First Ever Field Pilot on Alaska's North Slope to Validate the Use of Polymer Floods for Heavy Oil Enhanced Oil Recovery (EOR)

a.k.a Alaska North Slope Field Laboratory (ANSFL)

DE-FE0031606

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U.S. Department of Energy
National Energy Technology Laboratory
Addressing the Nation's Energy Needs Through Technology Innovation – 2019 Carbon Capture, Utilization, Storage, and Oil and Gas Technologies Integrated Review Meeting
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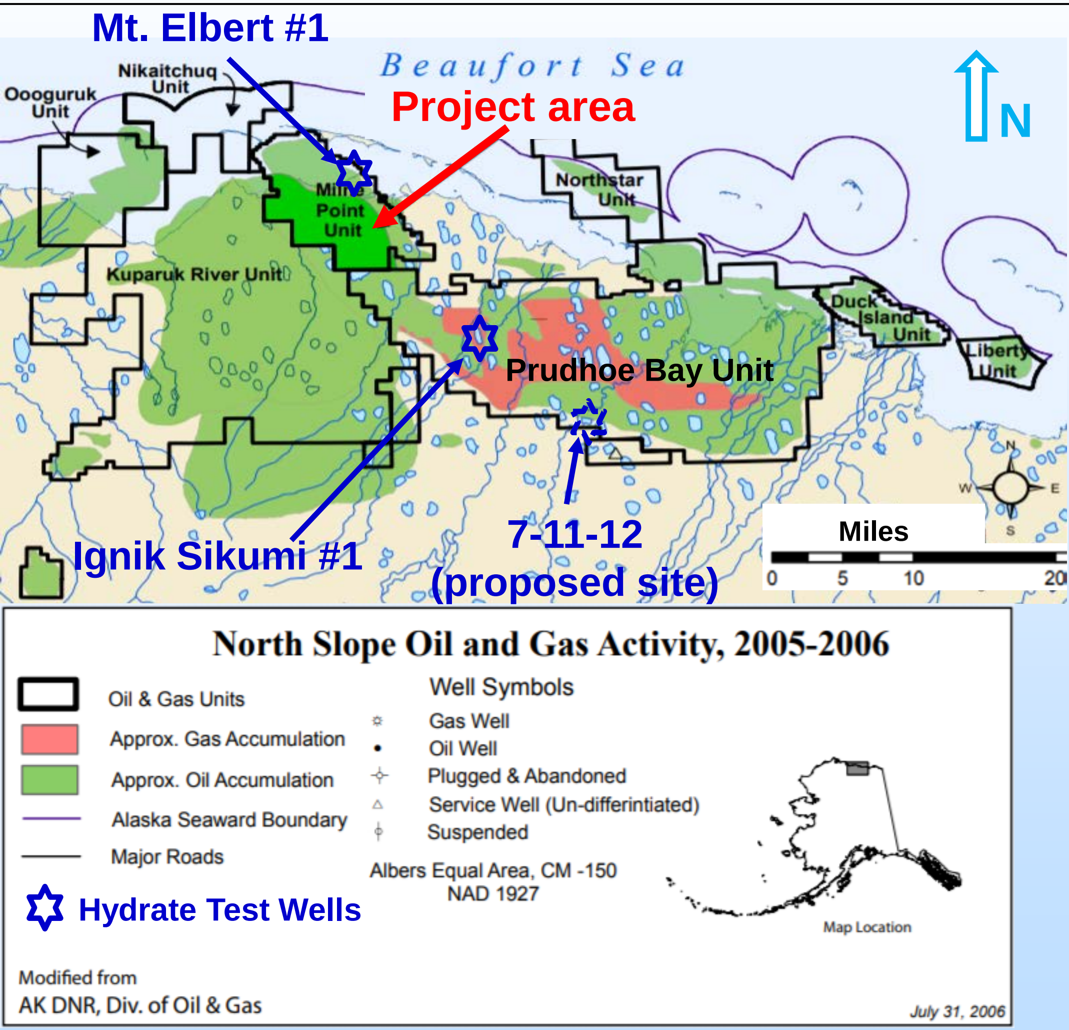
Presentation Outline

- ANSFL Overview
- Pilot Wells, Patterns and Polymer Slicing Unit
- Technical Approach and Status
- Task-wise Project Progress
- Accomplishments to Date
- Lessons Learned
- Synergy Opportunities
- Project Summary
- Appendix

Alaska North Slope Field Laboratory (ANSFL): Overview



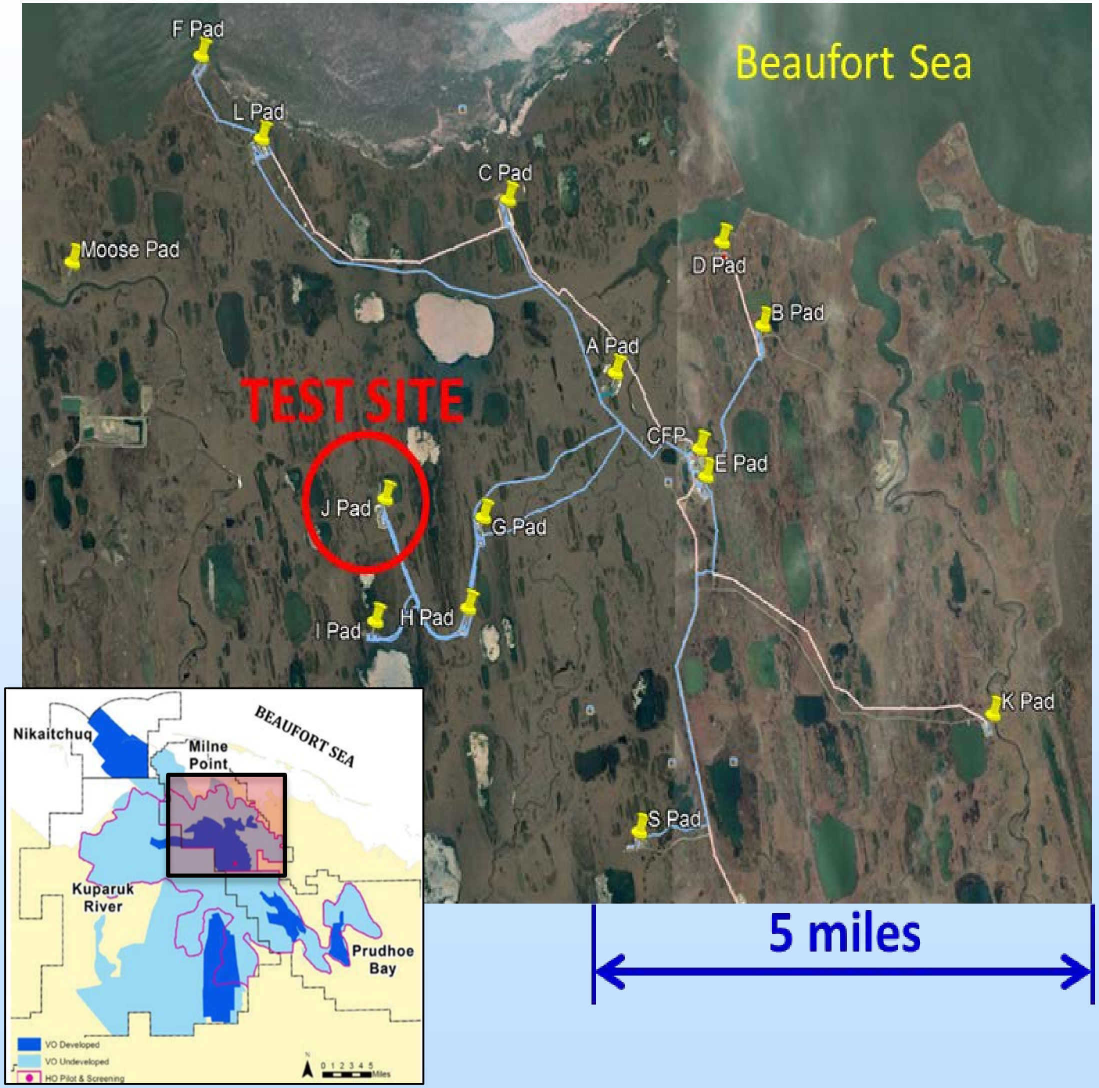
Source: AK DNR, Division of Oil & Gas

- Significant heavy oil resource (20-25 billion bbls); too large to ignore.
- <u>Poor waterflood sweep due to mobility contrast</u>.
- Limitation of deploying thermal methods due to “permafrost”.
- Light crude diluent still available for high viscosity oil transport through Trans Alaska Pipeline System.

ANSFL Overview

- Joint efforts among government, academia, and industry
- Primary objectives
  - ✓ Utilize multiple technologies to develop heavy oil EOR process
  - ✓ Observe field performance to optimize design
  - ✓ Minimize disruption to field operations
  - ✓ Resolve technical issues regarding heavy oil polymer flooding
  - ✓ Integrate lab work, reservoir simulation, field pilot performance, injection conformance and flow assurance studies in an iterative optimization process

ANSFL Overview

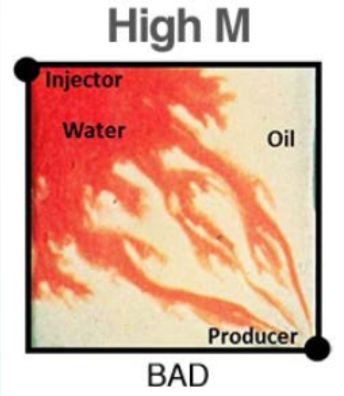


- Milne Point Unit
- ~50,000 acres
- ~250 wells -12 pads – 1 CFP
- Field Development - 1985
- Cumulative Production - 353 MMBO
  - Light oil – 267 MMBO
  - Heavy oil – 86 MMBO
- Current oil rate: ~30 MBD
- WIO: Hilcorp 50%, BP 50%
- Polymer Test Site - J Pad

Ning et. al. URTeC, 2019

Polymer Flooding

- **What is polymer** -
  - Non-toxic polyacrylamide powder
- **What does it do -**
  - Increases the viscosity of injected water
- **Why inject it -**
  - Increases sweep efficiency by reducing the mobility ratio (viscosity oil / viscosity water)
- **Timing -**
  - Typical polymer flood design 0.5 to 1 pattern pore volume
  - Long term, several years of injection



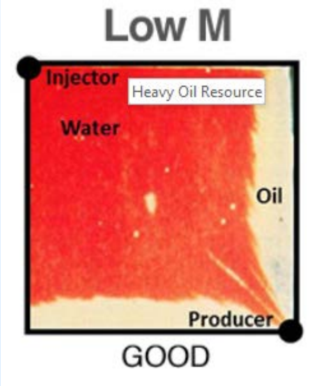
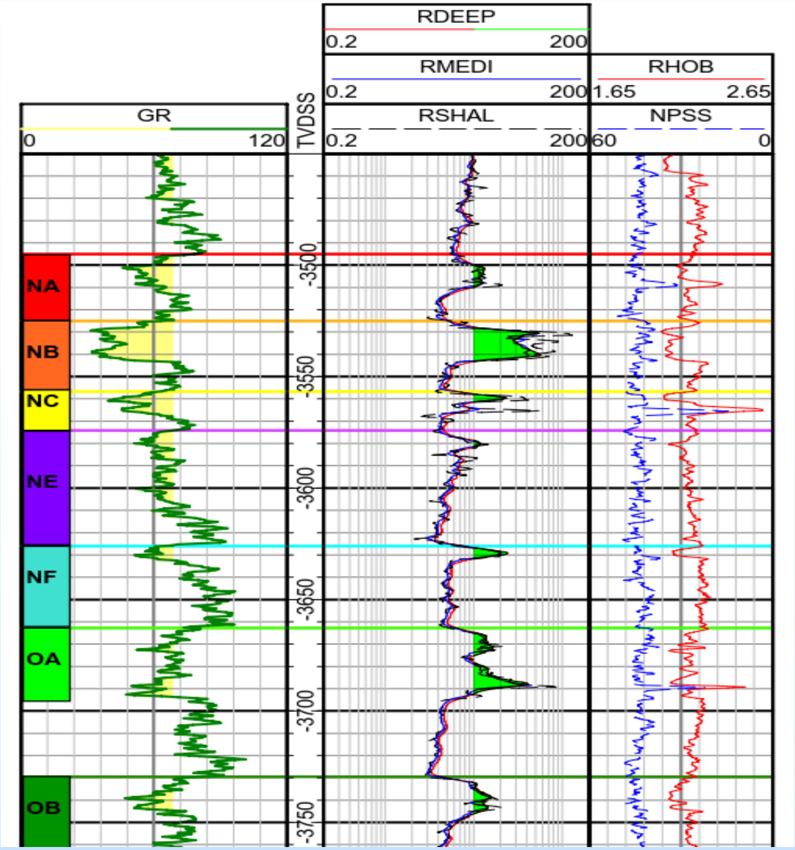


Image Source - https://www.surtek.com/chemical-eor/chemical-enhanced-oil-recovery/

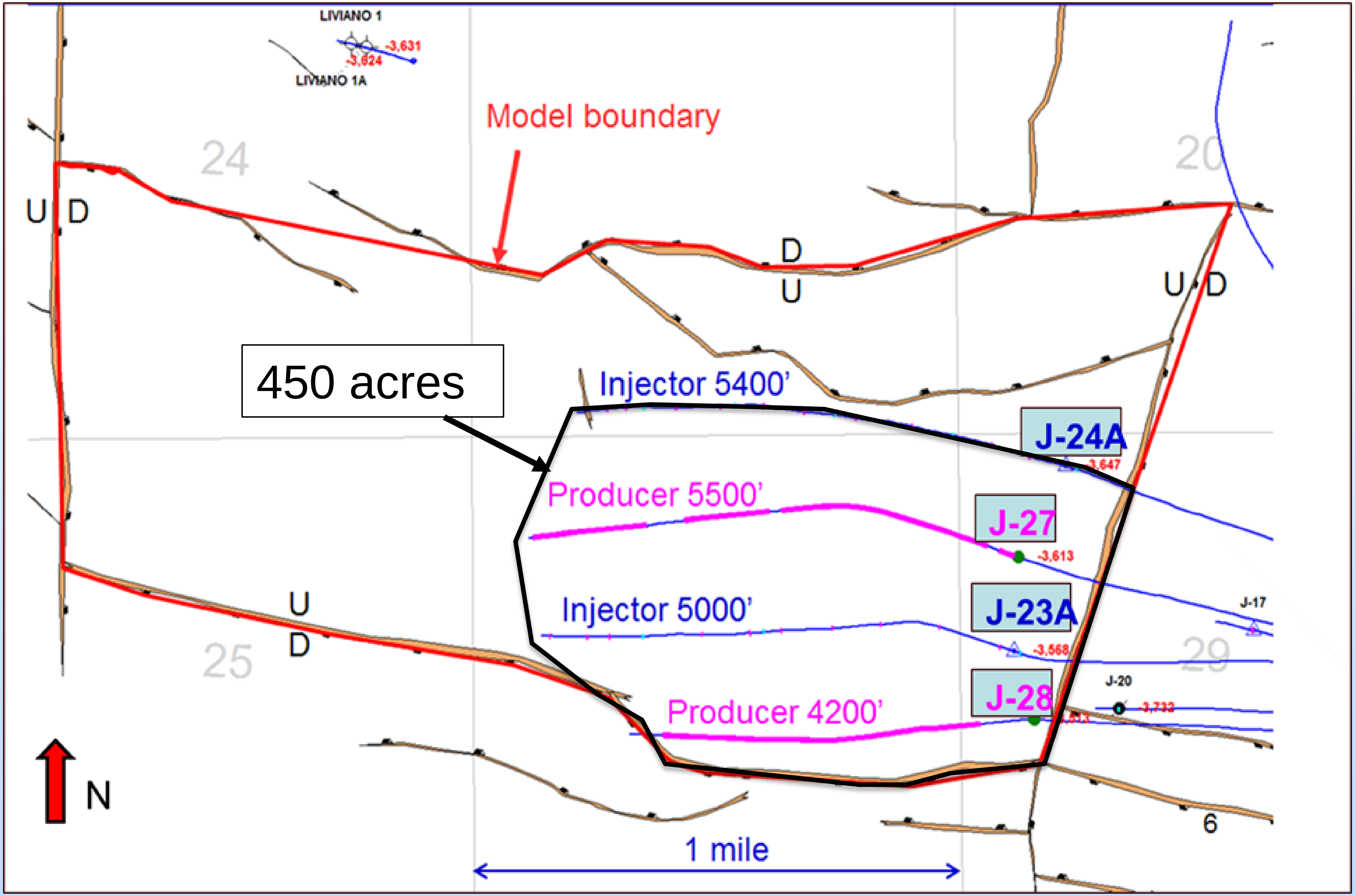
Target Formation

- Schrader Bluff
  - Shallow marine / Fluvial deltaic
  - 3,400' – 4,500' SSTVD
  - Gross thickness ~250' (Net – 60')
  - ~7 intervals

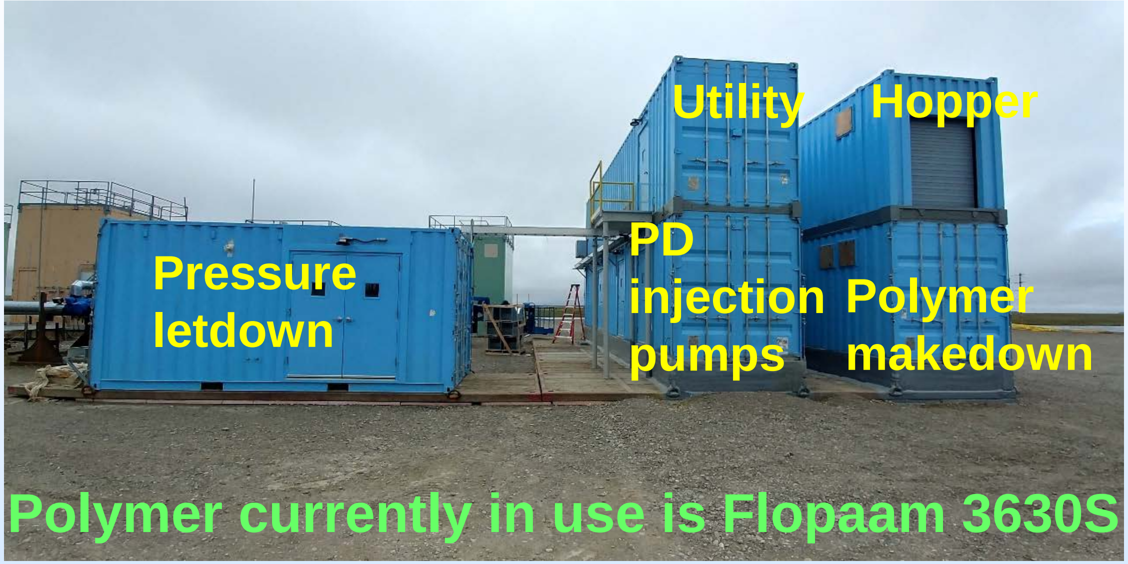
- Target Interval - Nb sand:
  - Net pay = 10-18 ft
  - Porosity = ~32%
  - Permeability = 500-5,000 md
  - Oil gravity = ~15 API
  - Oil viscosity = ~300 cp



Pilot Wells and Patterns



Polymer Slicing Unit



Technical Approach

No large scale polymer projects in the US, and many unresolved issues that need to be addressed via:

- Laboratory corefloods (***Tasks 2 and 3***)
  - optimization of injected polymer viscosity/concentration, quantification and retention.
  - optimization of injection water salinity and identification of conformance control strategies.
- Reservoir simulation (***Task 4***)
  - history matching (HM) of laboratory corefloods, field waterflood, and polymer flood pilot.
  - optimization of the polymer injection strategy for the project reservoir.
  - scale up to full field oil recovery from polymer injection.

Technical Approach

- Implementation of polymer flood field pilot (***Task 5***)
  - prior lab studies used in initial polymer selection.
  - interactively integrate lab tests, reservoir simulations, and field tests.
  - long time (years) required for polymer injection to quantify the benefit.
- Flow assurance (***Task 6***)
  - develop literature based initial strategy to deal with produced fluids from a separation and processing standpoint.
  - revise flow assurance strategy concurrently.

Technical Status

Milestones	Task No.	Planned Completion Date	Actual Completion Date	Verification Method	Comments
Project Management Plan	1a	o 9/30/2022	o Ongoing (latest revision 4/30/2019)	Report	None
Data Management Plan	1b	o 8/31/2018	o 7/20/2018 (latest revision 4/30/2019)	Report	None
• Quantify polymer retention	2	o 3/31/2019	o Some tests completed but is ongoing	Report	None
• Effect of water salinity on S_{or} • Screening of gel products for conformance control	3	o 4/30/2019 o 6/30/2019	o Some tests completed but is ongoing o Initiated	Report	None

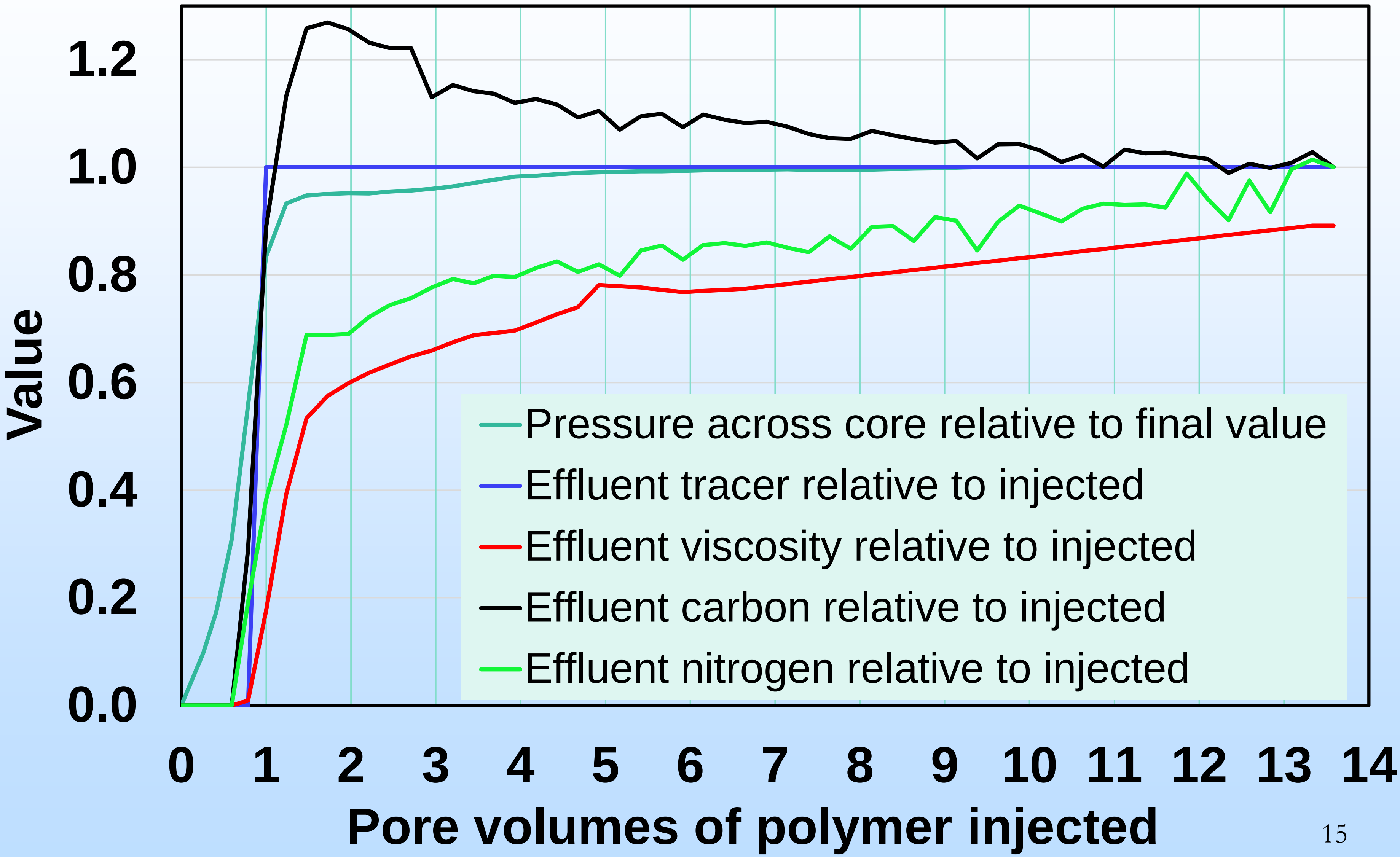
Technical Status

• Pilot area model waterflooding history match • Coreflooding model history match • Updated area model for polymer flood prediction • Reservoir modeling report	4	o 12/312018 o 4/30/2019 o 5/31/2019 o 5/31/2019	o 2/1/2019 o Some completed but is ongoing o Completed but is also ongoing refinement o Extensively reported in Quarterlies, but a formal report will be completed by the middle of July 2019 as special status report	Report	None

Technical Status

• Injection profile with polymer inj. • PFO (post-polymer) • Tracer tests (post-polymer)	5	o 12/31/2018 o 12/31/2018 o 12/31/2018	o Ongoing o Ongoing o Ongoing *Note – all have been completed, but also ongoing*	Report	None
• Initial treatment plan recommendation based upon literature survey • Finalization of the fouling flow loop design	6	o 12/31/2018 o 06/30/2019	o Ongoing (challenges with spent polymer present) o Ongoing	Report	None

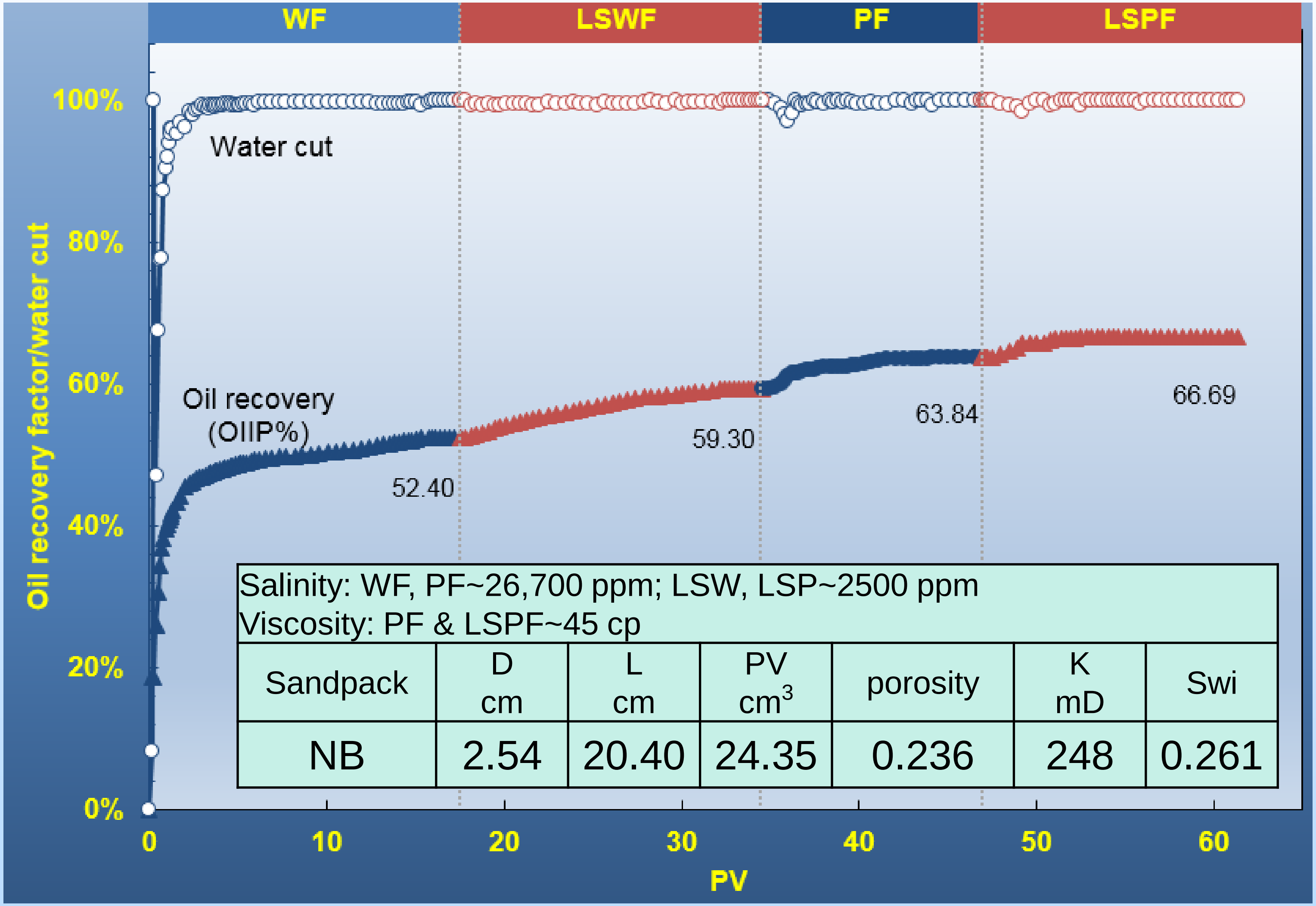
Task 2 – Polymer Retention



Task 2 – Polymer Retention

Sand	Polymer	Dv(10), µm	Dv(50), µm	K, md	k_w at S_{or}, md	Overburden pressure, psi	Polymer retention, µg/g	
							Nitrogen	Viscosity
1st NB	3630	36	166	10900	7000	0	28	45
1st NB	3630	36	166	548	50	1000	372	931
2nd NB	3630	73	179	625	73	1700	533	844
OA	3630	41	97	233	19	800	126	593
OA	3630	41	97	158	No oil	500	87	246
OA	3430	41	97	328	No oil	1000	0	33

Task 3 – Optimization of Injection Water Salinity

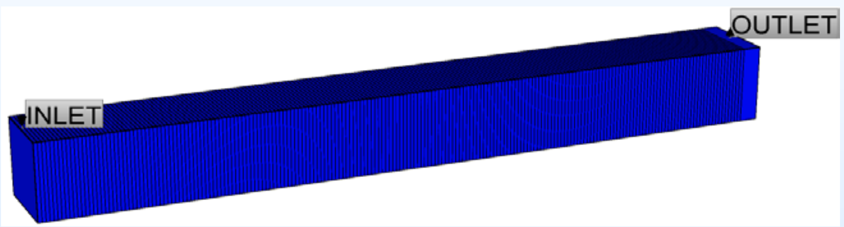


Salinity: WF, PF~26,700 ppm; LSW, LSP~2500 ppm
Viscosity: PF & LSPF~45 cp

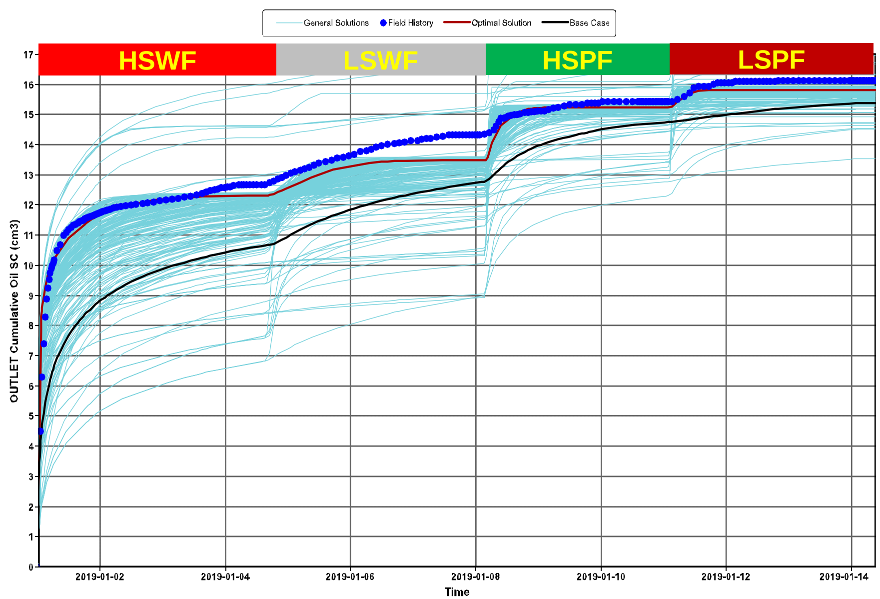
Sandpack	D cm	L cm	PV cm^3	porosity	K mD	Swi
NB	2.54	20.40	24.35	0.236	248	0.261

Task 3 – Optimization of Injection Water Salinity

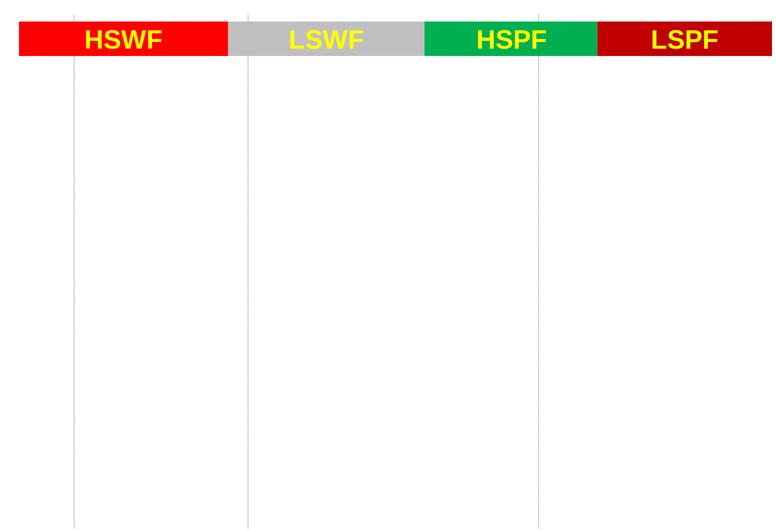
Homogeneous model



	Lower Limit	Upper Limit
No	0.8	5
Nw	0.8	5
Shear thin Coefficient	0.3	0.9



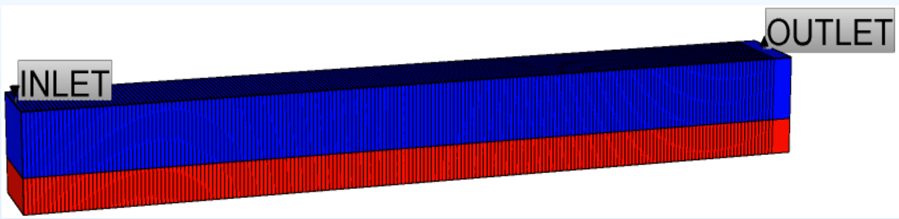
Oil Production History Match



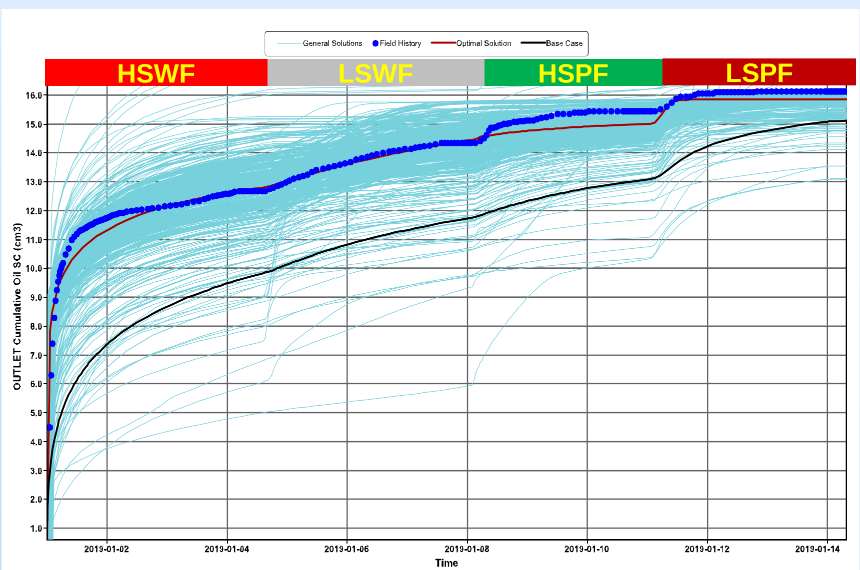
Injection Pressure History Match

Task 3 – Optimization of Injection Water Salinity

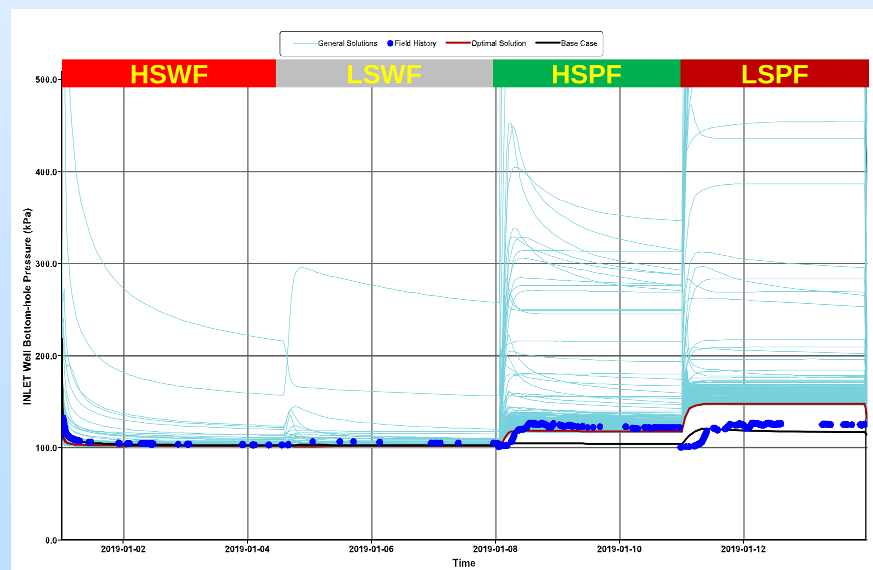
Heterogeneous model



	Lower Limit	Upper Limit
No	0.8	5
Nw	0.8	5
Shear thin Slope	0.3	0.9
Channel Thickness, cm	0.01	1.124
K_Ratio	1	100

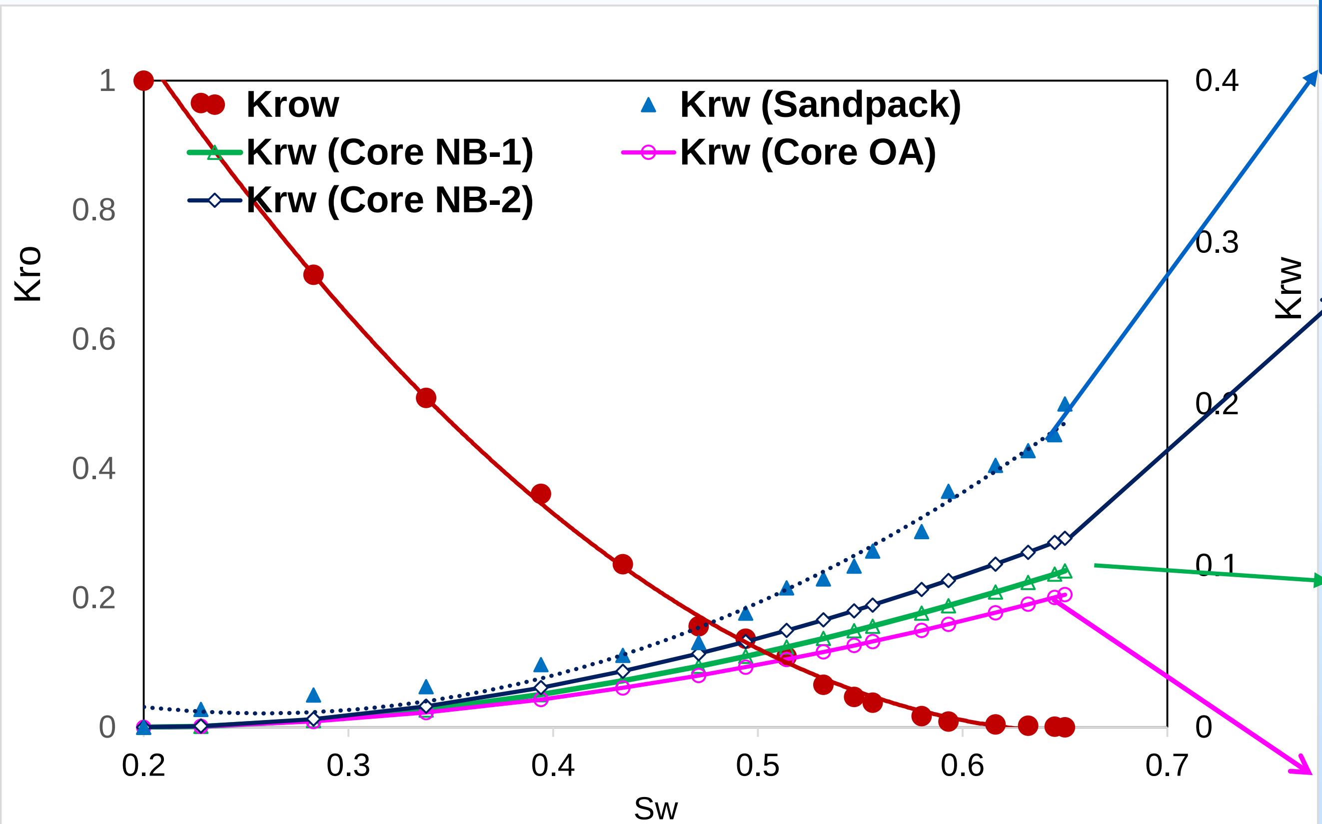


Oil Production History Match



Injection Pressure History Match

Task 4 – Numerical Simulation



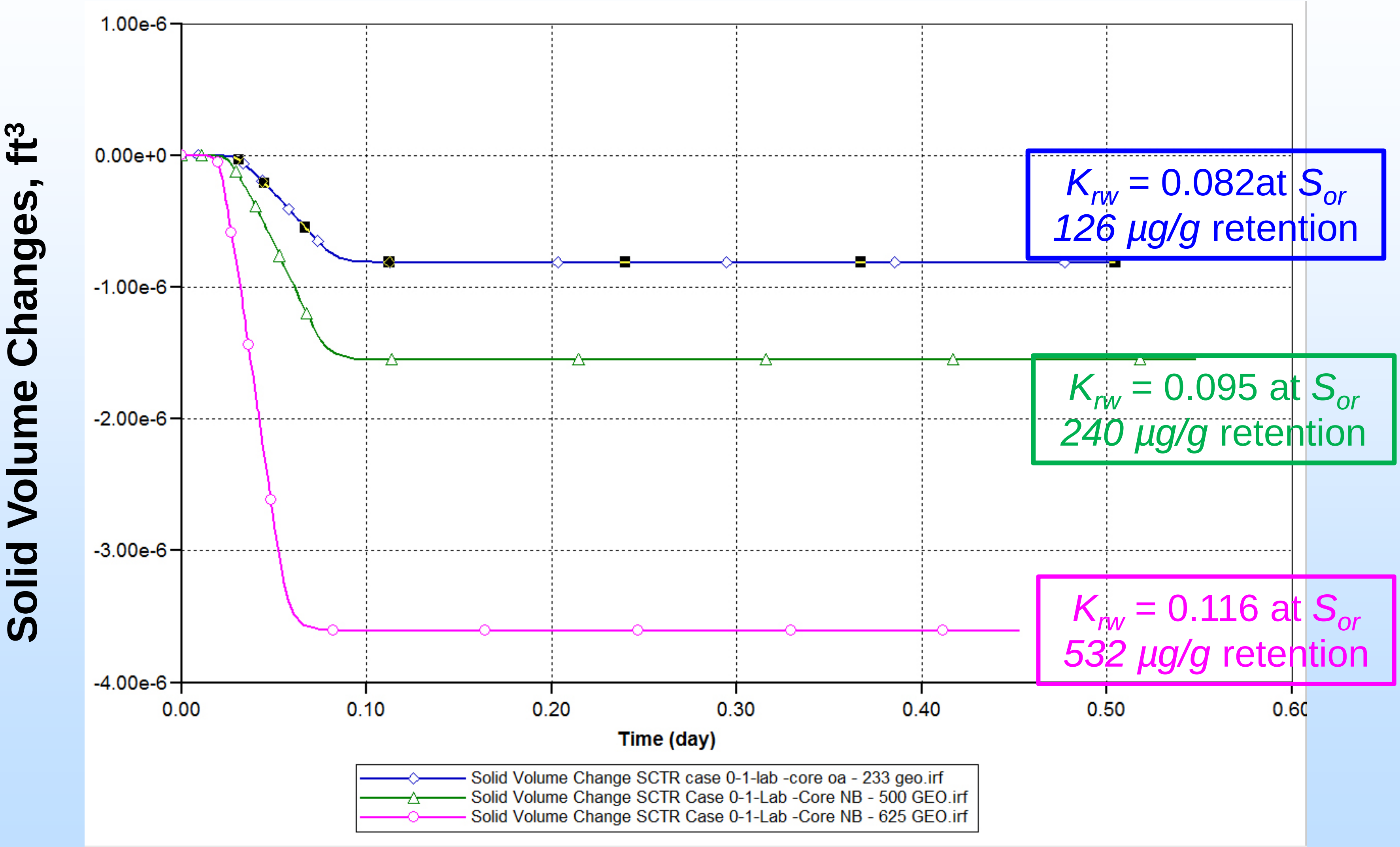
K_{rw} = 0.2 at S_{or}
0 psi of overburden

K_{rw} = 0.116 at S_{or}
1,700 psi of overburden

K_{rw} = 0.095 at S_{or}
1,000 psi of overburden

K_{rw} = 0.082 at S_{or}
800 psi of overburden

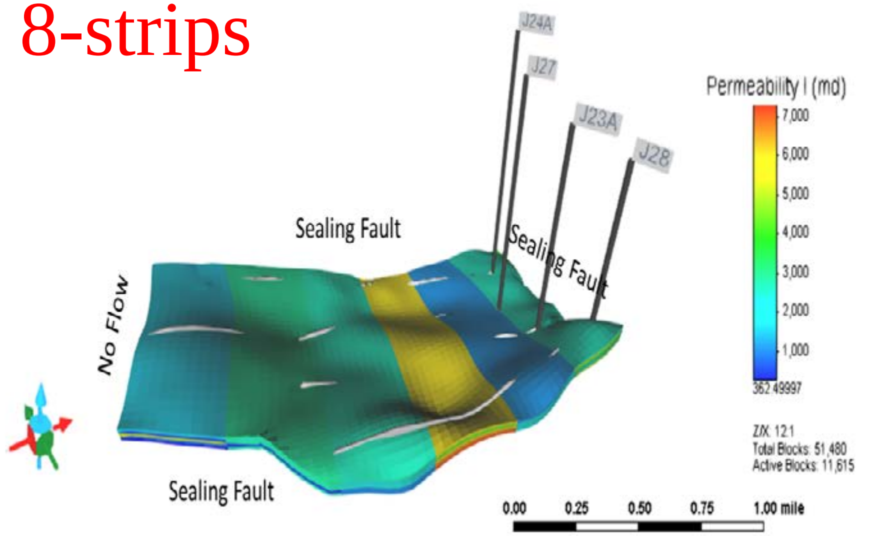
Task 4 – Numerical Simulation



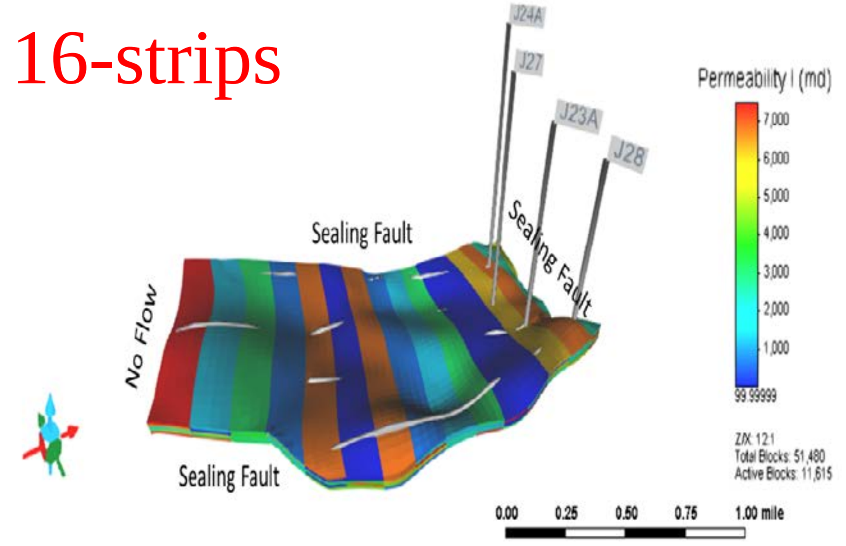
Task 4 – Numerical Simulation

Multiple permeability heterogeneity models

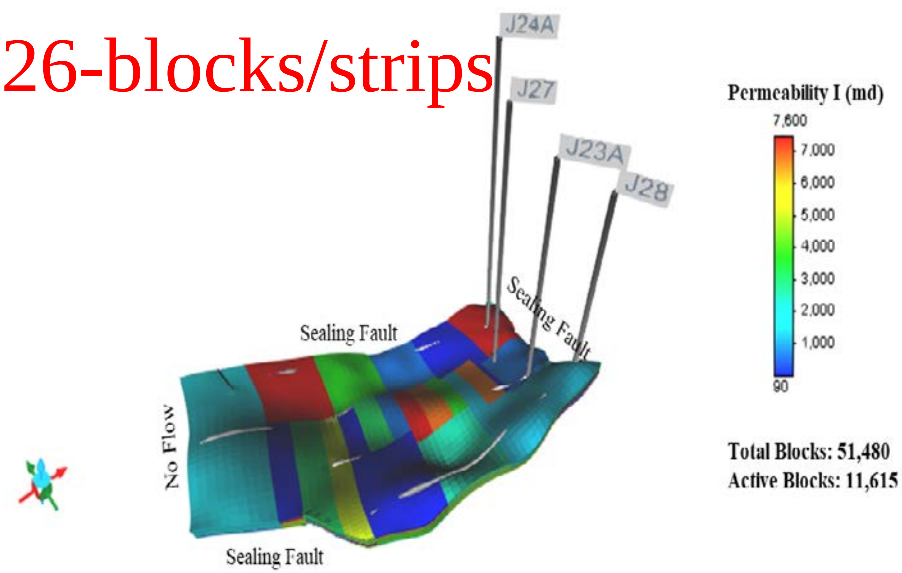
8-strips



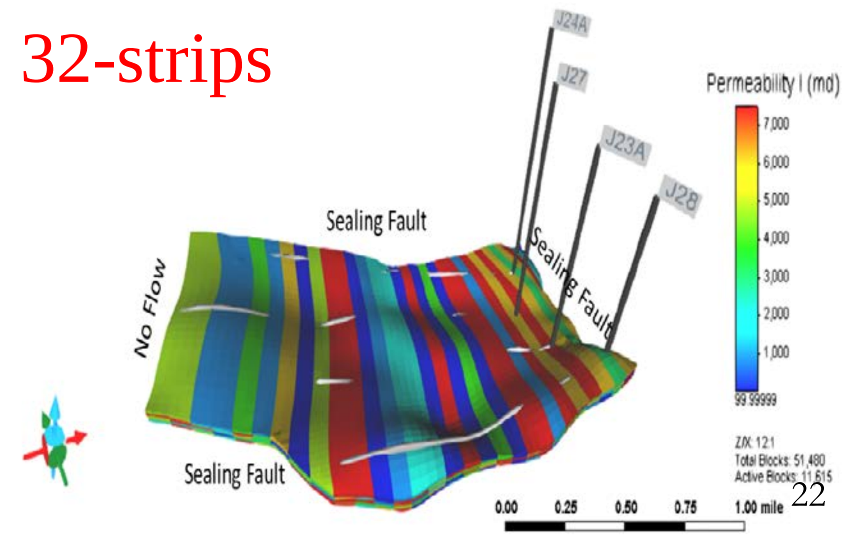
16-strips



26-blocks/strips

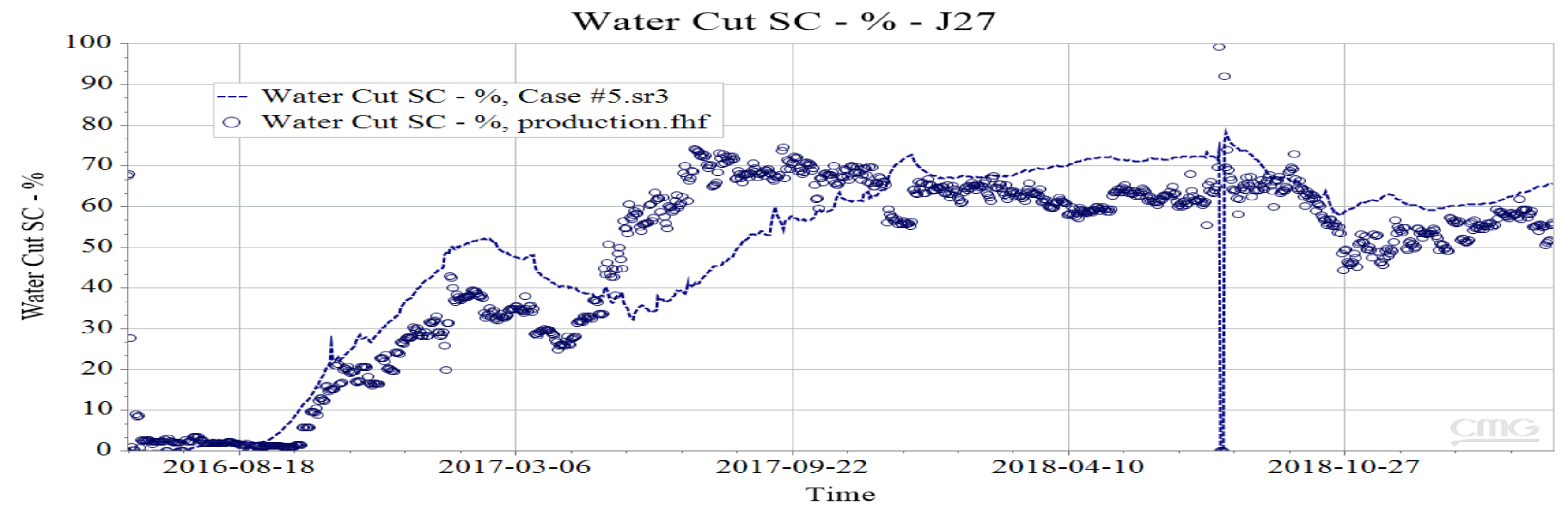


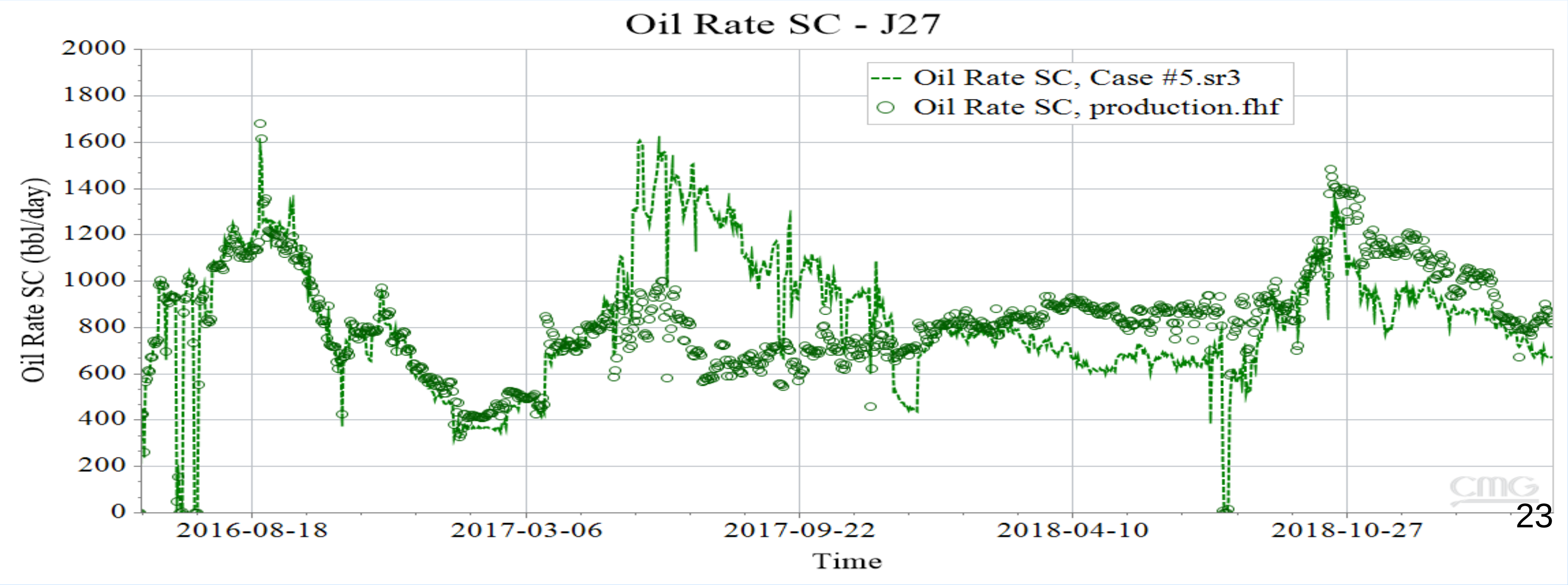
32-strips



Task 4 – Numerical Simulation

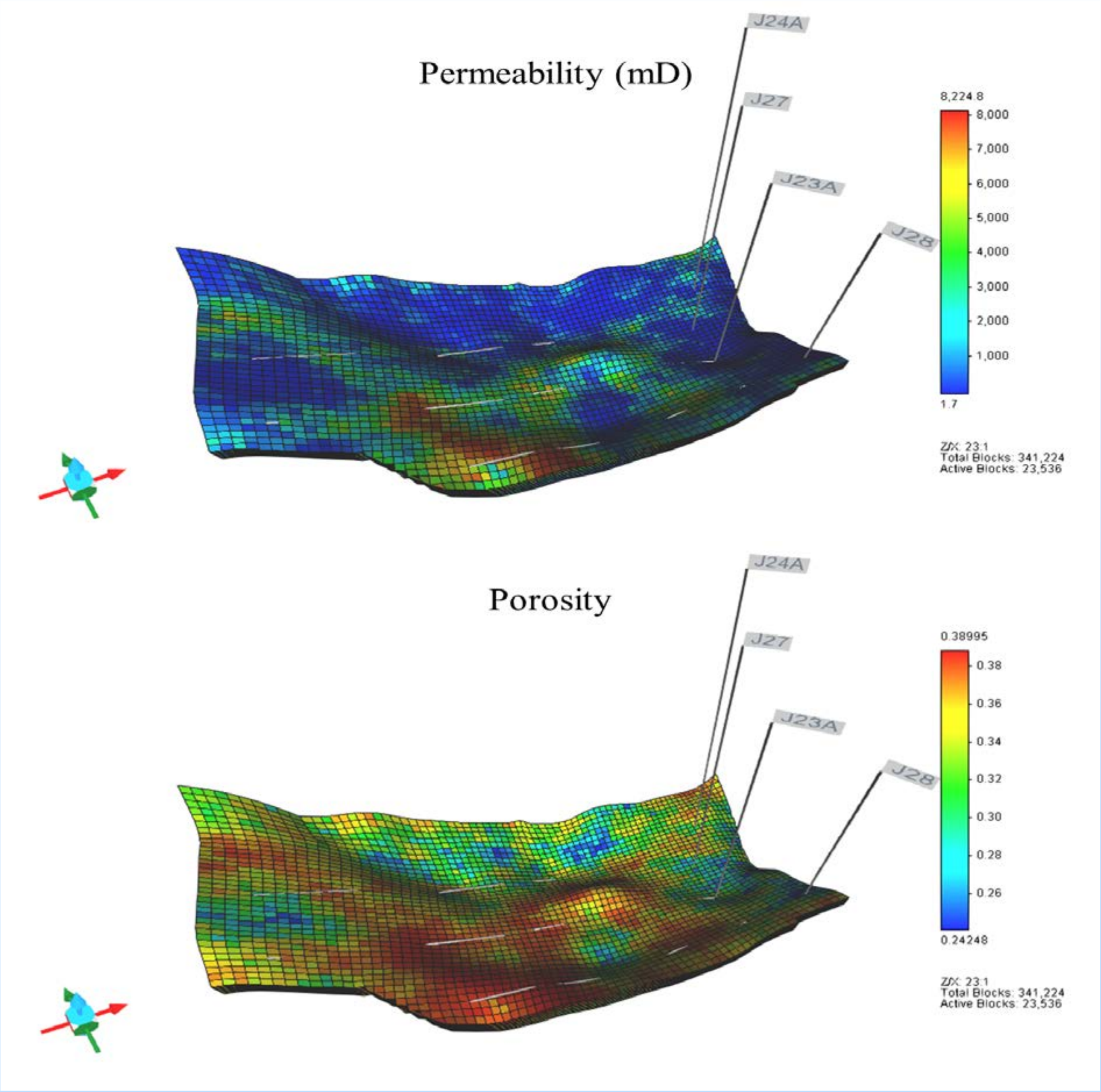
26-blocks/strips model history match using relative permeabilities





Task 4 – Numerical Simulation

The <u>new</u> heterogeneous model is developed by re-interpreting the seismic data.



Task 4 – Numerical Simulation

Ensemble smoother method

Model parameters can be updated by assimilating production data at all timesteps simultaneously in ES method.

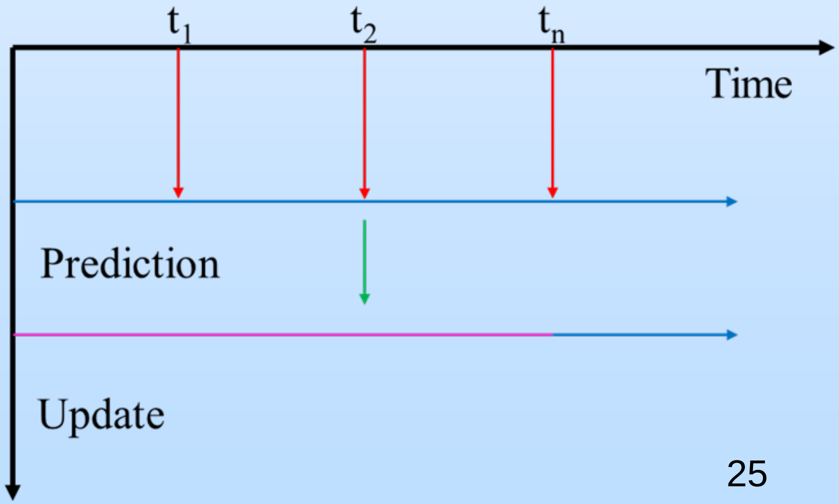
- ES-MDA analysis equation

$$m_j^u = m_j^p + C_{MD}\left(\alpha_i C_D + C_{DD}\right)^{-1}\left(d_{uc,j} - d_j^p\right), \quad j = 1, 2, \cdots, N_e$$

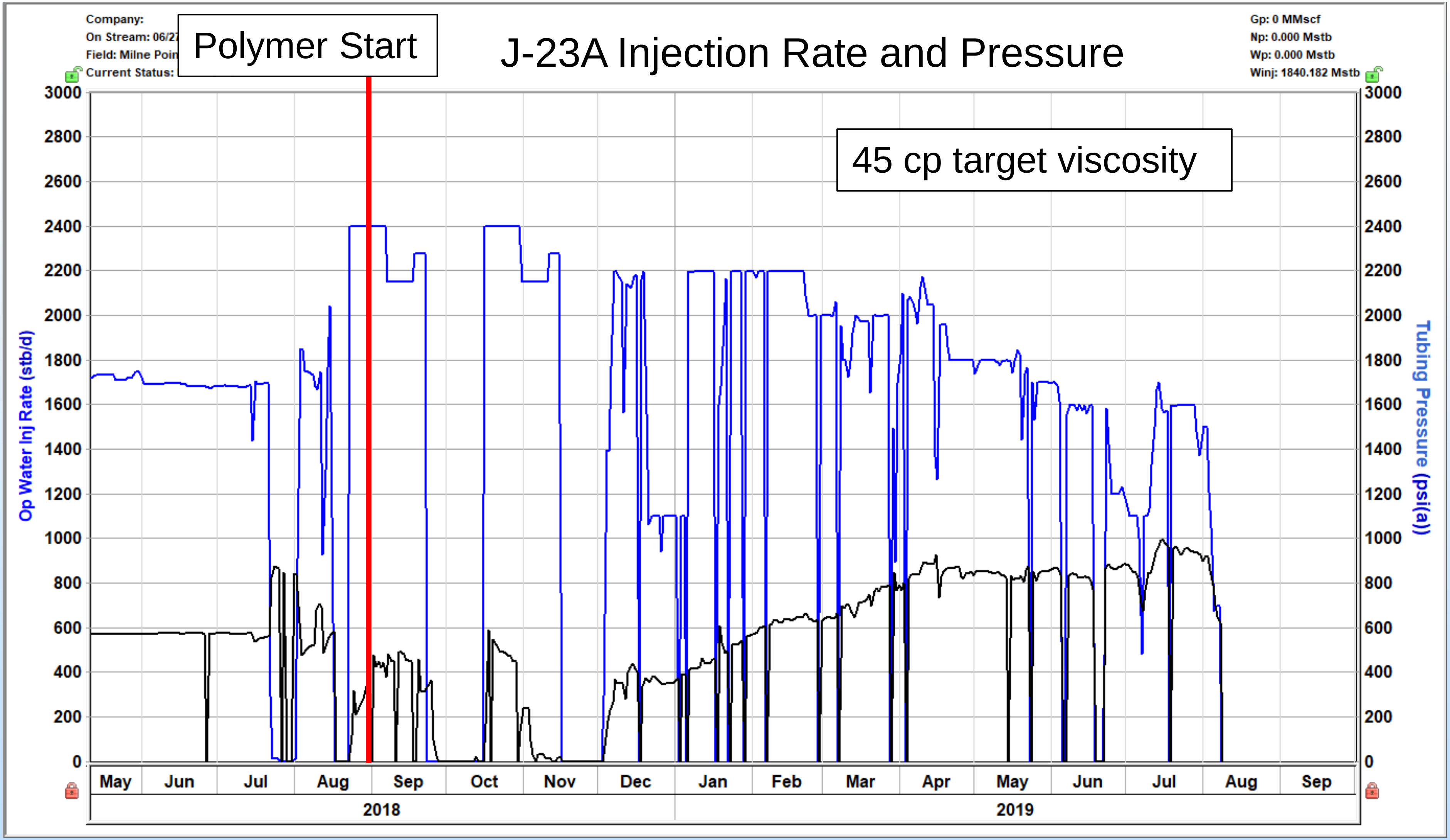
$$d_{uc} = d_{obs} + \sqrt{\alpha_i} C_D^{1/2} z_d$$

$$\sum_{i=1}^{N_a} \frac{1}{\alpha_i} = 1, \; i = 1, 2, \cdots, N_a$$

m: model parameters (porosity, permeability and relative permeability, etc.);
d: observation data (oil production rate, water cut and bottom hole pressure, etc.);
C_{MD}: cross-covariance matrix between the prior vector of model parameters and predicted data;
C_{DD}: auto-covariance matrix of predicted data;
C_D: covariance matrix of observed data measurement errors.



Task 5 – Polymer Field Pilot



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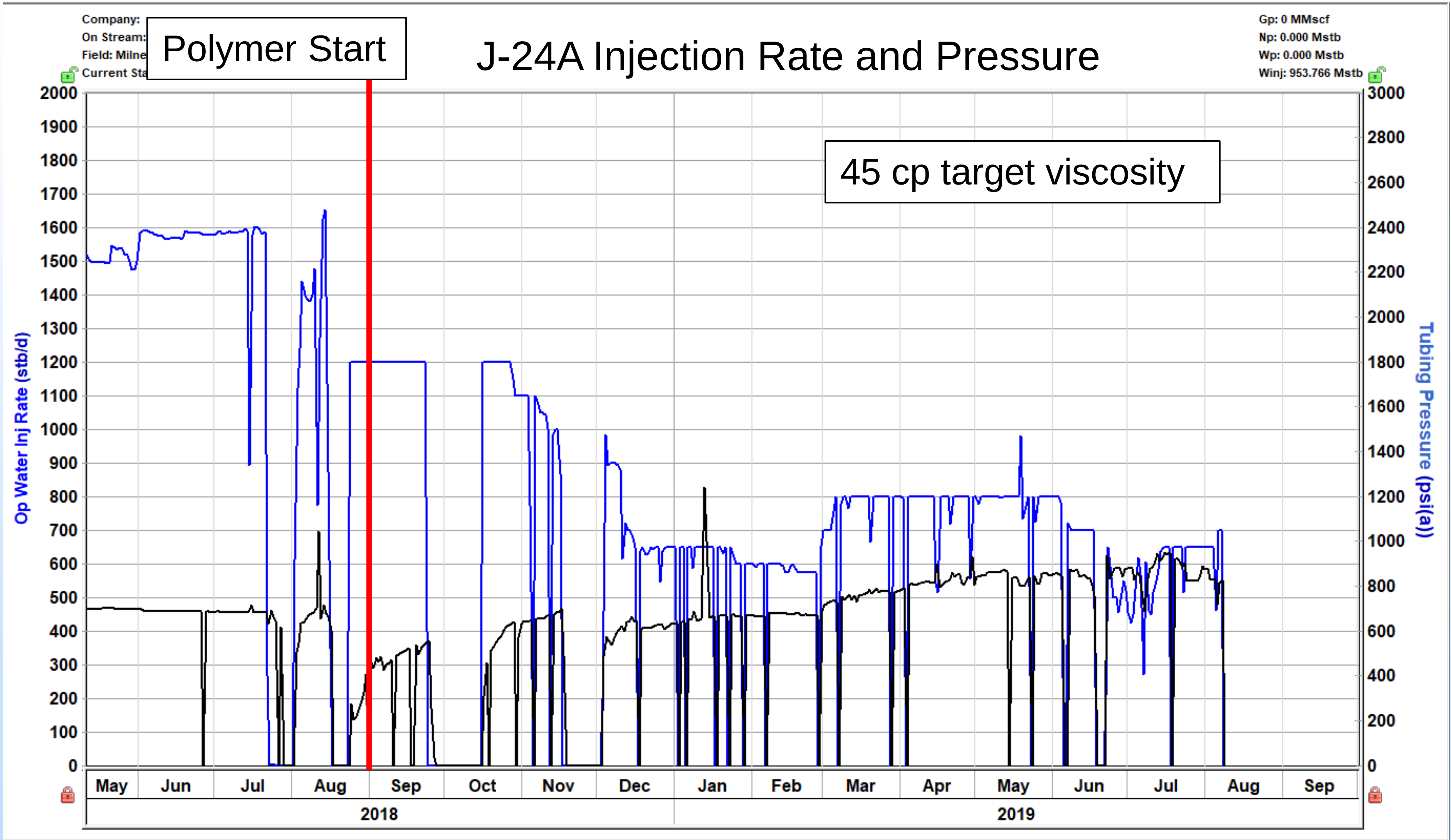
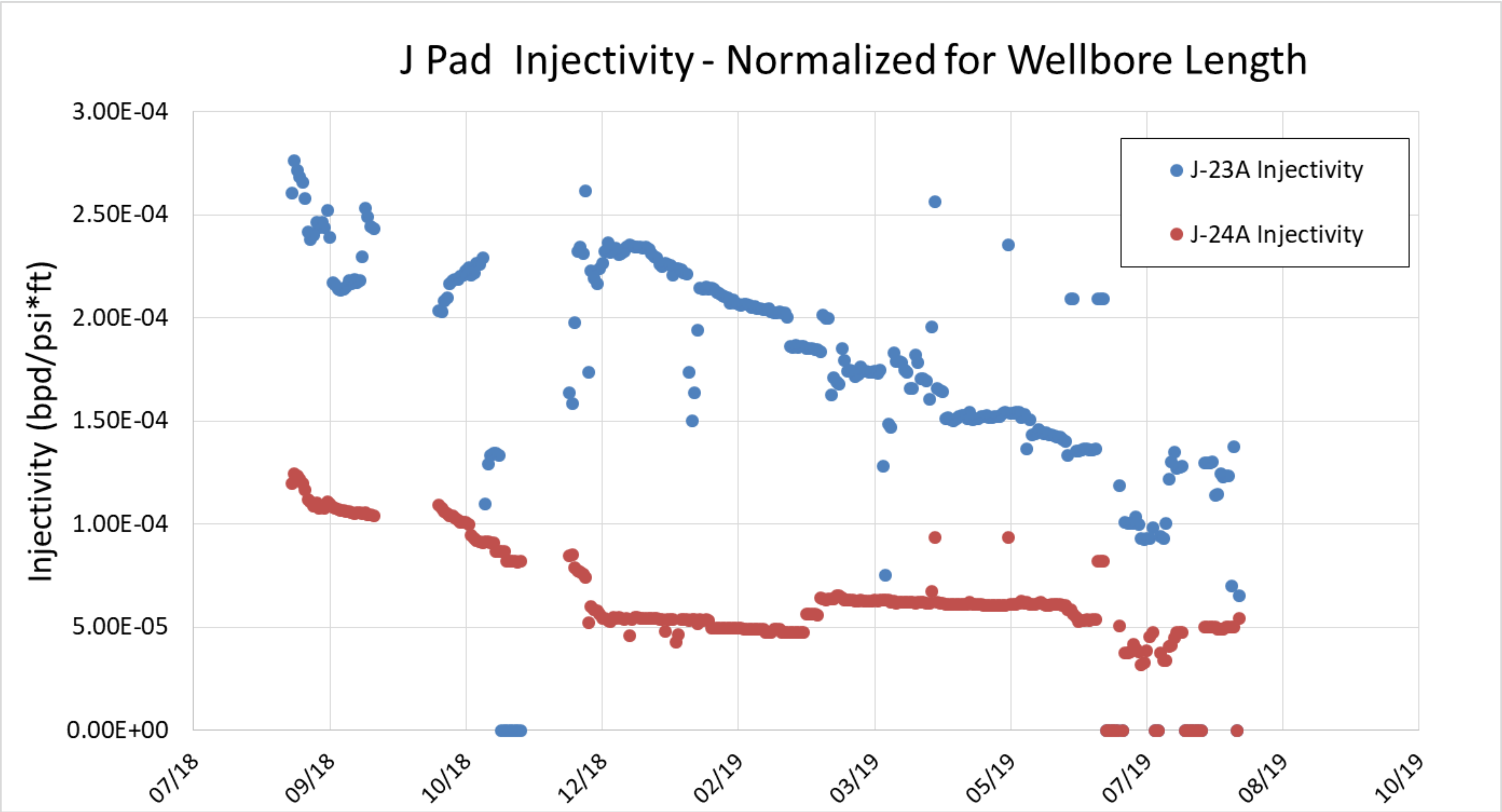
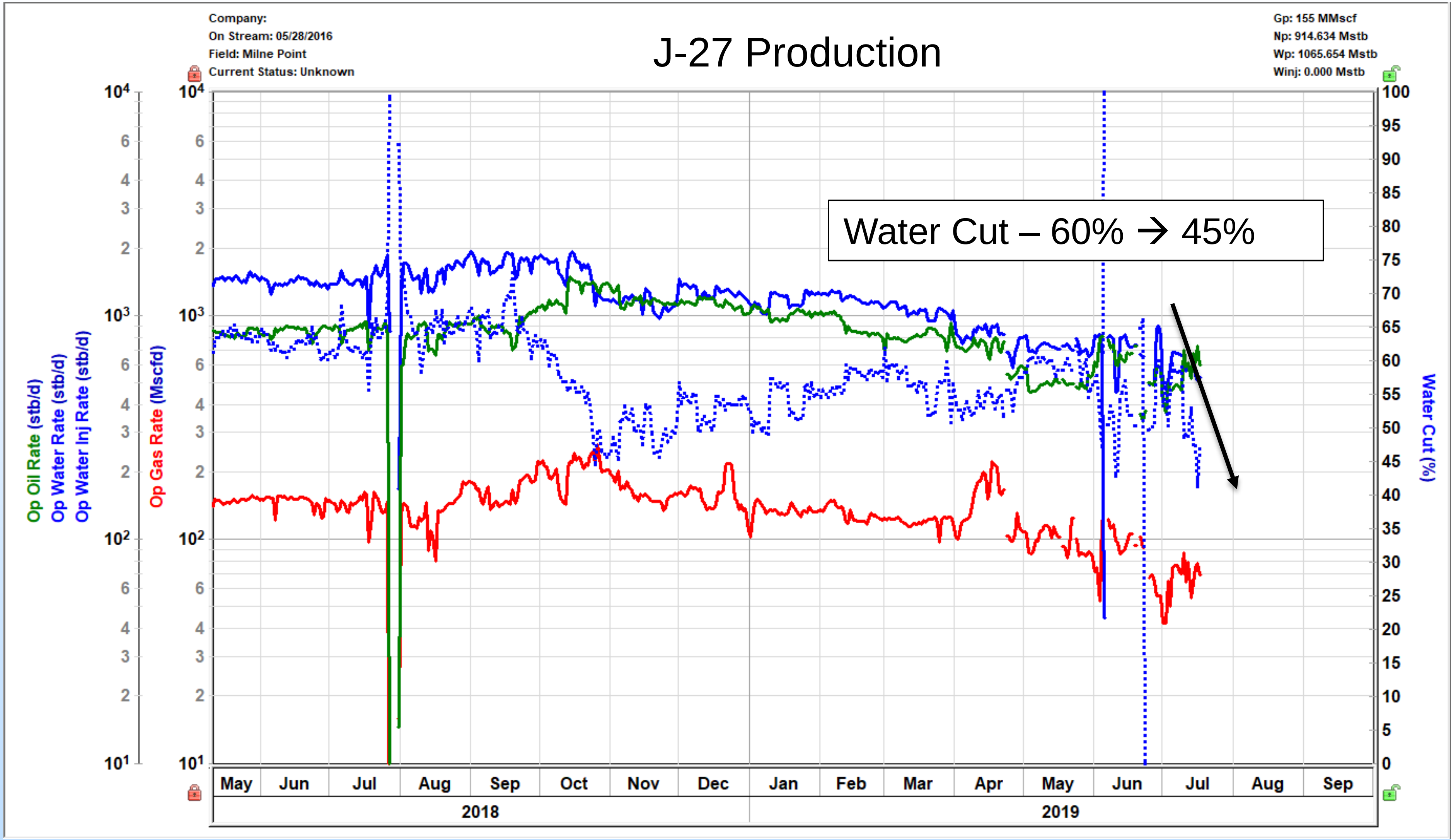


Task 5 – Polymer Field Pilot

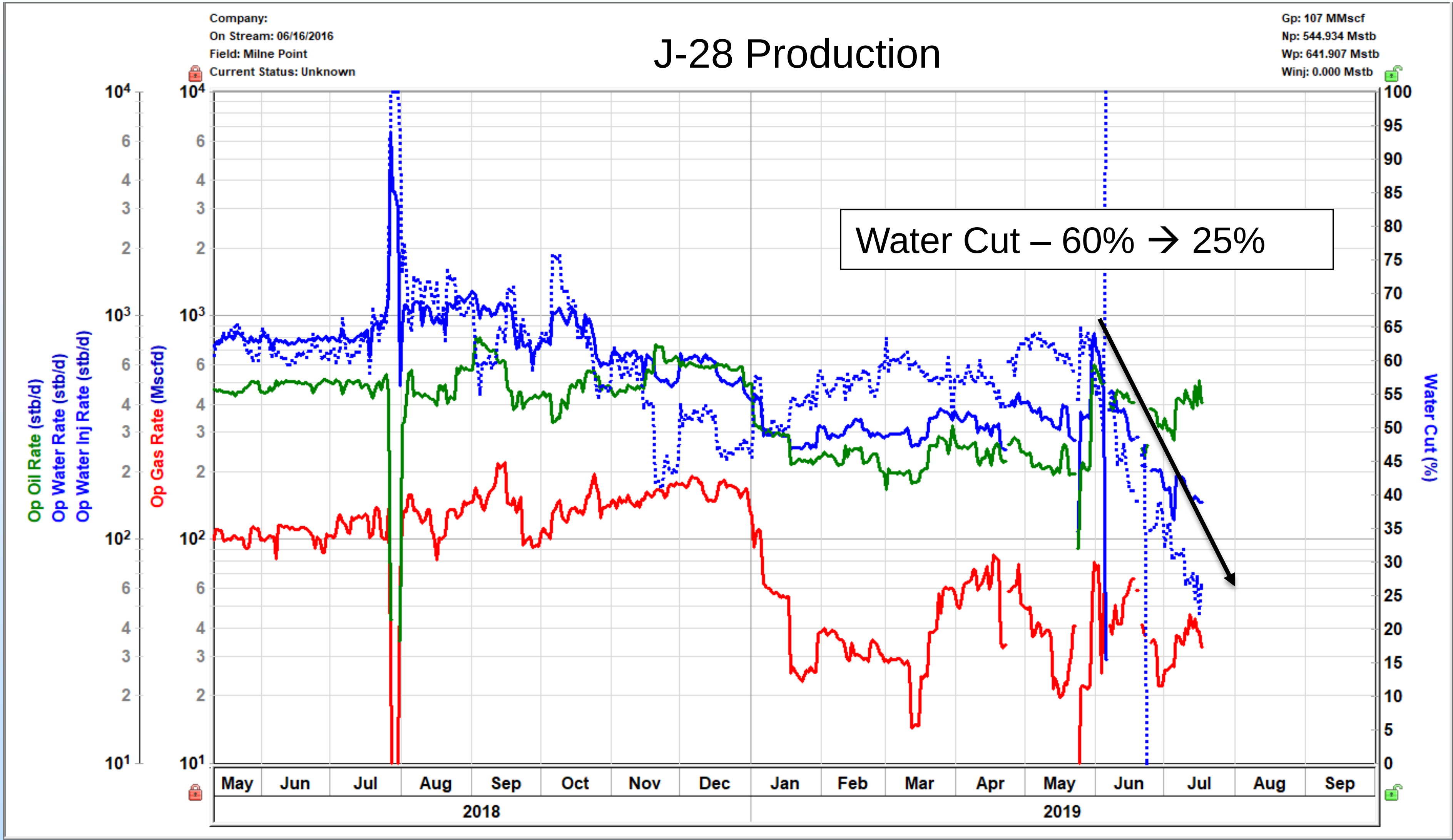


J-23A - 50% loss
J-24A - 60% loss

Task 5 – Polymer Field Pilot



Task 5 – Polymer Field Pilot



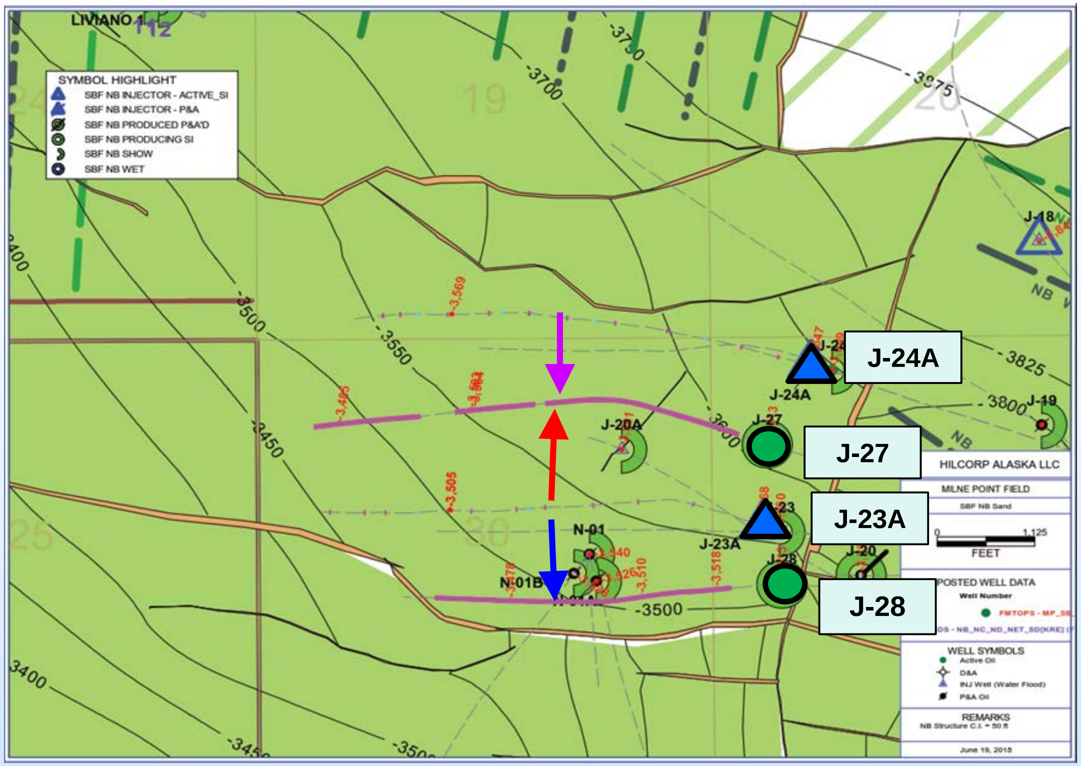
Task 5 – Polymer Field Pilot

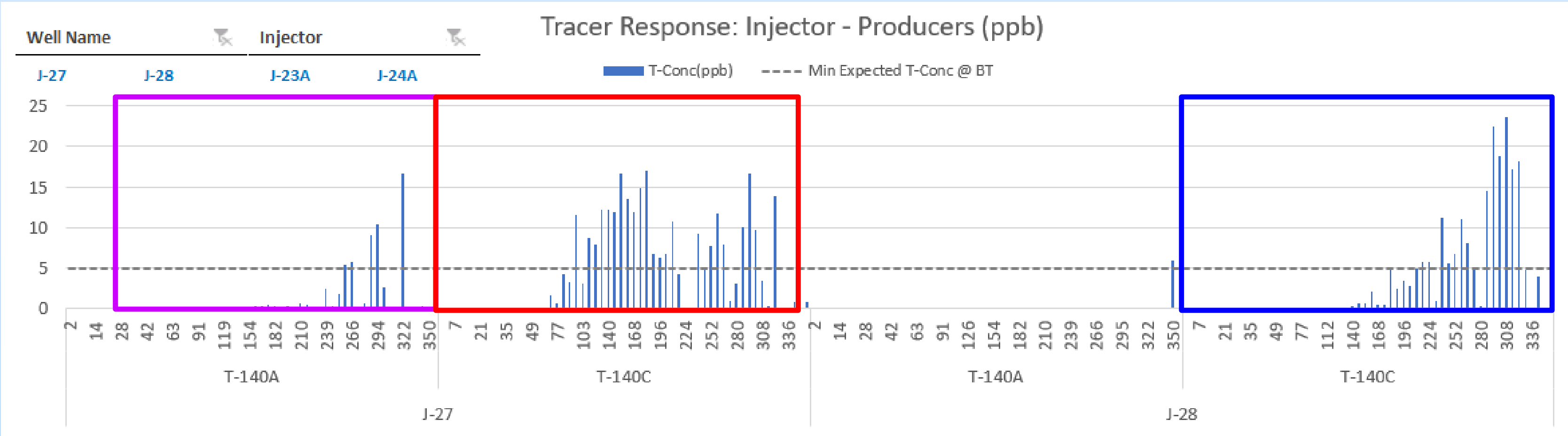
Pre Polymer Tracers

- Pumped 8/3/18 (3 week prior)
- J-23A to J-27 - 70 days
- J-23A to J-28 - 160 days
- J-24A to J-27 – 240 days

Post Polymer Tracers

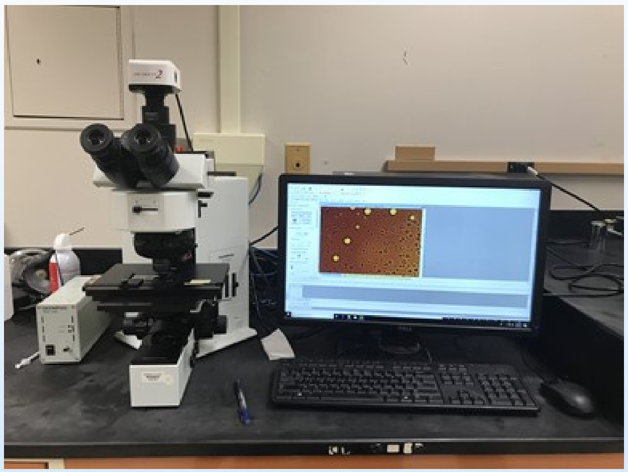
- Pumped 3/28/19
- As of 7/24/19 - No observed tracer response (118 days)

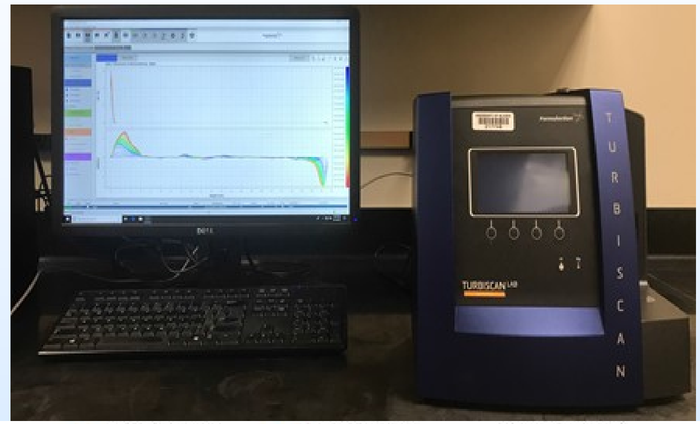


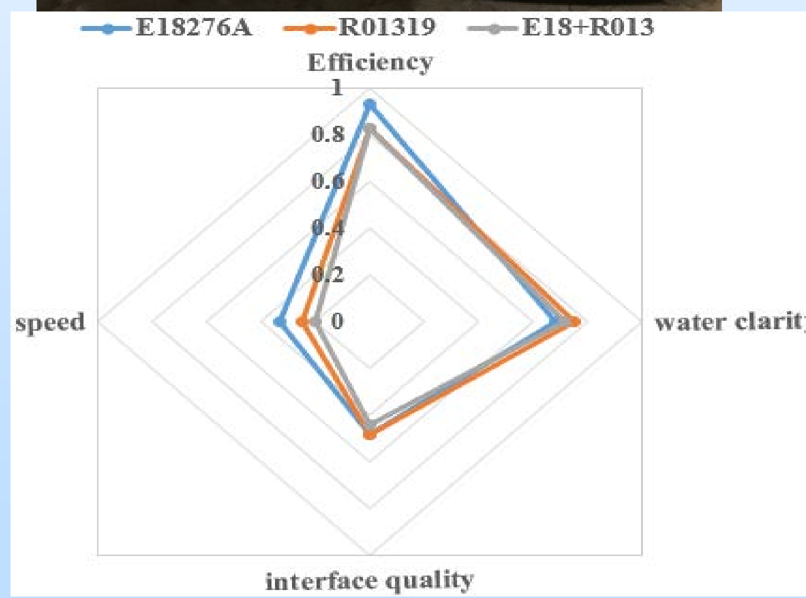


Task 6 – Treatment of Produced Fluids

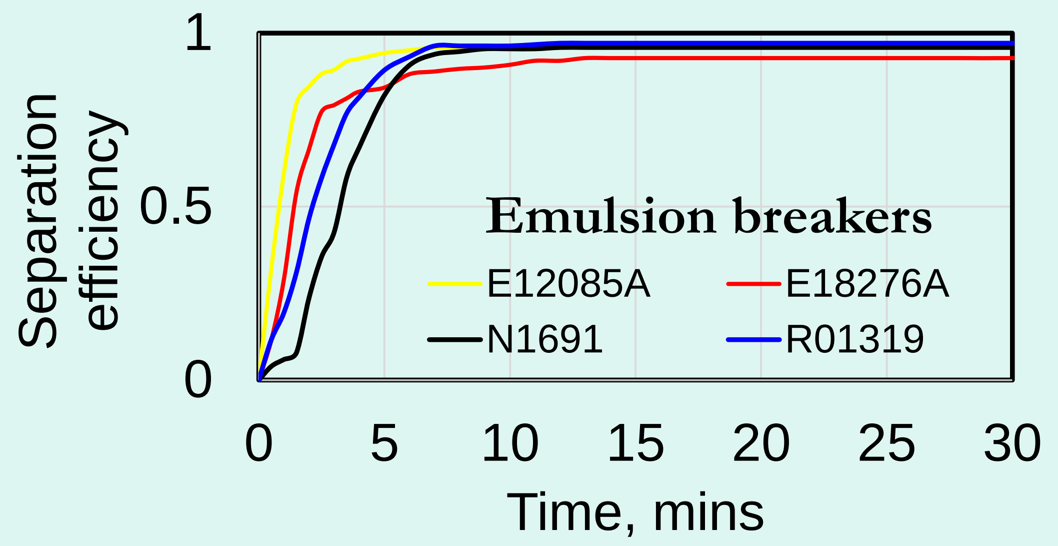
Emulsion studies







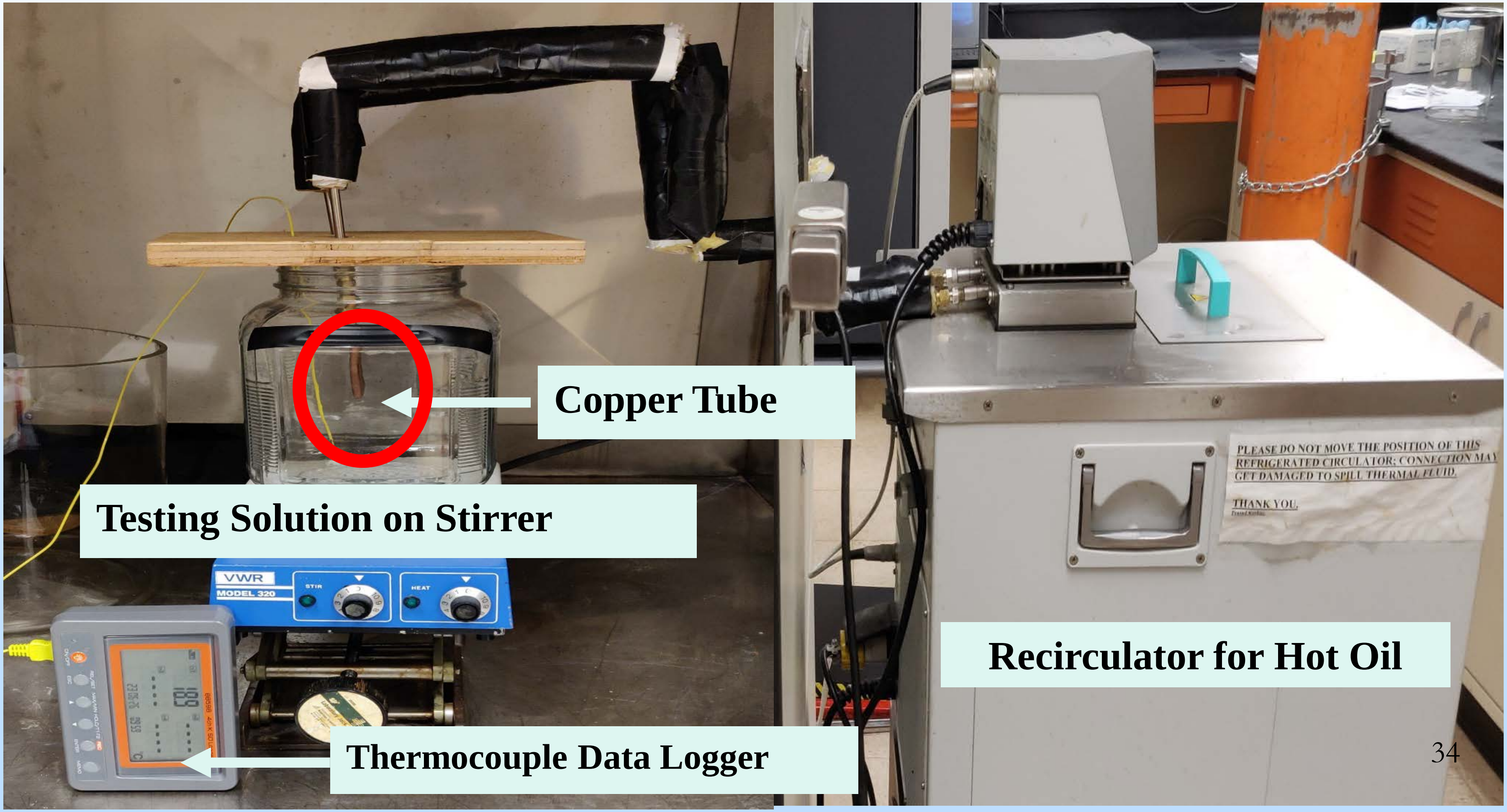
Task 6 – Treatment of Produced Fluids



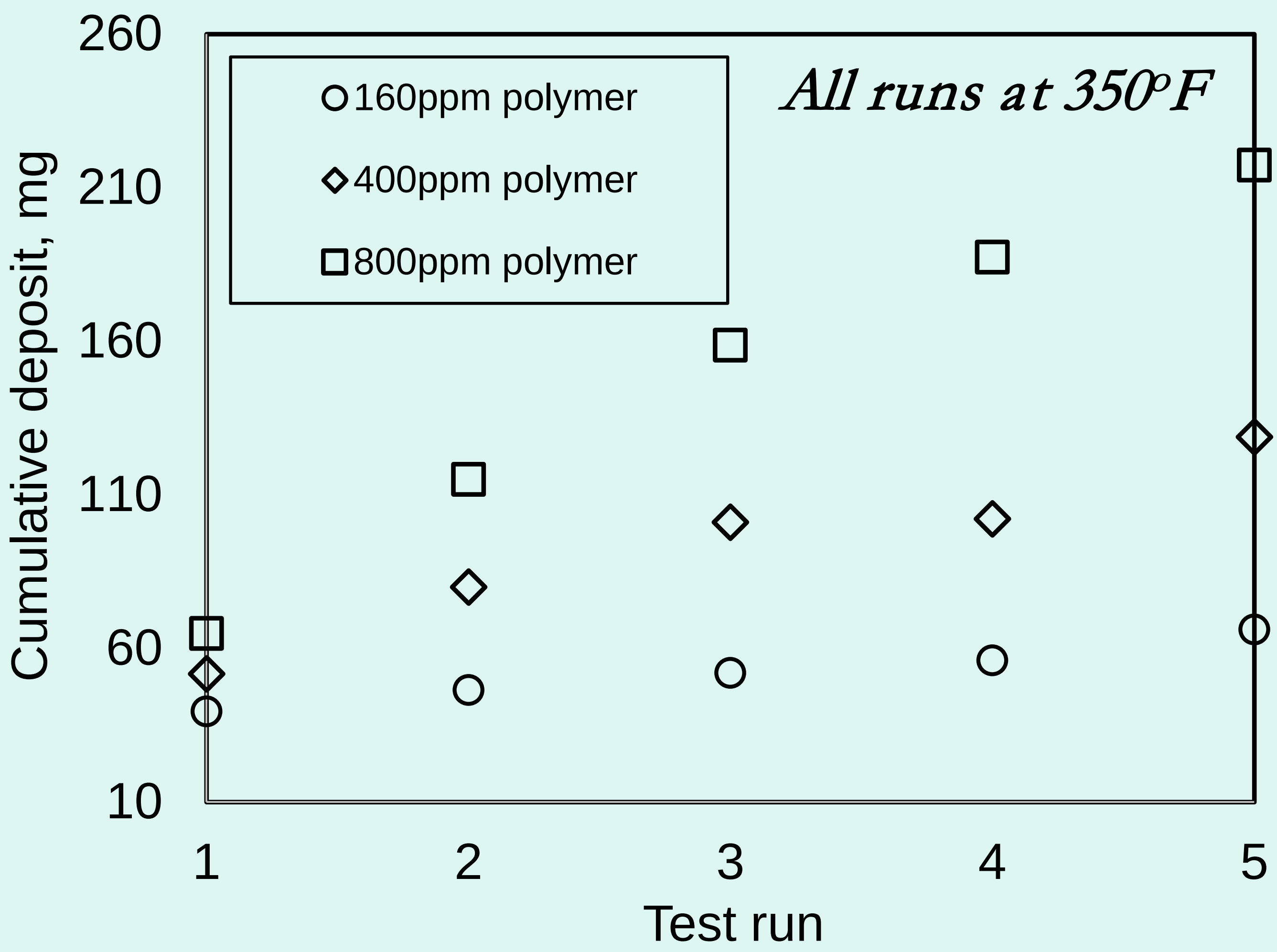
Characteristics	E12085A	E18276A	N1691	R01319
Separation efficiency	0.969889	0.931854	0.958379	0.978223
Water clarity@24hr	40.12ppm	25.39ppm	163.47ppm	29.3ppm
Interface neatness	sharp	sharp	bubble	sharp
Time for equilibrium	6mins	11mins	8mins	7mins

Task 6 – Treatment of Produced Fluids

Fouling of heater tubes



Task 6 – Treatment of Produced Fluids



Run 5 at 350°F, 160ppm

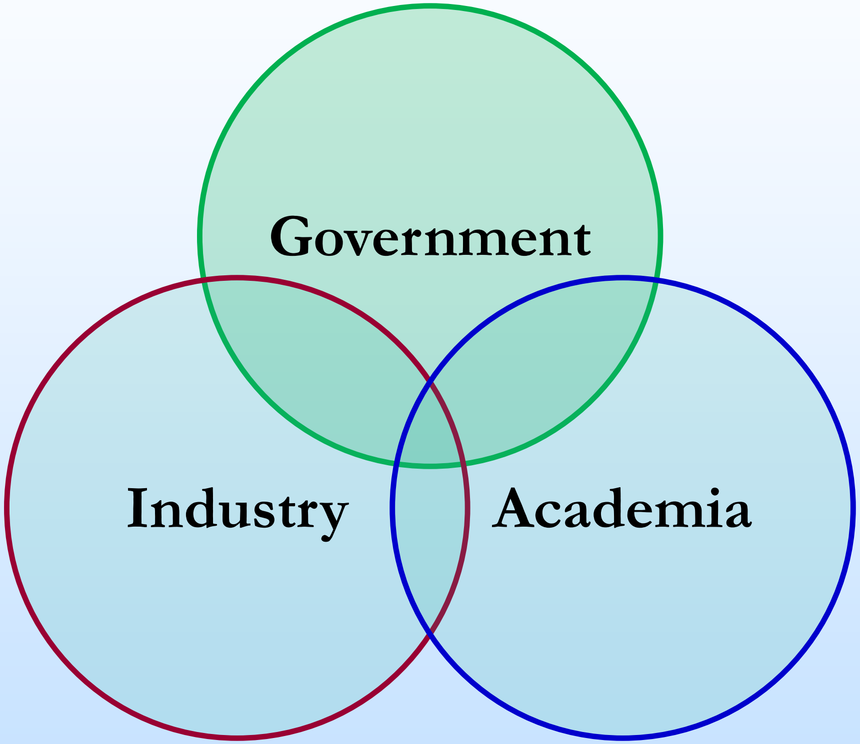
Accomplishments to Date

- Successful continuation into BP2; project on track.
- Two conference papers in a year. 2019 SPE WRM abstract received the highest TPC rating.
- Multiple polymer retention values determined.
- Consistent experimental evidence of increased oil recovery using low salinity water and low salinity polymer solution.
- History matched reservoir simulation model established.
- Pilot operations are ongoing as planned; no breakthrough yet.
- A reasonably effective emulsion breaker has been screened from bottle tests.
- Added new scope to flow assurance studies: heater tube fouling prevention.

Lessons Learned

- Multi-disciplinary industry – academia teamwork is a pre-requisite for successful execution of a research program of this scale.
- Abnormally high polymer retention values and complex O/W/O and W/O/W emulsions are scientific disappointments that constitutes some challenges for the project.
- Variability in the characteristics of the oil samples (some already containing water), including from the different pad, and uncertainty in the water composition received from the field posed challenges to some of the experimental tasks.
- More detailed reservoir heterogeneity description is necessary to achieve reasonable history match.

Synergy Opportunities



- BP Alaska, as a working interest owner, is fully supportive of the project.
- ConocoPhillips Alaska is keenly watching the developments, and is engaged in dialog with Hilcorp on the specifics of the field pilot.
- We believe that the short term polymer injectivity test and planned pilot polymer flood test by Eni Petroleum in Nikaitchuq was inspired by this field pilot.
- The (success) of this project will be an excellent segue into unlocking the stranded heavy oil in the Ugnu area.
- Access to field samples and data in the near future, conducive to continued public – private partnership.

Project Summary

- The project is currently on track and within budget, and has met all BP1 objectives and deliverables by the end of BP1, and has embarked on BP2.
- Given the (field) nature of this project, it is important to recognize that the polymer flood pilot is integrated with all the other supporting tasks, i.e., lab work, reservoir simulation, and flow assurance in an iterative optimization process.
- Resolved 2 biggest concerns: Pilot wells exhibited better polymer injectivity than predicted by models; No fast polymer breakthrough after nearly 1 year of polymer injection.
- It is still too early to quantify incremental oil recovery from polymer injection; however, the team is cautiously optimistic.

Appendix

– These slides will not be discussed during the presentation, but are mandatory.

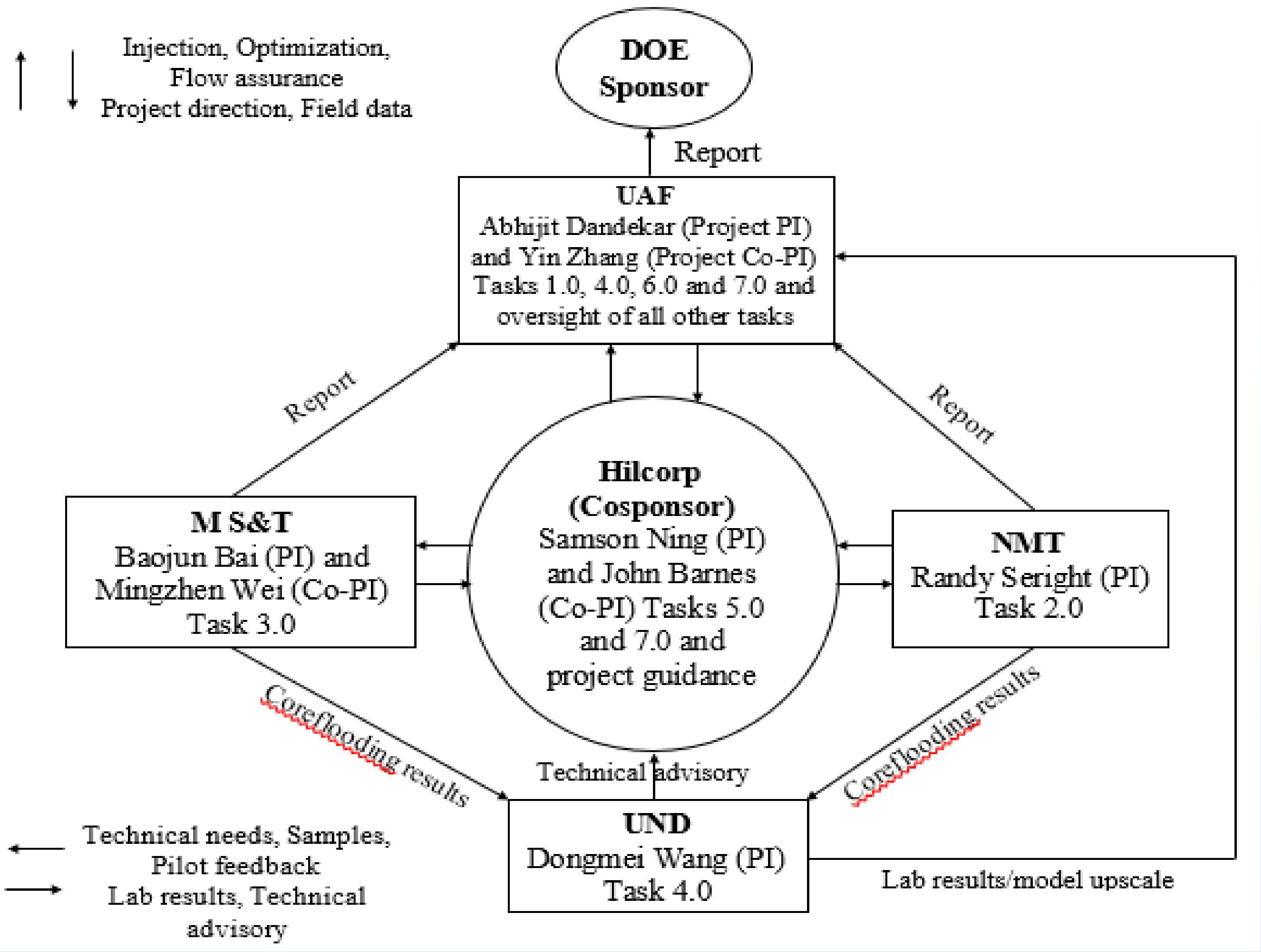
Benefit to the Program

- The primary goal of ANSFL project is to validate the use of polymer floods for heavy oil Enhanced Oil Recovery (EOR) on Alaska North Slope (ANS).
- Benefits to accrue from the proposed research:
  - 8-10% of OOIP recovery increment over waterflooding.
  - Extrapolate the results to the heavier Ugnu oil deposits on ANS.
  - Extend the life of the Trans Alaska Pipeline System.
  - Environmentally friendly EOR method.

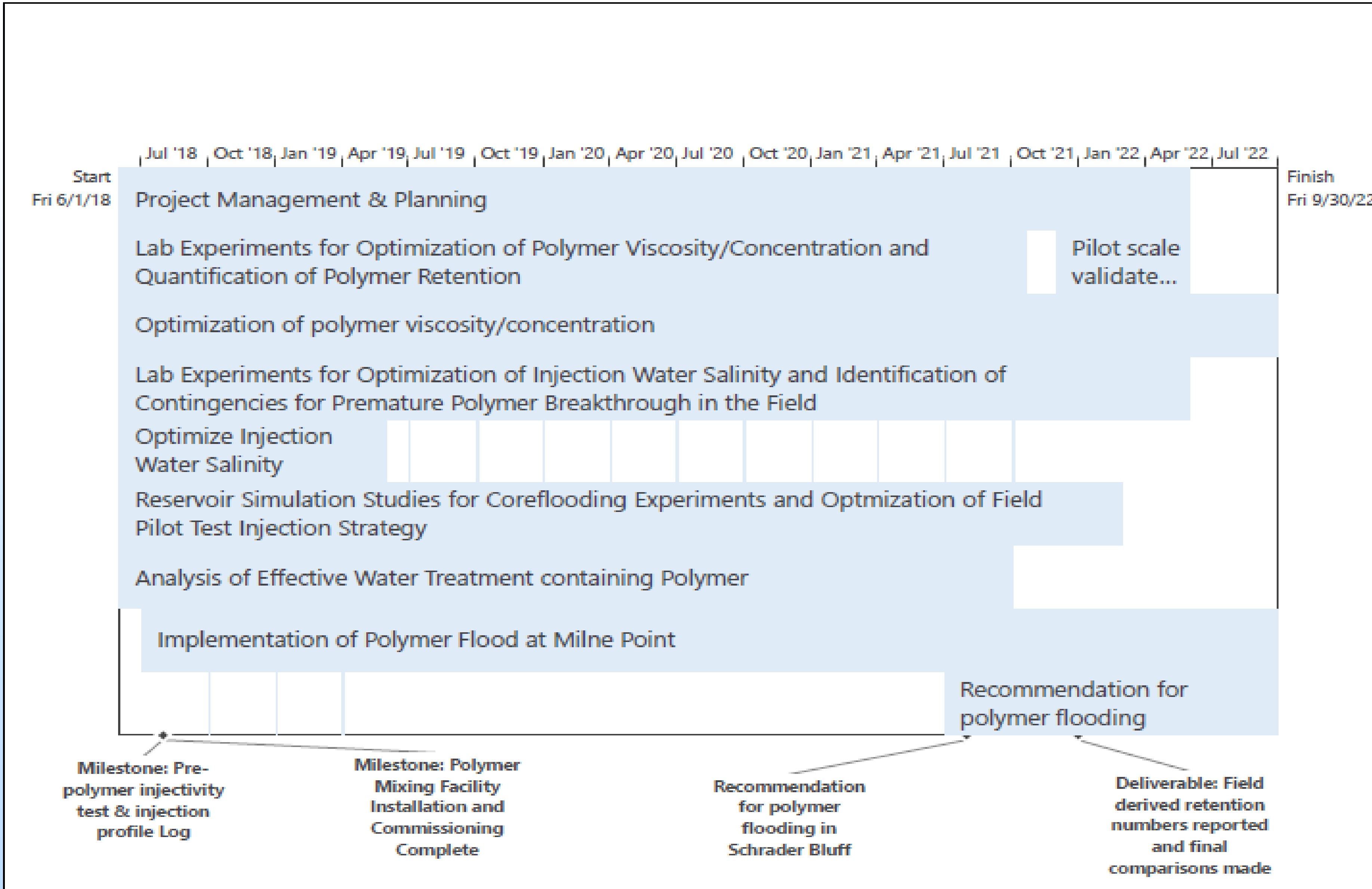
Project Overview
Goals and Objectives

- The specific objectives that would enable the achievement of project goals:
  - assess polymer injectivity into the Schrader Bluff formations
  - evaluate water salinity effect
  - estimate polymer retention
  - assess incremental oil recovery vs. polymer injected
  - assess effect of polymer flow back on surface facilities
- Major decision points and the success criteria based on:
  - polymer injectivity
  - conformance control
  - impact of produced polymer on facilities
  - switching from polymer to water injection
  - feasibility of polymer flood

Organization Chart



Gantt Chart



Jul '18
Oct '18
Jan '19
Apr '19
Jul '19
Oct '19
Jan '20
Apr '20
Jul '20
Oct '20
Jan '21
Apr '21
Jul '21
Oct '21
Jan '22
Apr '22
Jul '22
Start
Fri 6/1/18
Finish
Fri 9/30/22
Project Management & Planning
Lab Experiments for Optimization of Polymer Viscosity/Concentration and Quantification of Polymer Retention
Pilot scale validate...
Optimization of polymer viscosity/concentration
Lab Experiments for Optimization of Injection Water Salinity and Identification of Contingencies for Premature Polymer Breakthrough in the Field
Optimize Injection Water Salinity
Reservoir Simulation Studies for Coreflooding Experiments and Optmization of Field Pilot Test Injection Strategy
Analysis of Effective Water Treatment containing Polymer
Implementation of Polymer Flood at Milne Point
Recommendation for polymer flooding
Milestone: Pre-polymer injectivity test & injection profile Log
Milestone: Polymer Mixing Facility Installation and Commissioning Complete
Recommendation for polymer flooding in Schrader Bluff
Deliverable: Field derived retention numbers reported and final comparisons made

Bibliography

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❖ ***Three abstracts to be submitted to the 2020 IOR Conference – one each on reservoir simulation; oil-water separation; and heater fouling studies***

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