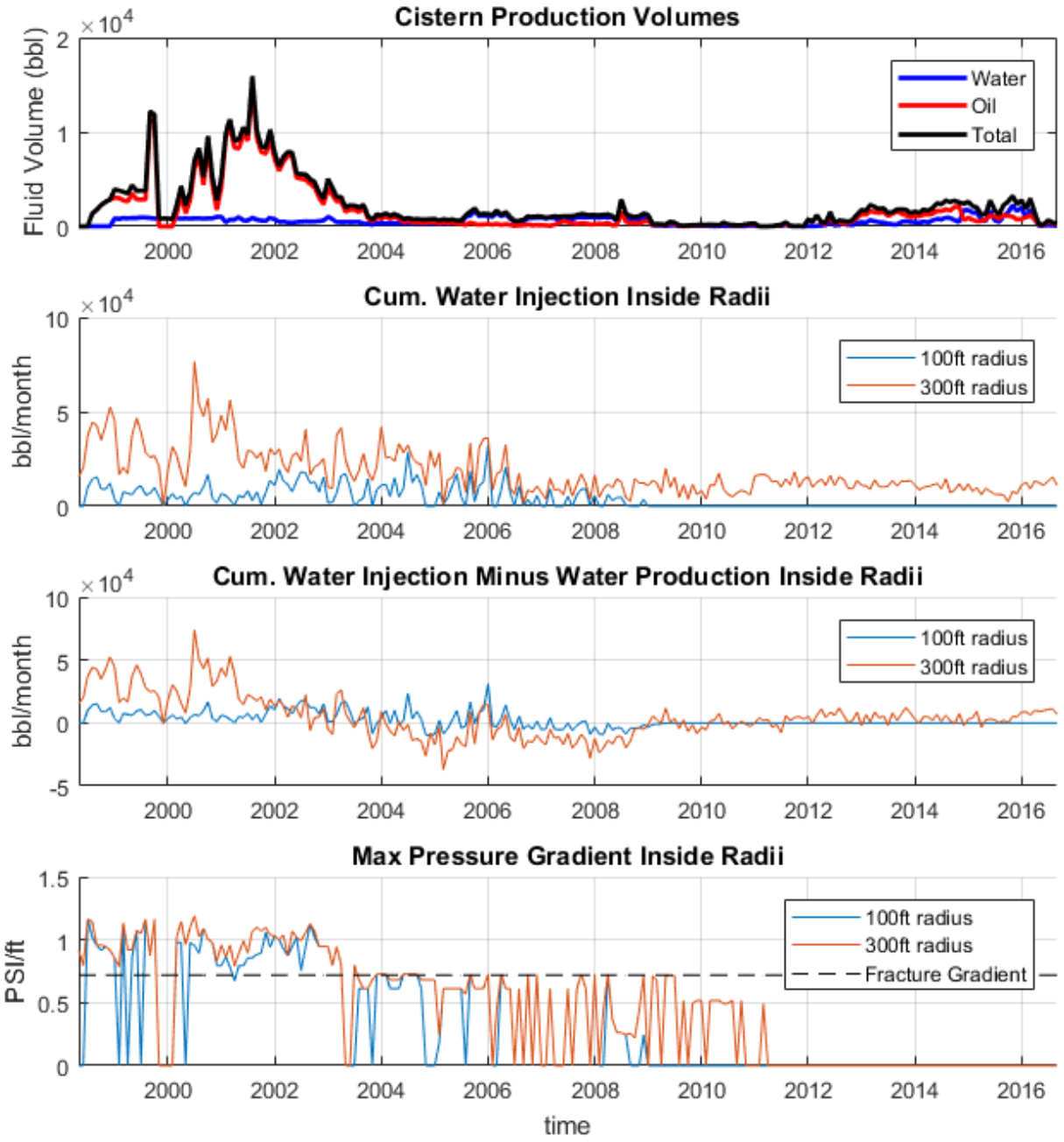


Dynamic Time Warping – More Flexible

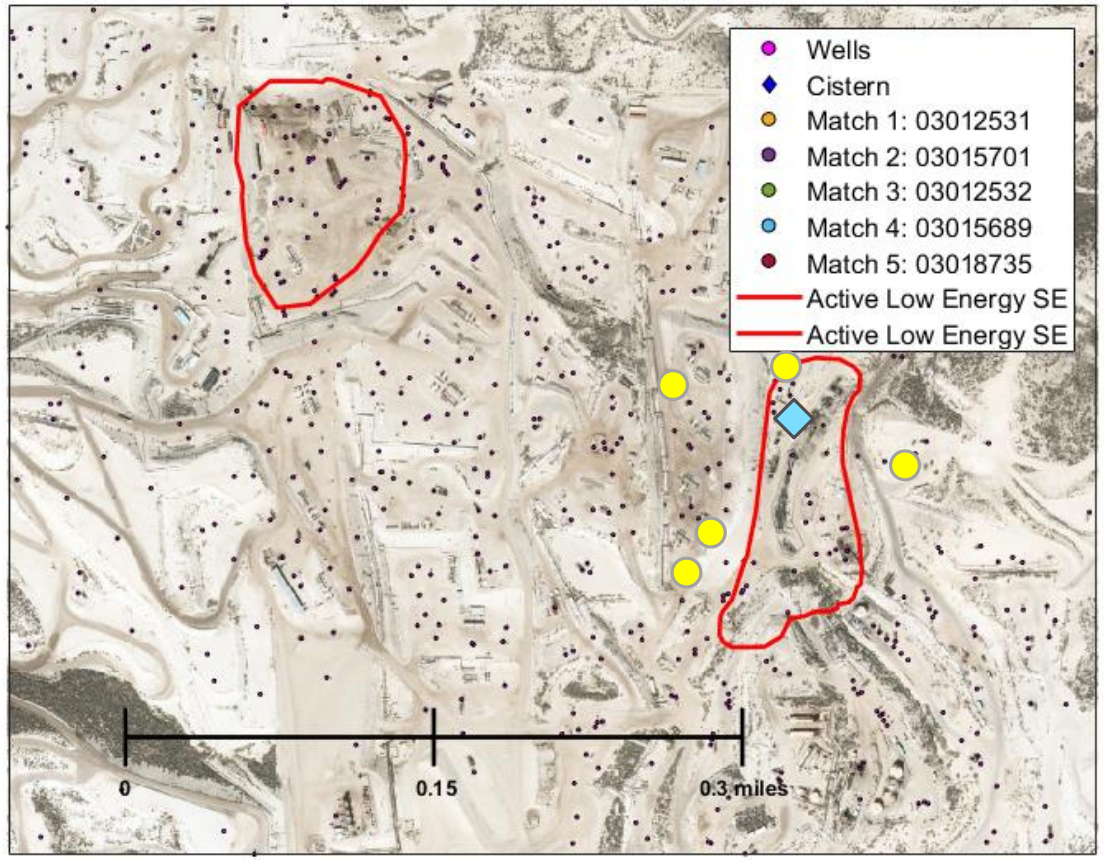


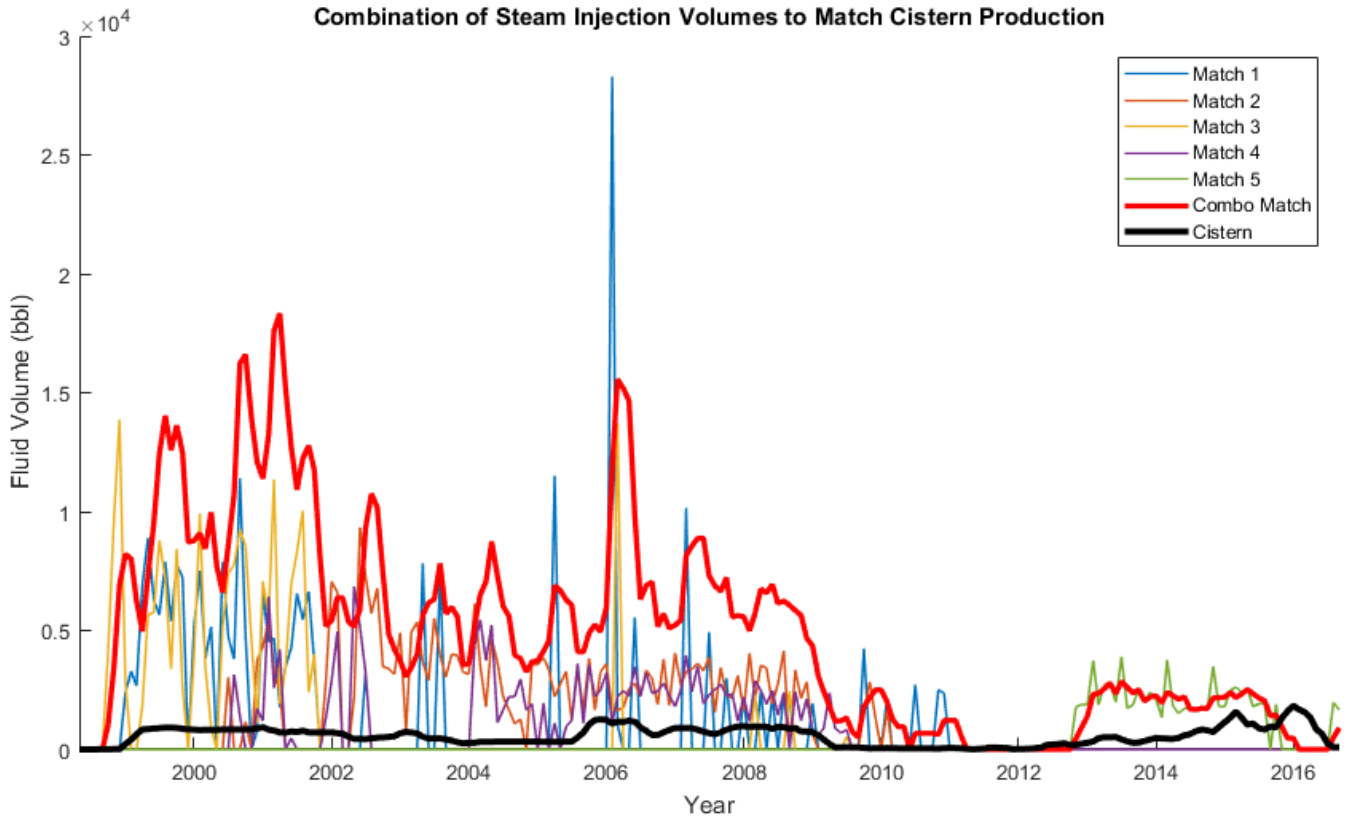
Zonal Correlation – Cistern Group 1



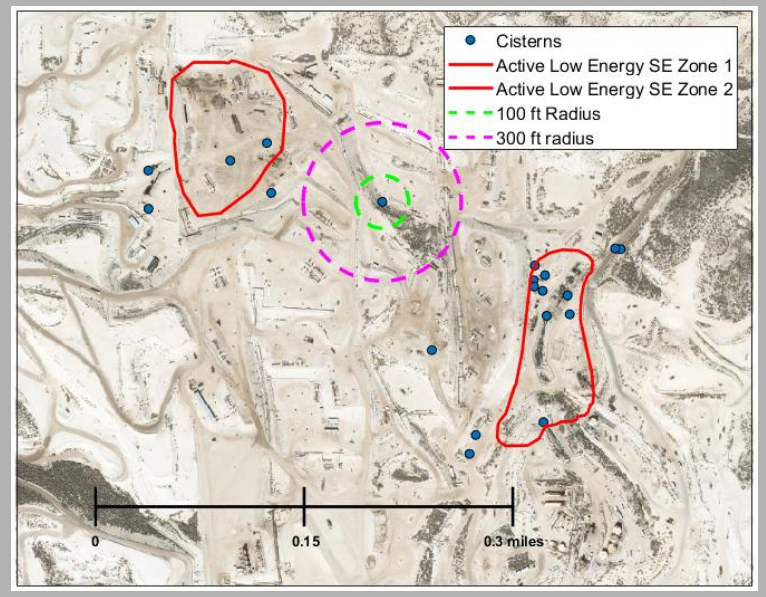


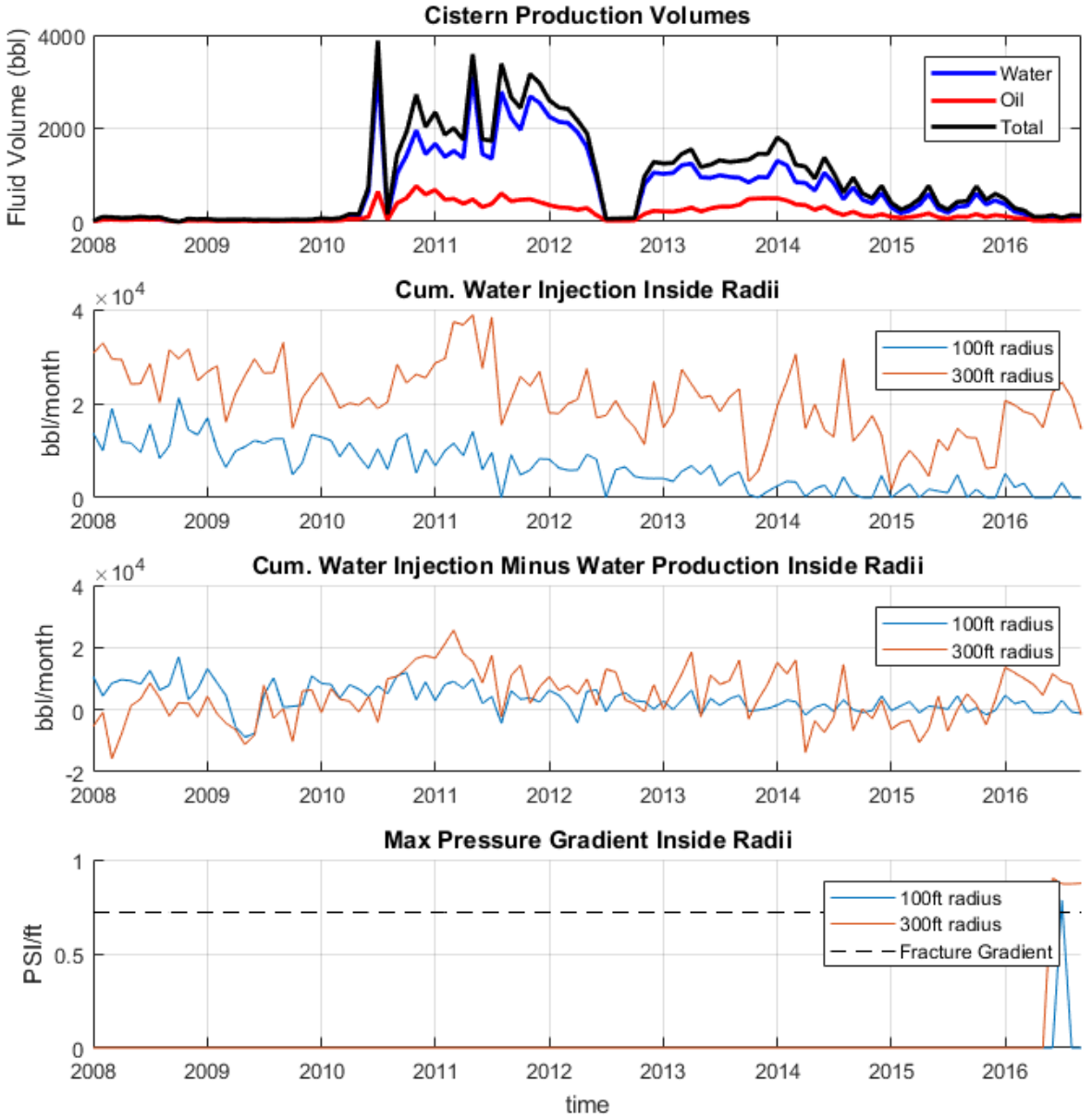
Correlation to a Group of Wells – Cistern Group 1



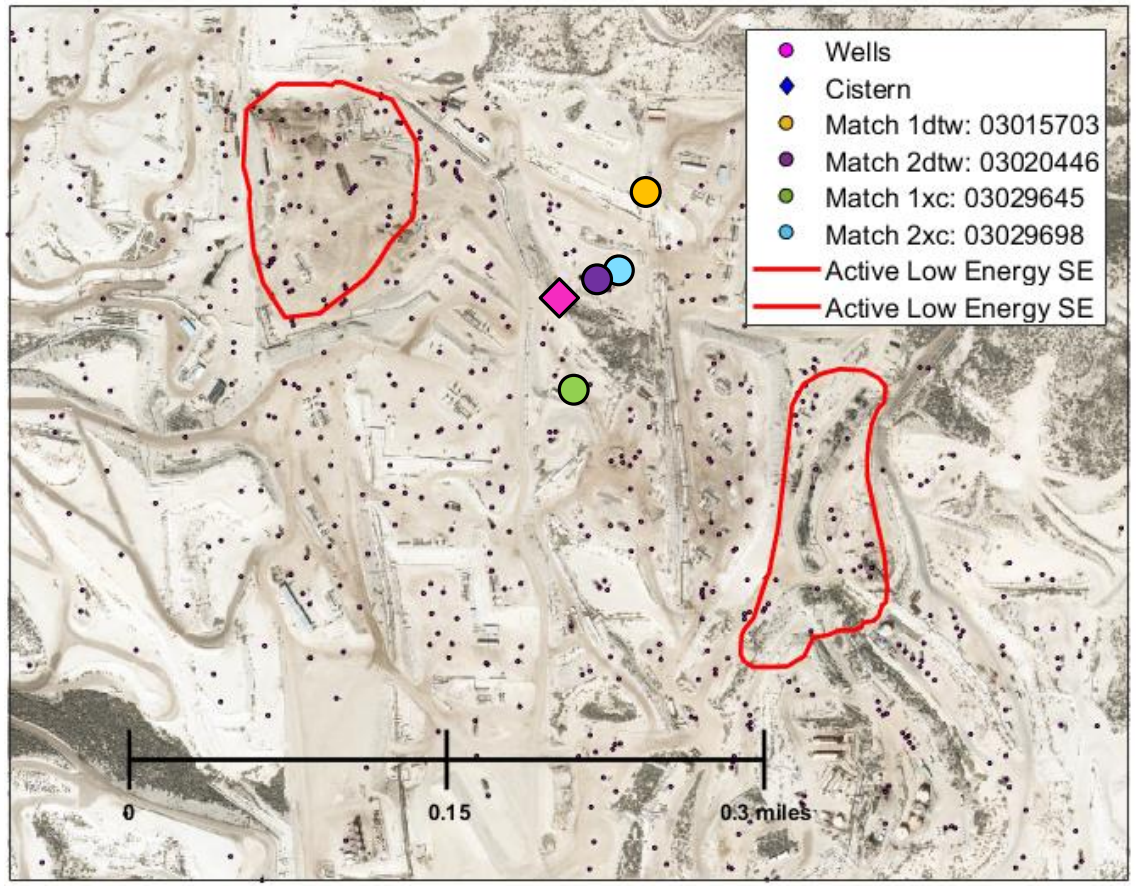


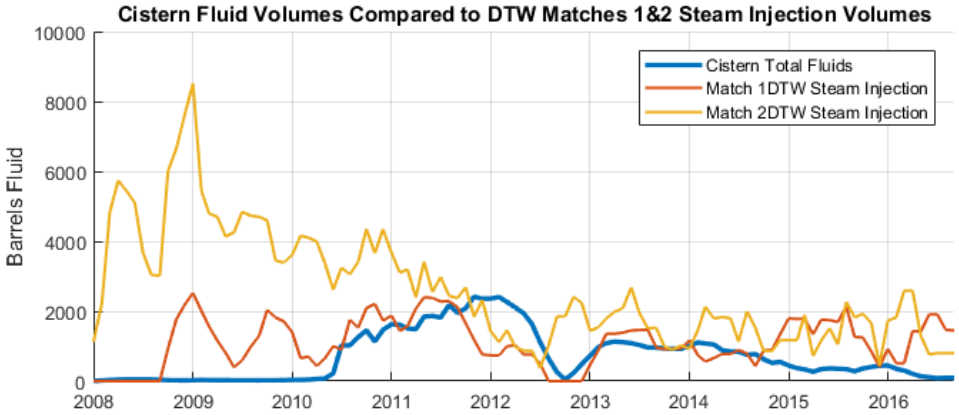
Zonal Correlation – Cistern Group 2

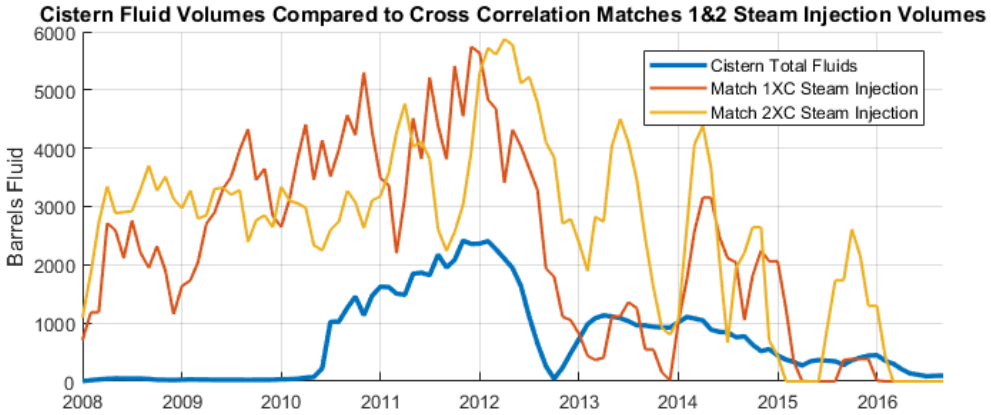




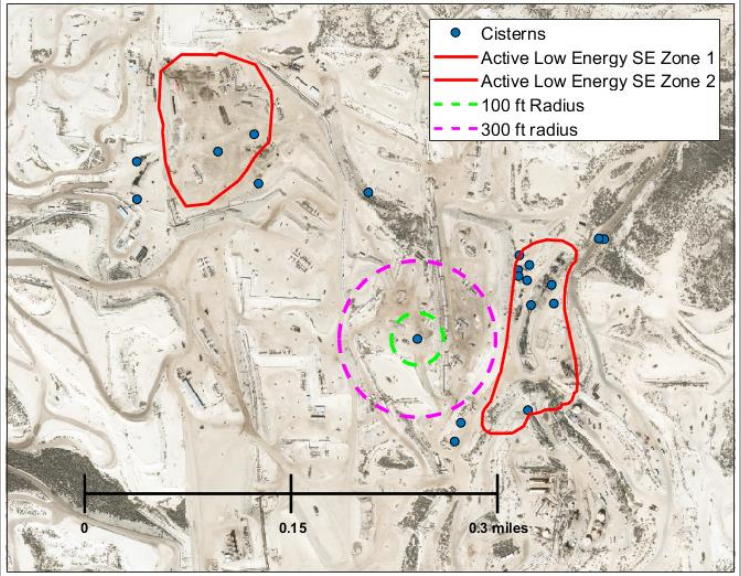
Correlation to a Single Well – Cistern Group 2

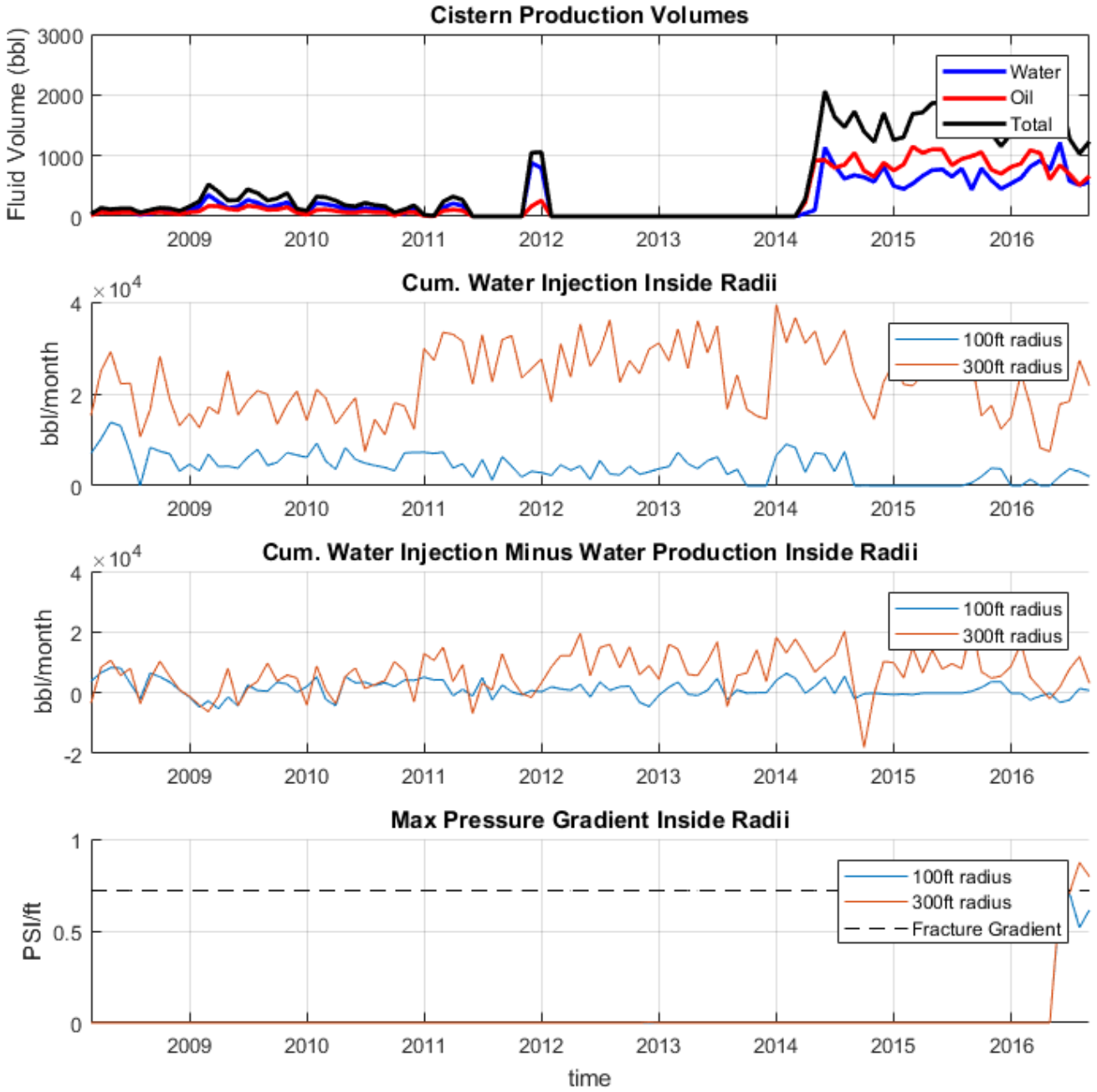




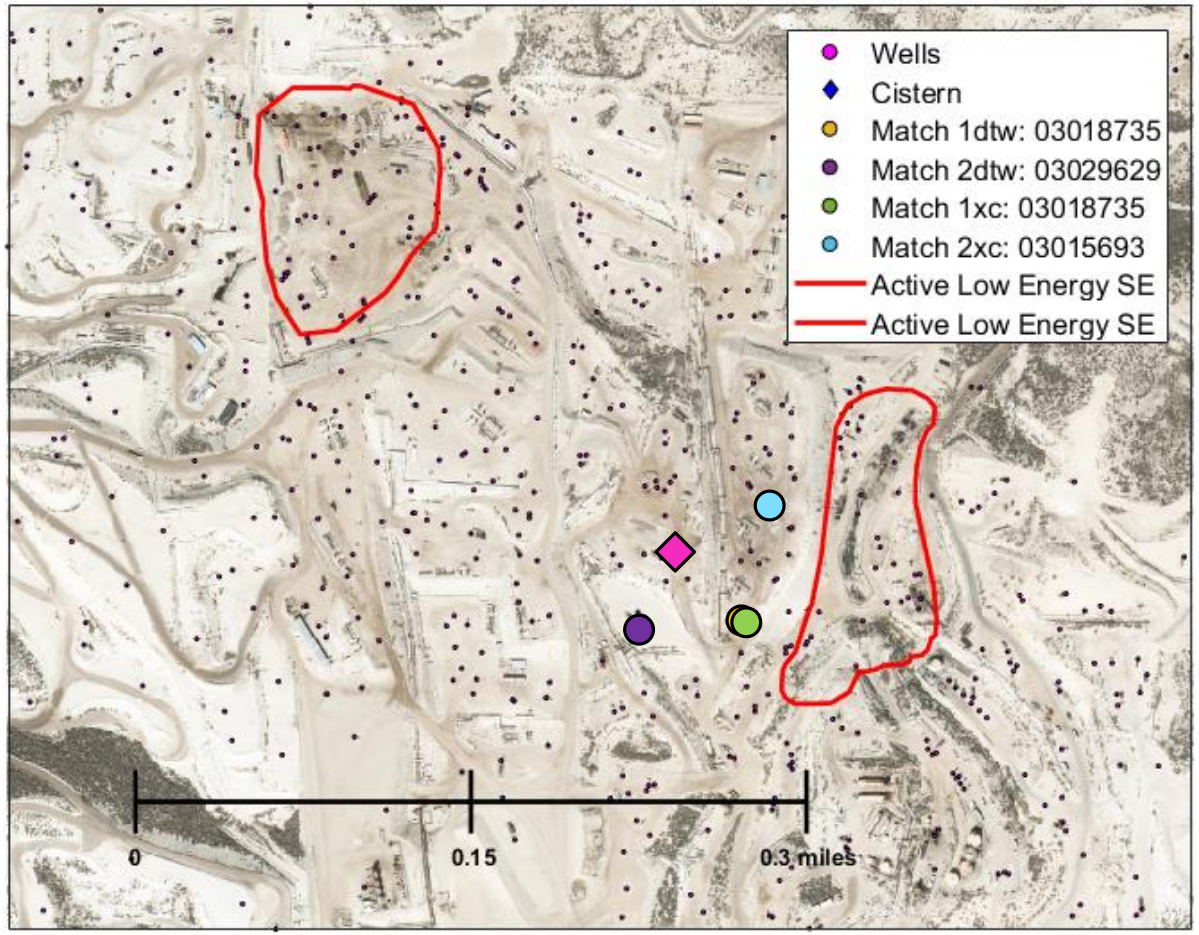


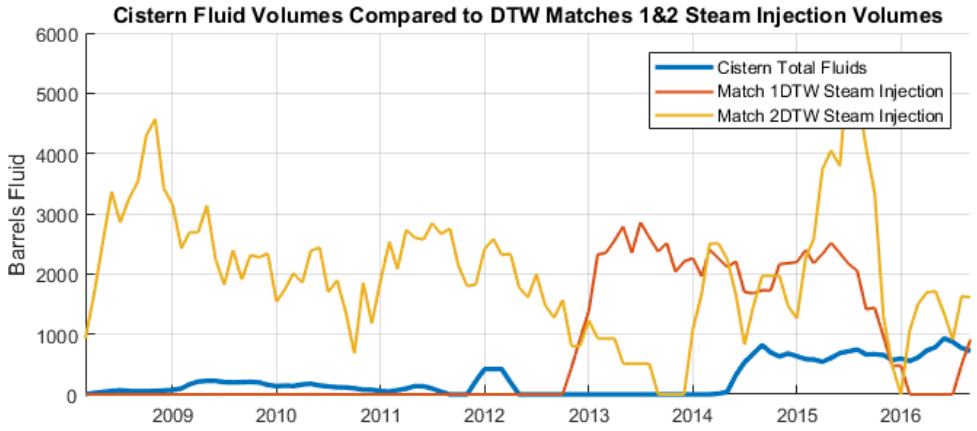
Zonal Correlation – Cistern Group 3

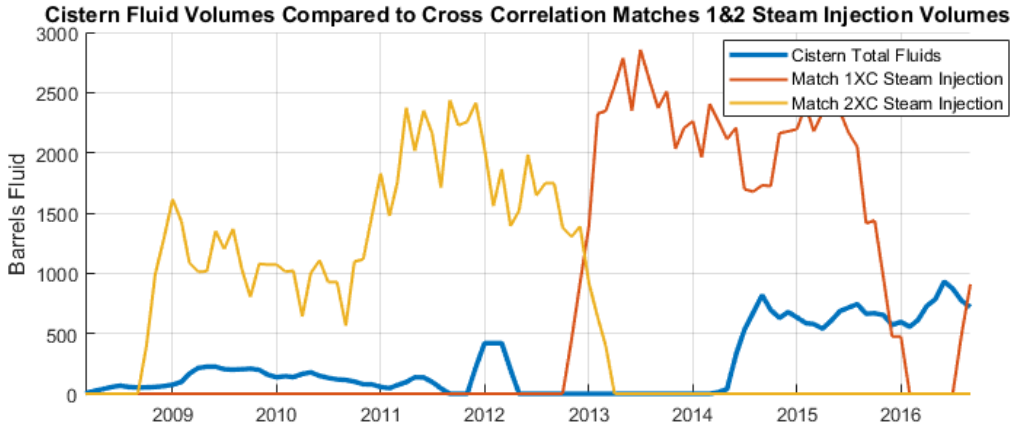




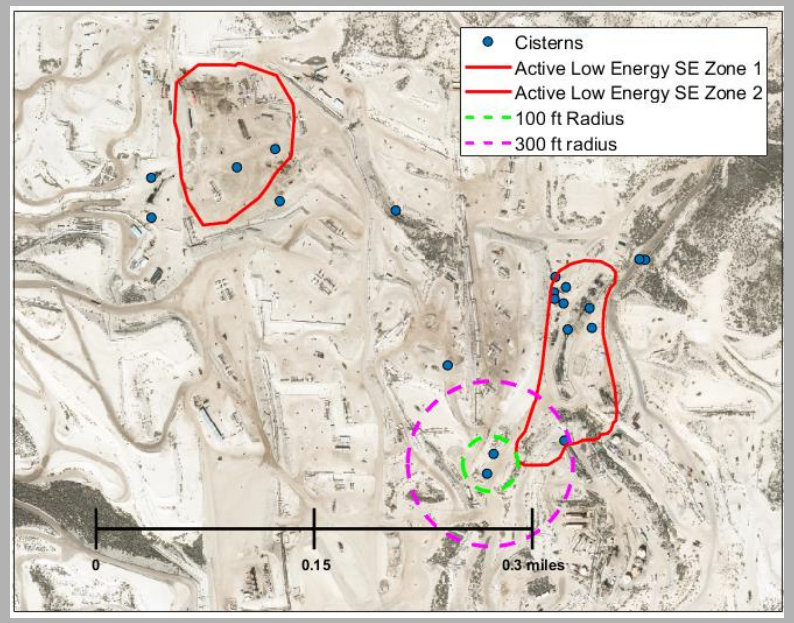
Correlation to a Single Well – Cistern Group 3

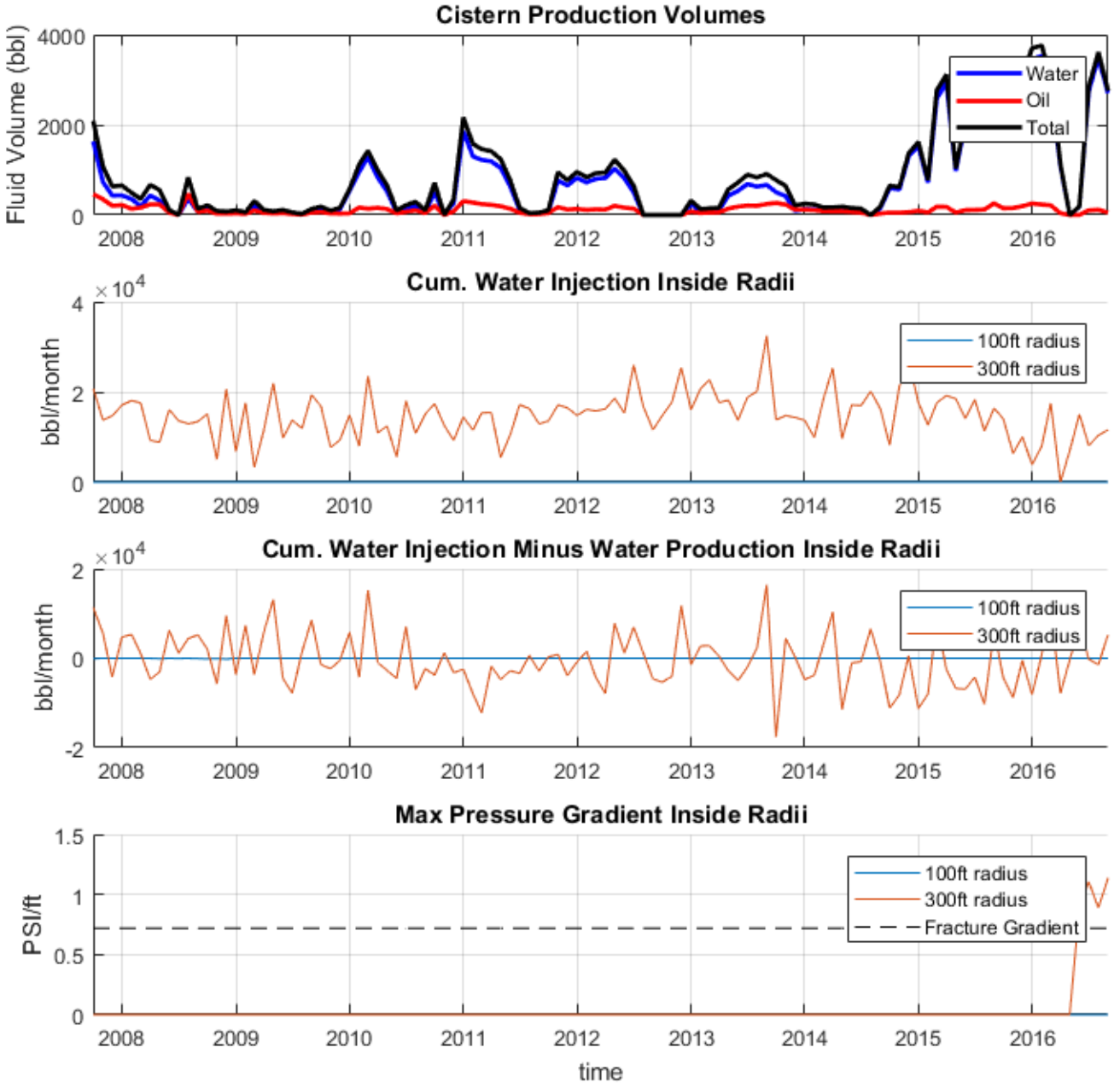




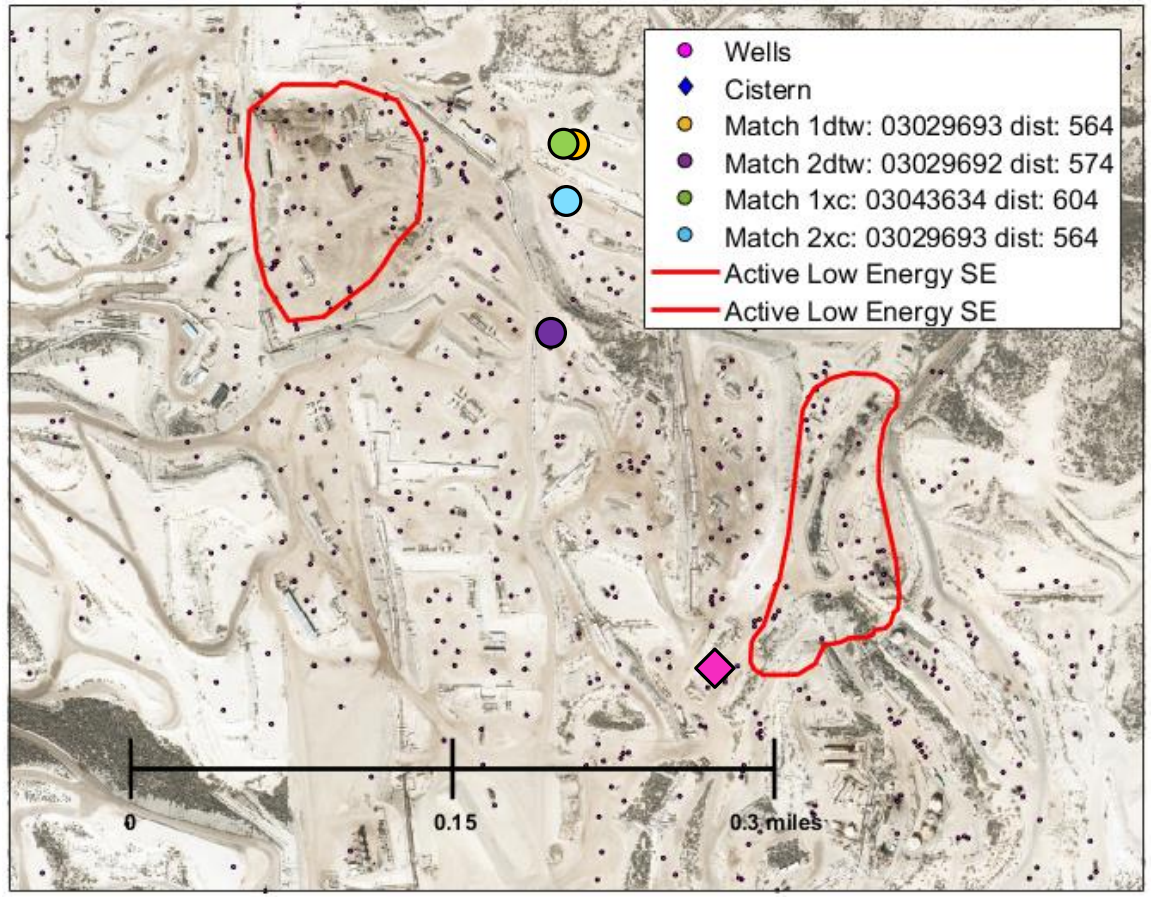


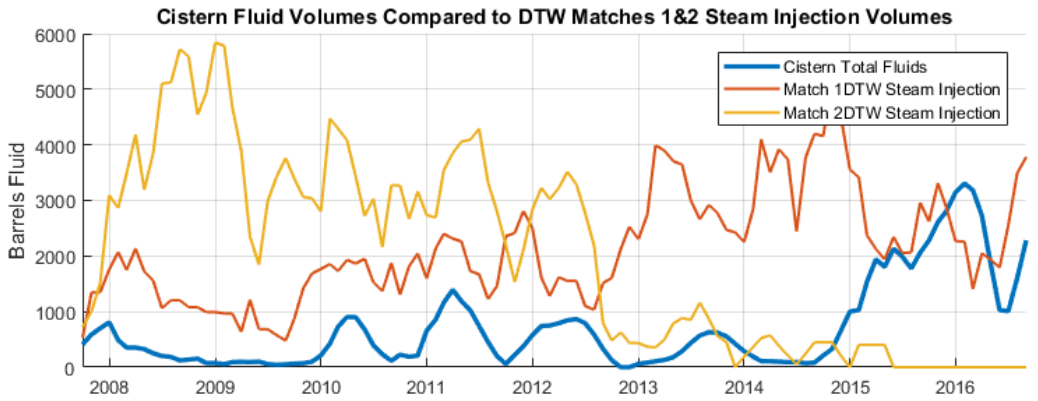
Zonal Correlation – Cistern Group 4

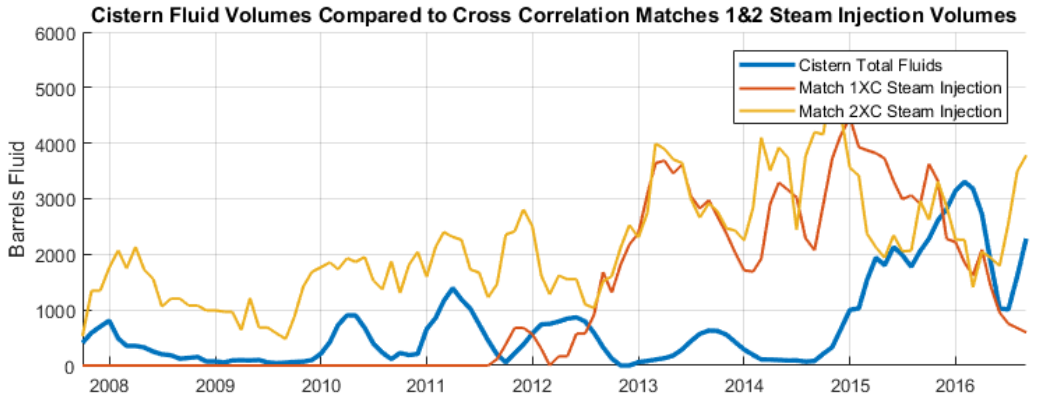




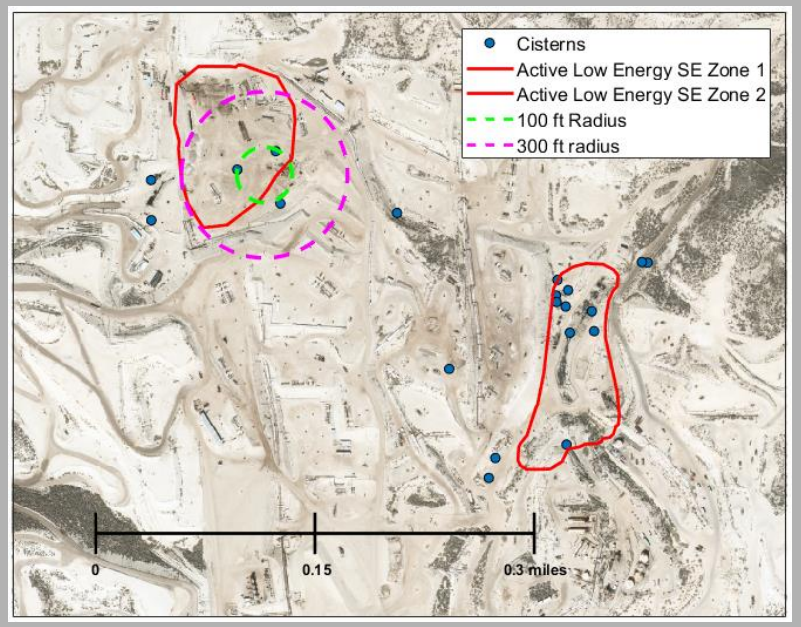
Correlation to a Single Well – Cistern Group 4

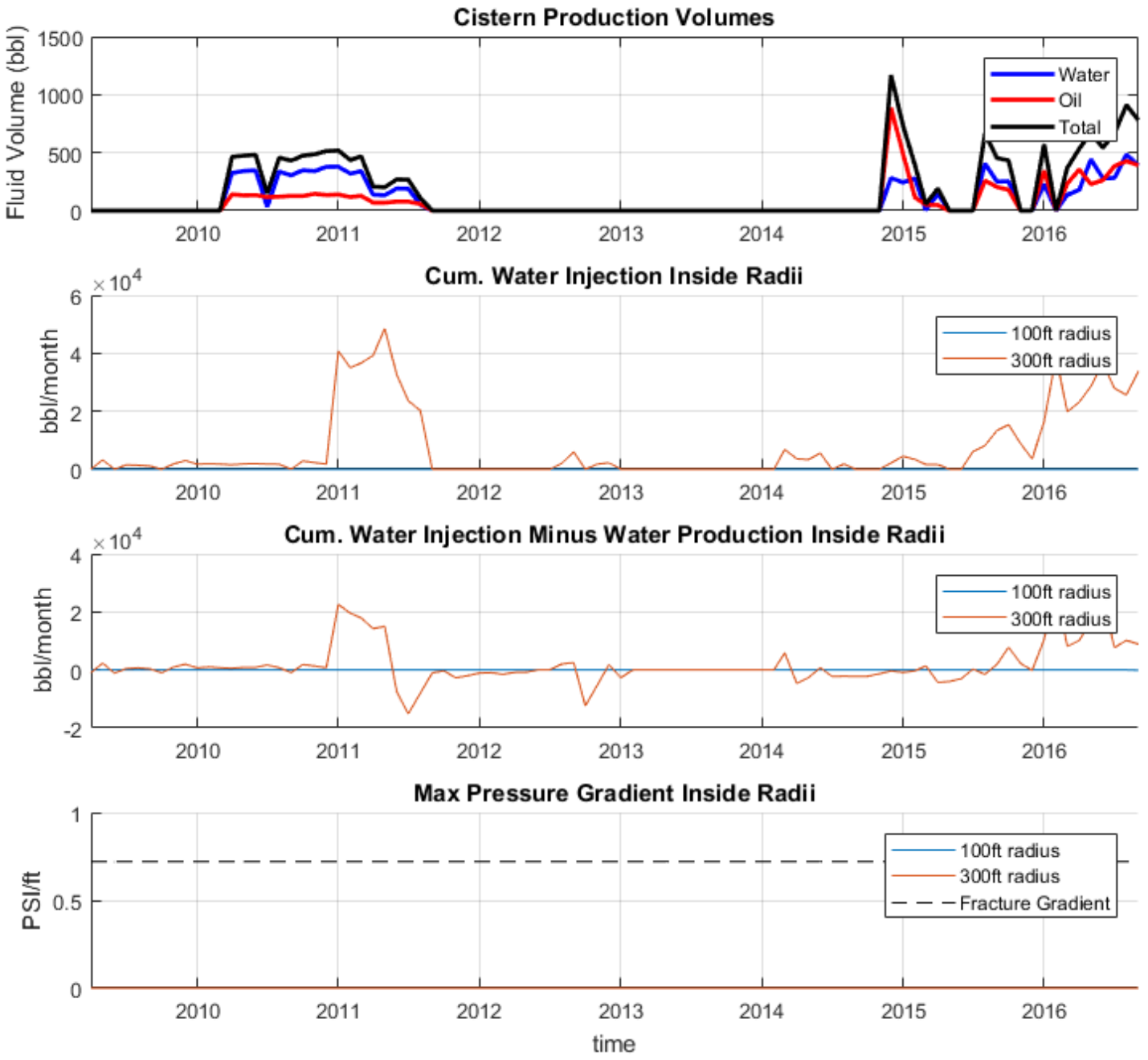




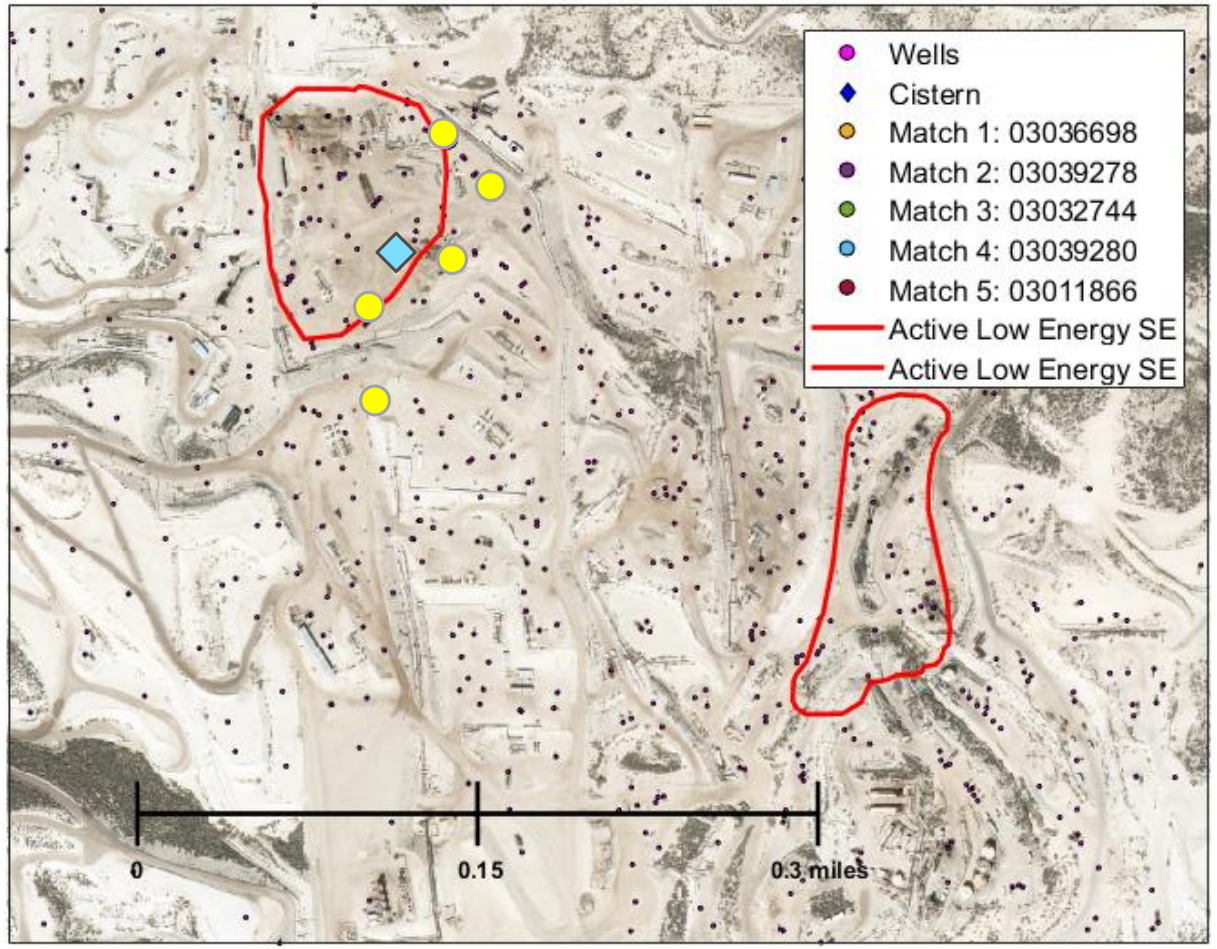


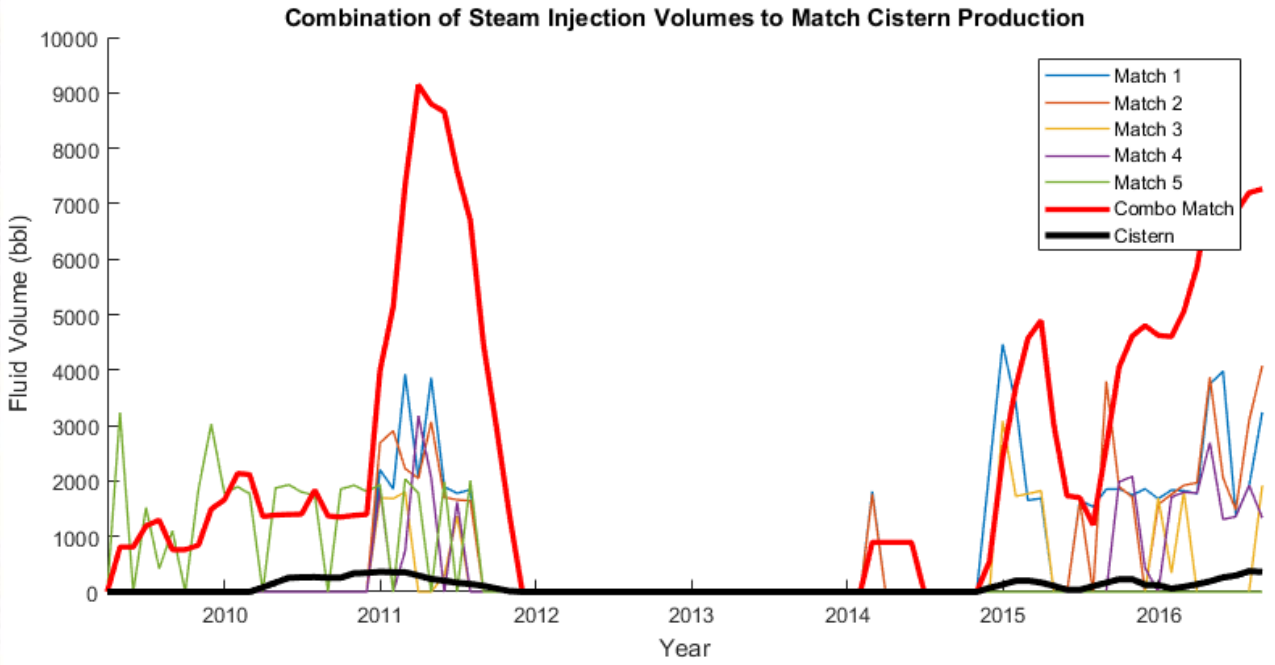
Zonal Correlation – Cistern Group 5



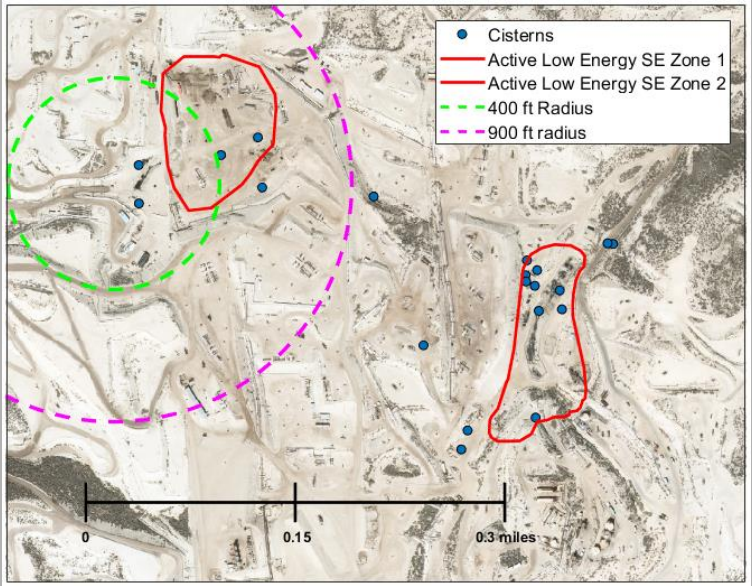


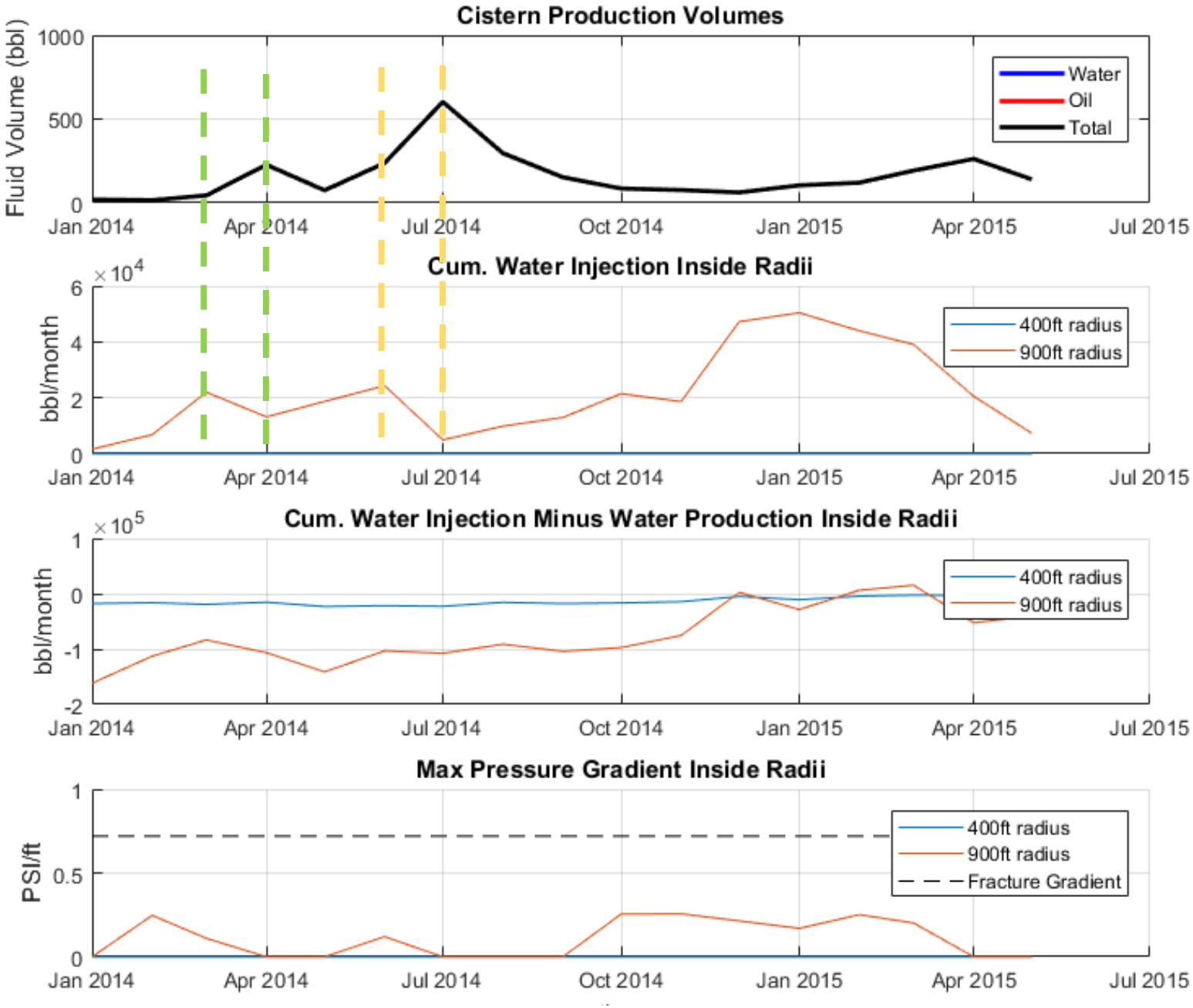
Correlation to a Group of Wells – Cistern Group 5



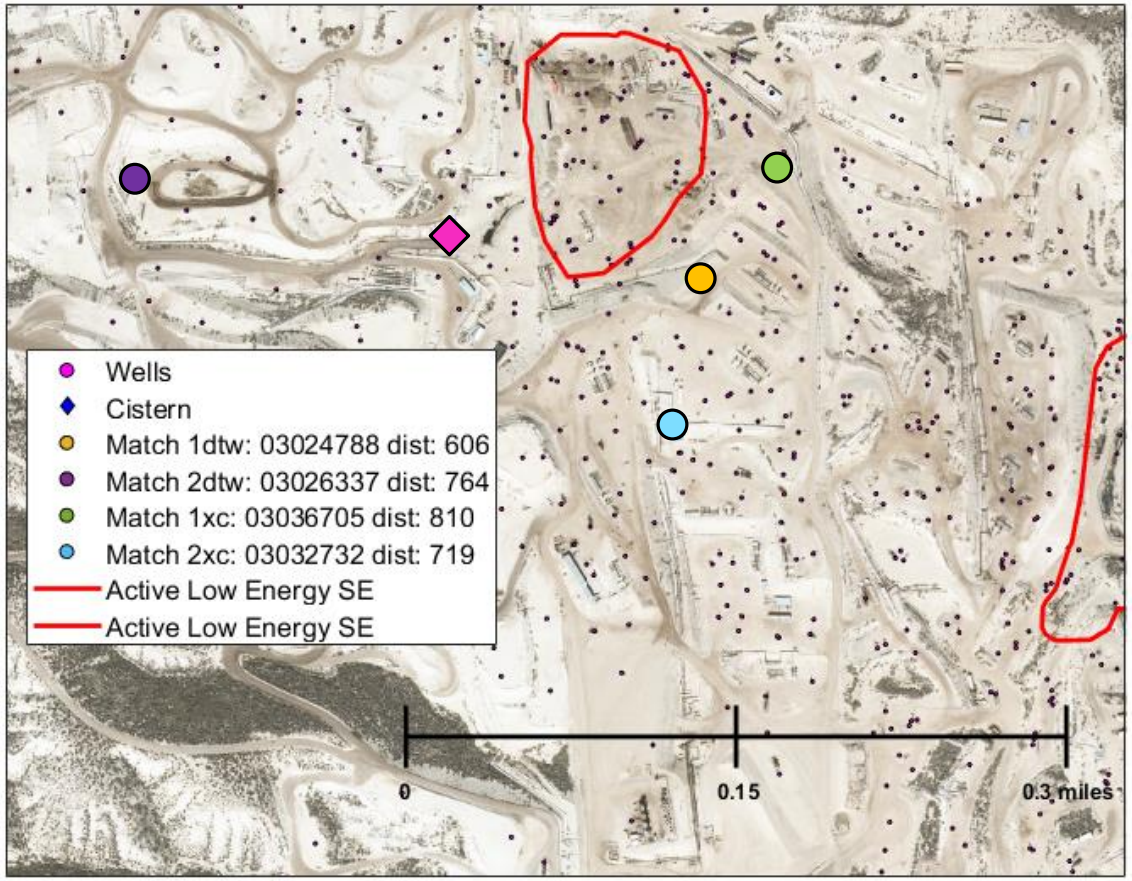


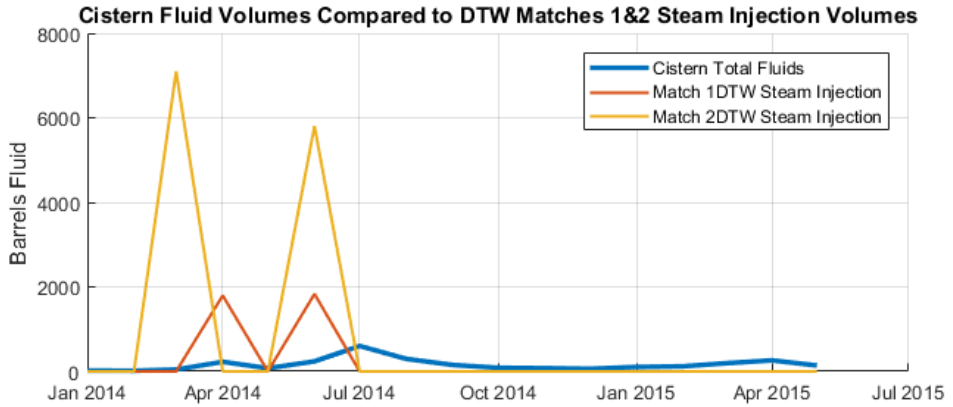
Zonal Correlation – Cistern Group 6 (Well 20)

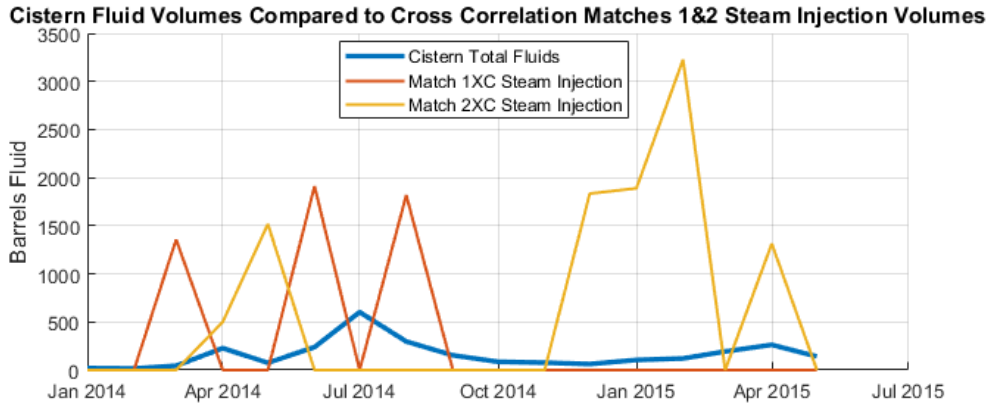




Correlation to a Single Well

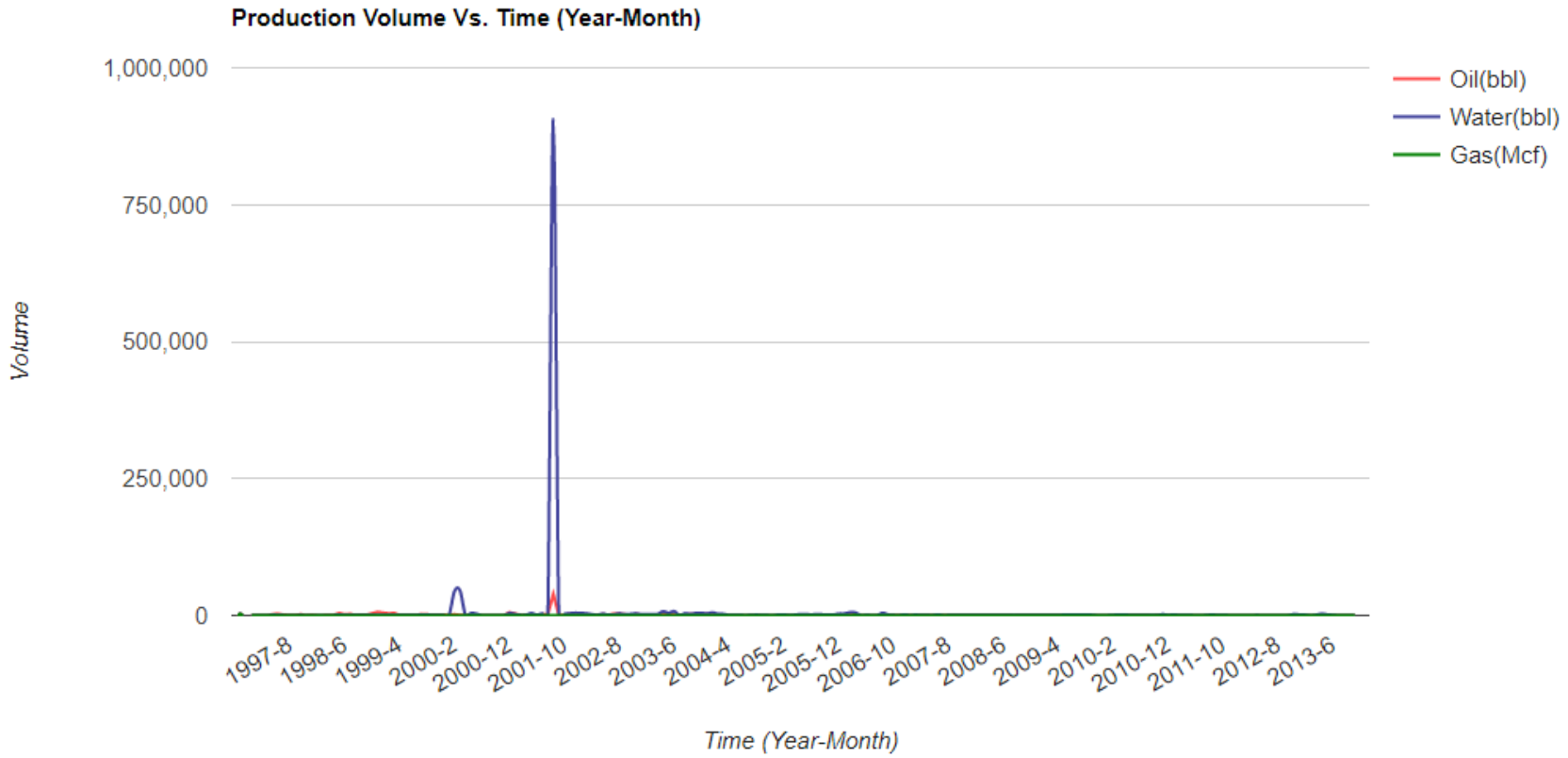






Caveats on Data Quality

- Human or machine error
- Comingled data



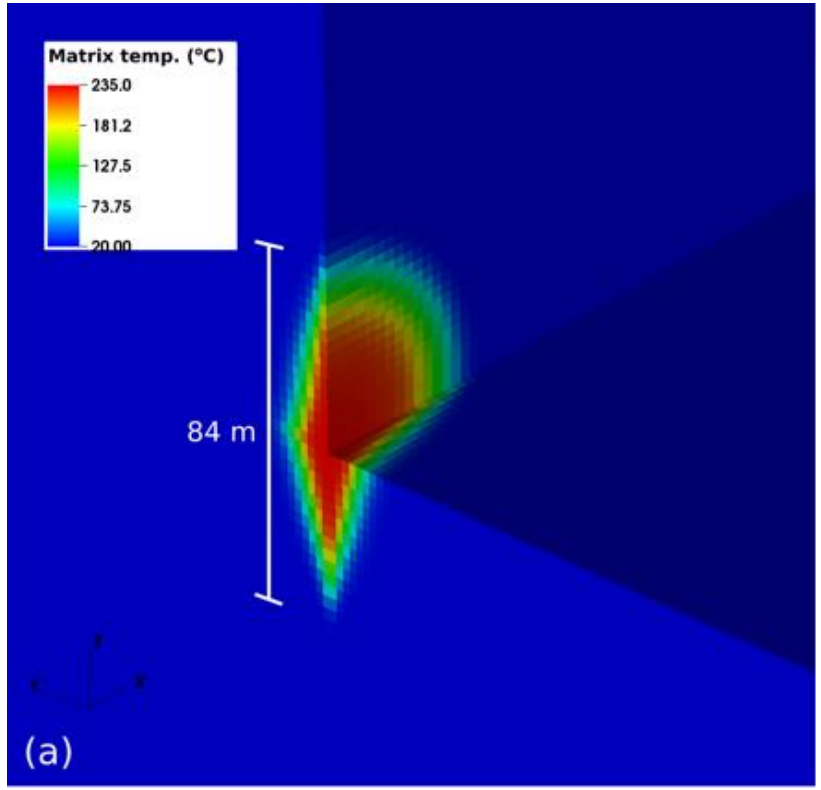
Conclusions of Temporal Analysis

- In the first cistern group, it was evident that the surface expression volumes followed the trend of the steam injection.
- In the second and fourth cistern groups, the areal cumulative injection didn't correlate to the cistern production, but several singular wells showed convincing correlation.
- In the third cistern group, neither the areal nor any singular well showed a good correlation to the cistern production volumes.
- The fifth cistern group showed some correlation to the areal injection trend, and improved correlation to the cumulative steam injection of a group of five wells.
- The sixth cistern group, Well-20 area, showed correlation to both singular wells and the overall trend of injection inside a radius of 900 feet around Well 20. The injection patterns, however, mostly match the initial and not the final parts of the Well 20 fluid production signal.
- Sometimes correlated signals can be at distance of over 800 feet away (as in the case of Well 20), and raise questions about the horizontal connectivity in the subsurface.
- There may be lag between the signals.

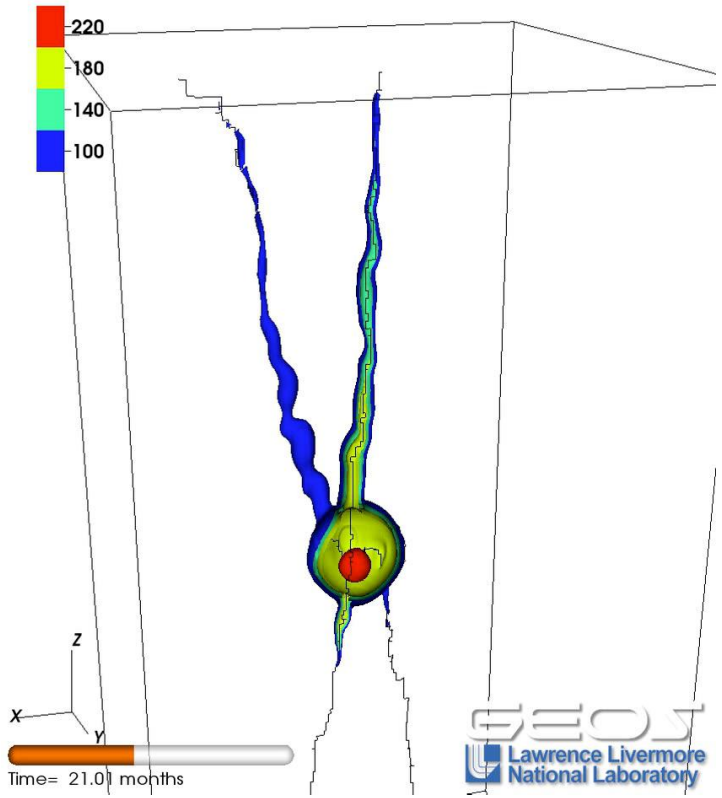
What Can Flow Simulations Teach Us?

Porous media

Fault

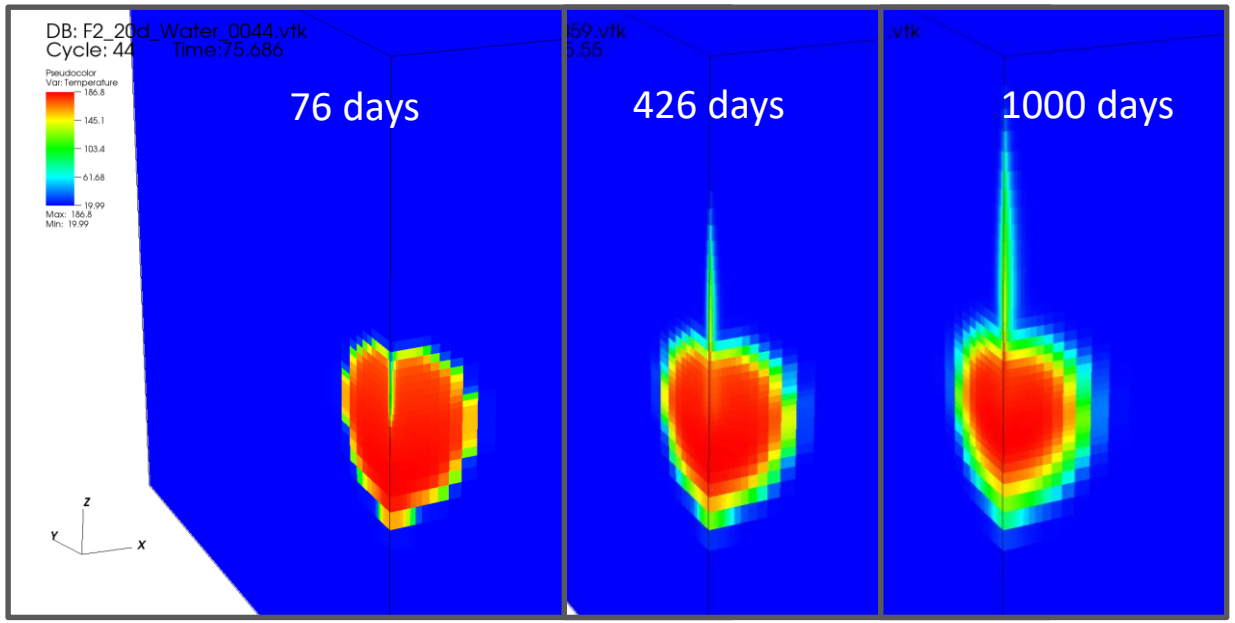


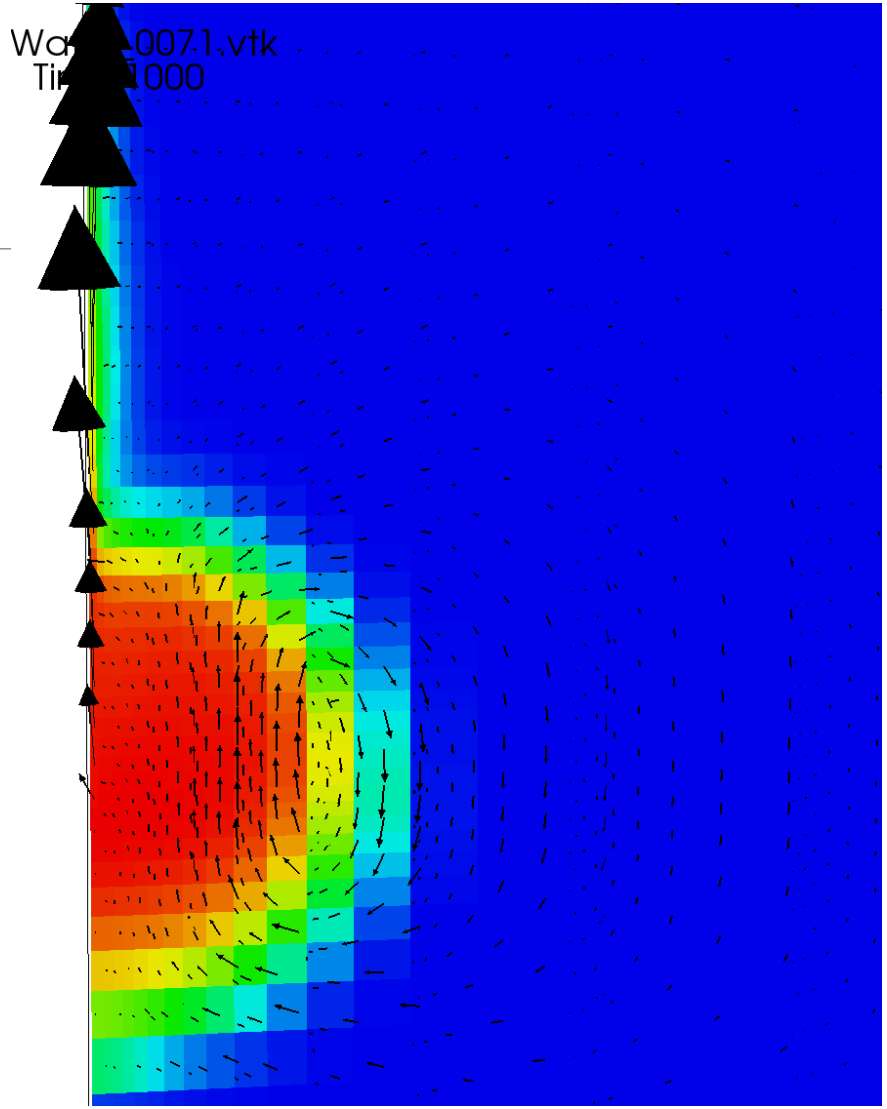
Thin channel



Fu, 2017

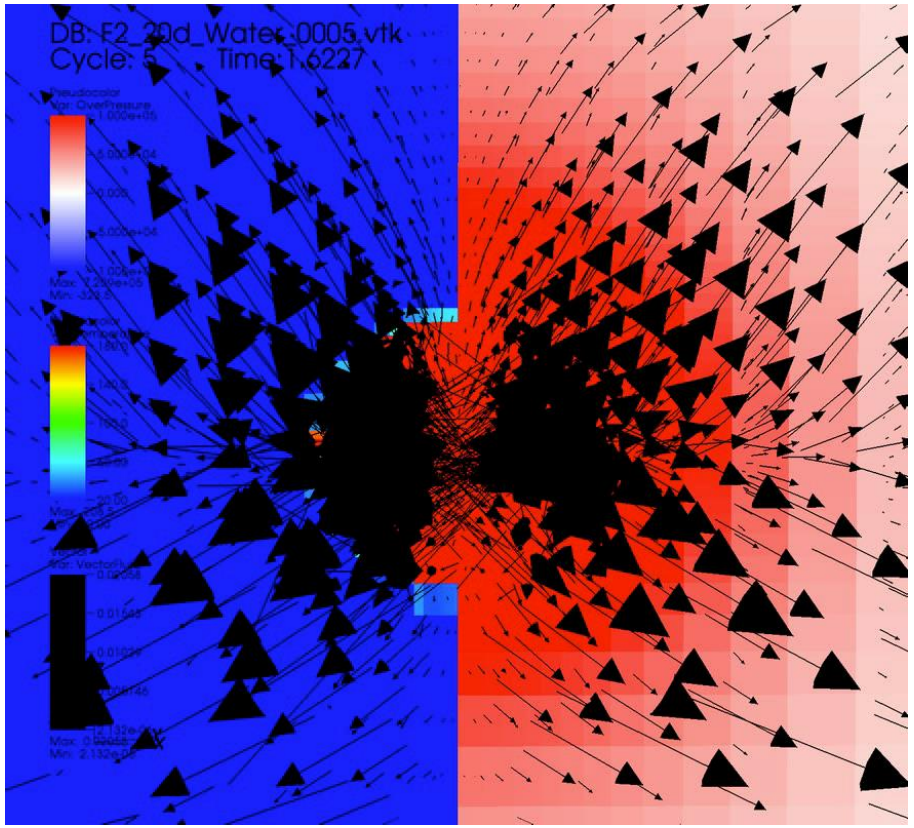
Convection Cell



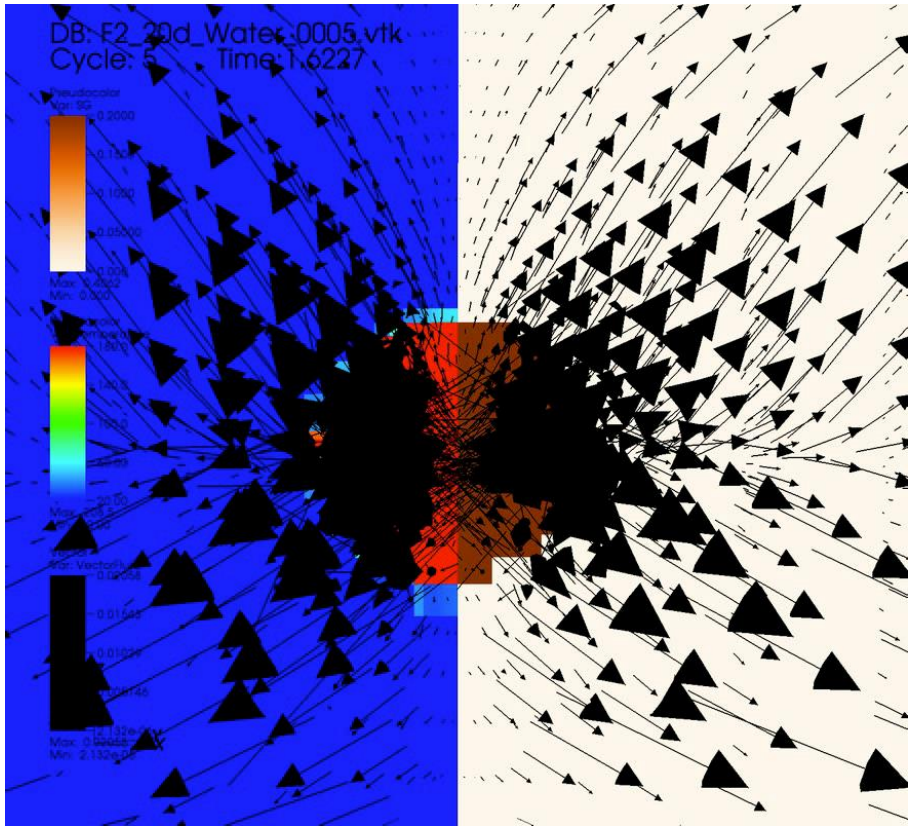


Visualization

Temperature | Overpressure



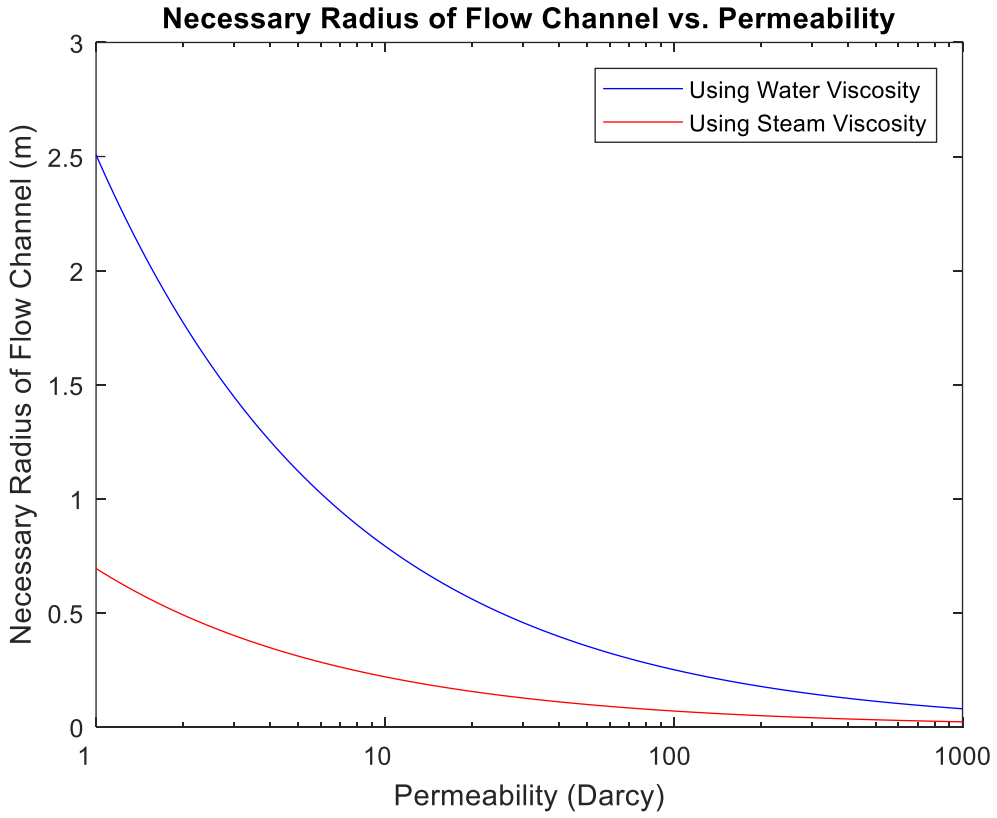
Temperature | Vapor saturation



What Radius of Flow Would You Need to Get a Flow of 1000 bbl/day?

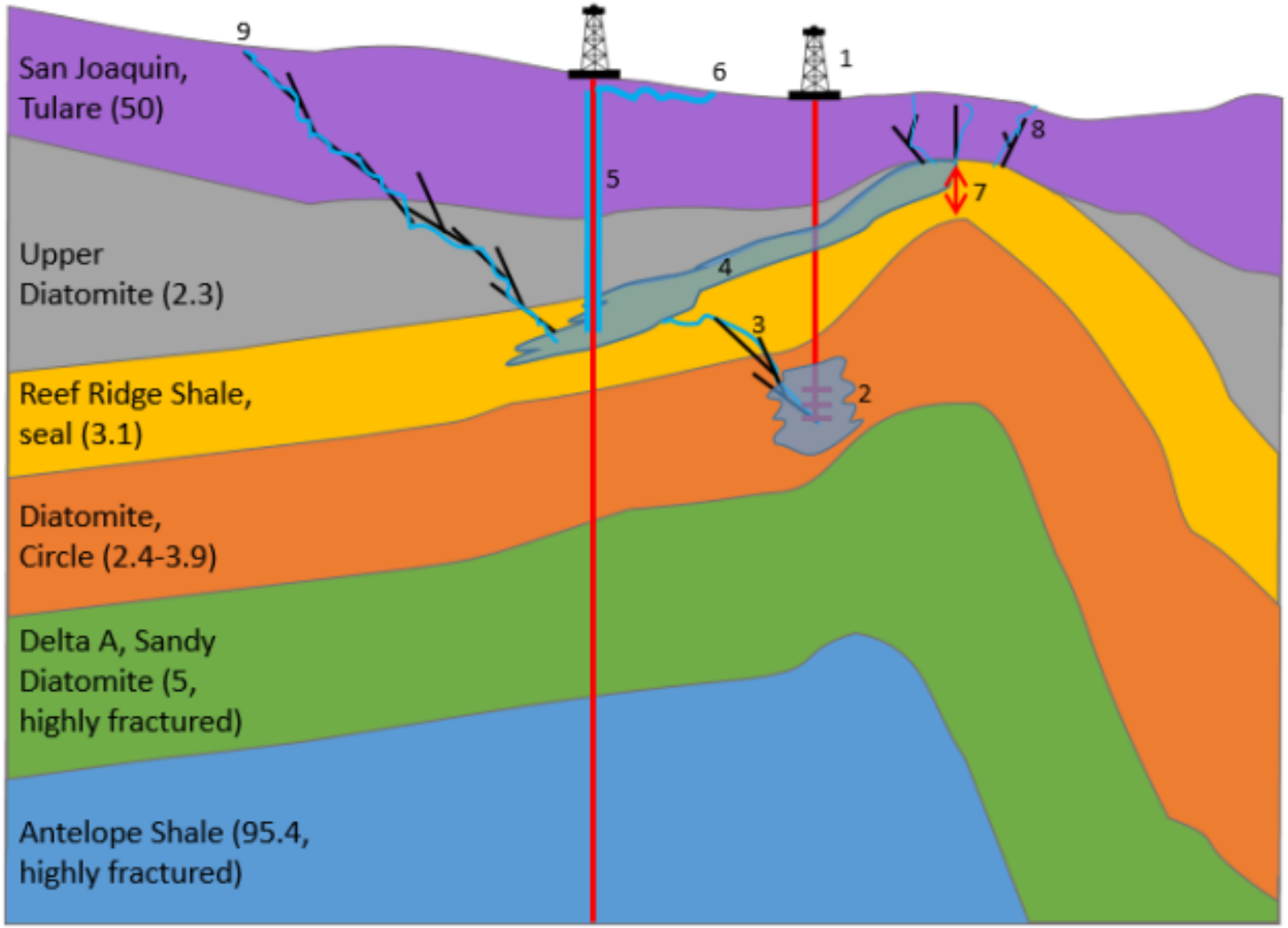
$$Q = -\frac{\kappa A(\Delta P)}{\mu * L} \rightarrow A = \frac{Q * \mu * L}{\kappa(\Delta P)} \rightarrow \pi r^2 = \frac{Q * \mu * L}{\kappa(\Delta P)} \rightarrow$$

$$r = \sqrt{\frac{Q * \mu * L}{\kappa(\Delta P)\pi}}$$



Conclusion

- All mechanisms are possible
- Need to operate as if they are all possible



Acknowledgements

- **This work has been done through partial support from the Division of Oil, Gas, and Geothermal Resources:** Don Nelson, Michael Toland, Andy Lopez, Cameron Campbell, Bill Bartling, Glenn Muggelberg
- Adviser: Prof. Tapan Mukerji
- Prof. Bob Lindblom
- David Medeiros, Stanford Geospatial Center

Suggested Future Work

- **Look into well damage in the study area.**
- **Further Flow simulations.**

Word	Count
• parted casing • parted csg	142
• broken casing	1
• hole in casing • hole in csg • casing holes • csg holes	35
• damaged casing • damaged csg	25

Thank You for Listening – Any Questions?

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