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Whole Value Chain CCUS Conference Week

CO_2 Foam IEOR Field Pilot in Texas

ConocoPhillips Chevron The Research Council of Norway Norwegian Consulate General San Francisco Colorado School of Mines

Prof. Arne Graue
Dept. of Physics and Technology
University of Bergen, NORWAY

Whole Value Chain CCUS Conference Week, Sept. 22nd–26th, 2025, Golden, CO, USA.

IPTC International Petroleum Technology Conference
18 – 20 February 2025
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CO_2 Foam Enables CCUS with Low Carbon Oil Production in Asia

Arne Graue[1] and Zachary Paul Alcorn[1]

[1]Department of Physics and Technology, University of Bergen, Bergen Norway

Sponsoring Societies

AAPG Advancing the World of Petroleum Geosciences™
EAGE European Association of Geoscientists & Engineers
SEG Society of Exploration Geophysicists
SPE International

Presentation Overview

- CO_2 EOR Background and Challenges
- CO_2 Foam Integrated Enhanced Oil Recovery (IEOR)
- CCUS Business Case
  - *Sustainable Economy*
  - *Reduced Carbon Footprint*
  - *Increased oil recovery & CO2 utilization*
- Technical Achievements and Conclusions on a CO_2 Foam IEOR Field Pilot

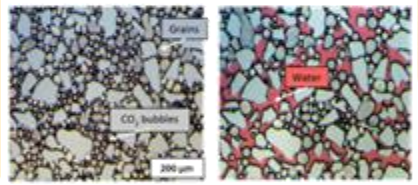
R&D Approach

Implementation

Pilot design

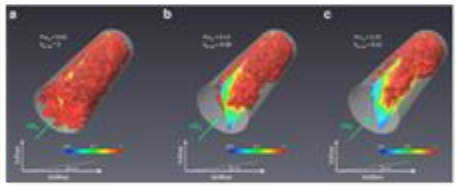
Foam system design

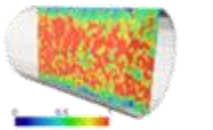
Pore-scale

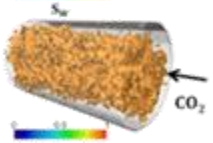


Wettability and reactive transport

Core-scale



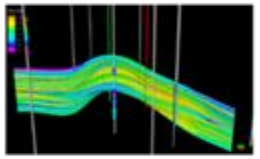




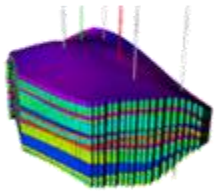
1 cm³/min
S_{CO2} = 0.25

Displacement and storage

Field-scale



Model parameters for upscaling



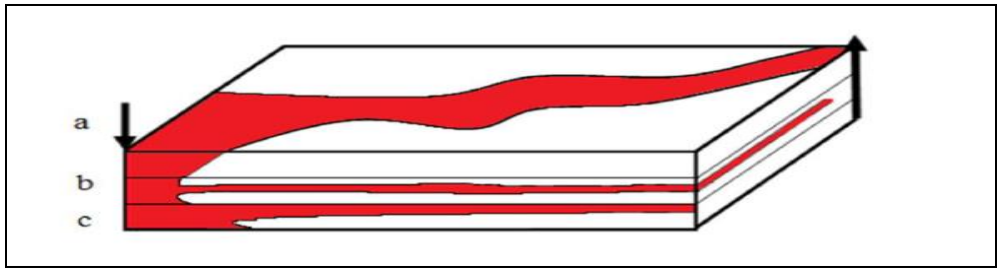
Onshore Pilot

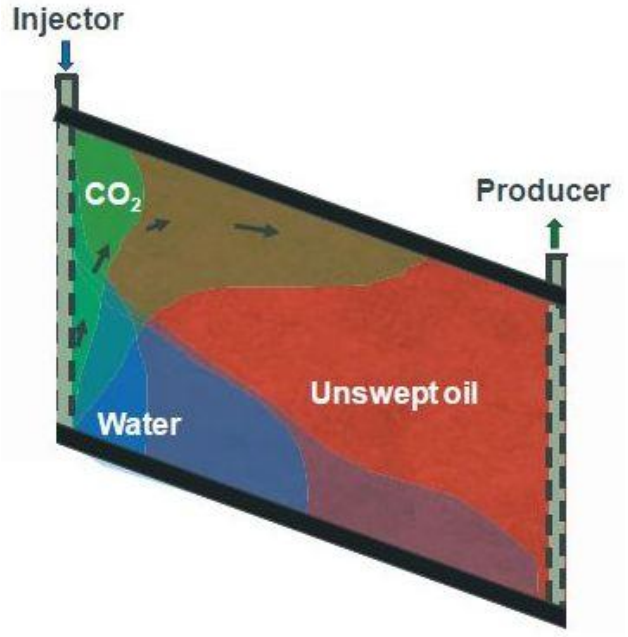
Offshore Pilot

Improved modeling and lessons learned from ongoing pilot

CO_2 Injection

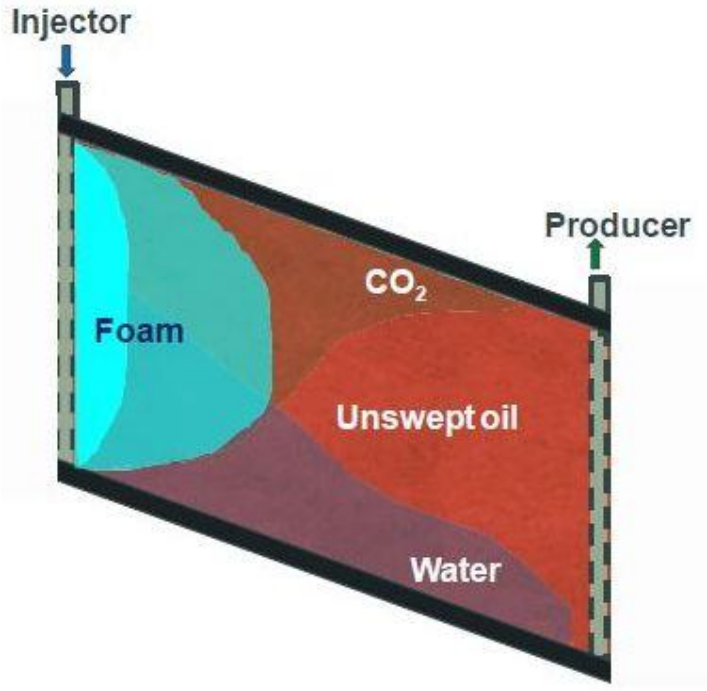
- Poor aerial sweep
- Gas channeling
- Gravity override (Hanssen et al., 1994)



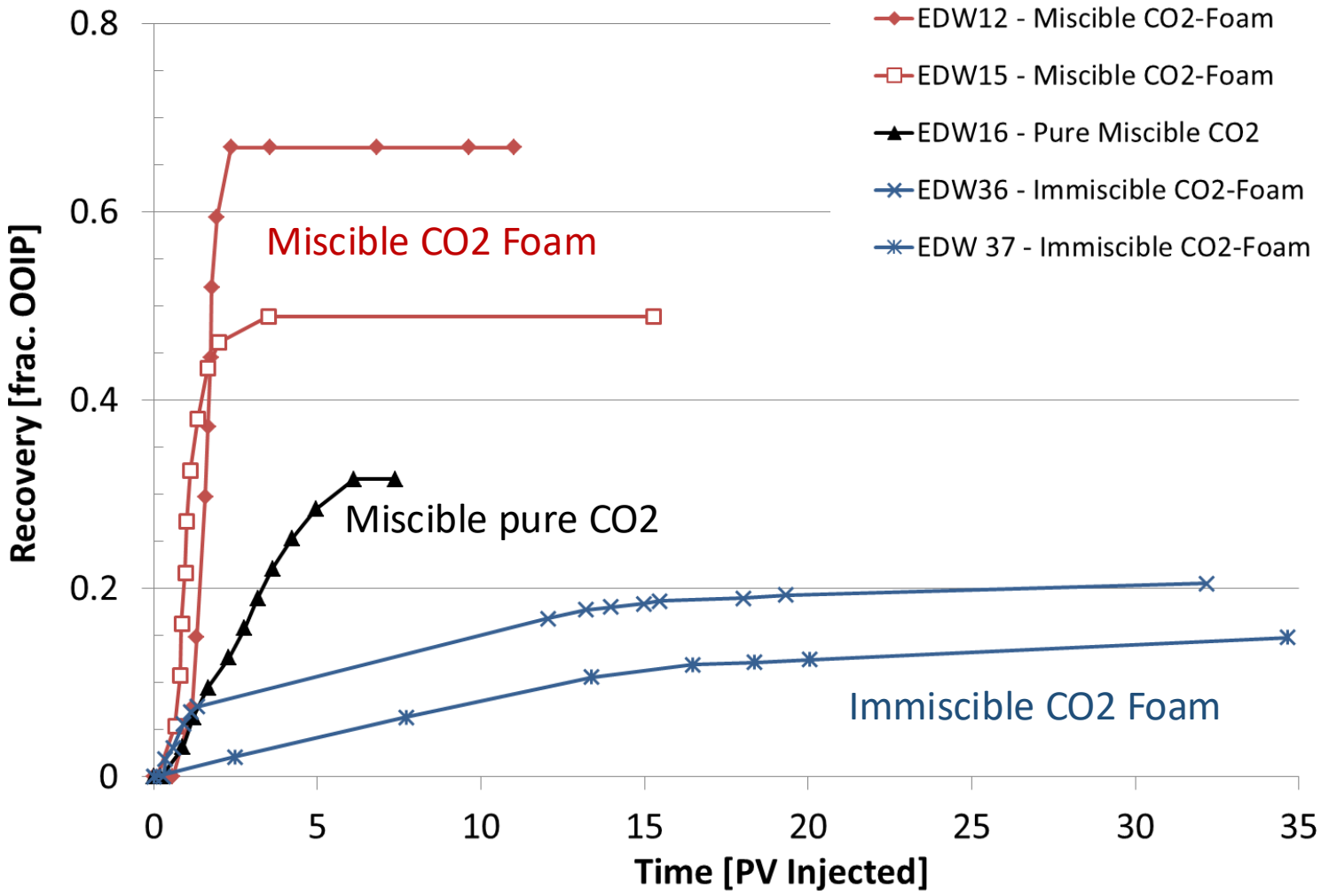


CO_2 Foam Injection

- Mitigates gravity override
- Improves sweep efficiency



Comparison between miscible CO_2 injection and immiscible and miscible CO_2-foam



Laboratory results indicated:

Up to 40% more oil recovered at significantly lower costs

Oil Production
Up to 40% more oil recovered, increased sweep & CO2 utilization

Production Time
Reduced operational time; less than 1 HCPV of CO2 foam needs to be injected to produce the residual oil after waterflooding

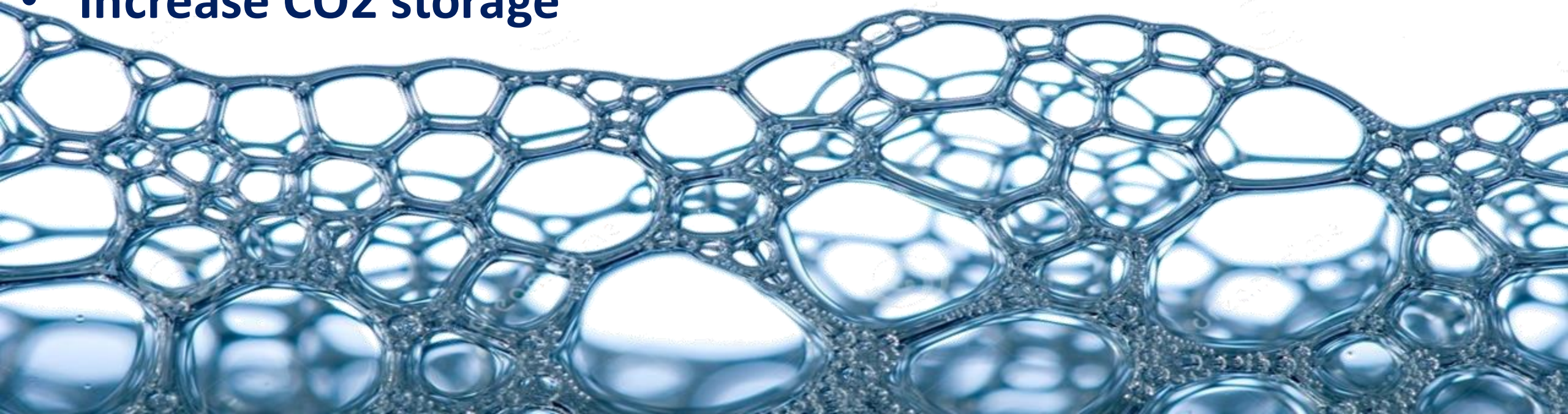
CO_2 Cost
CO_2 injected volume reduced by more than 30%

CO_2 Foam Less Expensive Than CO_2
At 70% Foam Quality more than 20% cost reduction

More CO_2 may be sequestered behind the foam front leaving behind more pore space available for CO_2 storage
Reduced Carbon Footprint

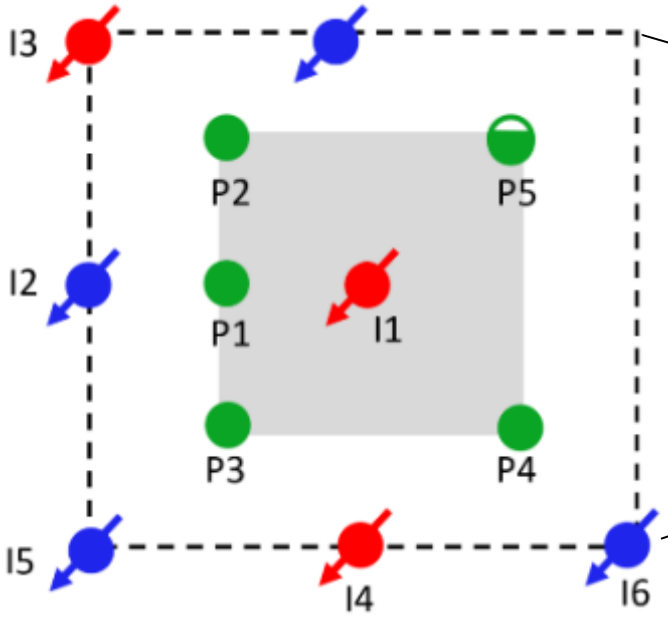
CO_2 Foam Pilot Objectives: *In-depth* CO_2 mobility control

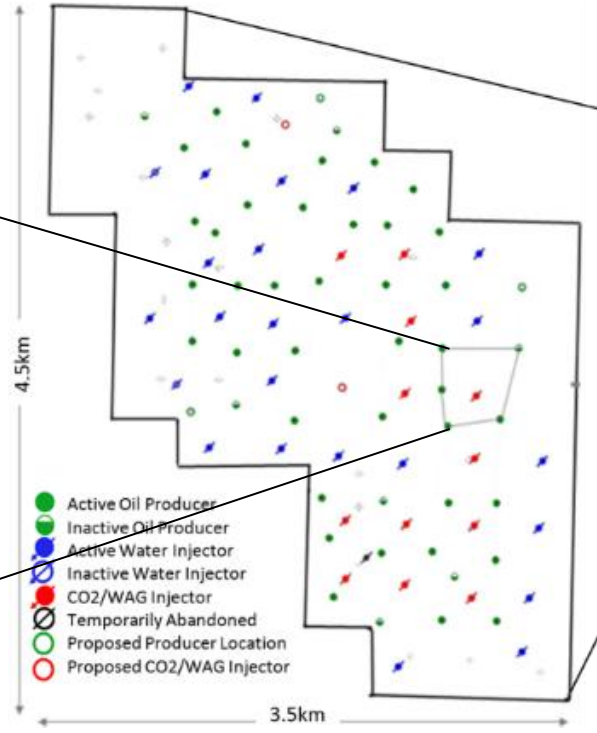
- Reduce producing gas-oil-ratio
- Improve CO_2 sweep efficiency, oil recovery and CO_2 utilization
- Increase CO2 storage



Pilot Start-Up: Surfactant unloading

Pilot Pattern





San Andres

Reservoir Characteristic	Value
Depth	5200 ft
Permeability	1 to 250 md (avg: 13 md)
Porosity	3% to 28% (average: 12%)
Pay thickness	110 ft
Reservoir pressure (initial)	2500 psig
Reservoir pressure (current)	3400 psig
Fracture pressure	3900 psig
Reservoir temperature	104°F
Oil gravity	31 °API
Formation brine salinity	70,000 ppm

Surfactant alternating gas (SAG):
10 days surfactant, 20 days CO_2

Pilot start: May 2019

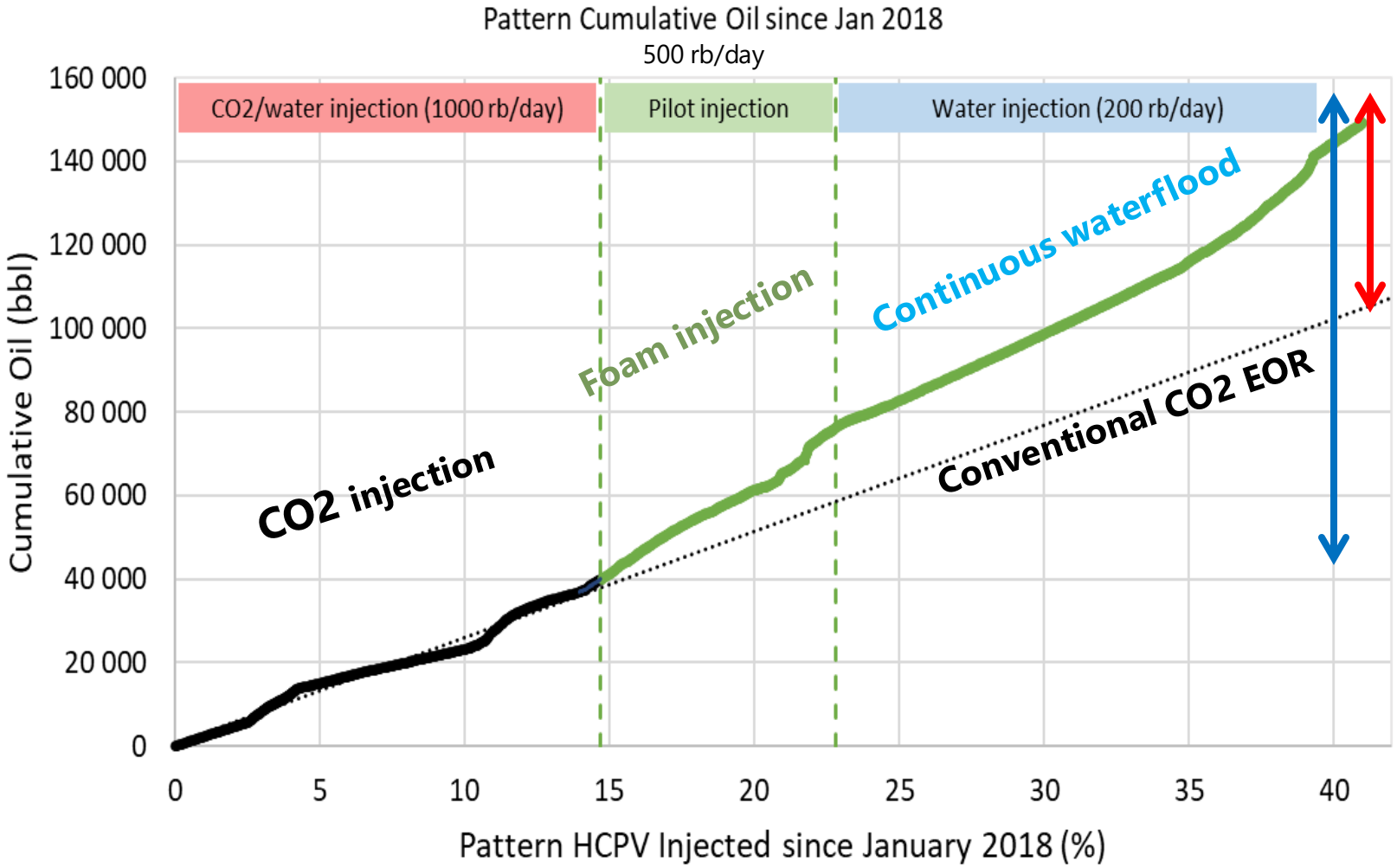
Pilot end: August 2020

May 2021

Production Analysis:

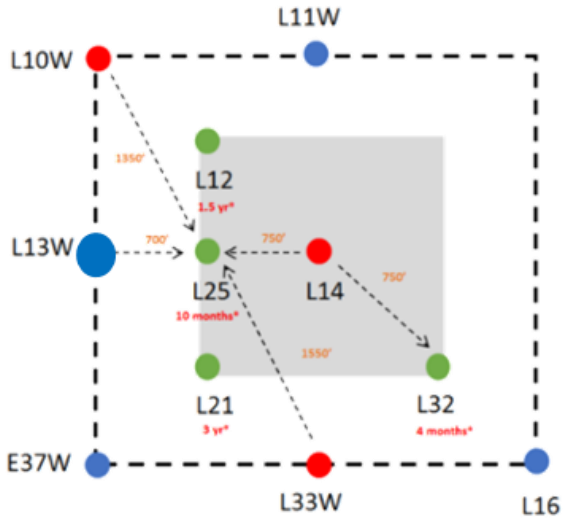
Foam Pilot started after 6 years of CO_2 injection.

Foam Pilot: 0.1HCPV foam injection at half the historical rate, followed by 0.25HCPV low rate waterflood.

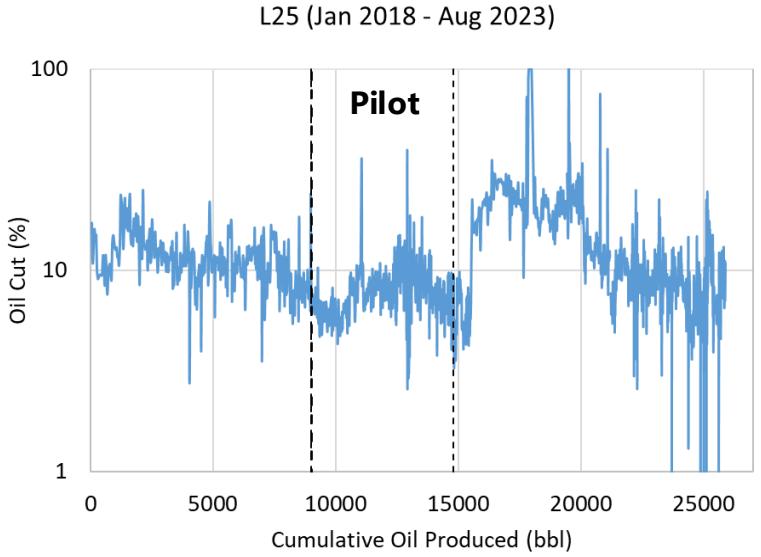


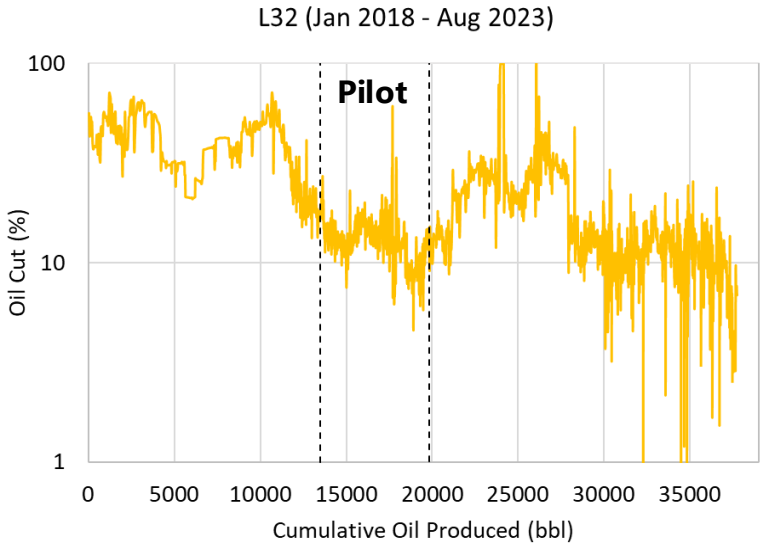
+50,000 bbls of oil,
40% increased oil recovery,
comp. to conventional CO_2 EOR

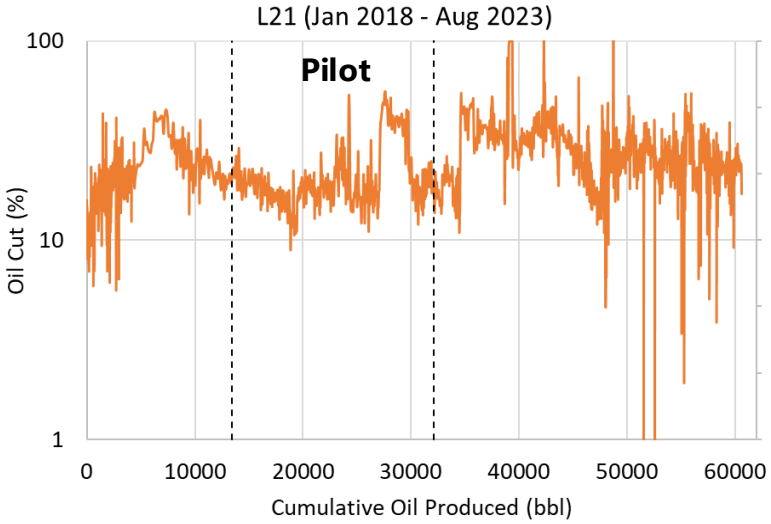
+150,000 bbls of oil recovery,
after CO_2 flooding

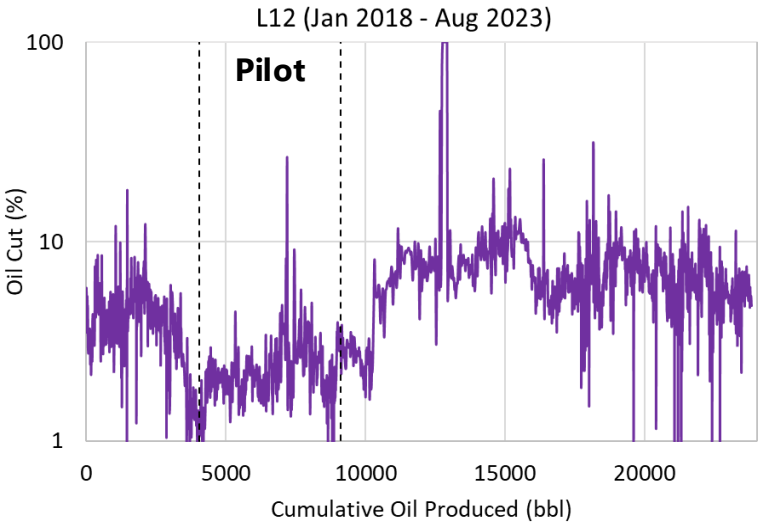


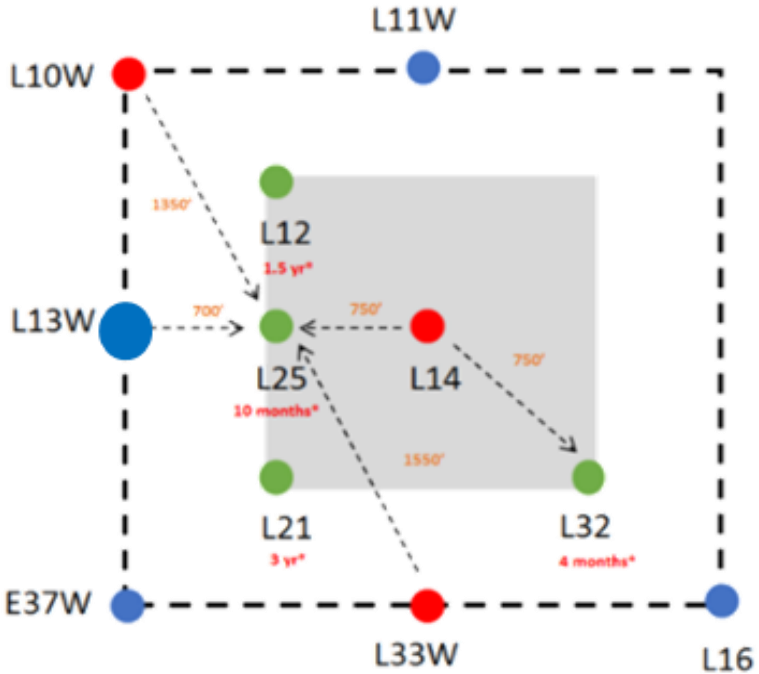
Oil-cut


L25 (Jan 2018 - Aug 2023)
Pilot
Oil Cut (%)
100
10
1
0
5000
10000
15000
20000
25000
Cumulative Oil Produced (bbl)

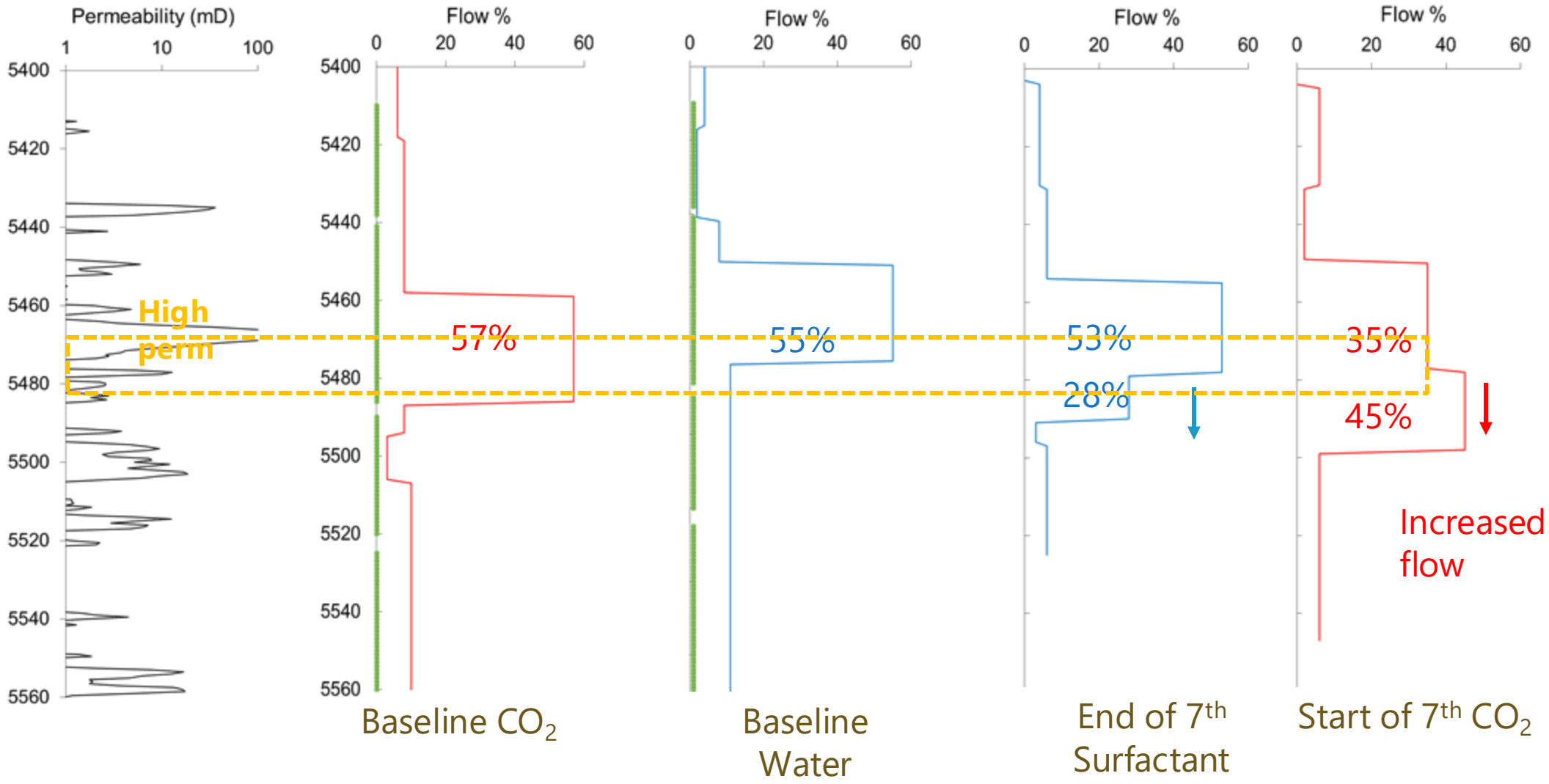

L32 (Jan 2018 - Aug 2023)
Pilot
Oil Cut (%)
100
10
1
0
5000
10000
15000
20000
25000
30000
35000
Cumulative Oil Produced (bbl)


L21 (Jan 2018 - Aug 2023)
Pilot
Oil Cut (%)
100
10
1
0
10000
20000
30000
40000
50000
60000
Cumulative Oil Produced (bbl)

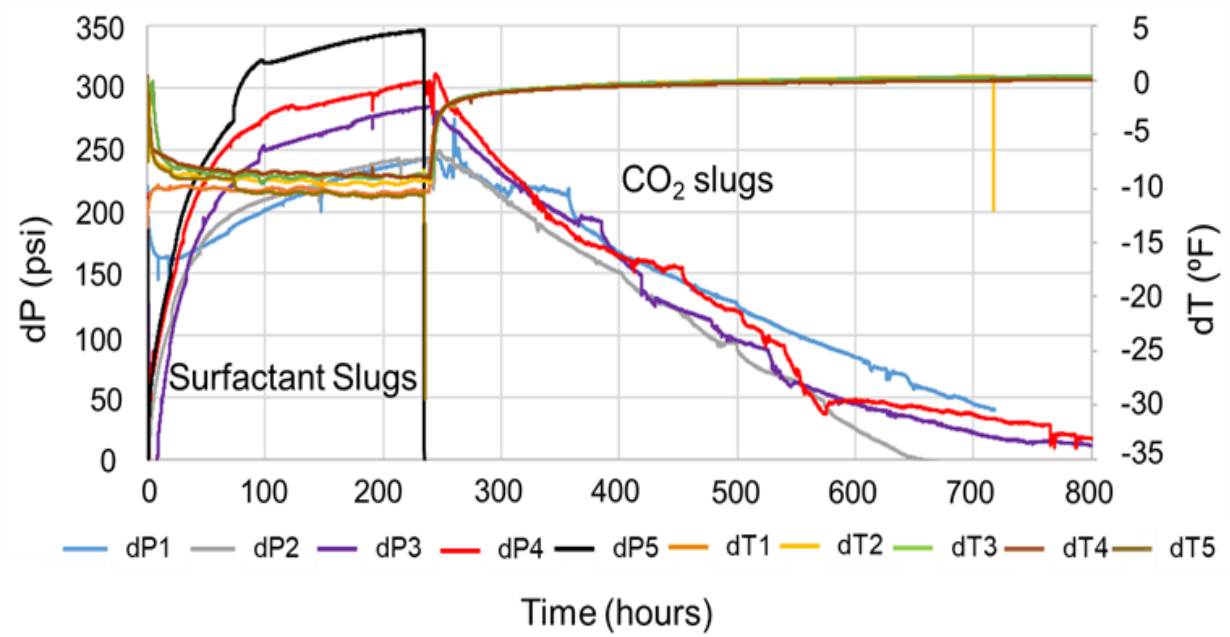

L12 (Jan 2018 - Aug 2023)
Pilot
Oil Cut (%)
100
10
1
0
5000
10000
15000
20000
Cumulative Oil Produced (bbl)


L11W
L10W
L12
1.5 yr*
L13W
L25
10 months*
L14
L21
3 yr*
L32
4 months*
E37W
L33W
L16
1350'
700'
750'
750'
1550'

Injection Profiles – Foam Injector

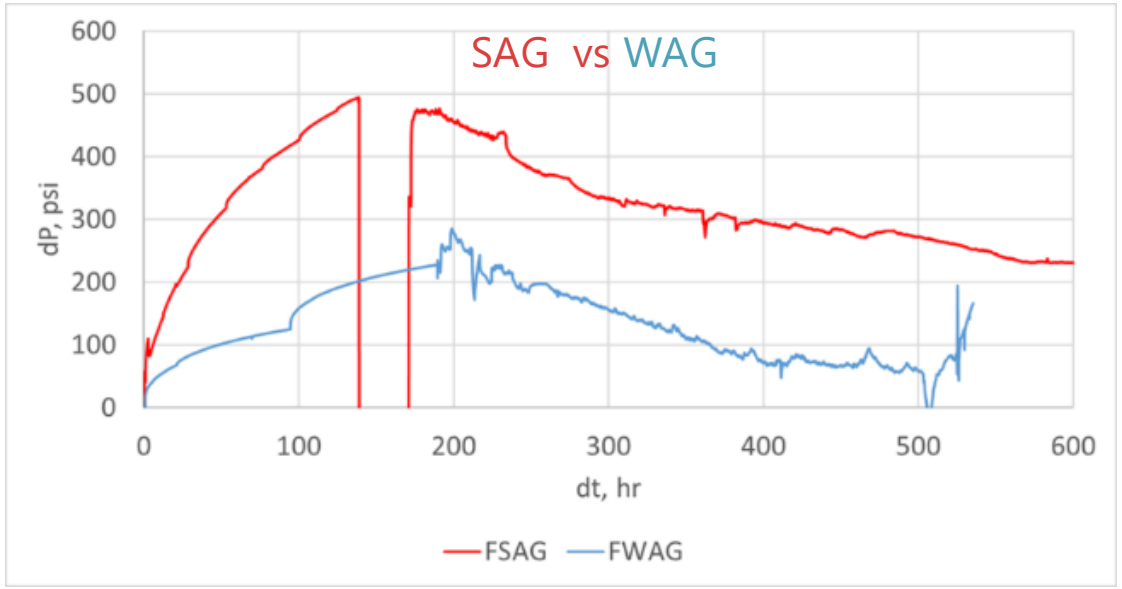


Transient Analysis



Reduced mobility of each cycle, indicating a foam bank developing further into the reservoir.

Reduced mobility during the SAG cycles compared to the WAG



Pilot start: May 2019

Pilot end: August 2020

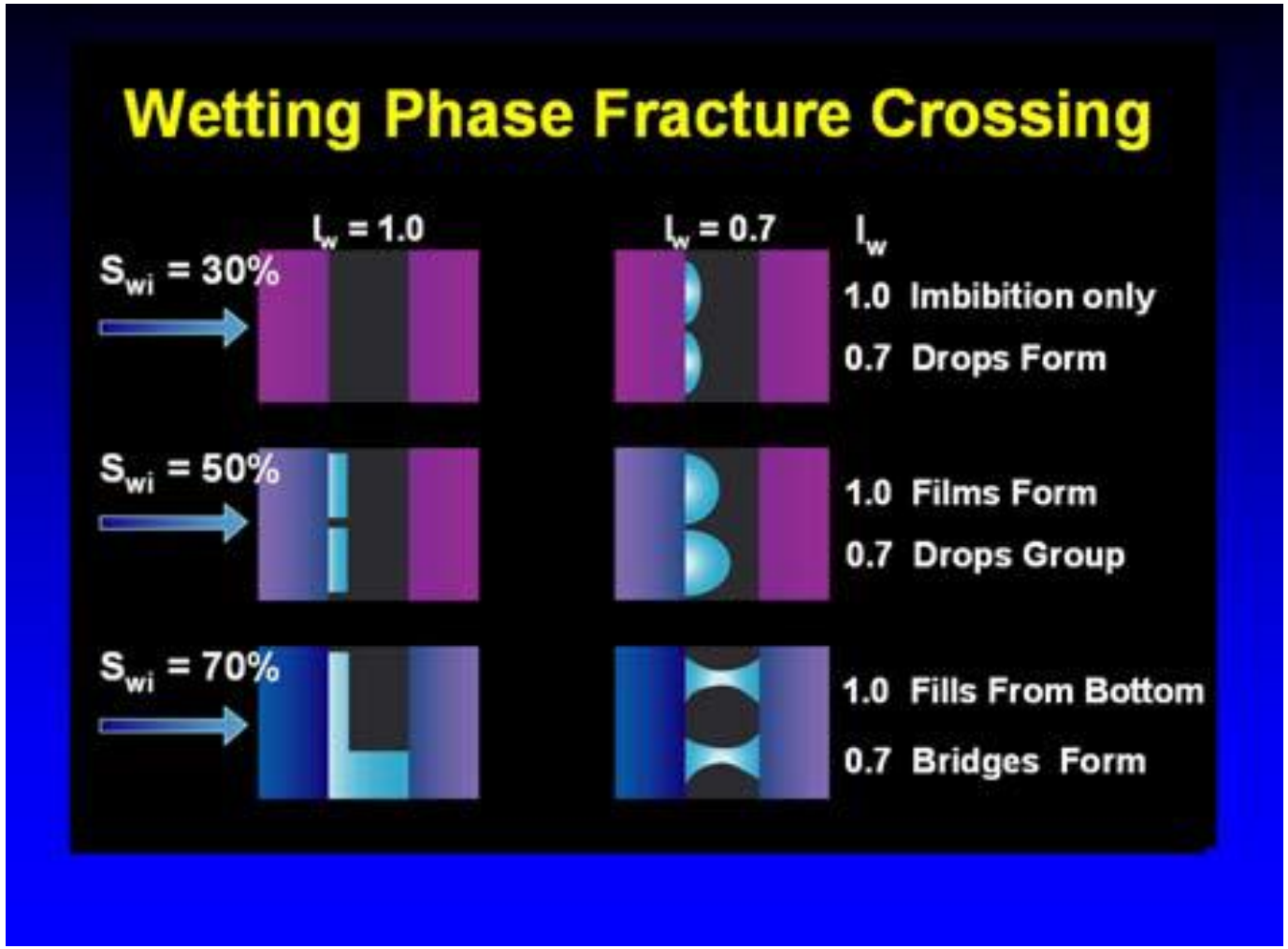
May 2021

Applying *Integrated EOR* (IEOR)

Injection Strategy:

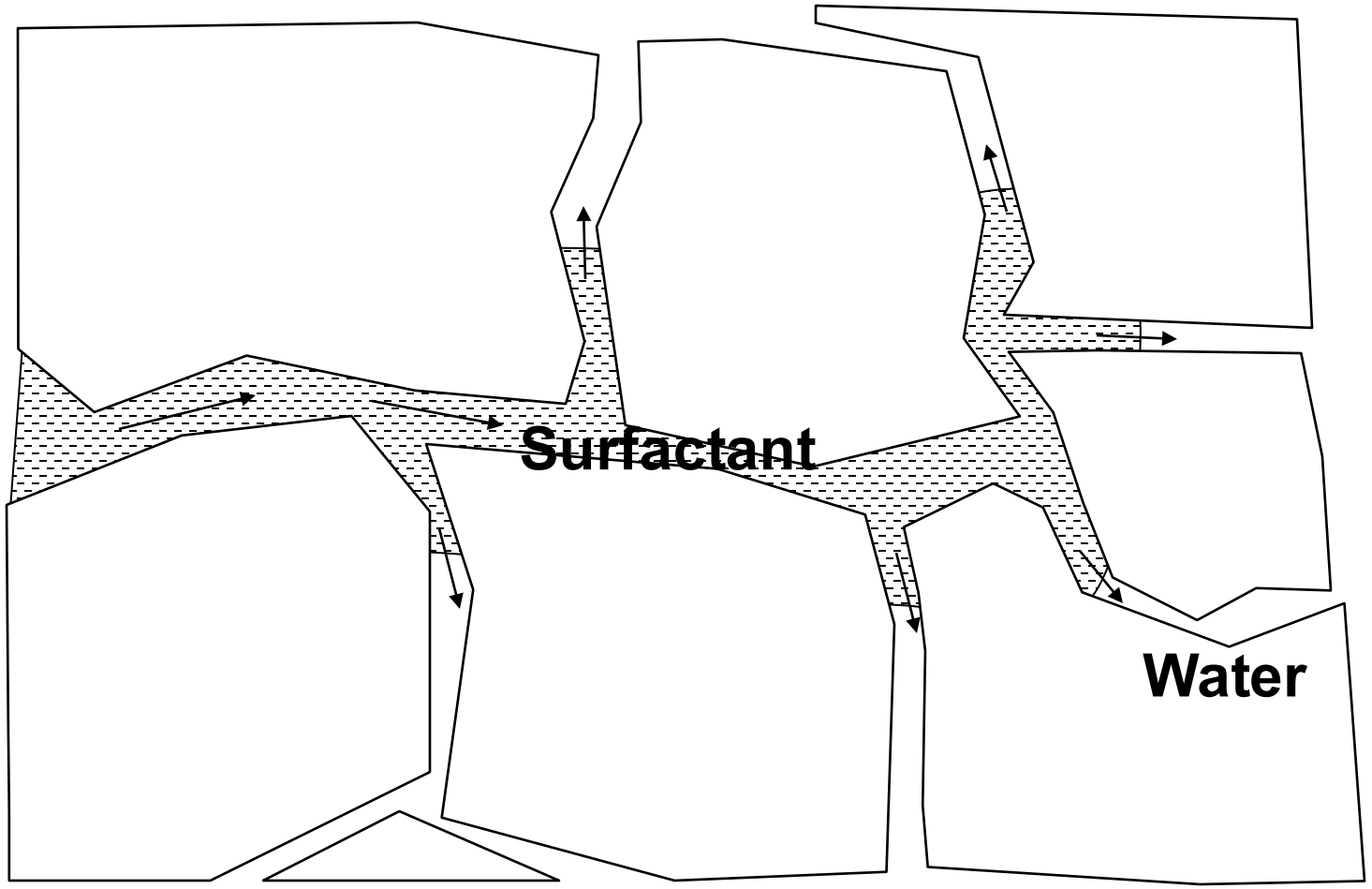
- ✓ 1FV Preflush for wettability alteration towards neutral wet fracture surfaces to obtain wetting phase bridges for capillary continuity and flow across fractures
- ✓ CO2 Foam SAG Injection

Wetting Phase Fracture Crossing



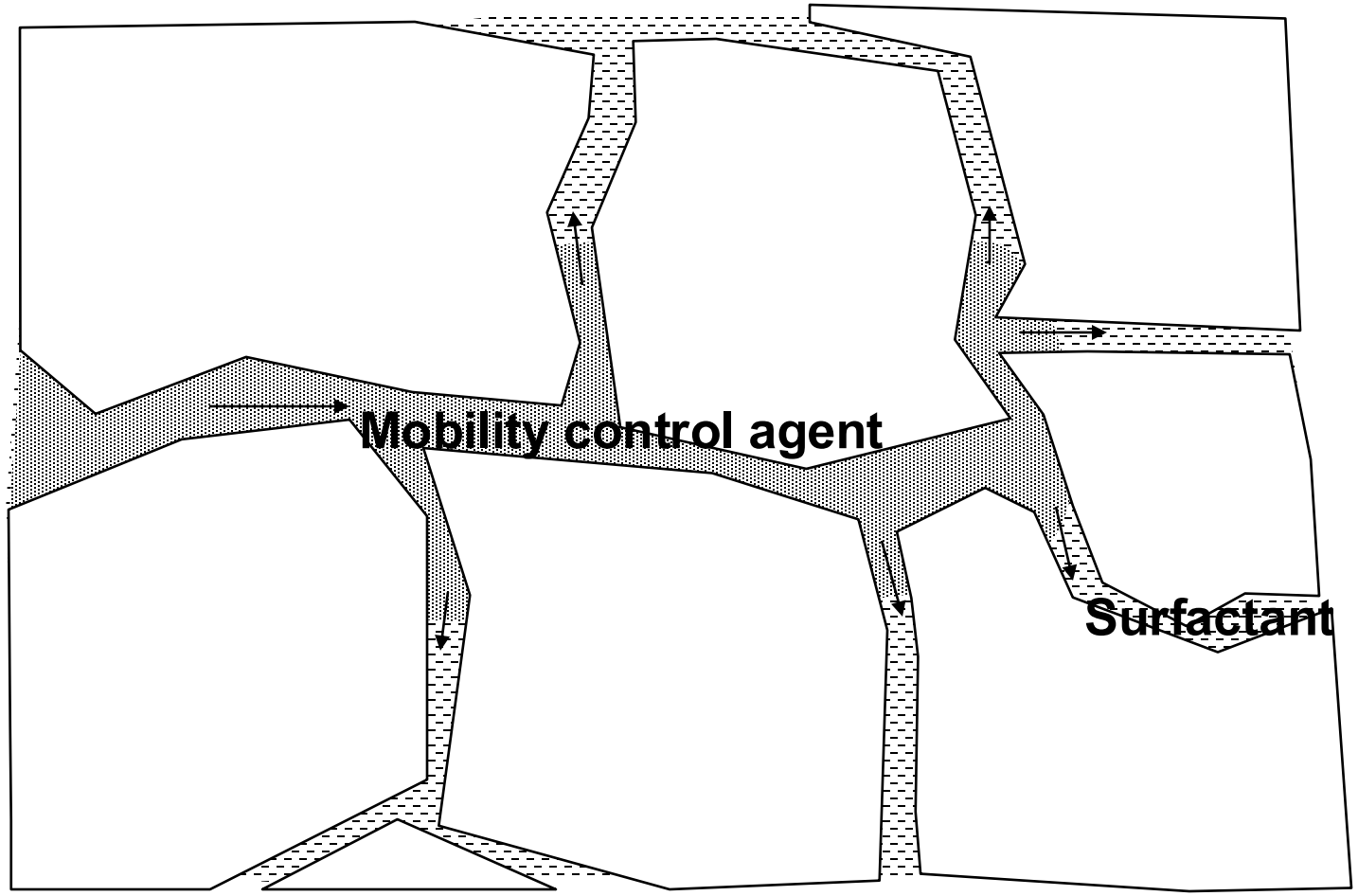
IEOR: Water + (Surf) + CO_2 Foam

Pretreatment of fracture surfaces



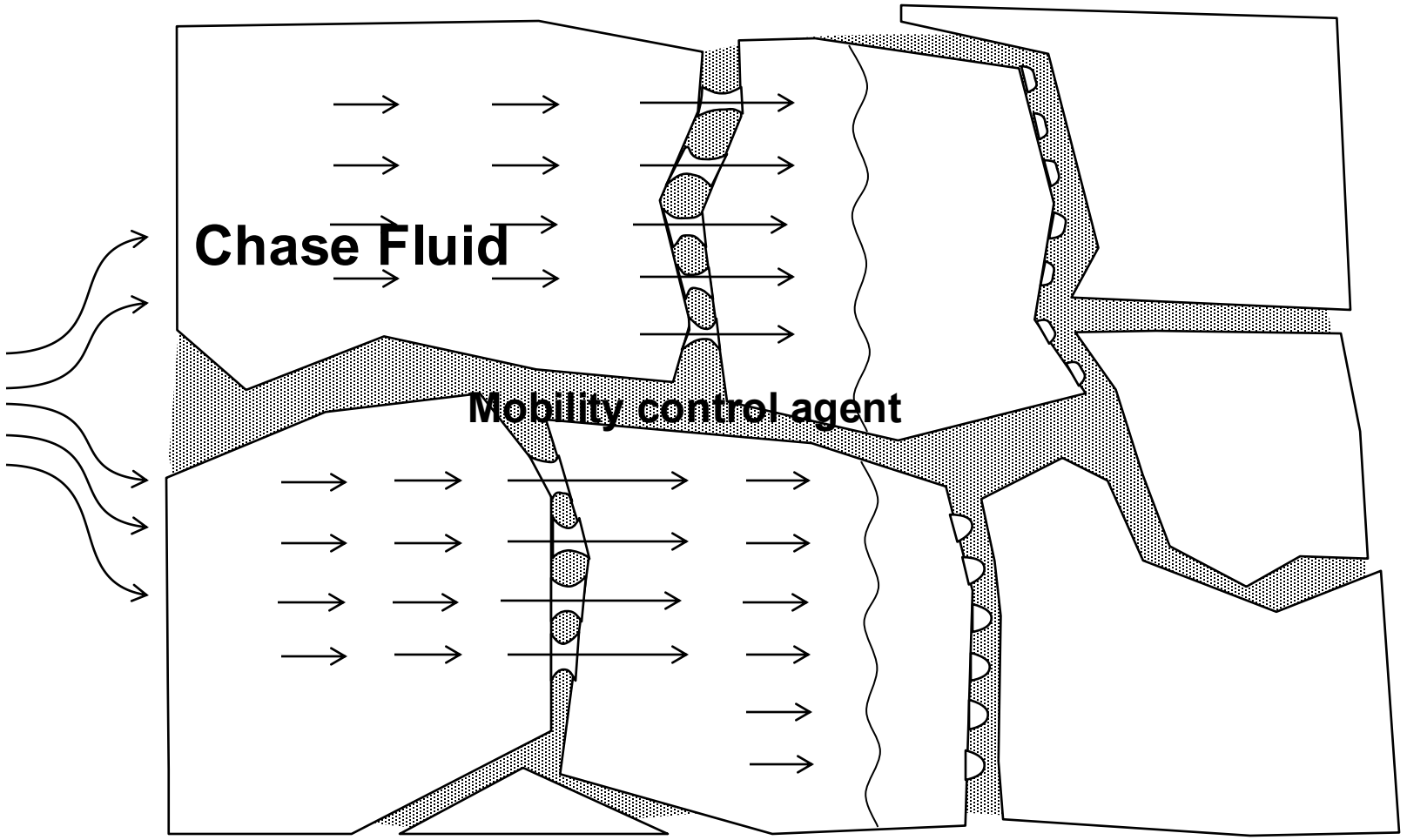
IEOR: Water + (Surf) + CO_2 Foam

Injection of mobility control agent



IEOR: Water + (Surf) + CO_2 Foam

Chase fluid injection



Technical Achievements

Reduced CO_2 mobility

Increased sweep

Improved oil recovery

Increased CO_2 storage volumes

Ongoing monitoring and analysis

Litt. Ref.: SPE 190204, SPE 200450, SPE 209359, SPE 190168

Conclusions

CO_2 Foam IEOR Field Pilot Results

- **40%HCPV increased oil production compared to predicted conventional CO_2 EOR**
- **50 000 additional bbls of oil produced despite CO_2 foam flood being initiated after 6 years of CO_2 flooding**
- **Rate of Return (RR) is more than 20 (US$ 4mill / US$ 110K)**
- **Surfactant cost per additional bbl produced is US$ 2 - 5**
- **Break even after 0.01PV injected (immediately)**