

DEVEX 2022: Kraken Field Development

Jan Manoharan
10th May 2022



DEVEX 2022: Kraken Presentation

Kraken field overview

Two fields; Kraken Main and Kraken North

- Licence P1077
- Equity Partners

EnQuest	70.5%
Waldorf	29.5%

Located in Block 9/2b, East Shetland Platform

- Quad 9 heavy oil province, including Bressay and Bentley heavy oil fields. Both now operated by EnQuest.
- Water depth 110m

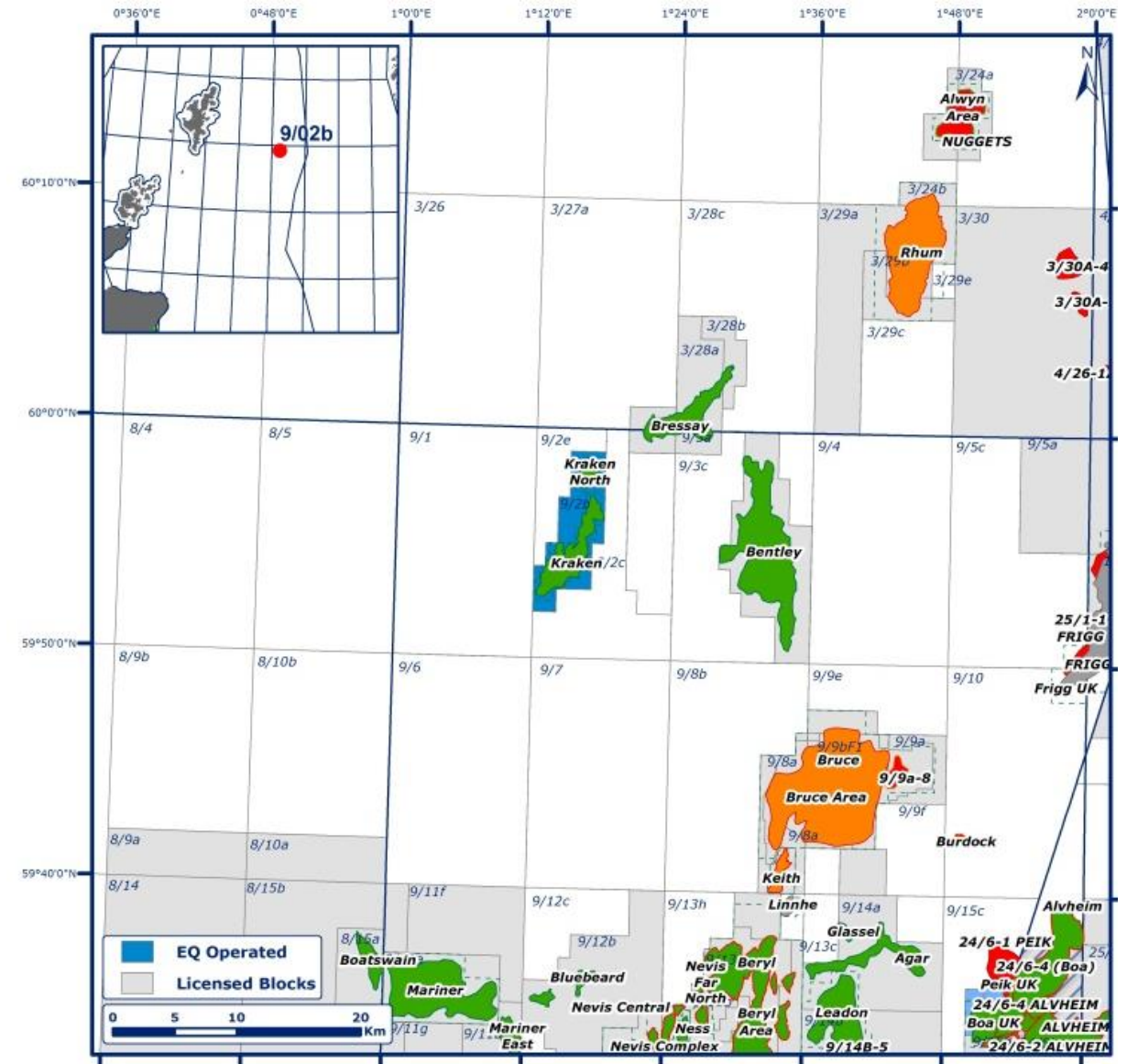
Excellent quality Palaeocene reservoir (Heimdal Sands)

- Typically high N/G, 36% porosity and multi-Darcy permeability

Sweet Heavy Crude (c. 13.7° API): 100 - 500 cP

Produced via the Armada Kraken FPSO

- On-stream June 2017
- Waterflood; alternating producer / injector pairs
- Artificial lift from Hydraulic Submersible Pumps (HSPs)
- FPSO designed for HSP/heavy oil; 460kbd liquid handling capacity
- 26 wells in 4 drill centres; 14 producers / 12 injectors

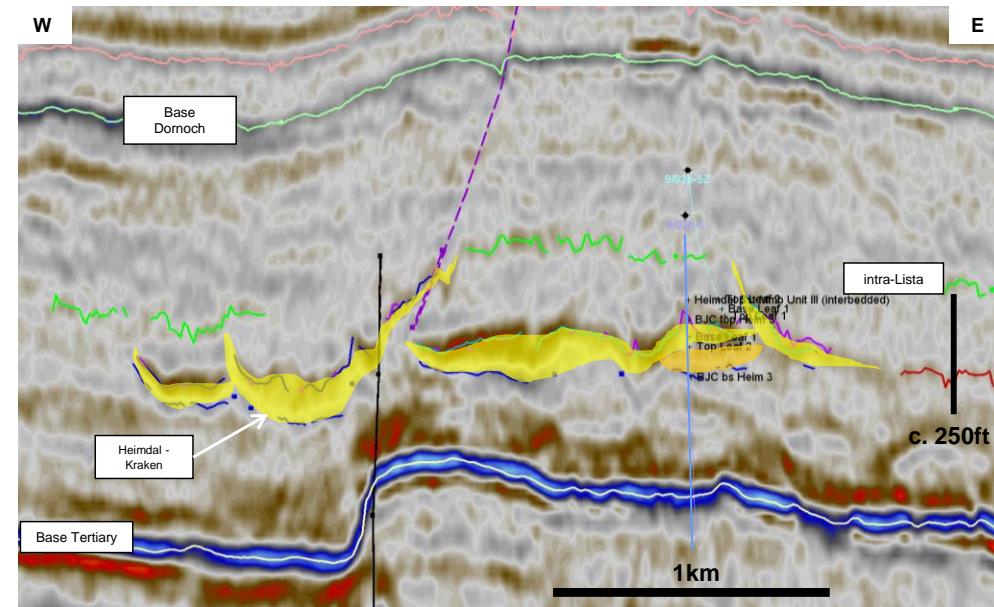
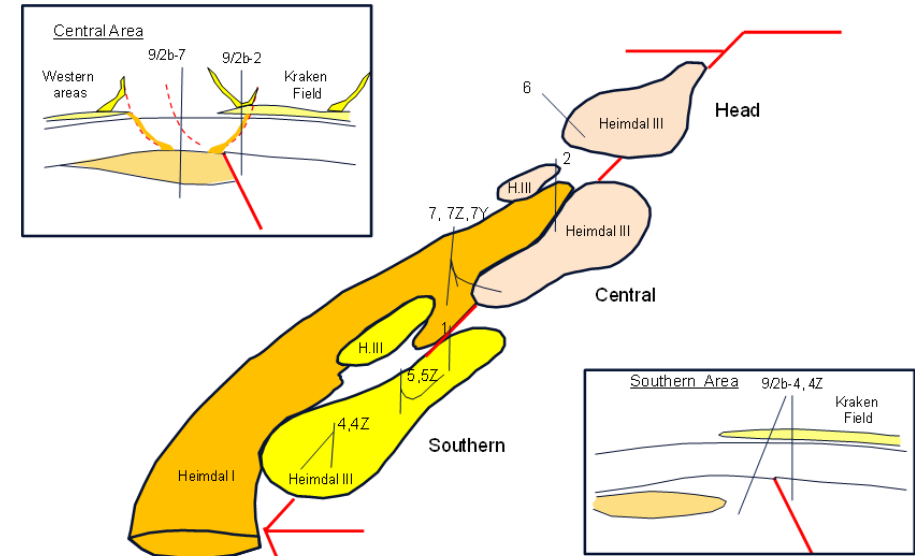
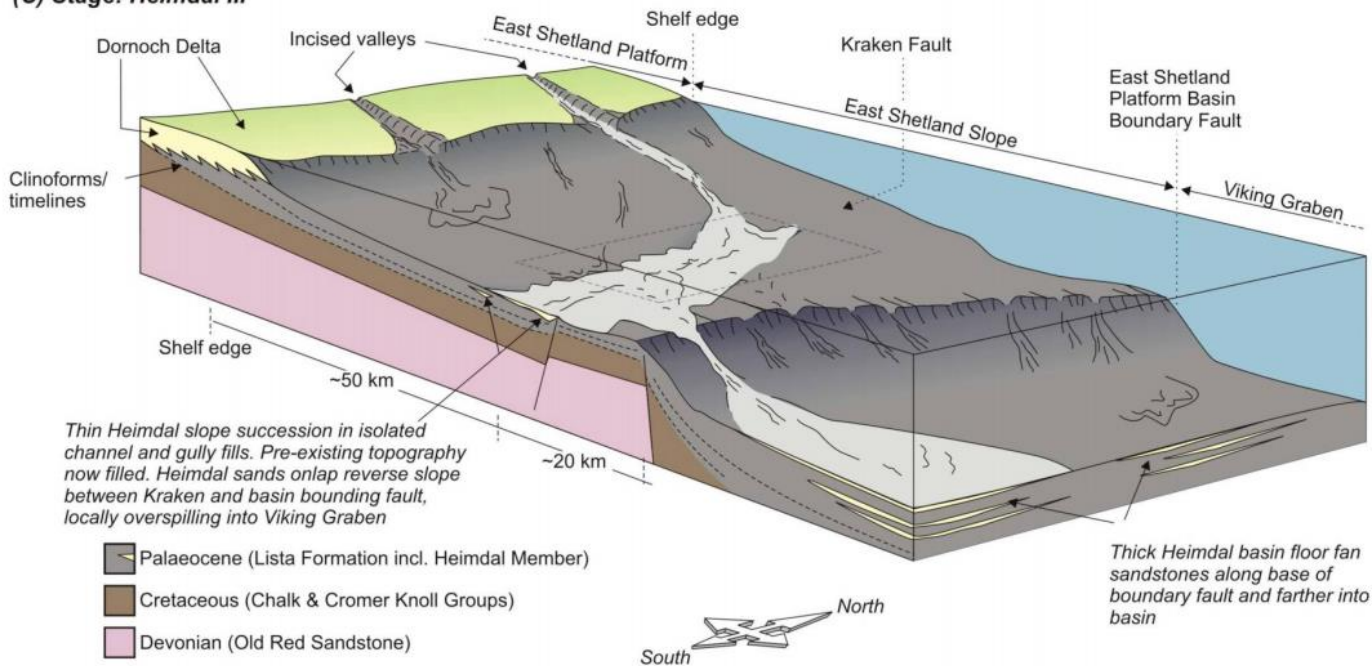


DEVEX 2022: Kraken Presentation

Kraken geology

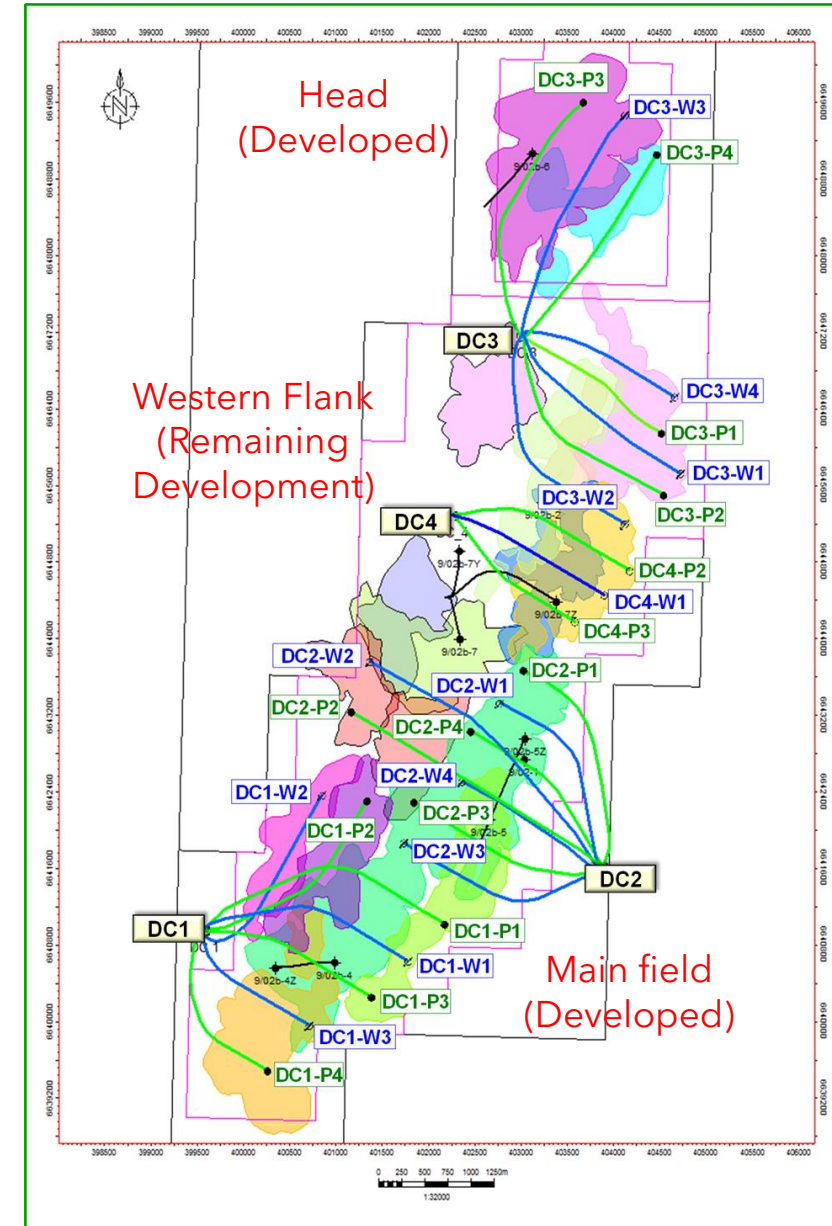
- Deep water marine setting
- Isolated channel and gully fills
- Post depositional sand remobilisation
- Sand bodies identified with high confidence on seismic

(C) Stage: Heimdal III



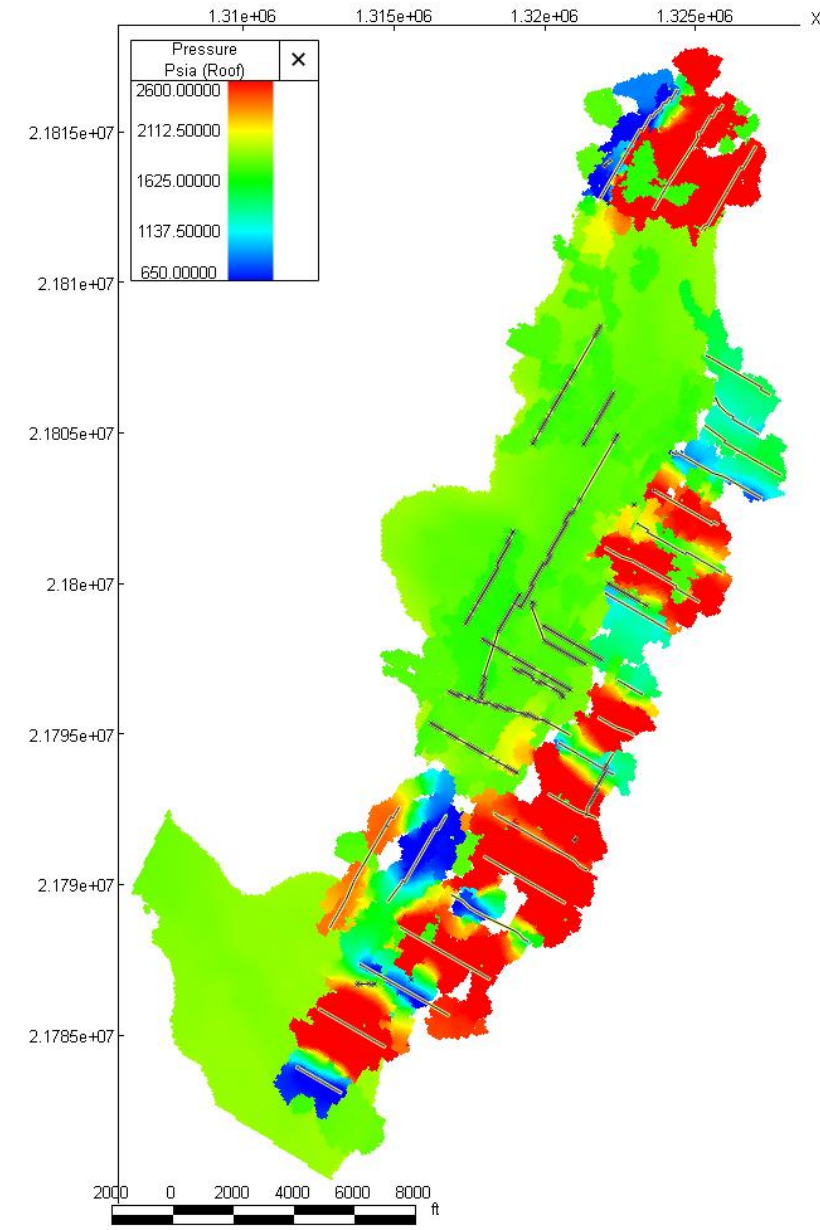
Reservoir Model

- Kraken reservoir consists of a large number of sand bodies
- These are mapped on seismic with sand prediction validated by the results from the initial 24 development wells
 - A producer-injector pair recently added into the Western Flank and shows greater discrepancy with current seismic
- Reservoir distribution in Kraken main field constrained by seismic and Geosphere data
- There is a known PVT variation in the field with the lowest oil viscosity in the northern part of the main field and highest viscosity oil in the deep south
- Same relative permeability curves applied to entire field



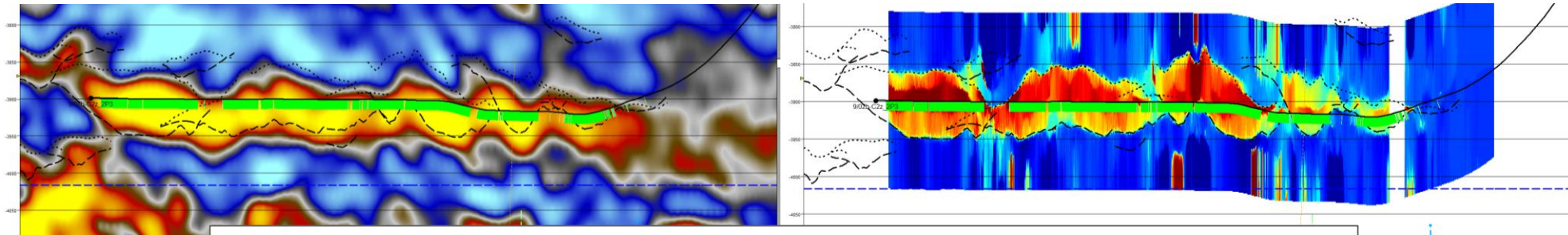
Sand body connectivity issue

- Sand body geometries based on seismic data, further constrained by well Geosphere data
- A model based on sands picked on seismic and geosphere alone shows poor pressure communication between injectors and producers
 - Higher pressures at injectors and lower pressures at producers than observed
- Need to enhance connectivity between sand bodies to account for observed field pressure trends
 - Improve sand to sand connection within the Heimdal
 - Additional pathways established through connection to the underlying Maureen reservoir
- There must be additional sands providing this connectivity; where are they located?



Improving connectivity

- Geobodies are seismically mapped, discrete subdivisions of the reservoir with a geologically realistic geometry.
- These are often confirmed on Geosphere data with the stacking and amalgamation of bodies being evident.
- Tapered and complex lateral pinch out, often abrupt.
- Connectivity between geobodies is an important factor for explaining field/wells performance



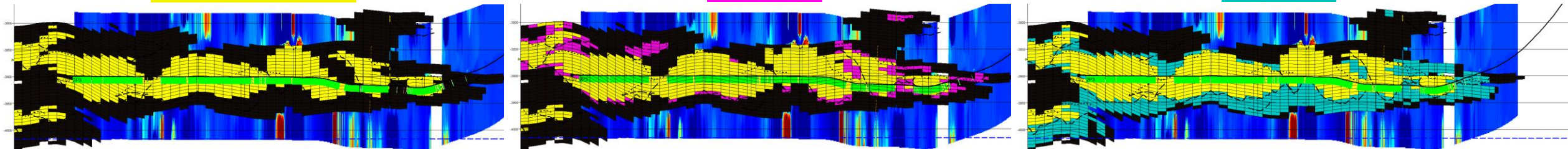
Multiple geobodies intersected along C2Z illustrating their seismic and Geosphere character

- The halo sands are added around the discretely mapped geobodies to help improve connectivity
- The distribution of halos is controlled by distance to mapped Geobody (30, 50 and 75 ft) and seismic facies probability volume (probability of sand \geq 20%)
- Volumetric contribution of the halos is controlled via the NTG/porosity assigned to these additional cells

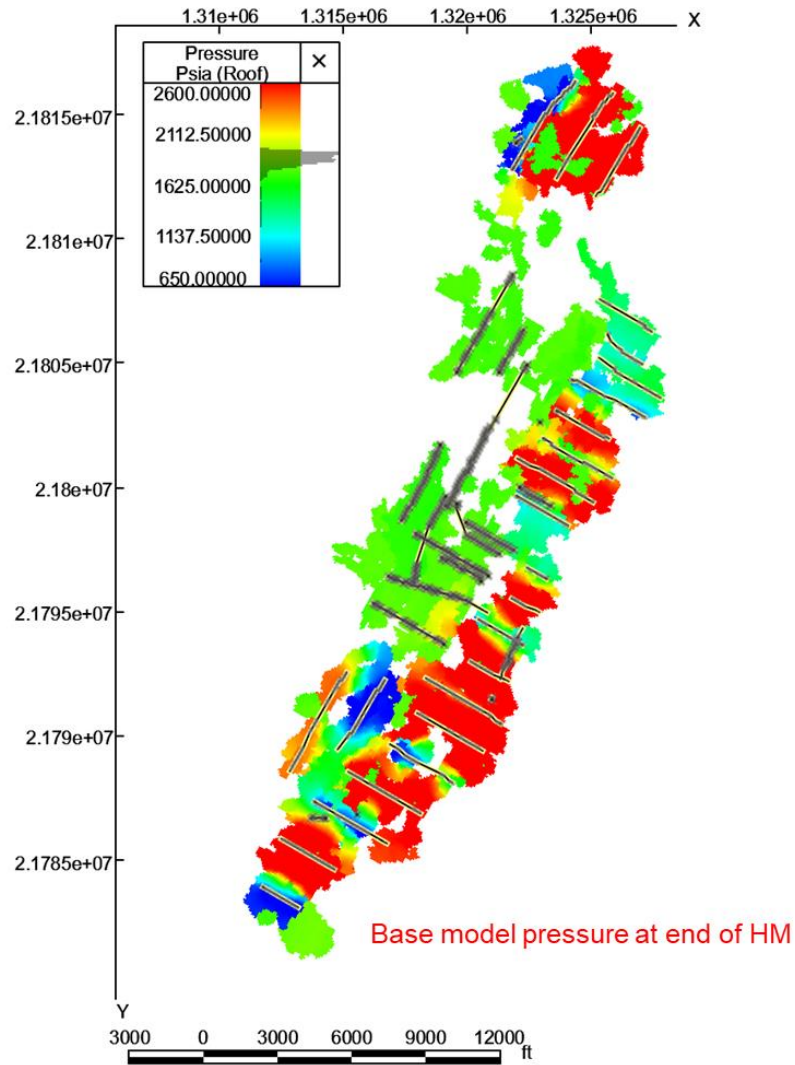
No Halos

Halo 30'

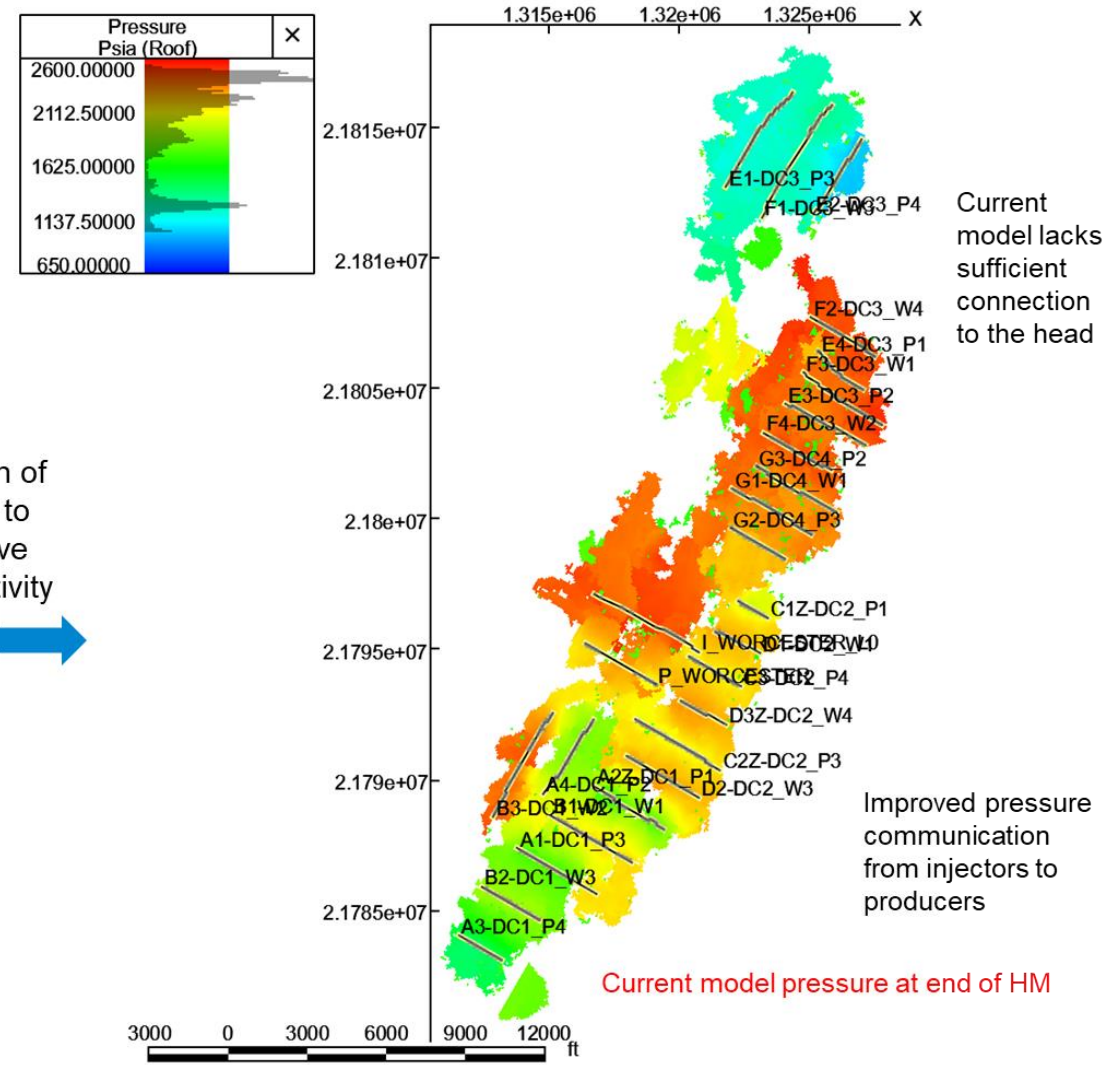
Halo 75'



Improved Pressure Match / Connectivity

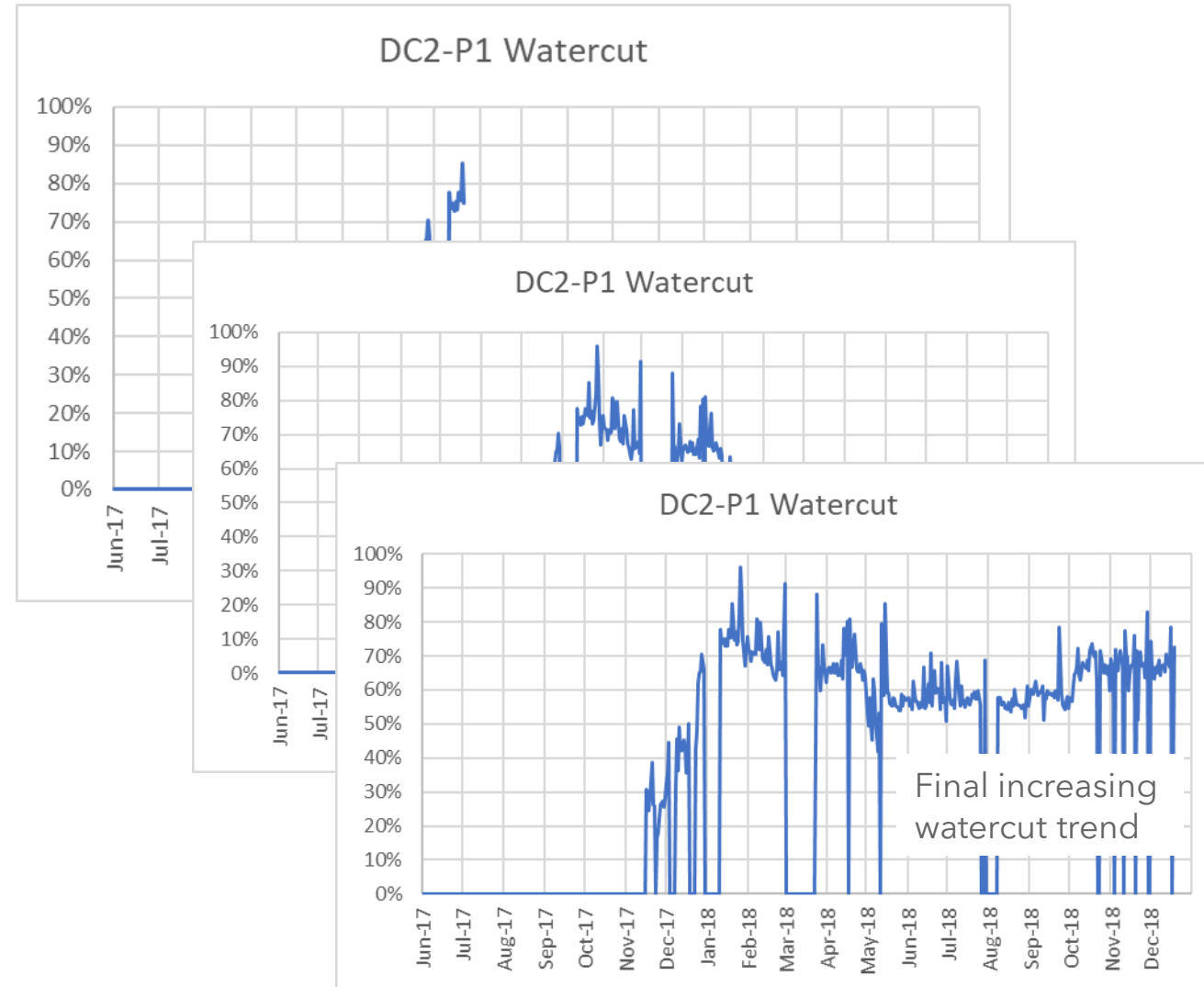


Addition of Halos to improve connectivity



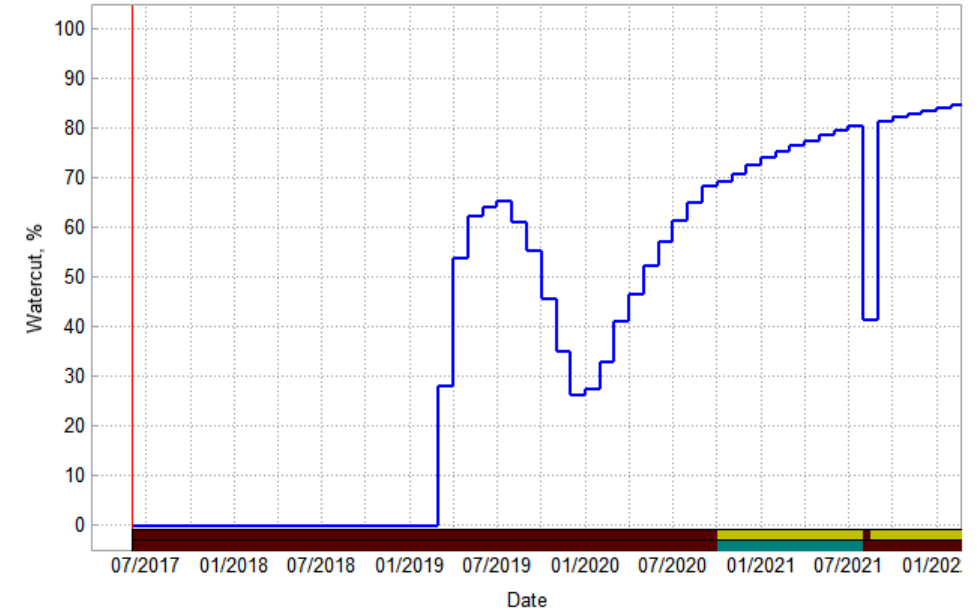
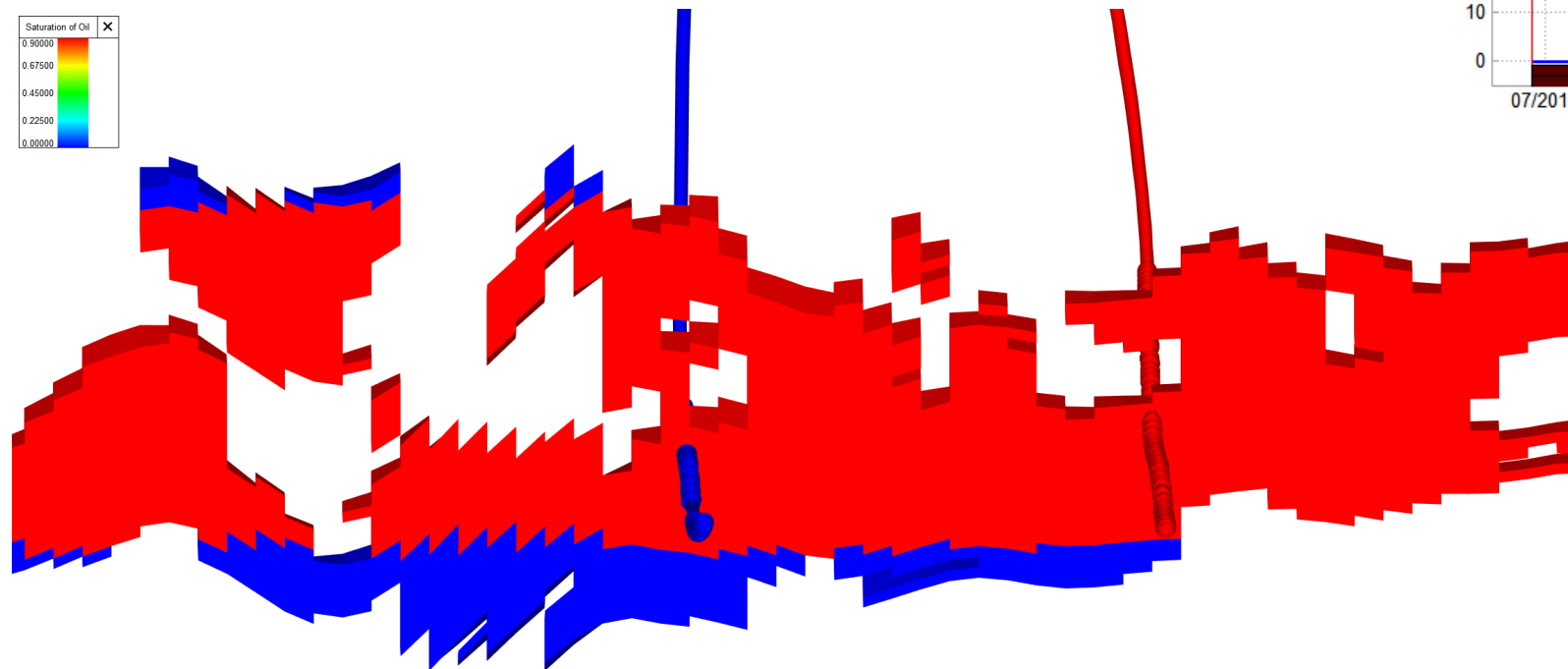
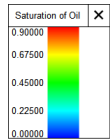
Early Water Production

- Rapid early watercut increase; 80% in 3 months
 - Kraken has good metering solutions with multiphase flow meters on each drill centre combined with flow rates from Venturi meter on each well and regular well testing via the test separator
 - Chemical analysis showed this was formation water
- After a few months, watercut starts to decrease
- A longer term increasing watercut trend is established and injection tracers are observed



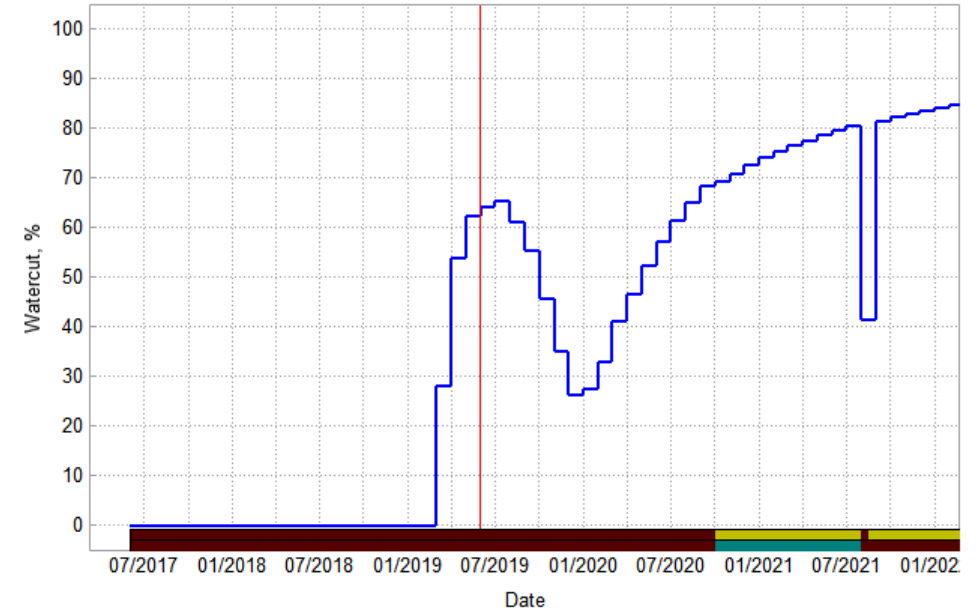
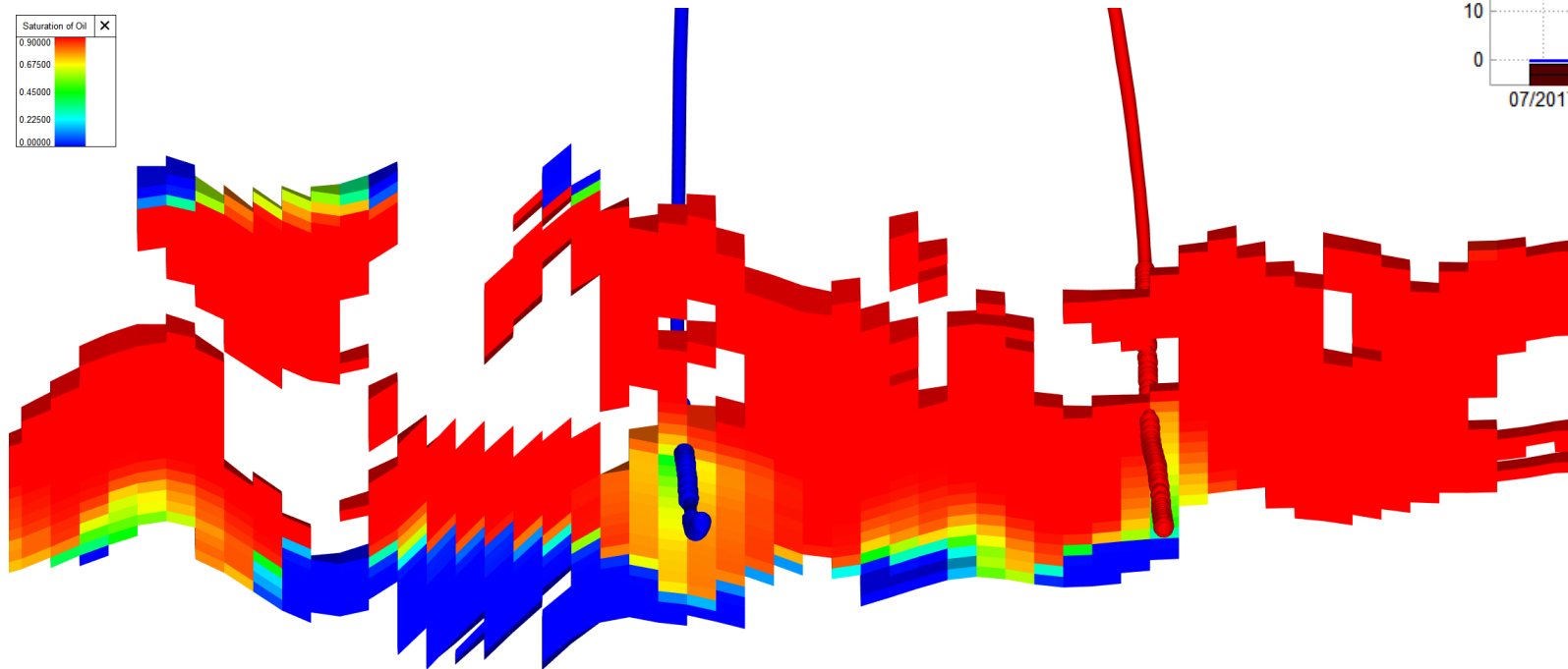
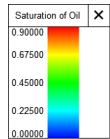
Watercut Trend Explained #1

- Producer-Injector with underlying perched water
- Initial condition



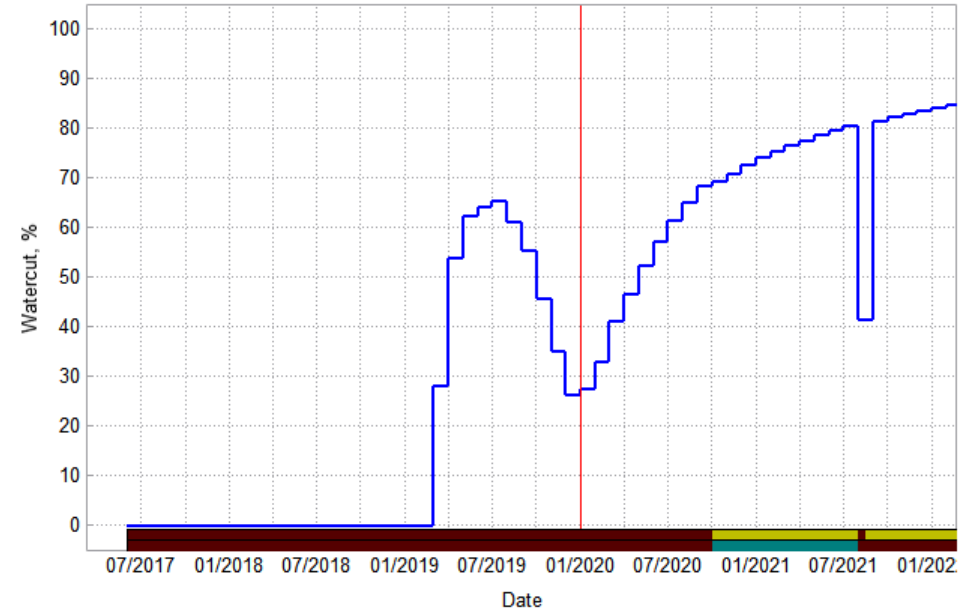
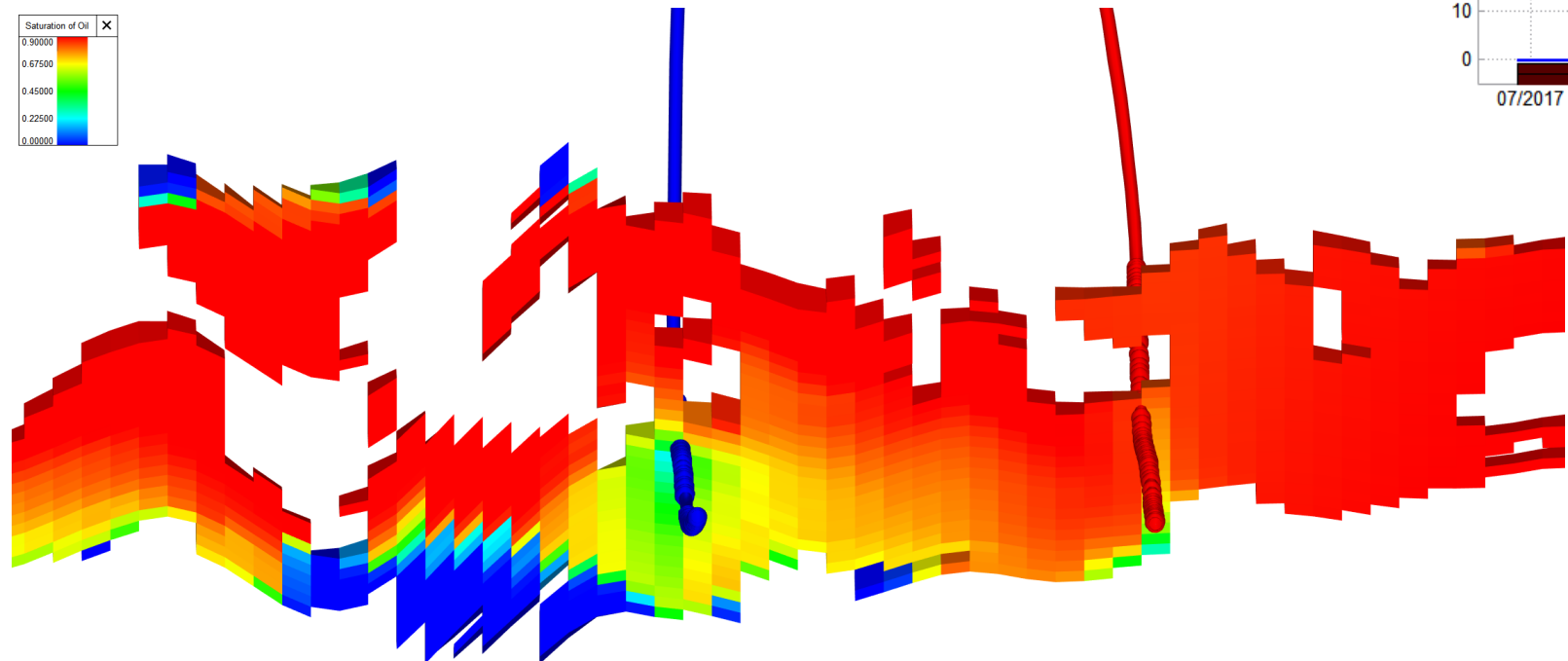
Watercut Trend Explained #2

- Injected water displaces oil into water leg
- Perched water produced



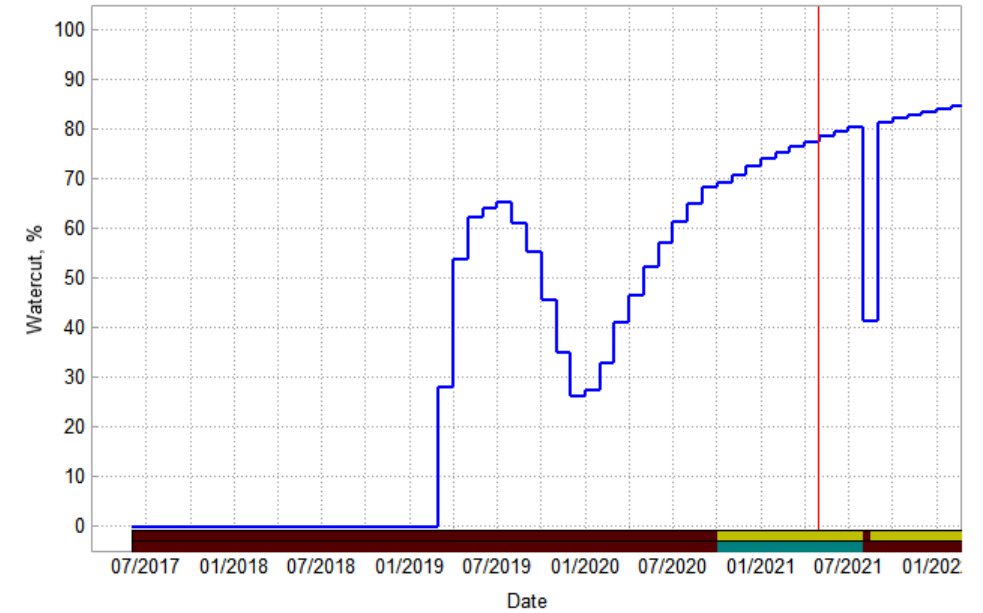
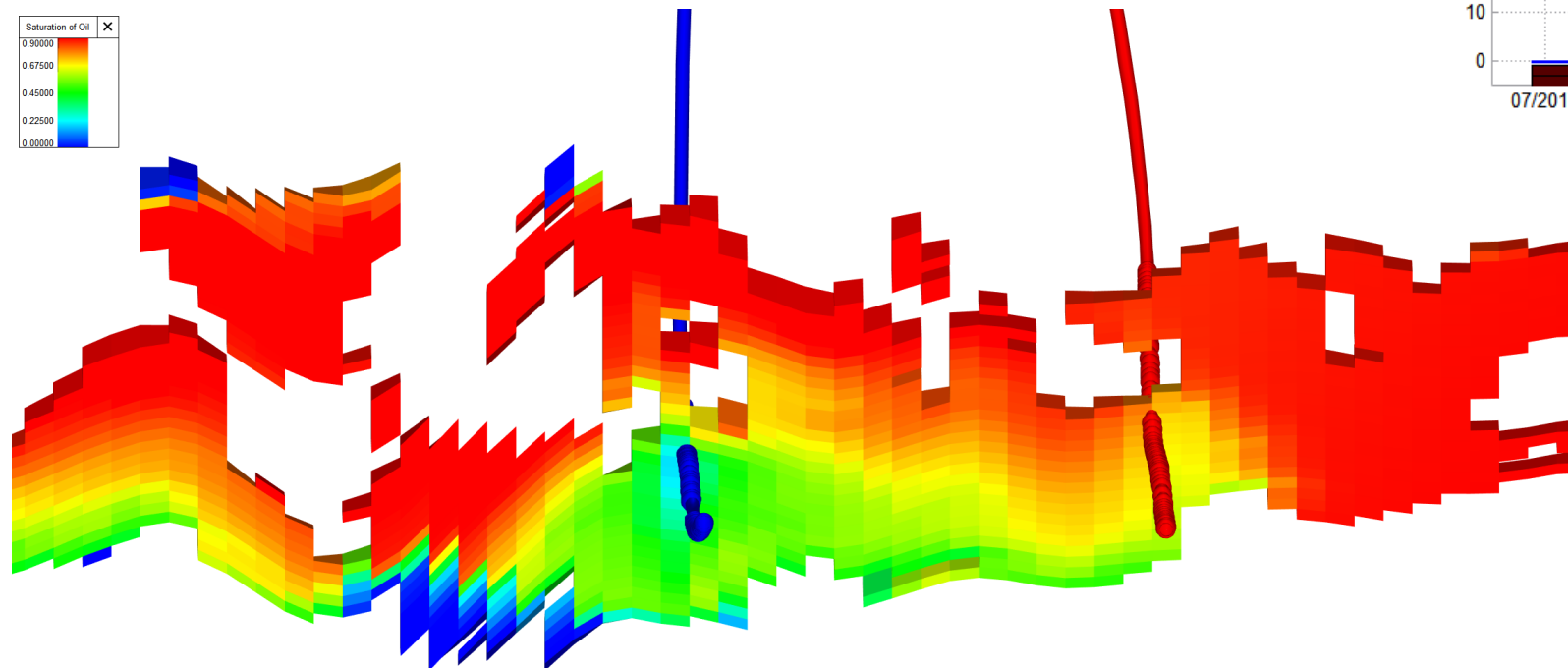
Watercut Trend Explained #3

- Perched water under producer depleted
- Dryer oil production



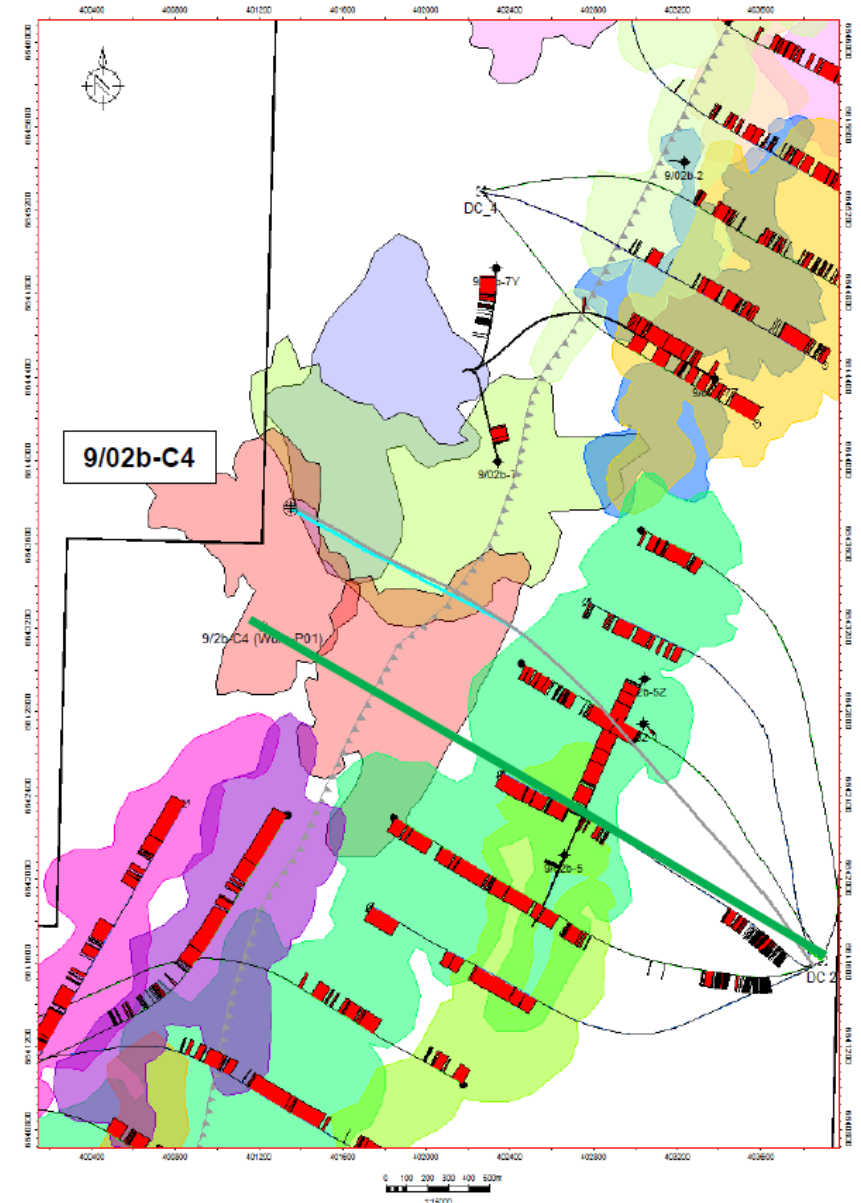
Watercut Trend Explained #4

- Injected water arrives at producer
- Increasing watercut



Western Area Development

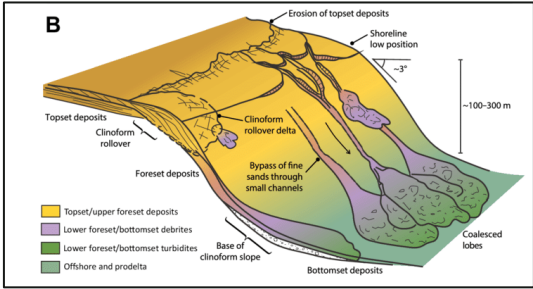
- With the main field developed, additional opportunities exist in the Western Flank of the field
- The first development well into the Western Flank was drilled in June 2020
- Target was identified on seismic however the well encountered less sand than predicted
- Current seismic has proved to be less reliable in the Western Flank than in the main field
- New high density multi-azimuthal 3D seismic was acquired over the entire field in 2021 to improve reservoir visualisation and to assist with future opportunities



Next Generation Kraken Model

Consider alternate depositional concepts

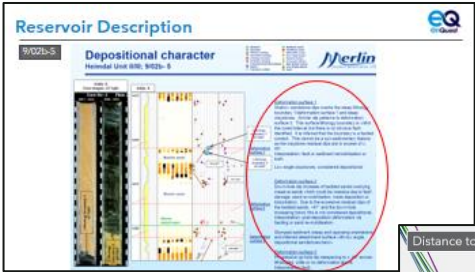
- Geometries
- Remobilization
- Injectites



Extract maximum value from new seismic

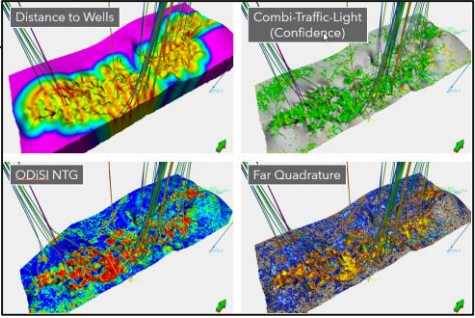
Updated reservoir description and analysis

- Reservoir architecture
- Connectivity
- Sweep



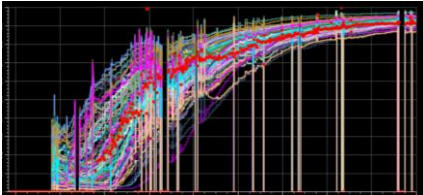
Redesigned modelling workflows

- Multiple scenarios
- Seismic attributes integrated into workflow



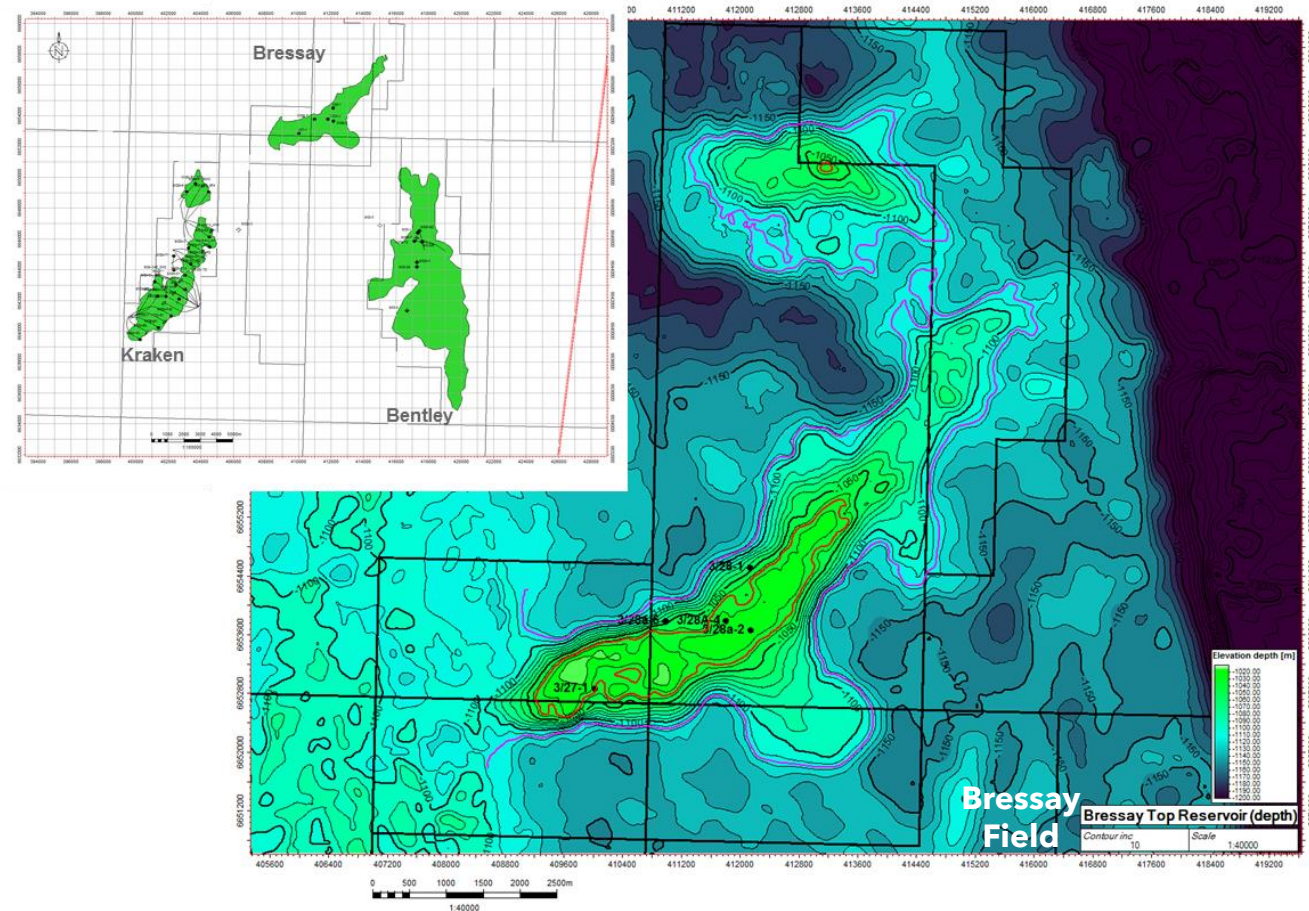
Ensemble based history matching

- Improved full cycle integration
- Improved uncertainty definition



Unlocking Bressay & Bentley

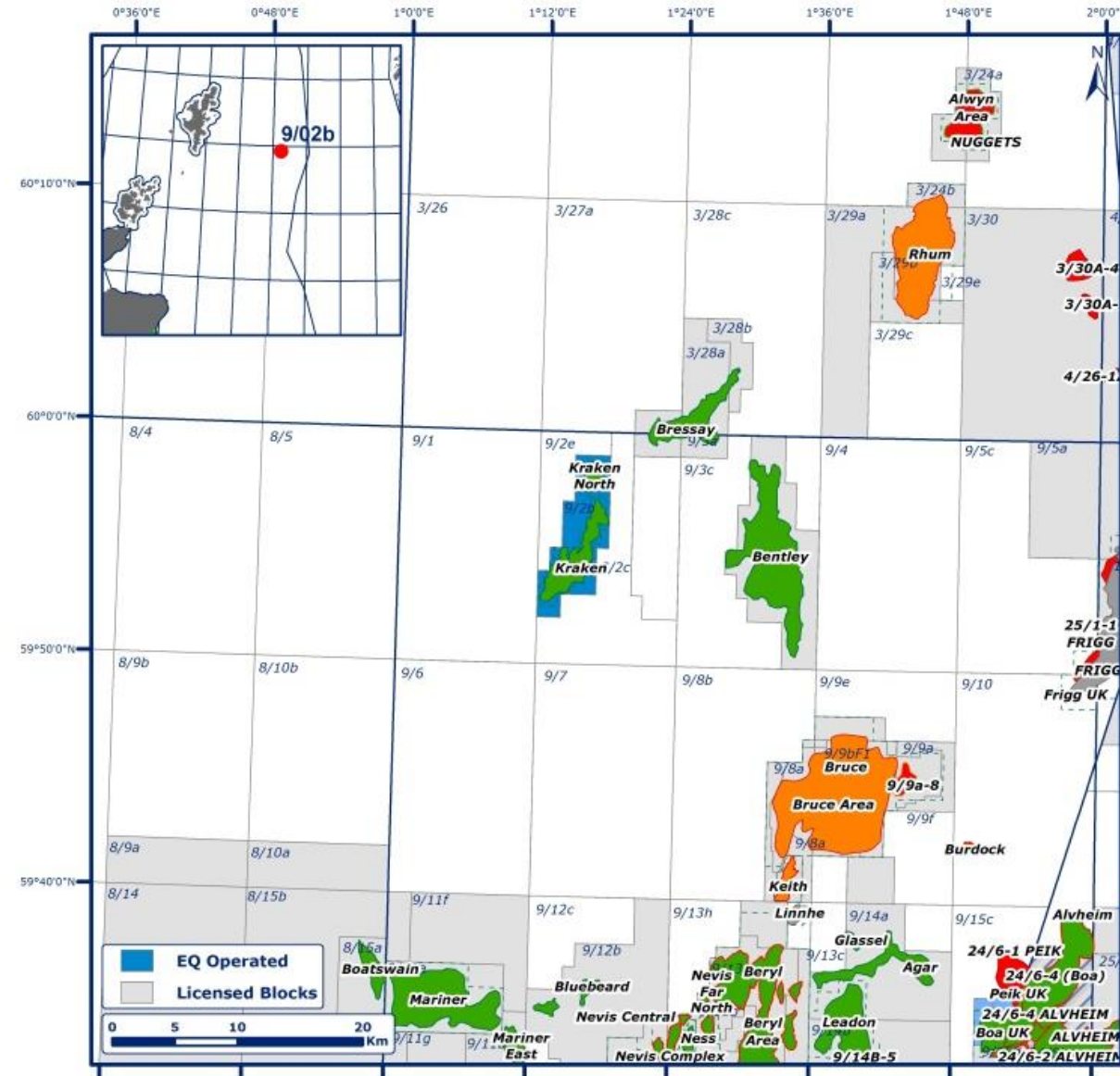
- EnQuest took operatorship of Bressay and Bentley fields in 2021
- Both fields discovered in 1970s and remain undeveloped
- Learnings from Kraken are being integrated into reservoir characterisation and development planning for Bressay
- Success at Bressay and Bentley fields would represent another step change in UK offshore heavy oil capability, unlocking material remaining resources



DEVEX 2022: Kraken Presentation

Summary

- The successful development of Kraken is a step change in heavy oil capability in the UK offshore sector
 - Kraken fluids at 100 to 500cP are significantly heavier than prior developments and required effective implementation of key technologies
- Kraken established a development framework for unlocking challenging heavy oil fields
- EnQuest-operated Kraken, Bressay and Bentley fields comprise several billion barrels of oil in place
- EnQuest is leveraging in house heavy oil capabilities and integrating JV experience to progress Bressay and Bentley developments



Thank you

