
Technology Collaboration Programme
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eor
Enhanced Oil Recovery

Implementing EOR Offshore Europe

Success and learnings from the Captain field

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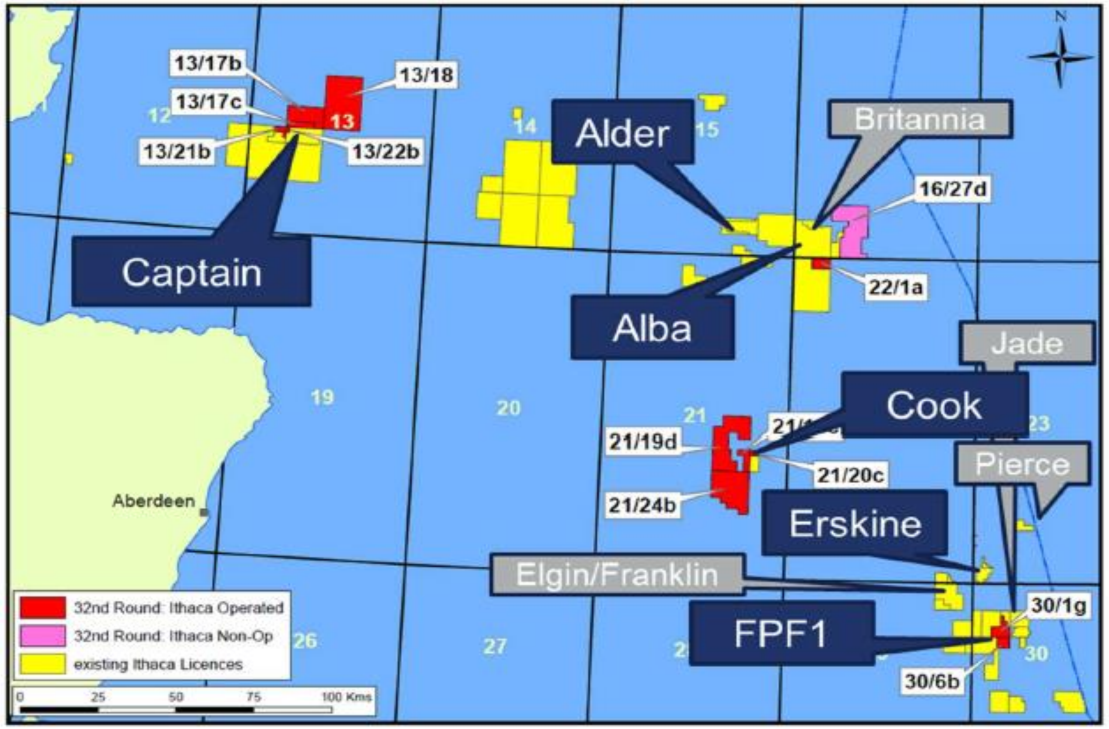
IEA EOR TCP

Enhanced Oil Recovery

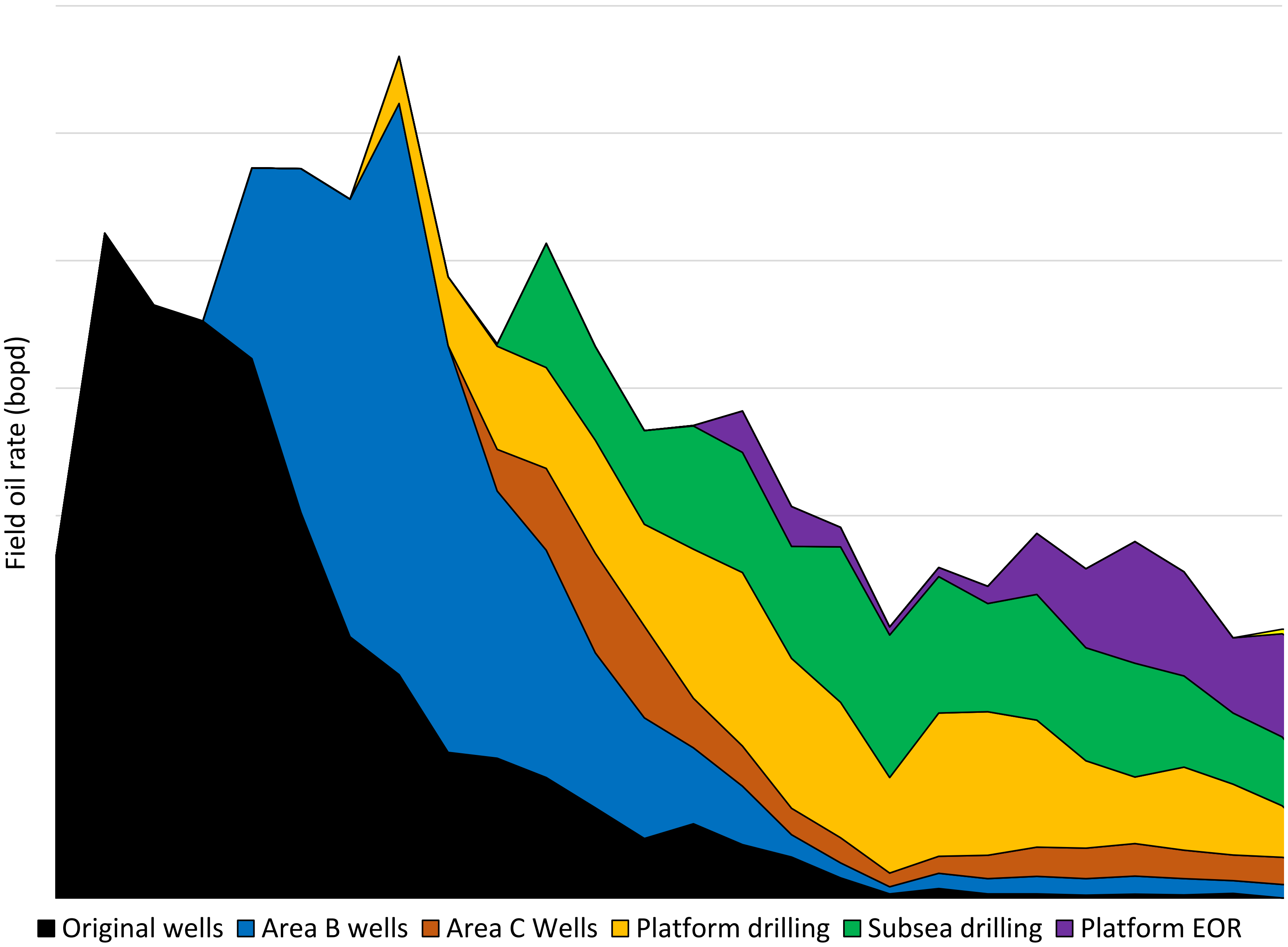
Captain Asset Overview



- Operated by Ithaca Energy (UK) Ltd (85%) with Dana Petroleum (E&P) Limited (15%)
- Offshore UK North Sea
- Discovered 1977, 1st production 1997
- 1 billion barrels STOOIP
- Sea depth 350ft

- 3 - 11 Darcy sandstones
- Temperature = 31˚C
- Pressure = 1,270psi
- Oil 40 - 140 cP
- End-point mobility Ratio for Waterflood ~40
- Produced Water Re-Injection
- 94% watercut

Captain production performance from waterflood



Water has a viscosity of ~ 0.85cP
Oil 80+cP

Viscosity ratio ~ 100:1

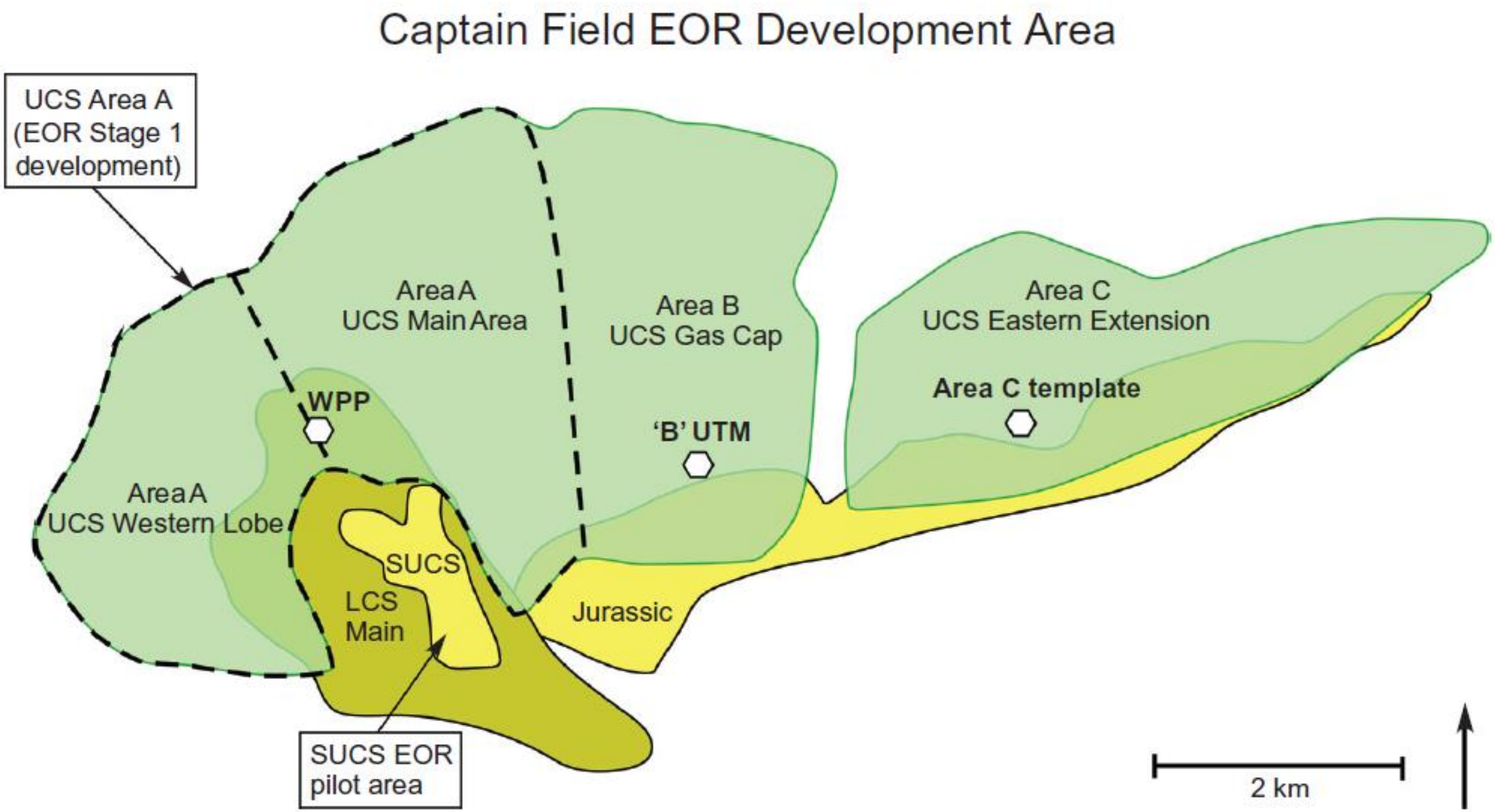
Very unstable displacement of oil by water

Very fast water breakthrough, water slumping and bypassed oil left in the reservoir

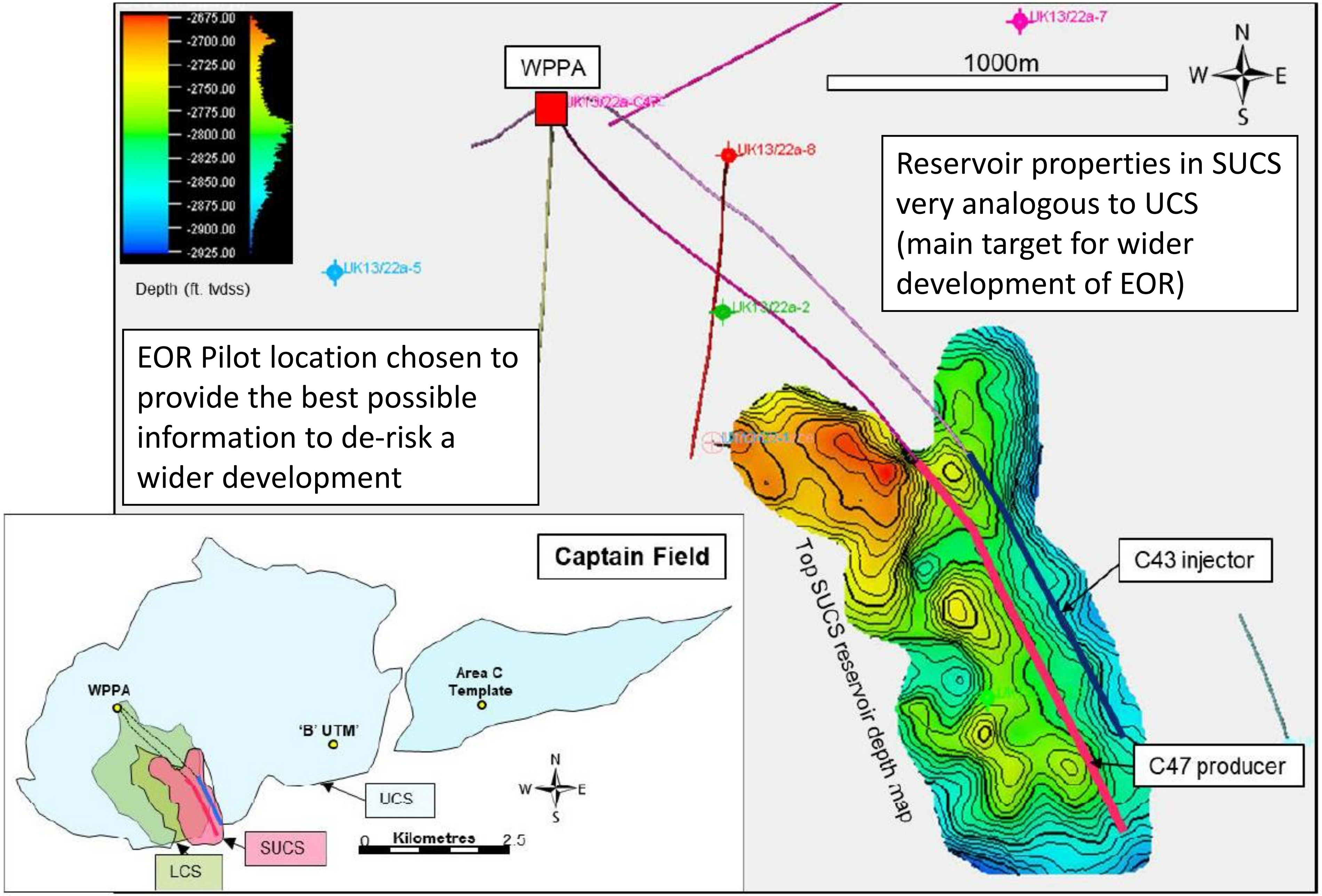
Very steep oil rate decline from new wells

Prior to polymer injection, infill drilling targeted the stranded oil in the reservoir (108) but target size has been reducing

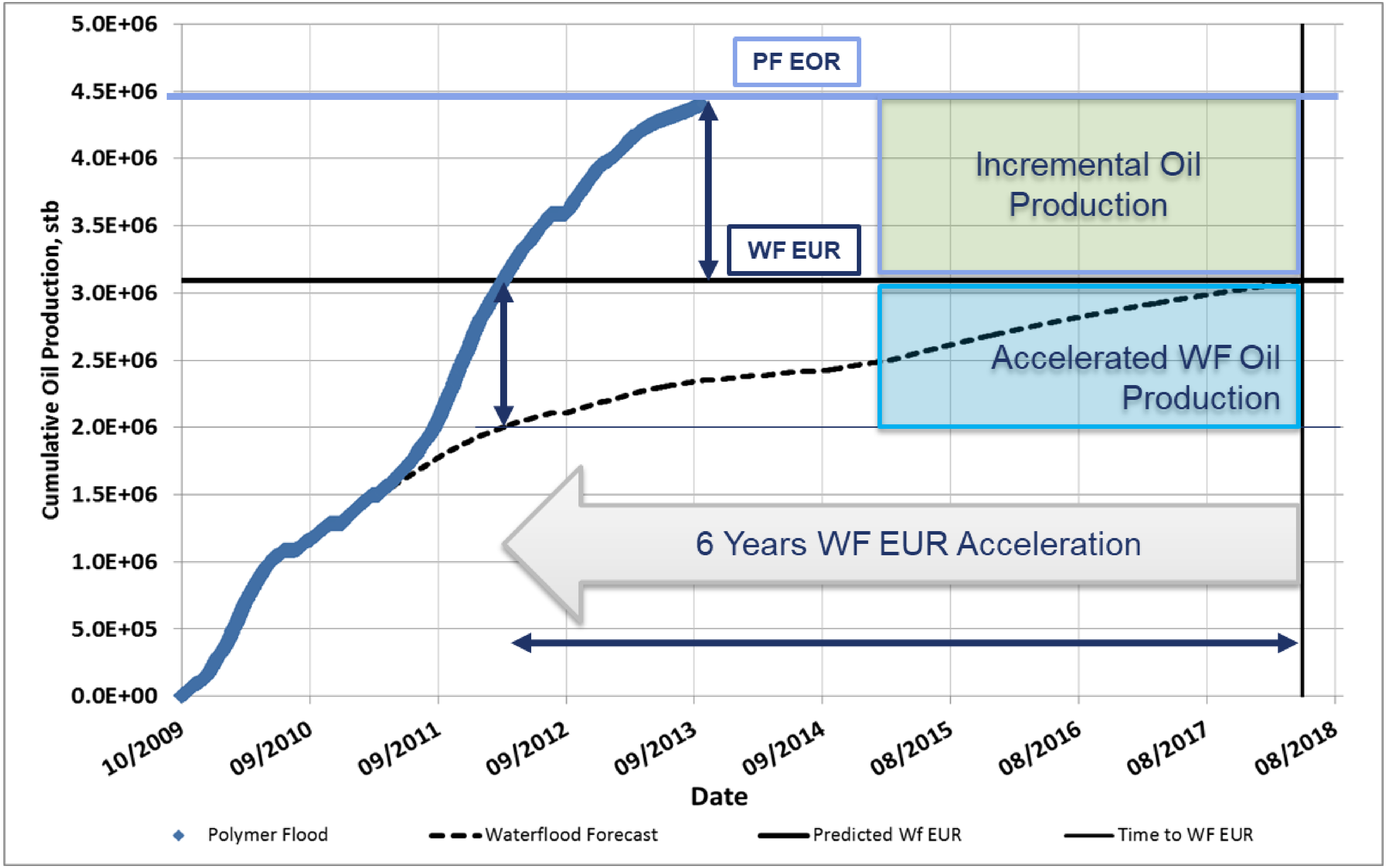
Captain, with SUCS pilot location



Pilot 1: SUCS (Southern Upper Captain Sand) Location



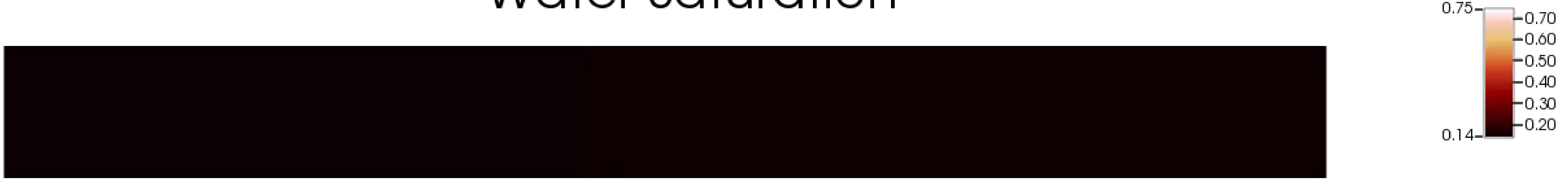
Pilot 1: SUCS Results: Increased oil recovery and significant acceleration



Field Scale Simulations – 2D Vertical

- Significant water slumping
- High water saturation at bottom of reservoir
- Attic oil completely un-swept by water flooding
- Polymer slug crossflows oil into water channels before sweeping attic oil

Water Saturation



Water Viscosity

Why do we need to do lab work to support Captain?

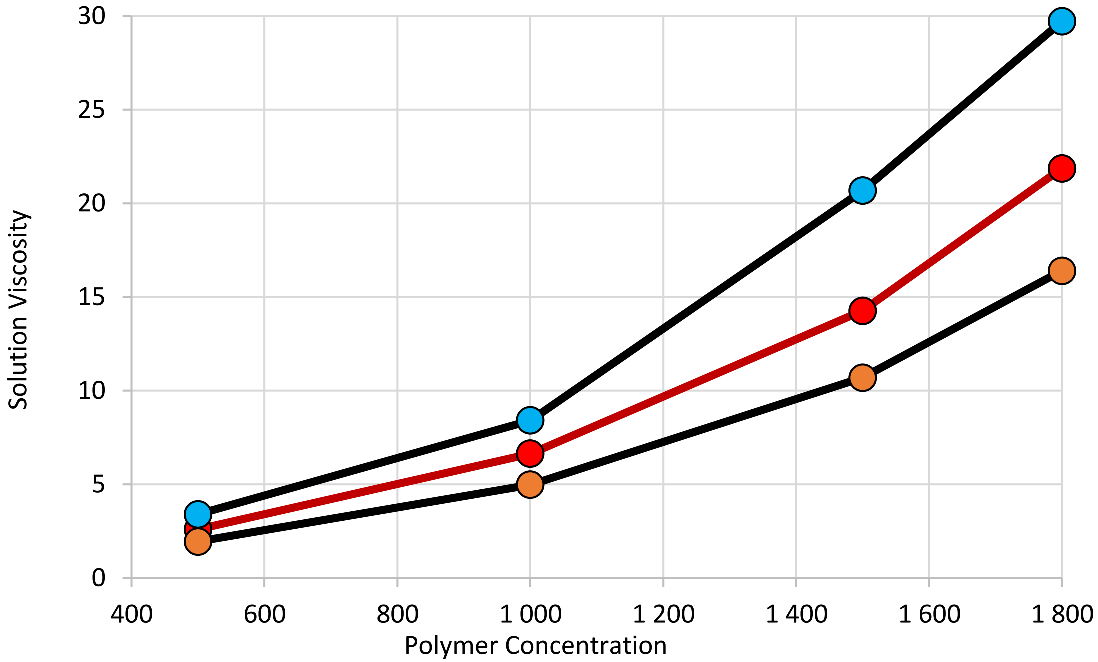
1. Polymer viscosity

- The injected polymer solution has been chosen to maximise the oil recovery
- Loss of polymer viscosity reduces sweep to the production wells and results in a loss of oil rate

- Careful to ensure the target injection viscosity is met through QAQC of the delivered and injected product

- Polymer solution viscosity may be lost in a number of ways, including:
    a) Under-dosing the injection wells (too low concentration)
    b) Low yield from delivered product
        a) Batch to batch variation
        b) Poor inversion
    c) Polymer degradation
        a) Chemical, Mechanical, Thermal

- Each of these is tested in the labs to identify any potential issues and minimise their effect in the field



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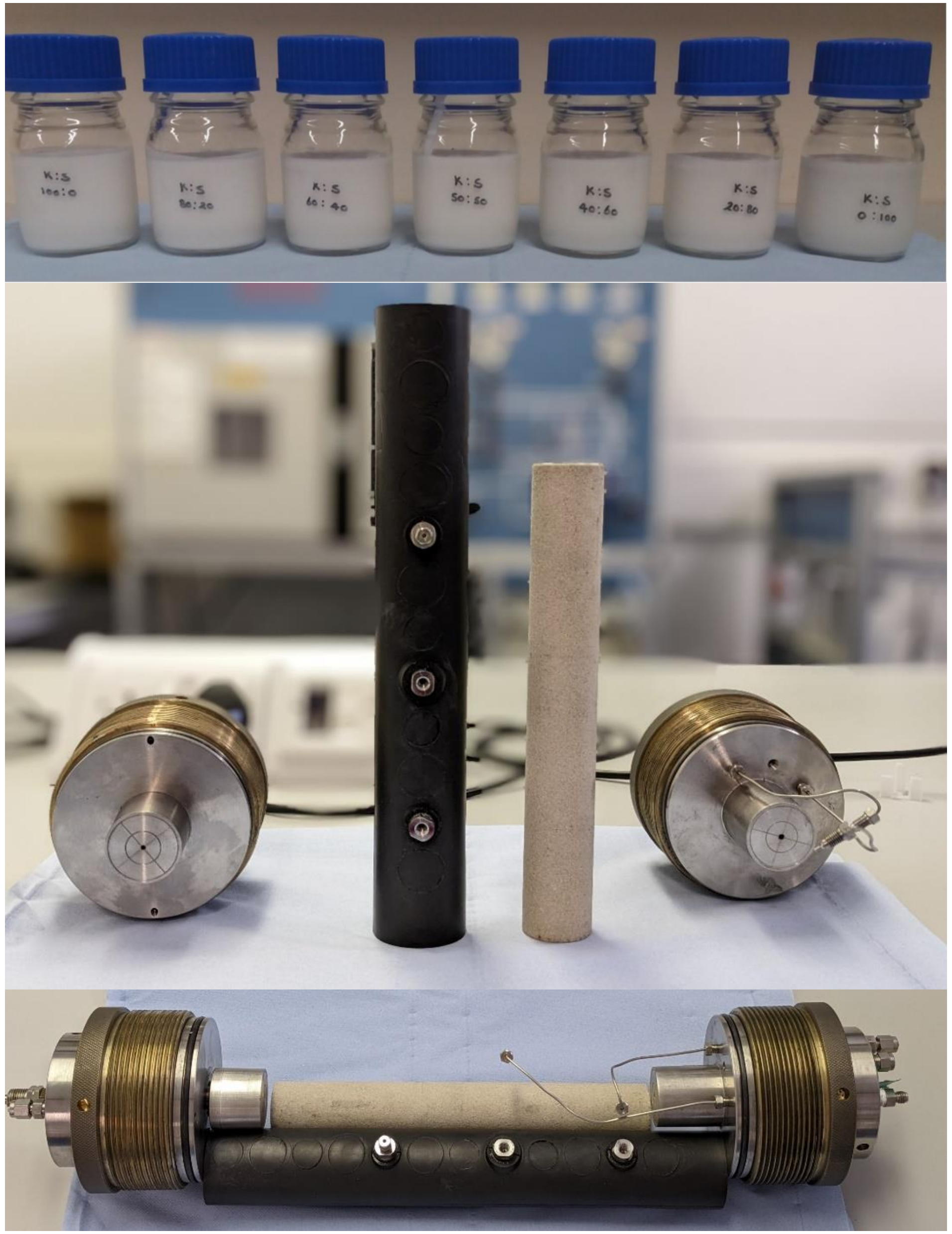


2.Injectivity

- Injection rates need to be kept high to maximise oil recovery
- Loss of injectivity reduces sweep to the production wells and also reduces the overall field water handling capacity

- Ensure the highest possible injectivity. Minimise damage from the polymer products, and identify the root causes of injection decline in all wells

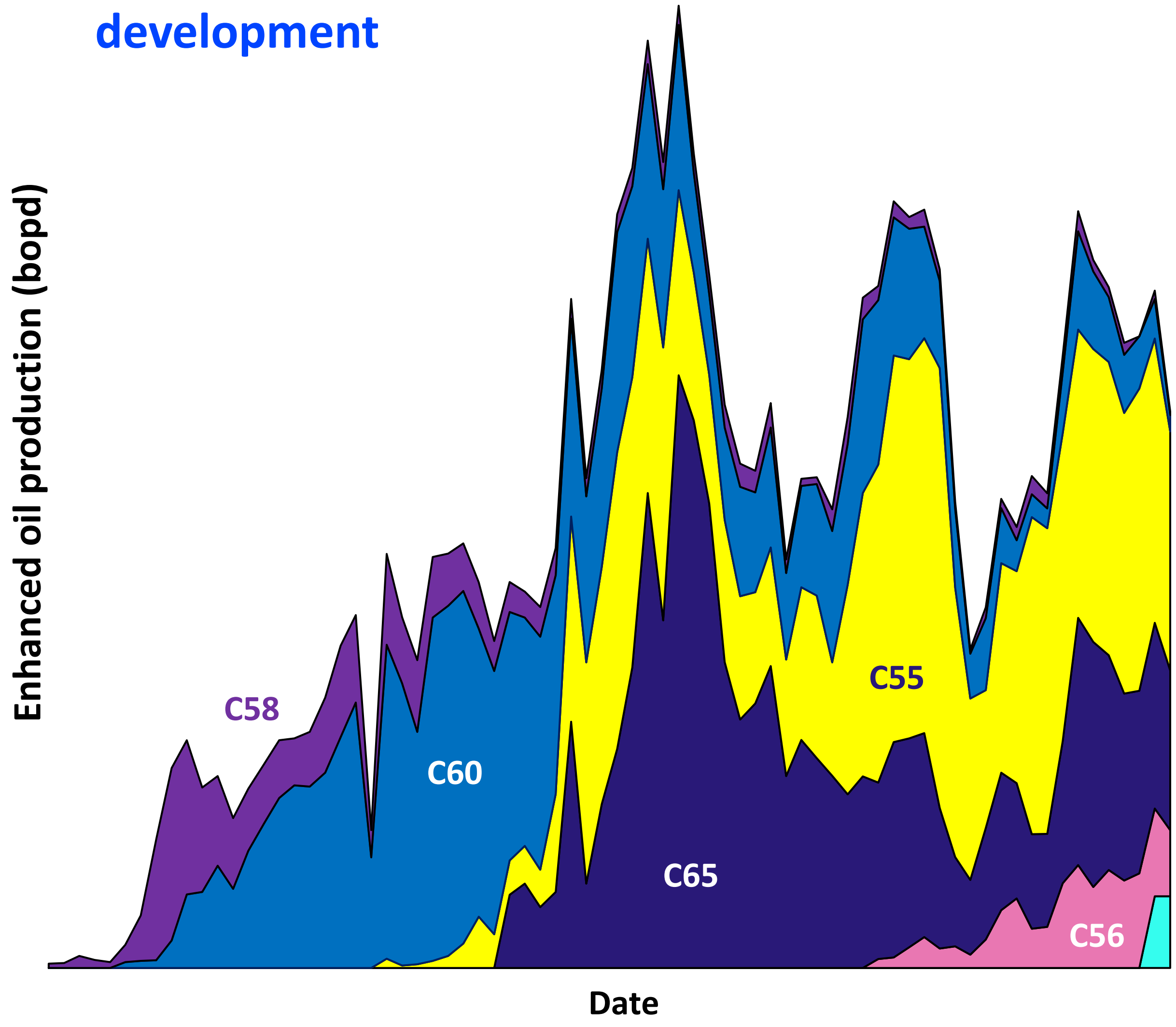
- Root causes of field injection decline are investigated, which may be due to oil in water, fines, bacteria or the polymer itself

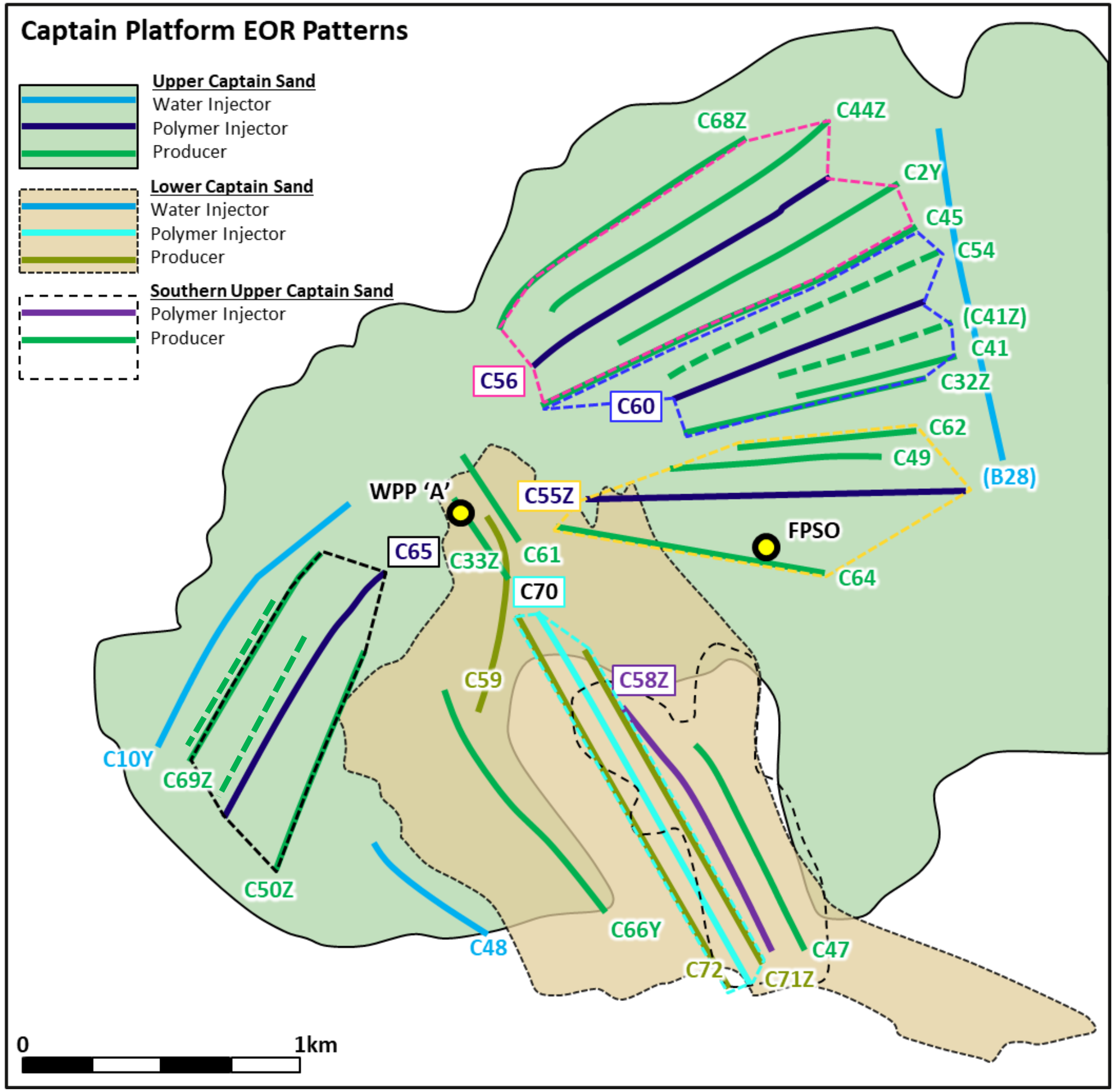
- Injectivity loss may result from the polymer in a number of ways (gels, inversion, incompatibility)

- Lab testing ensures injectivity during the polymerflood remains high through product QAQC

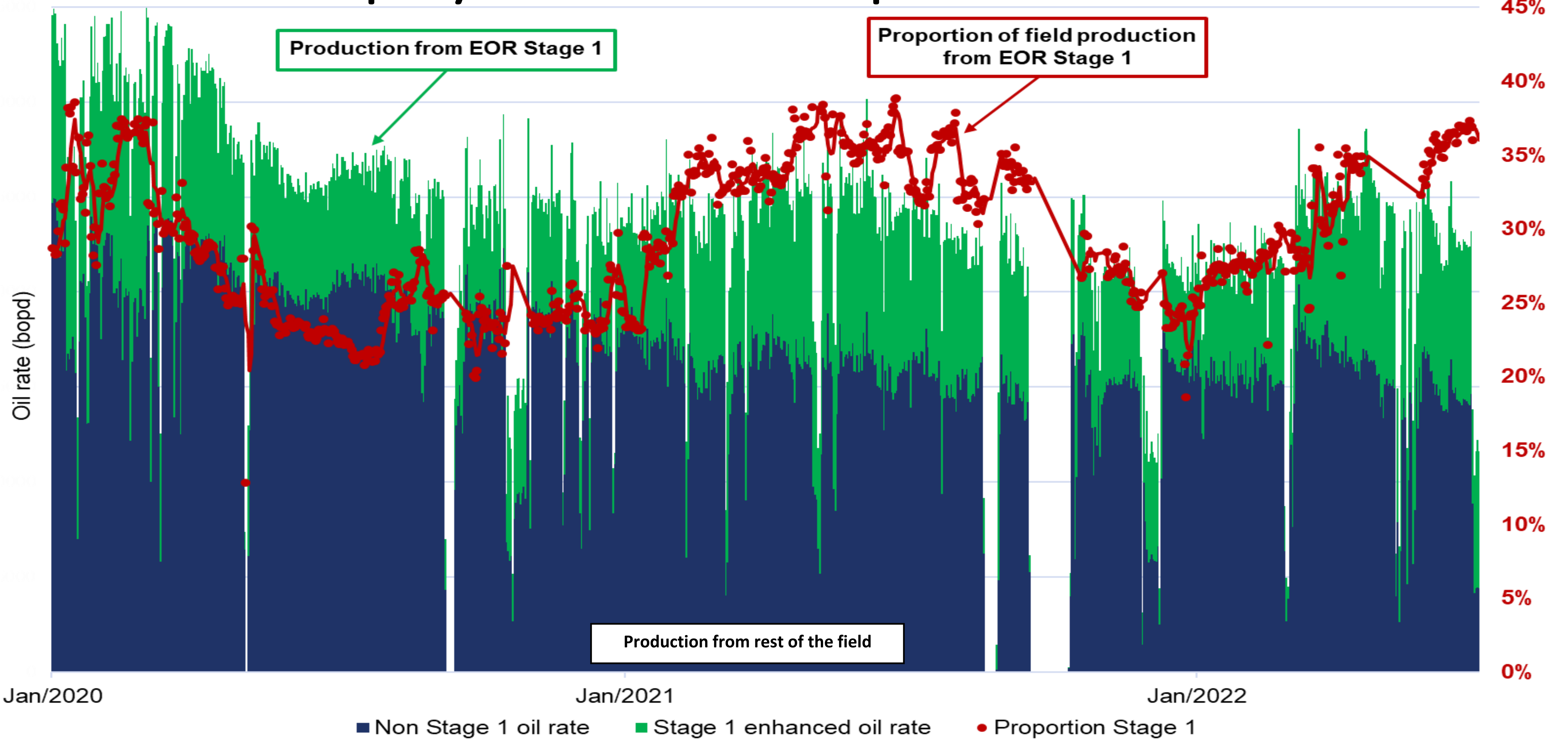
Enhanced oil production across Captain

Consistent enhanced oil success across the Captain reservoir development

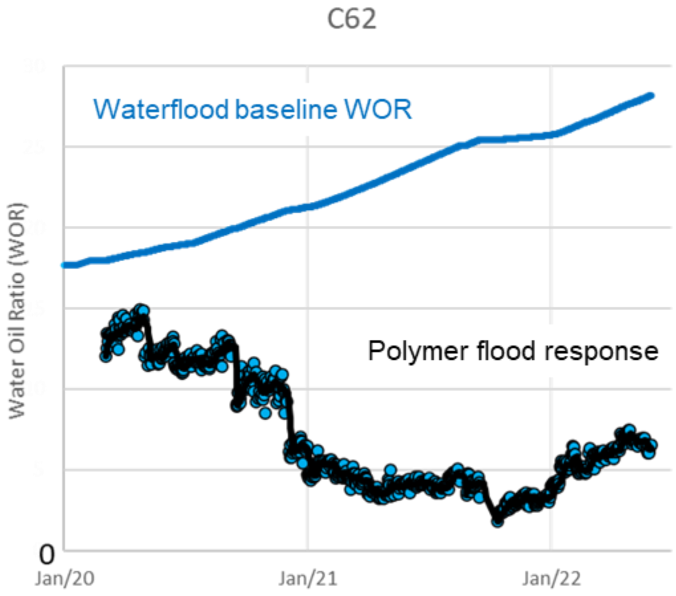


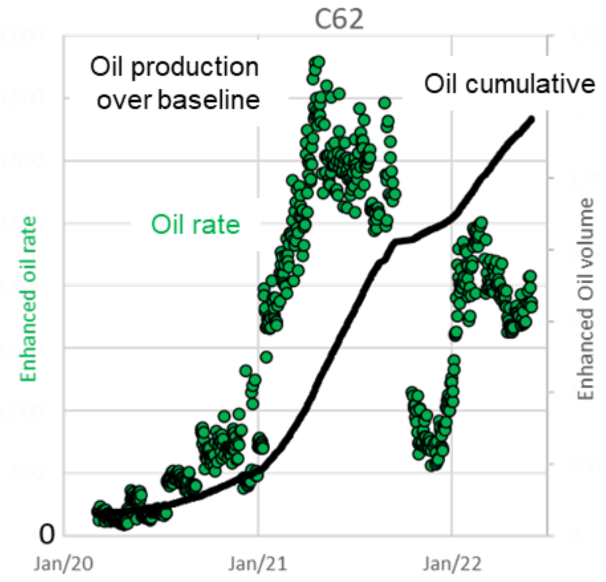


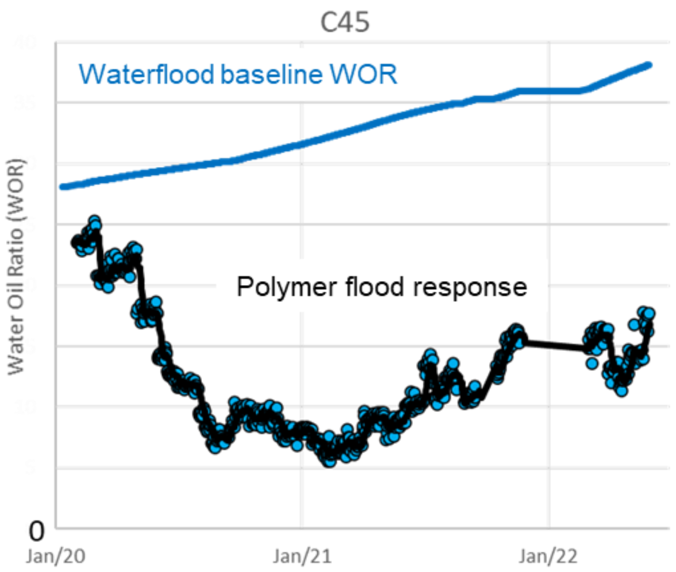
Contribution of production associated with polymerflood at Captain

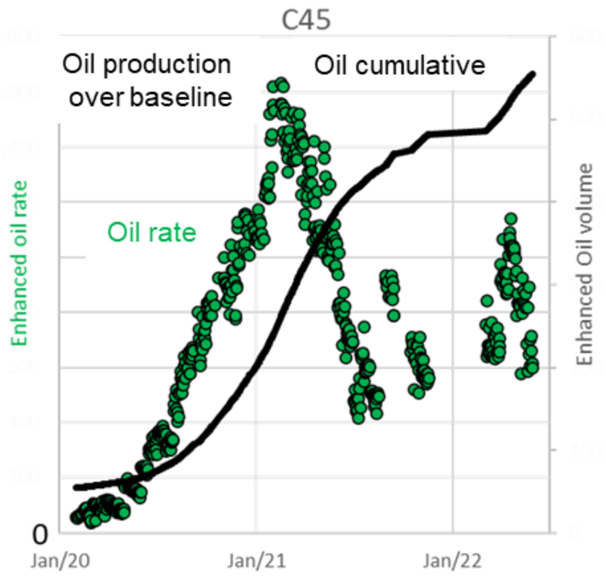


Examples of Water Oil Ratio (WOR) reduction through polymerflood









- Sharp WOR reduction observed across the well stock for EOR Stage 1
- These reproduced the behaviours and success observed in the EOR pilots
- First and second line wells have shown the same success – expanding the flood size and increasing the pore volume
- Response is characterised by a sharp WOR reduction, followed by a gradual increase over time
- Orientation of the well and geology play a large role in the response characteristics

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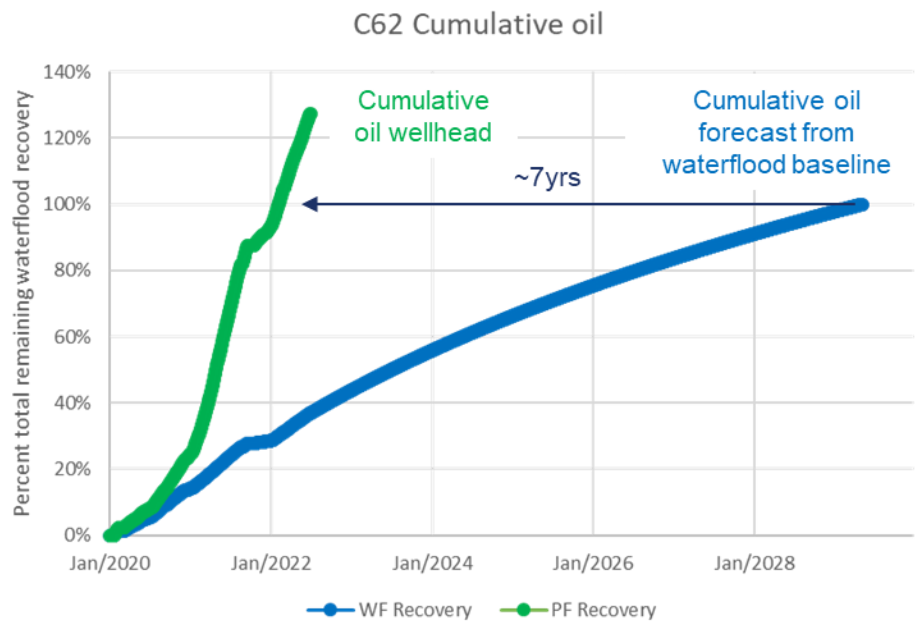
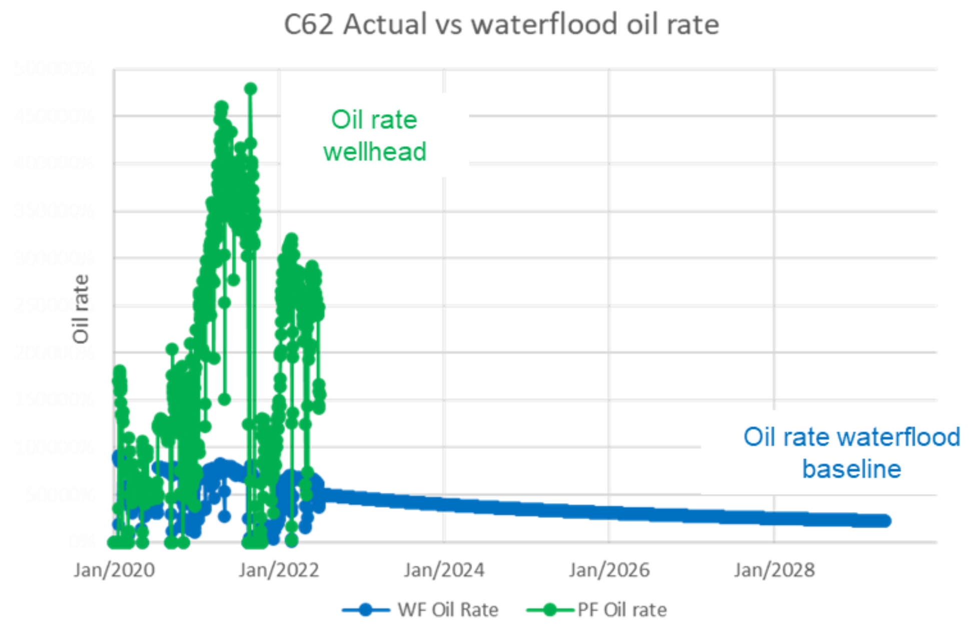
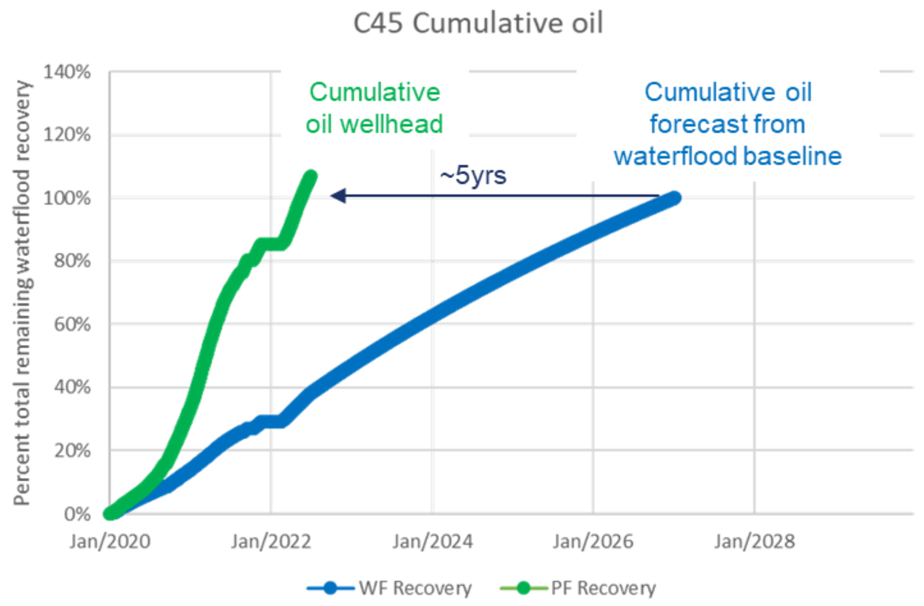
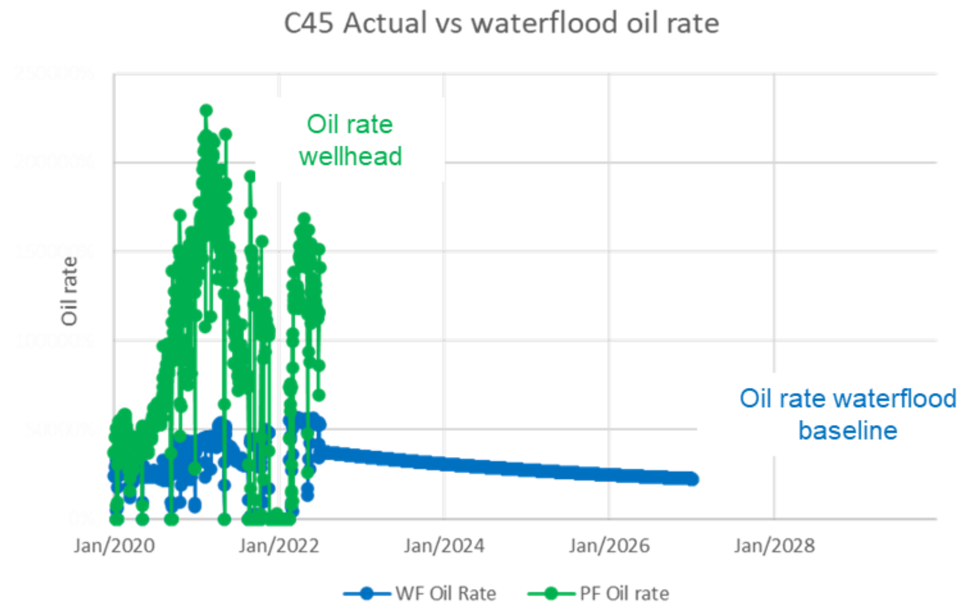




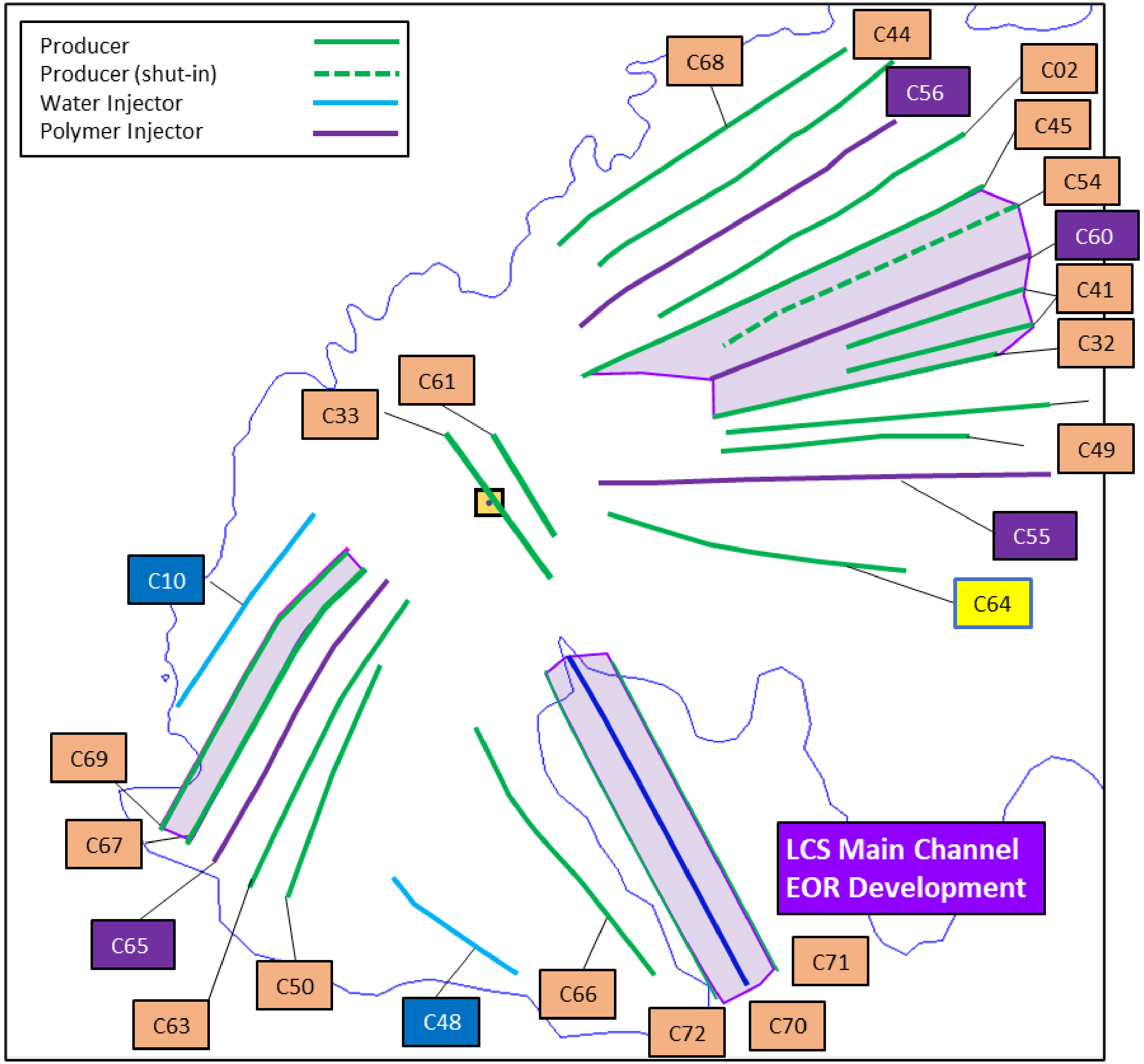




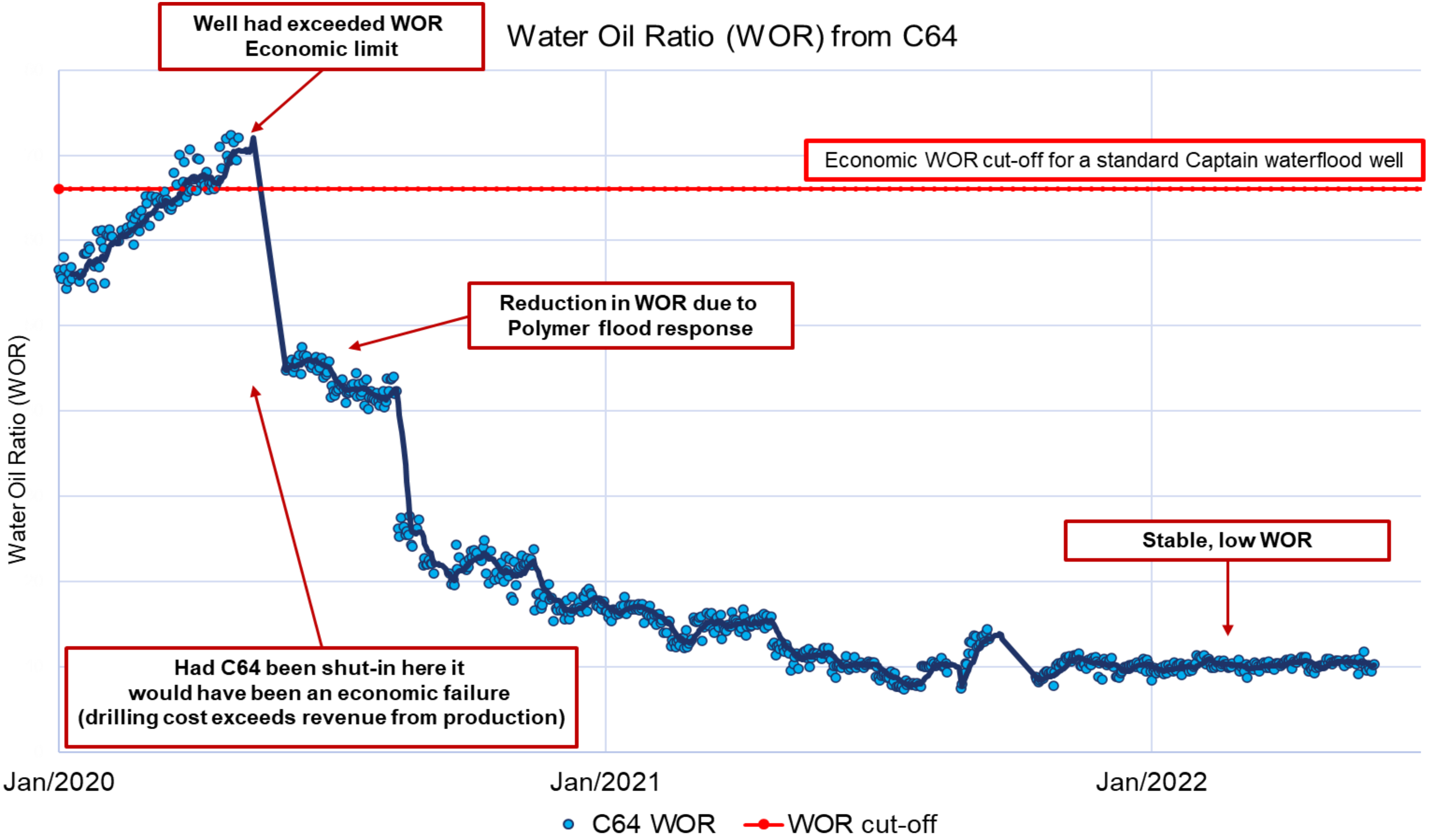
C64 - non-economic target made economic through polymerflood

Economic success story:

- **C64 located in C55 pattern, south of C55 (injection well)**
- **A non economic target under waterflood – very poor oil recovery due to swept location**
- **Polymerflood response observed in 2020**
- **Second highest well by oil rate in the whole Captain field inventory by 2021**
- **Still producing significant oil volumes in 2022**



Example of non-economic target made economic through polymerflood



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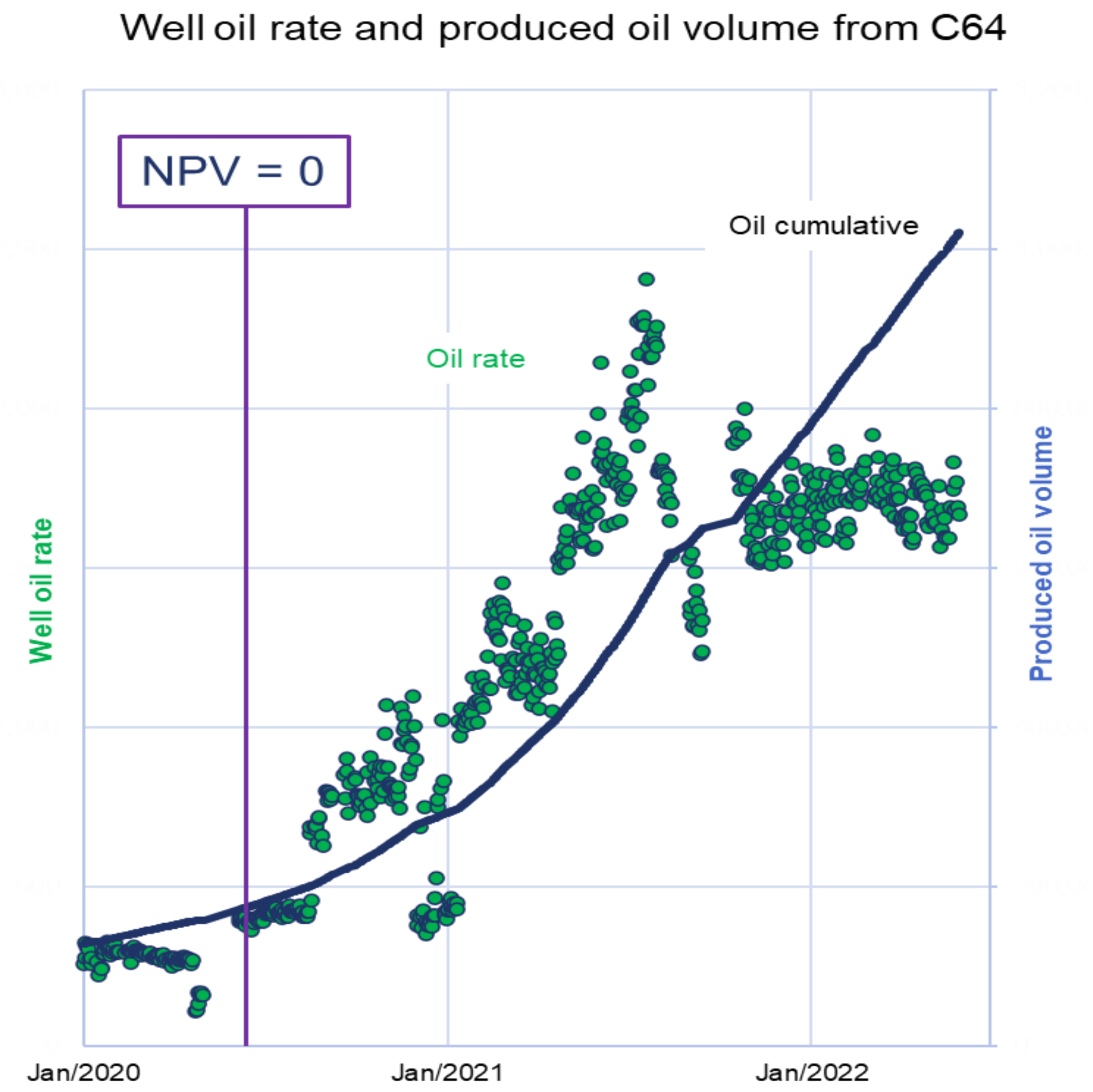
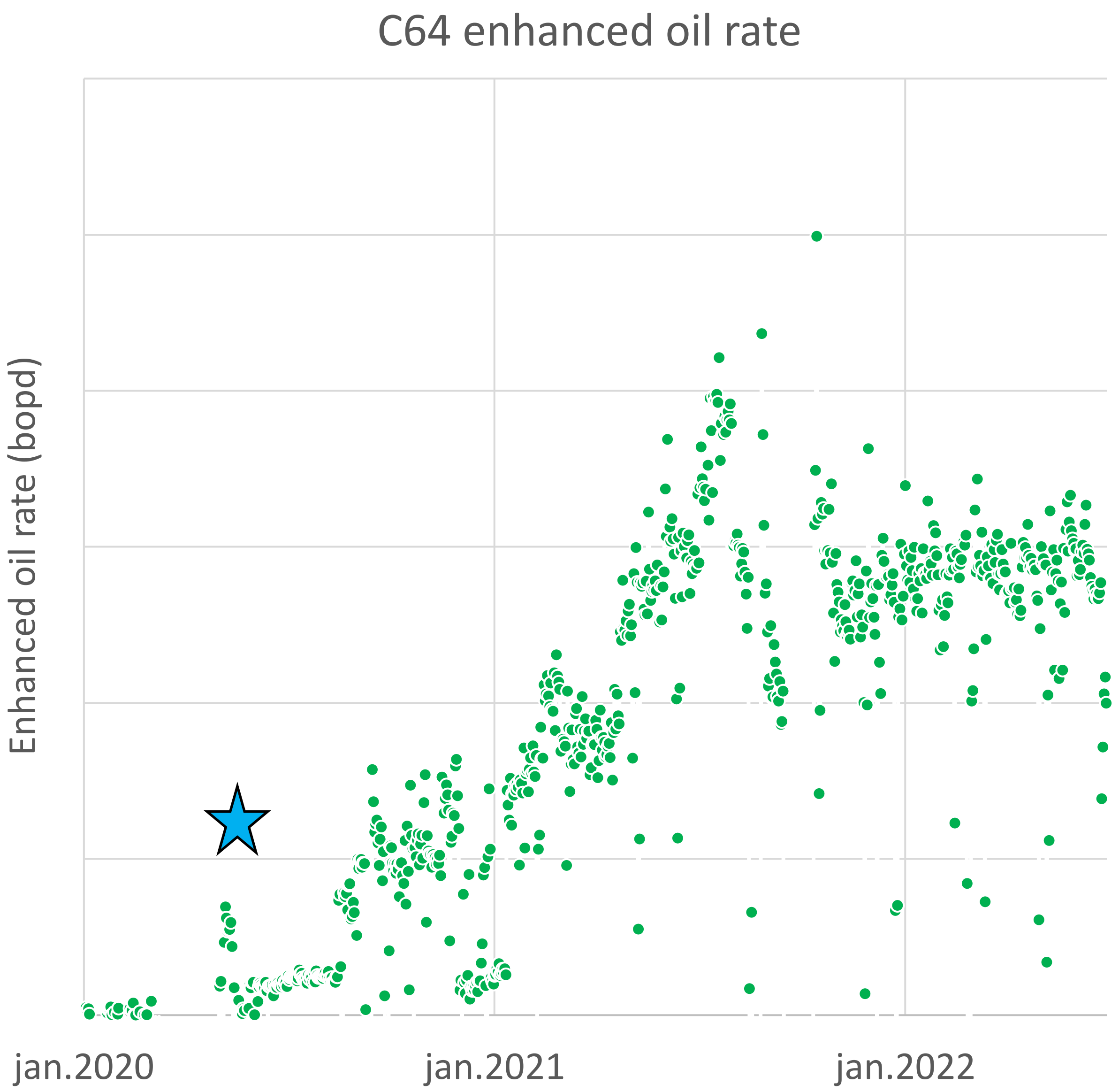
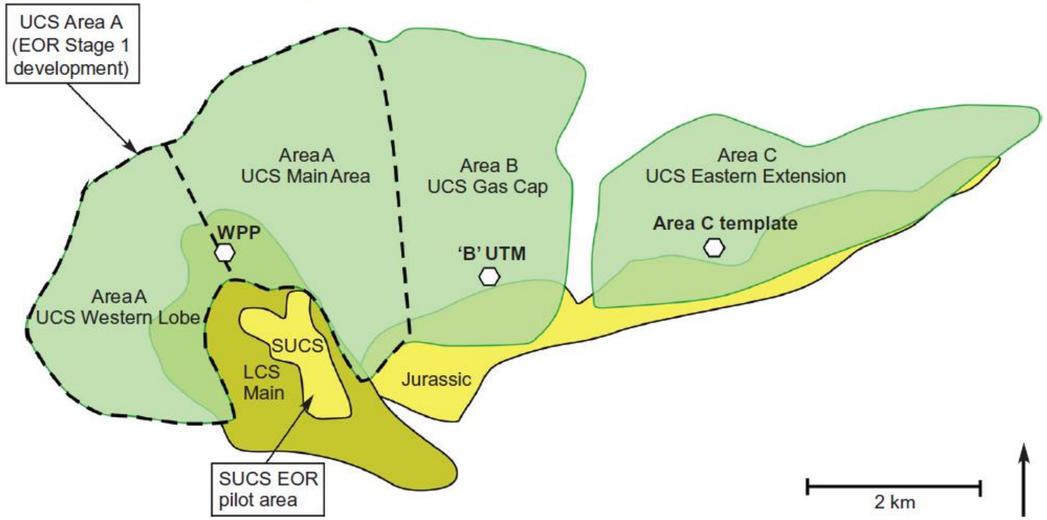




Captain Field EOR development summary

- The Captain Field has a very successful polymerflood EOR scheme, which is currently being expanded across the field in an offshore environment
- Strong water coning due to gravity observed from waterflood development results in remaining attic oil, which can then be swept using polymerflood
- Polymerflooding has been shown to accelerate waterflood reserves, enable additional incremental reserves and reduce water handling requirements for the field
- Field oil rate decline has been offset by enhanced oil production from the Captain polymerflood
- Production responses from the individual wells has been very positive to date for each polymer injection pattern
- Further investment in polymer flood EOR is continuing with the development of the LCS reservoir from the platform area and EOR Stage 2 in the subsea area

Captain Field EOR Development Area

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