Engineered Water for Improvement of Oil Recovery from Fractured Reservoirs

Project # 12842957

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Project Overview

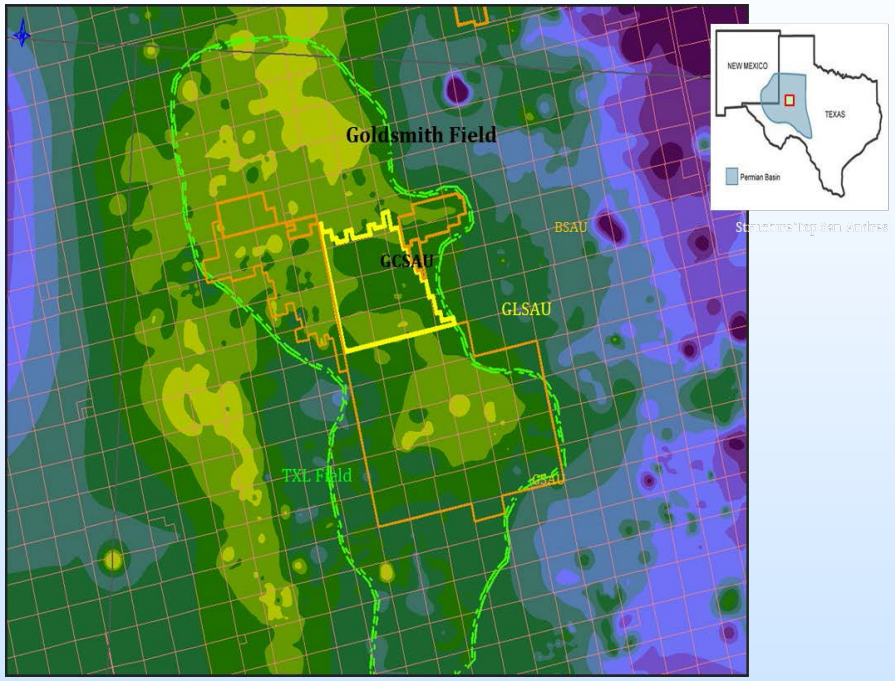
- Funding
  - DOE: $7,919,227
  - Cost Share: $1,979, 808
- Overall Project Performance Dates
  - October, 2019-September, 2024
- Project Participants
  - The University of Texas: K. Mohanty, W. Song, M. Pyrcz
  - Kinder Morgan: M. Panda, R. Valdez

Project Objectives

- Identify wettability altering agents (using ions, surfactants and/or nanoparticles) to enhance oil recovery in Goldsmith Field (GLSAU) in West Texas
- Conduct field tests using the wettability agents
- Evaluate field tests
- Develop criteria to apply these chemical processes economically in carbonate reservoirs

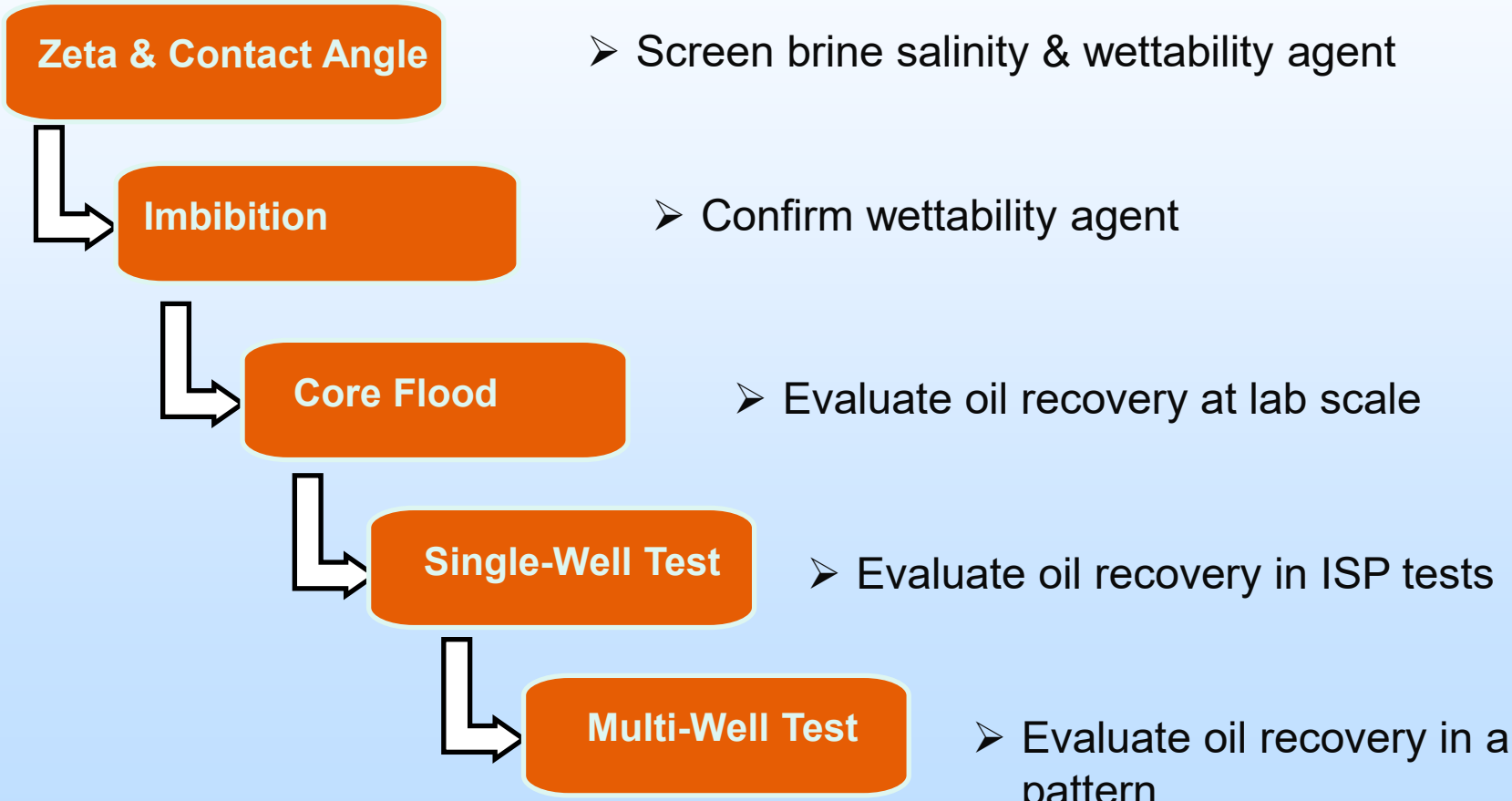
Background: GLSAU

- Cumulative oil recovery < 20%
- Oil is bypassed due to
  - -heterogeneity
  - -oil-wettability
- Improve oil recovery by imbibing water into the bypassed regions
- Improve water-wettability by
  - -ions
  - -surfactants
  - -nanoparticles



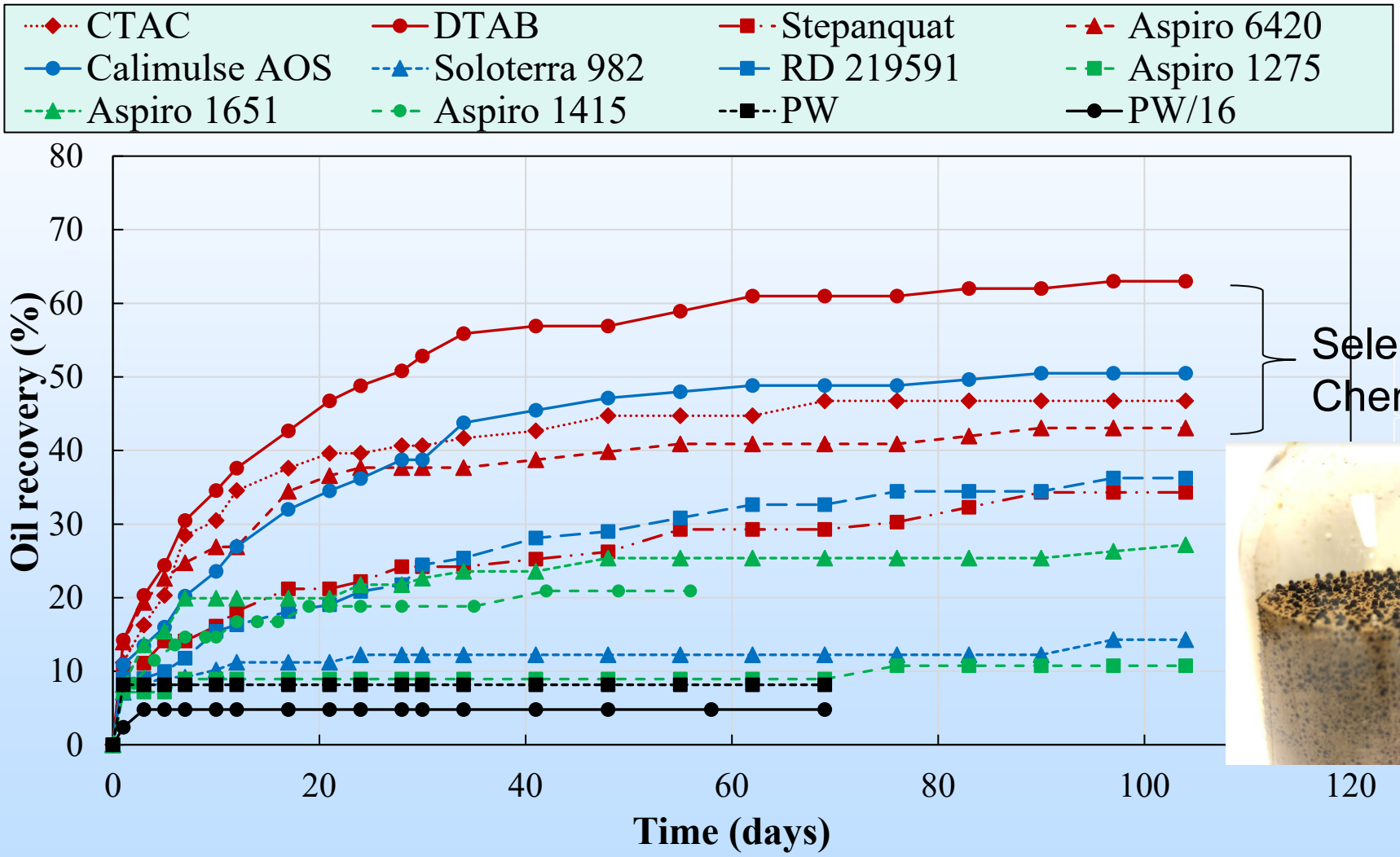
- Vuggy, slightly fractured dolomite
- Produced water salinity: 60,000 ppm
- T ~35 ºC

Methodology



- Screen brine salinity & wettability agent
- Confirm wettability agent
- Evaluate oil recovery at lab scale
- Evaluate oil recovery in ISP tests
- Evaluate oil recovery in a pattern

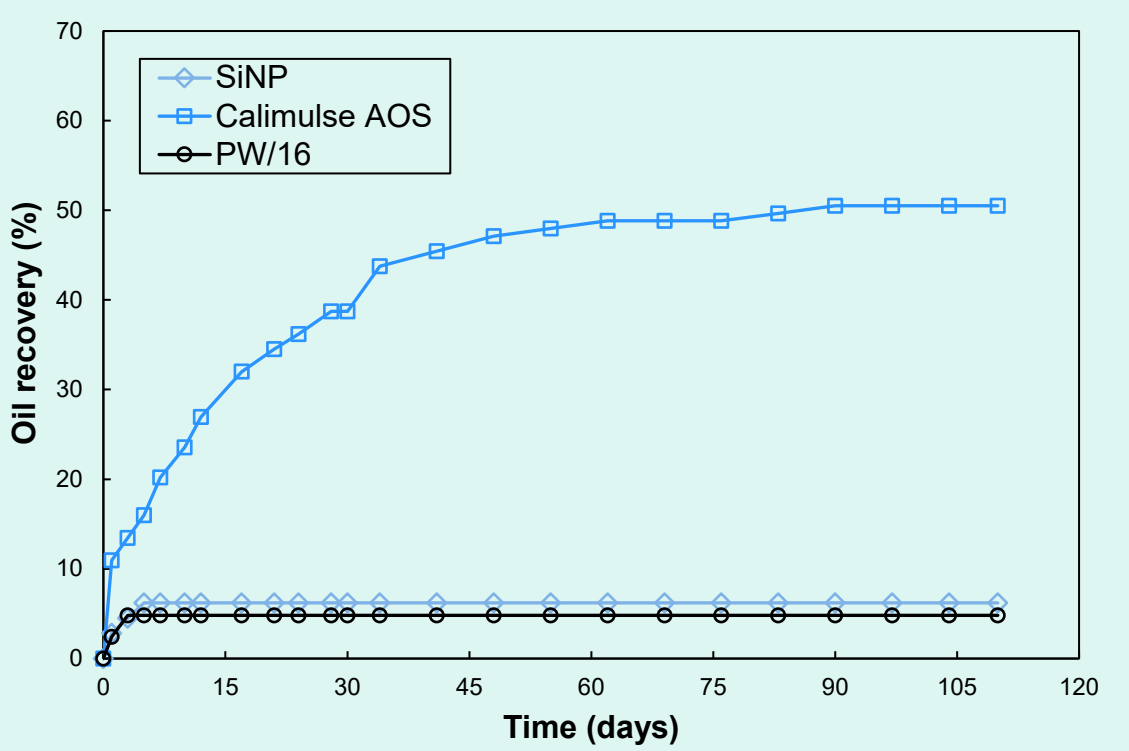
Identified Surfactants & Brine (PW/16)



Tested Nanoparticles for Wettability Alteration

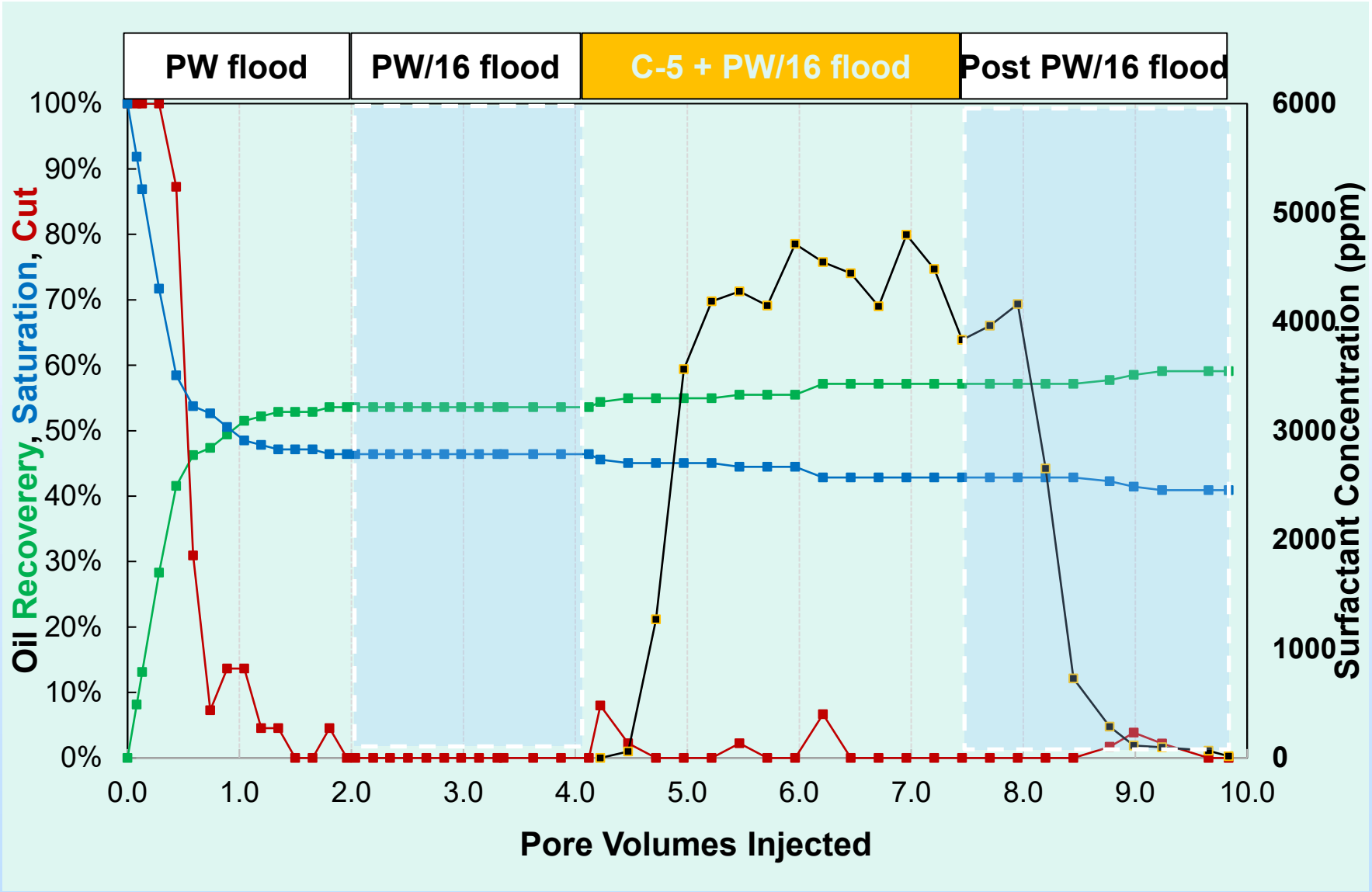
Oil-aged chip in SiNP solution

Imbibition into an oil-wet carbonate core



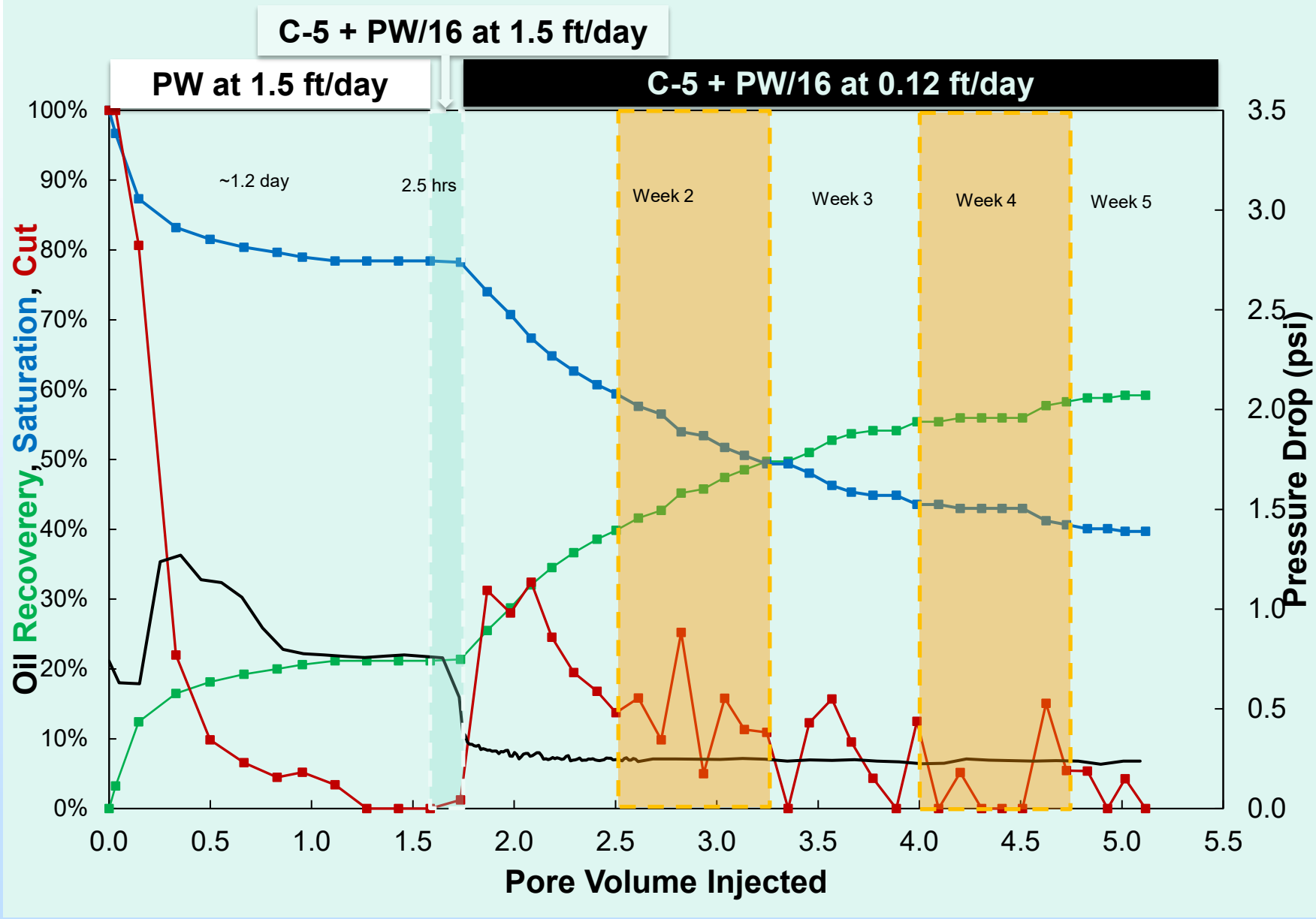
Nanoparticles do NOT alter wettability, but retain wettability

Identified EOR Mechanisms: Long Core Flood



WF: 53.6%
SF: +3.6%

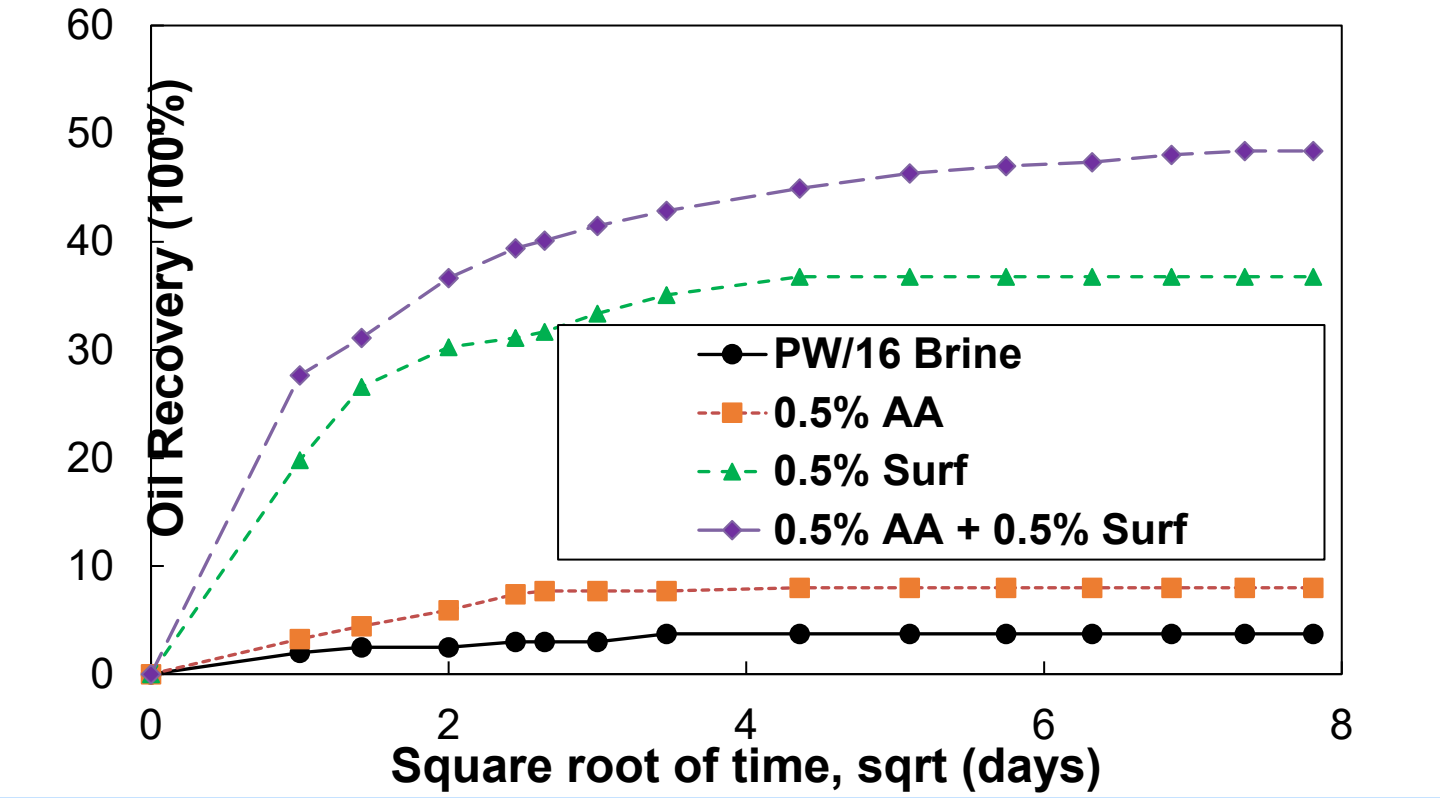
Identified EOR Mechanisms: Heterogeneous Core Flood



WF: 21.2%
SF: +38%

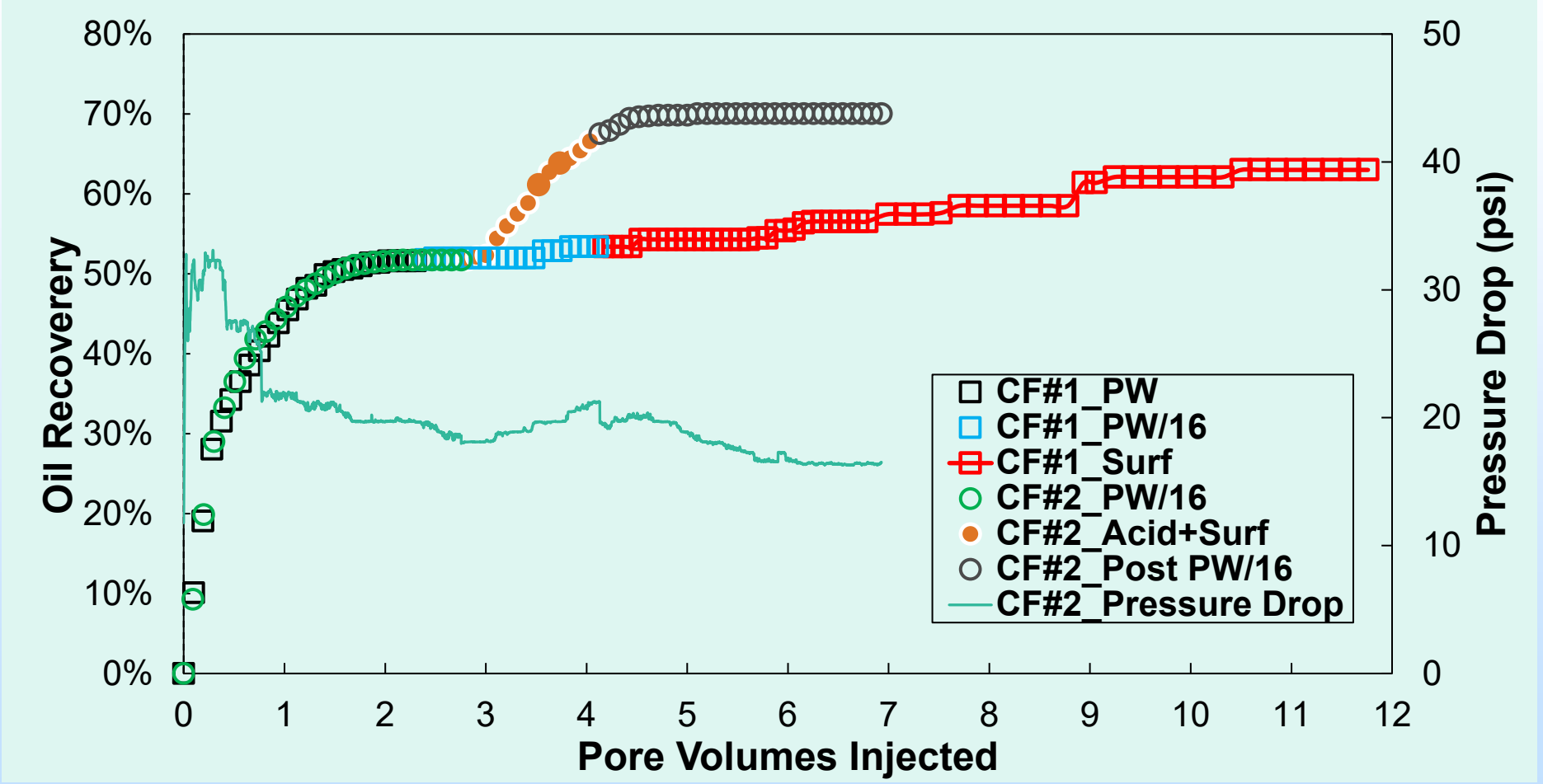
WA recovers oil from the bypassed regions.

Imbibition with Slow Acid and Surfactant



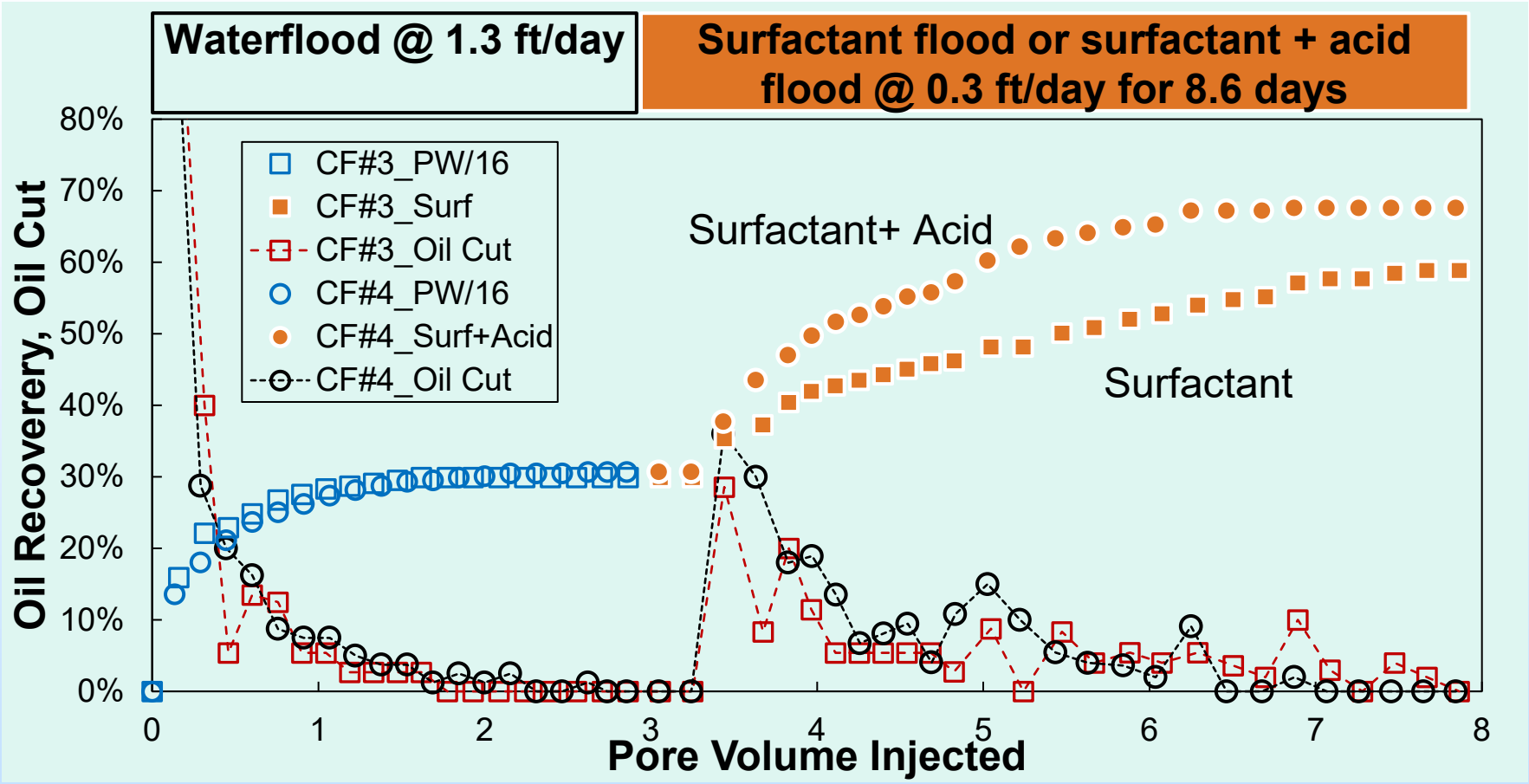
Synergy between acid and surfactant

Surfactant (CF#1) vs. Surfactant + Weak Acid (CF#2) Homogeneous Core



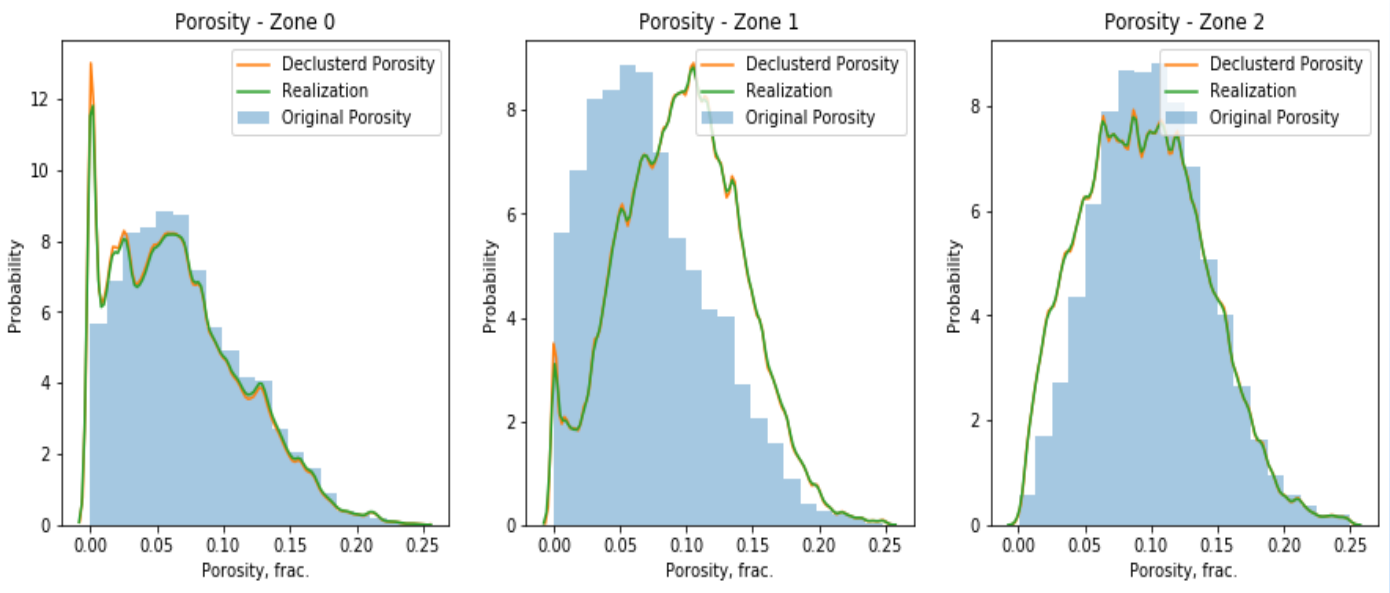
- Weak acid + surfactant flood enhances oil recovery rate
- SPE-210436-MS

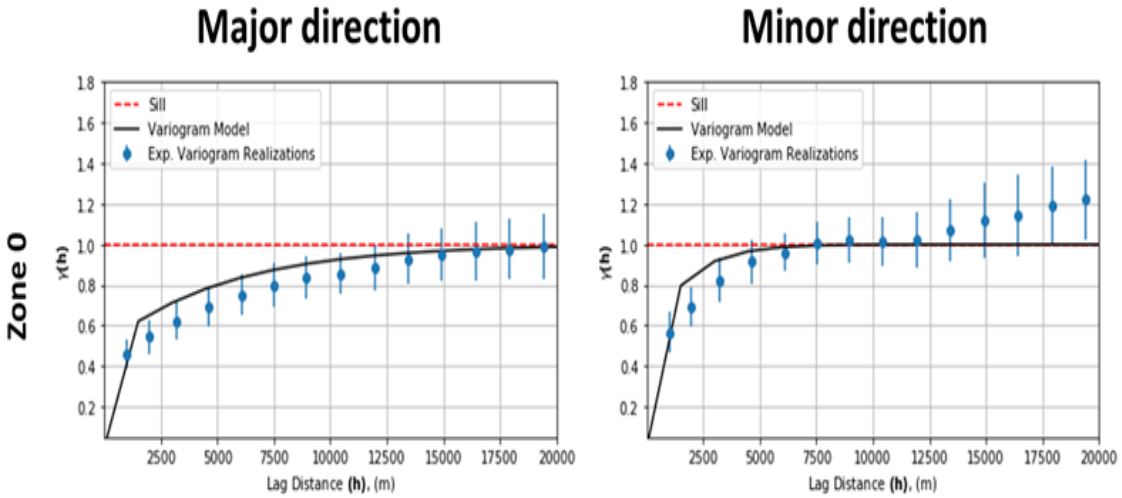
Surfactant (CF#3) vs. Surfactant + Weak Acid (CF#4) Heterogeneous Core



- Weak acid + surfactant flood enhances WA, increases oil recovery rate
- CO2 may provide carbonic acid; CO2 WAG with WA surfactant
- SPE-210436-MS

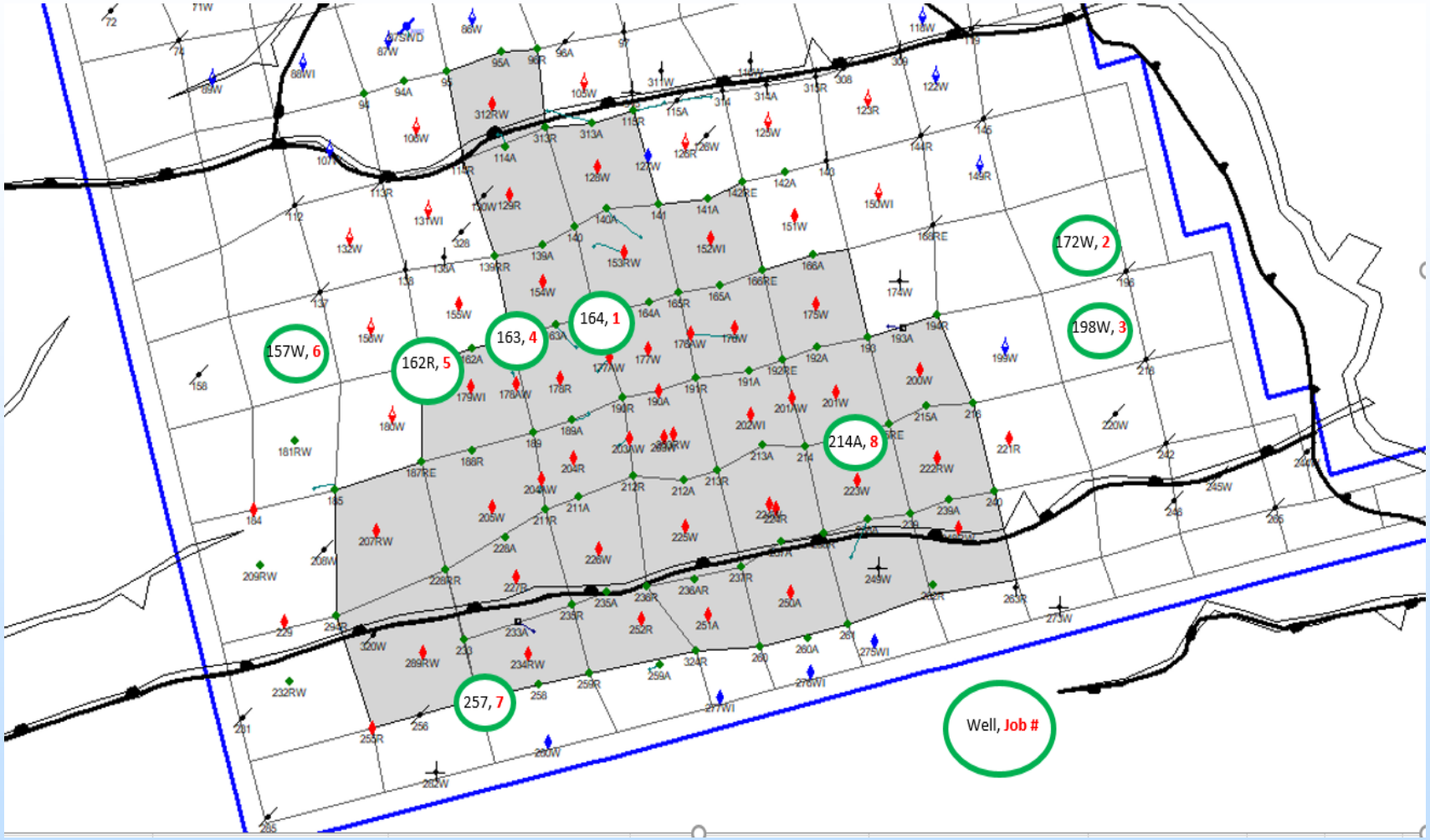
Modelled Subsurface Heterogeneity





Quantitative model checking with representative, corrected target statistics.

Selected Candidates for Well Tests



- Low GOR – not exposed to CO2
- Workover needed to convert
- Access to fresh water supply

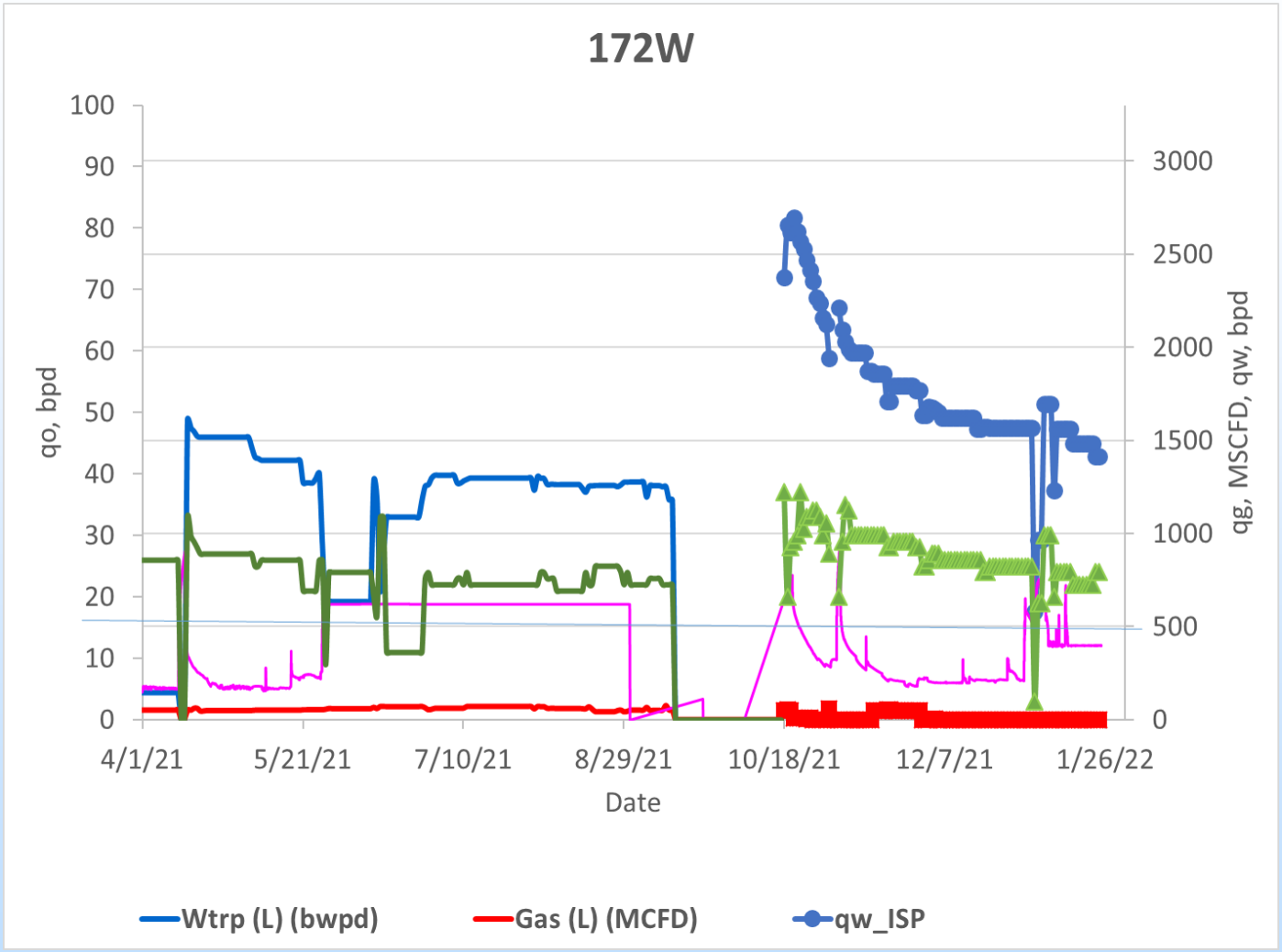
Refurbished Wells for Single-Well Tests

Well 157W

Designed Injection-Soak-Production Tests

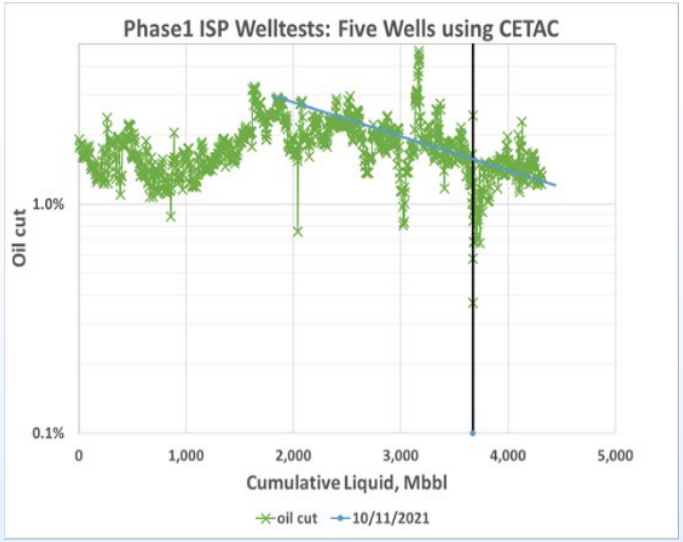
Test#	Well	Surf	Conc, ppm	Brine	SO4	Soak, days	PV	Comment
1	163	C5	5000	PW/16		30	2	Base case for C5
2	172W	C5	2500	PW/16	Y	30	2	1&2: Eff. Of SO4
3	162R	C5	5000	PW/16		60	2	1&3: Eff of soak time
4	157W	C5	5000	PW/16		30	2	1 & 4: Outside CO2 area
5	214A	C5	5000	PW		30	2	1&5: Effect of PW
6	260A	C3	5000	PW		30	1	6&8: Effect of PW
7	198W	C3	2500	PW/16	Y	30	2	8&7: Eff of SO4
8	164	C3	2500	PW/16		30	2	8: Base case C3

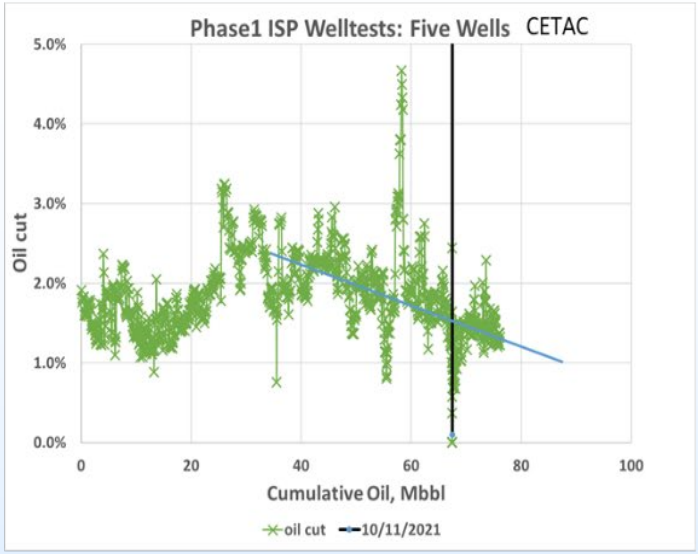
Individual Well Performance

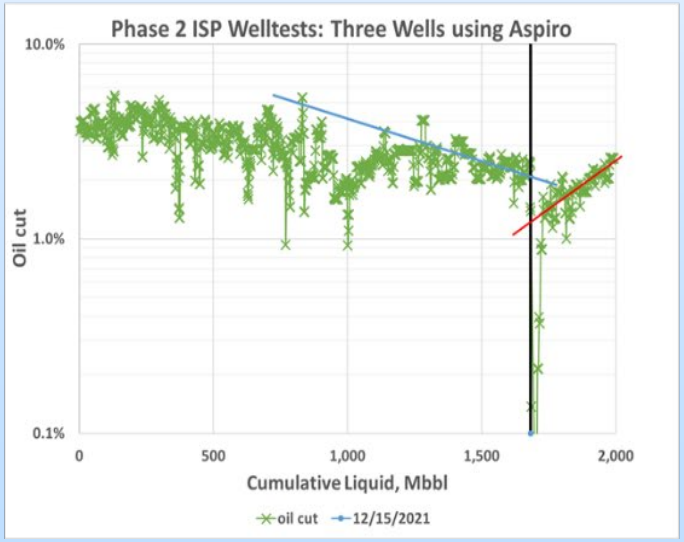


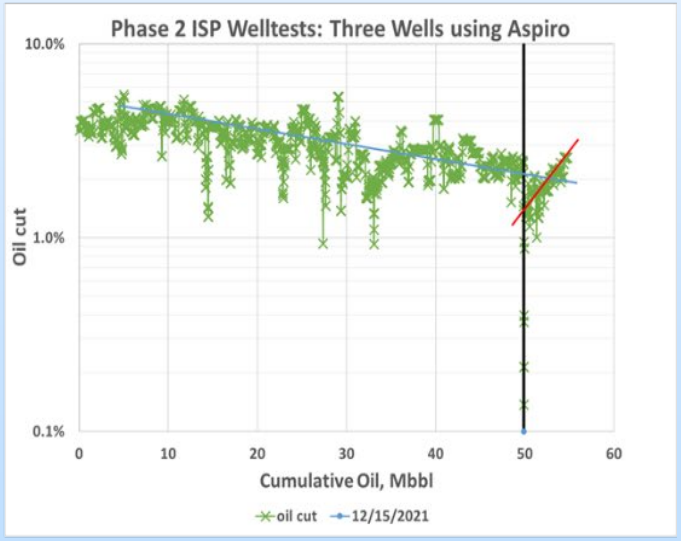
-Wells outside the CO2 area or on the edge performed better
-2500 ppm surfactant + SO4 performed well

Field Performance



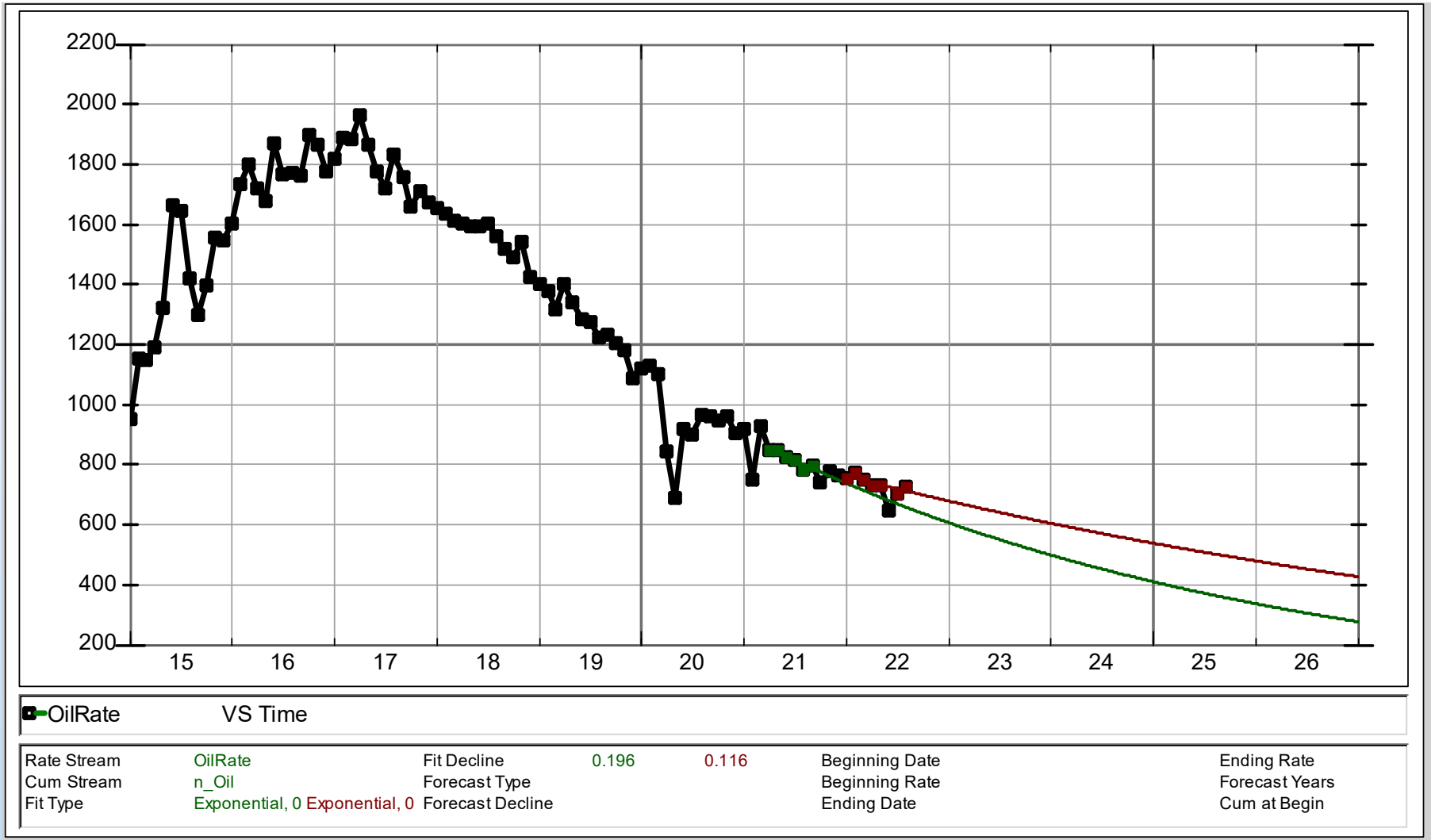






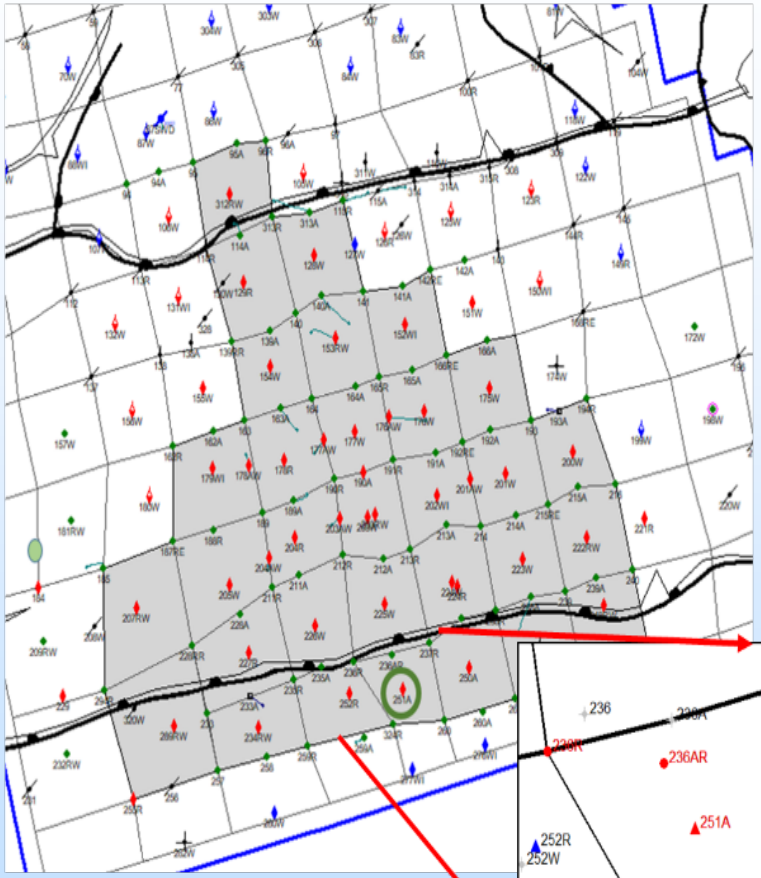
Aspiro surfactant performed better

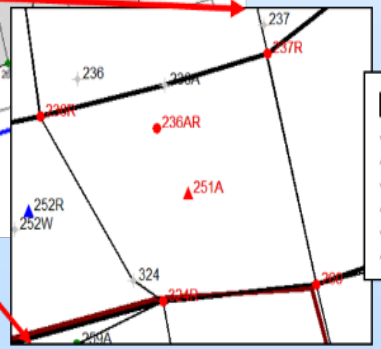
GLSAU Decline Pre and Post Surf. Treatment



The production decline decreased with the ISP tests in the periphery

Plan for Multi-Well Test





Objectives:

- Improve oil recovery of pattern 251A by injecting an engineered water slug
- Use CETAC surfactant
- Chase EWF slug with PW
- Monitor and analyze performance to support H13

Pattern 251A

- Rock quality – good
- Relatively immature WAG – large oil target
- Short producer-injector distance –quick response

- Injected a tracer on June 30th; no breakthrough Sept.15 in production well
- WAG with surfactant, WAG ratio =2:1, 3 cycles, waiting on surfactant

Accomplishments to Date

- Optimized brine salinity
- Identified surfactants for wettability alteration
- Identified weak acids that can improve WA
- Identified mechanism of oil recovery from core floods
- Developed geostatistical reservoir characterization
- Identified and reconditioned eight wells for single well tests
- Conducted 8 Injection-Soak-Production well tests
- Conducting inter-well tracer test and planning for a multi-well test

Lessons Learned

- Surfactants change wettability of oil-wet rocks at low T; weak acids help; nanoparticles do not change wettability, but keep calcite surfaces water-wet
- Wettability alteration does not necessarily improve oil recovery in well-swept regions, but it does improve oil recovery from bypassed regions
- Modeling wettability alteration by changing the relative permeability (the common approach) does not capture the physics; use Pc also
- ISP tests show incremental oil, but not necessarily in the inj. well; Multi-well tests need to be conducted

Next Steps

- Upscale slow acid / CO2 addition to engineered water
- Characterize multi-well test region (doing tracer test)
- Design and conduct the multi-well test

Acknowledgements

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- Kinder Morgan