Harbour Energy

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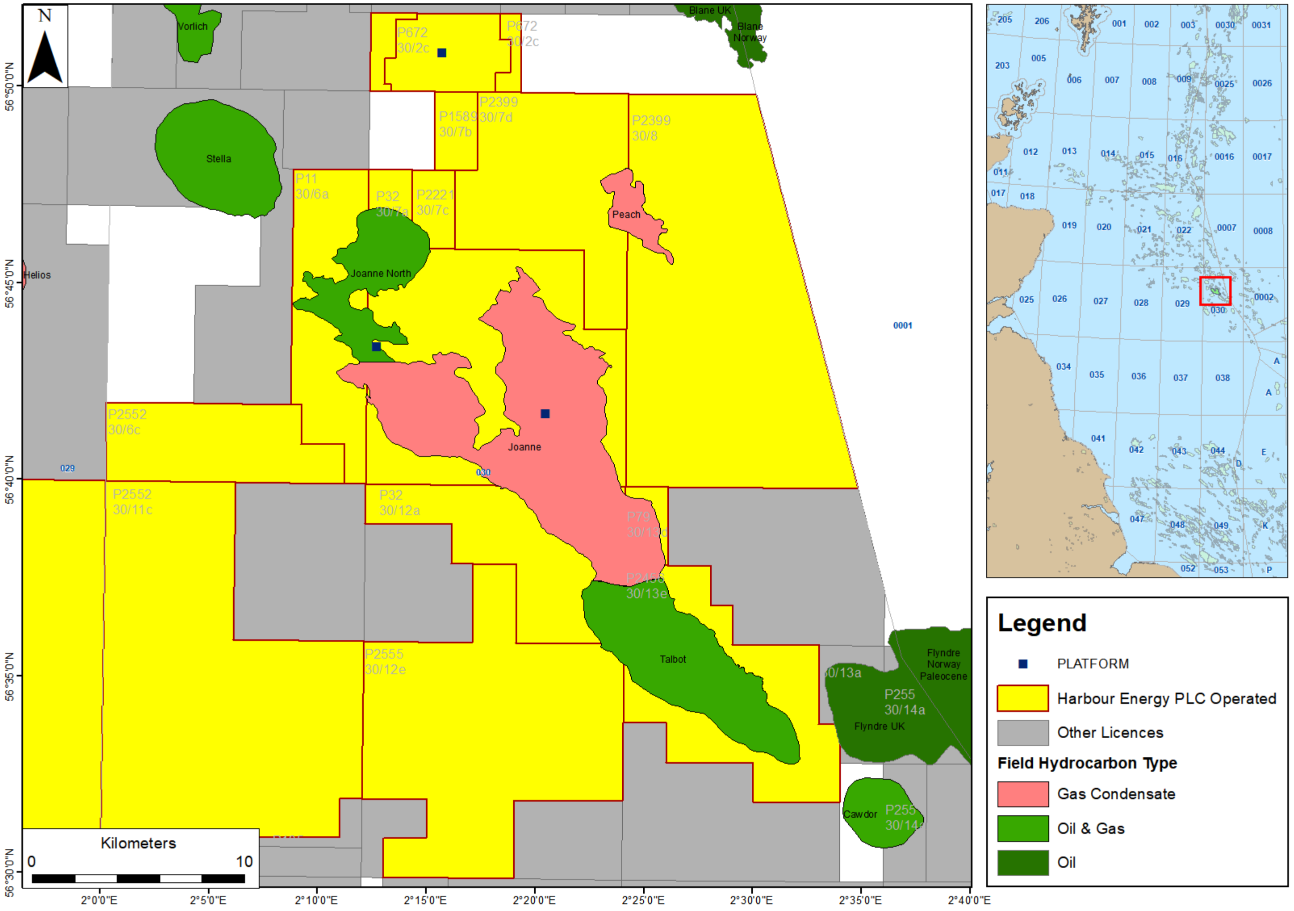
DEVEX 2022

Back to life: a case study of how new thinking and technology reinvigorates the production and performance understanding of a mature CNS Paleocene field



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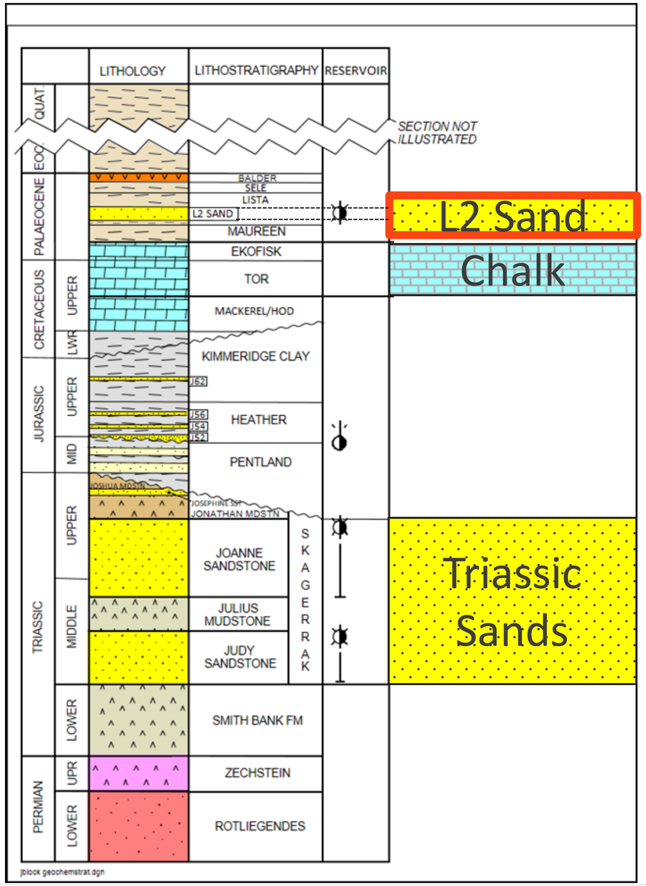
Agenda

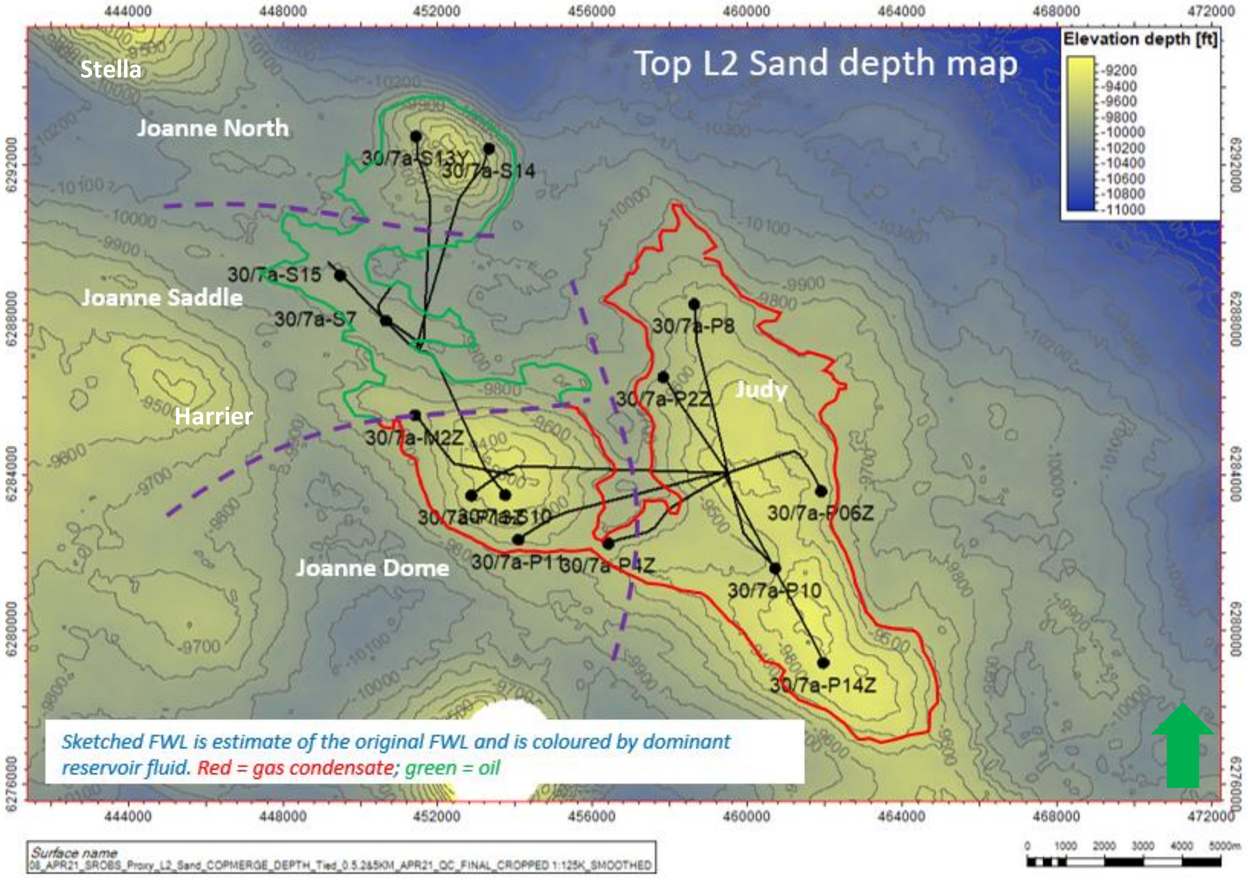
- Background
- Phase 1 development – Historical well performance challenges
- Phase 2 development learnings
  - Well placement and reservoir productivity
  - Joanne North reservoir productivity
  - Joanne Saddle well & reservoir productivity
- Summary and take-away

J-Area Paleocene reservoir – Background information

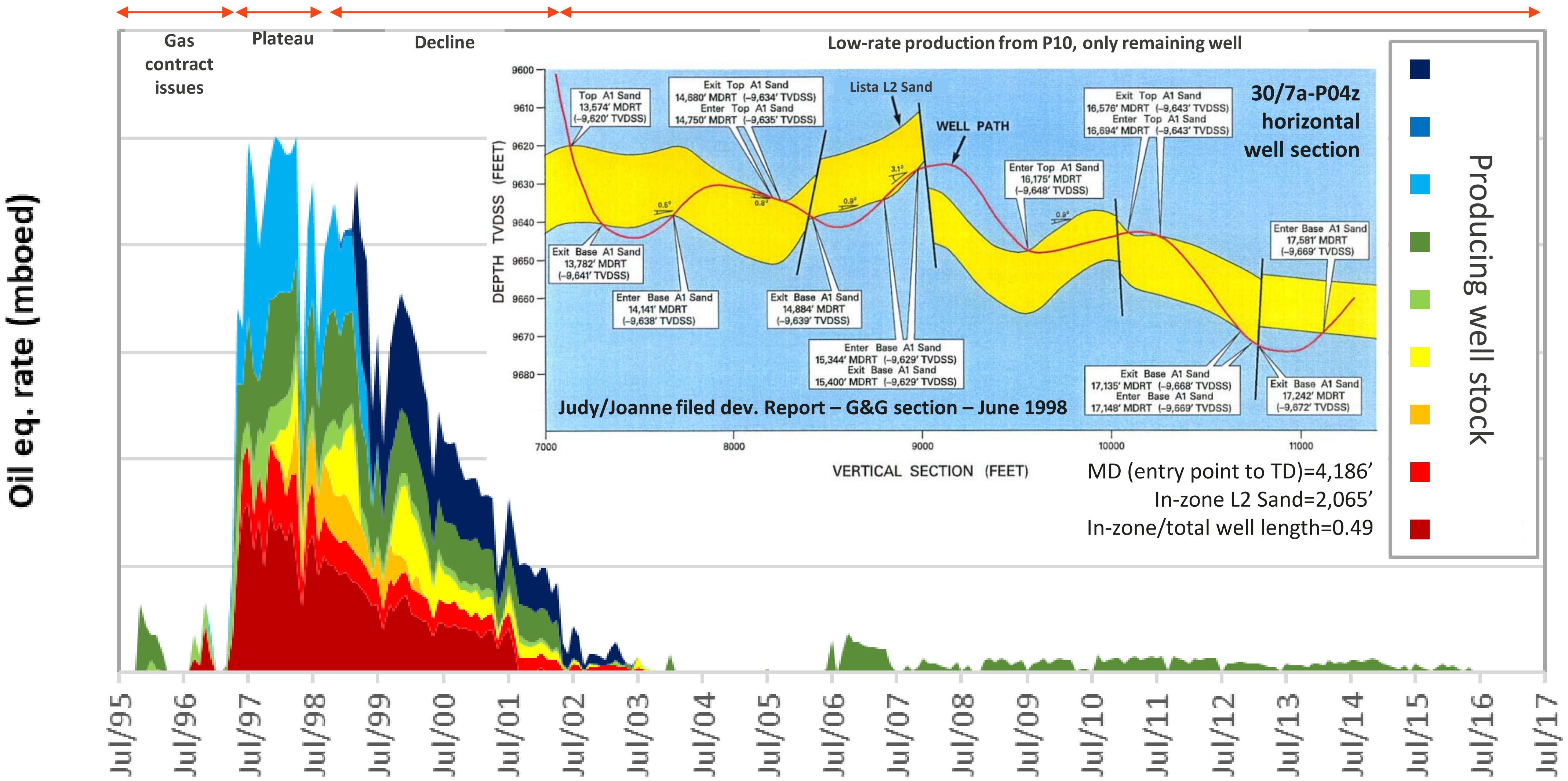
- 20ft thick turbidite reservoir
- 20% porosity, ~20mD permeability
- Two fluids: light oil and gas condensate

- Large scale fluid movement both laterally and vertically (from over and underburden)
- Significant pressure recharge since 2002



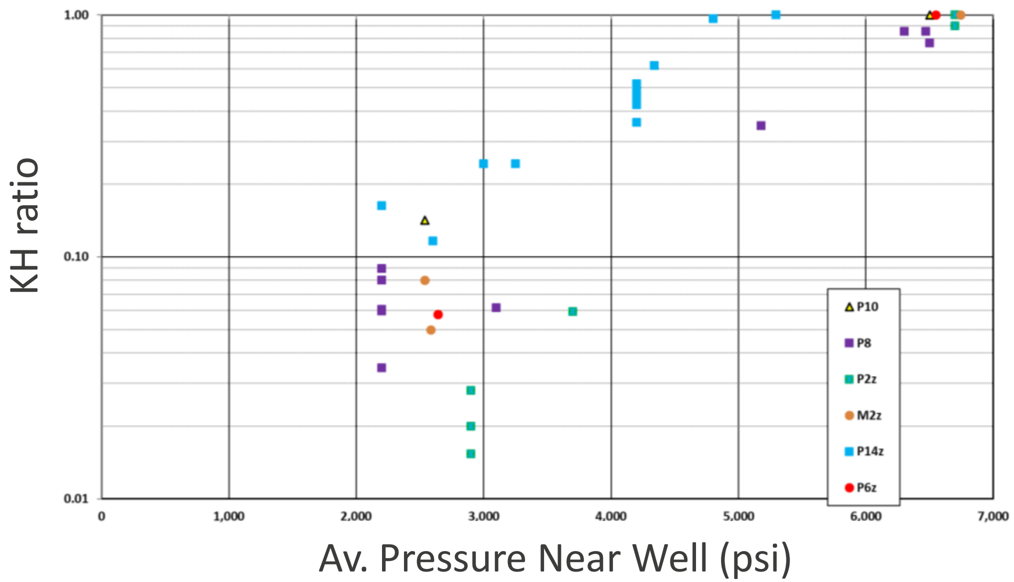


Phase 1 development – Strong early performance but rapid decline

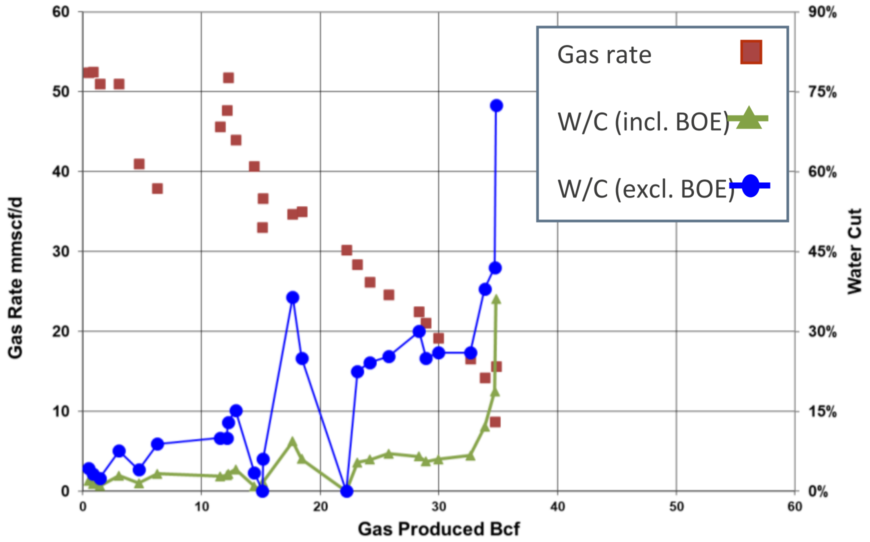


Phase 1 development – Productivity loss origin not fully identified

Loss of effective k.h with depletion



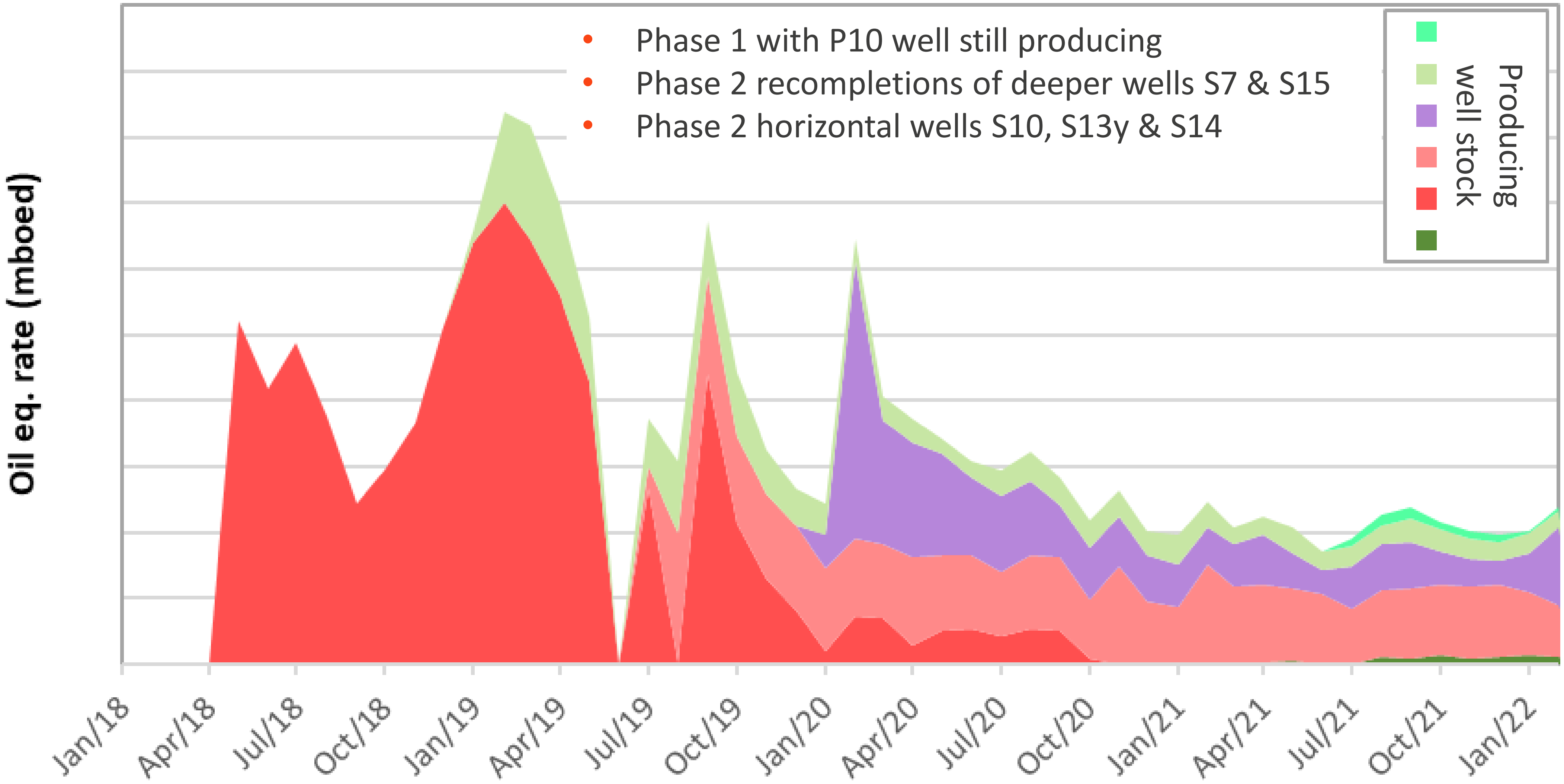
Significant Rapid Water Breakthrough – Pal. well example



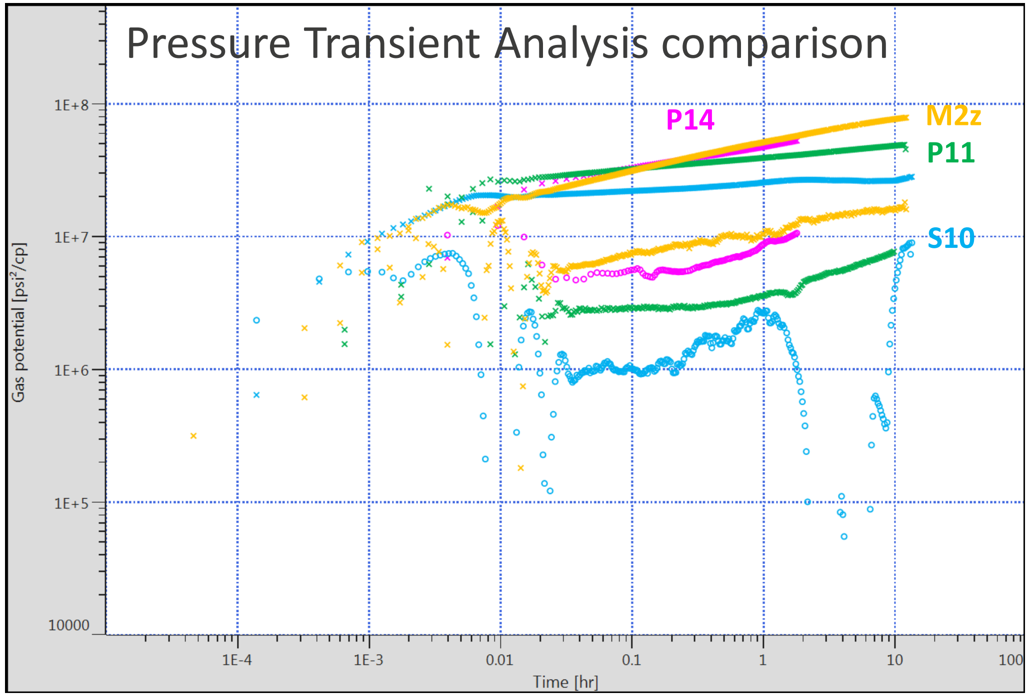
- Well test data shows significant loss of effective KH as reservoir depletes
  - Stress dependent permeability? 3 Phase rel perm effects? Mechanical loss of well length ?
- Significant rapid increase in water rates in late life
  - P14z was vertically and laterally distant from the mapped contact
  - After long shut-ins watered out wells have flowed 1,000+ bbls/d water
- Several wells have suffered significant solids & mechanical problems

Solids production and mechanical failures

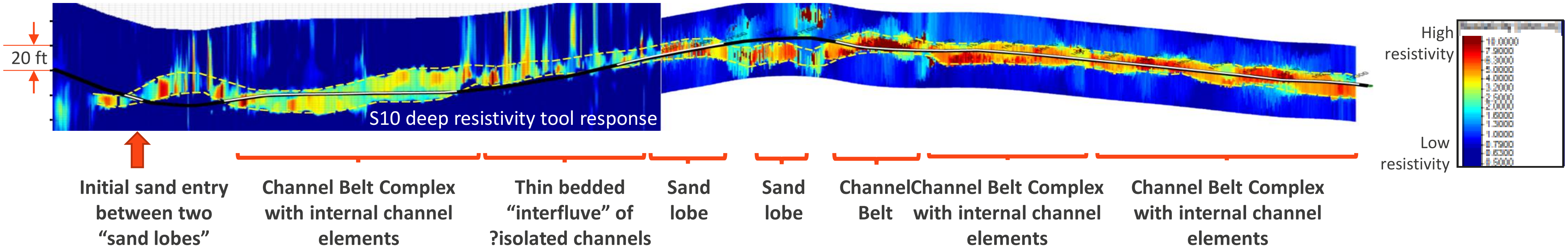
Phase 2 development – Progressing continuous learnings and implementing



Phase 2 development – S10 example – Improved execution and performance

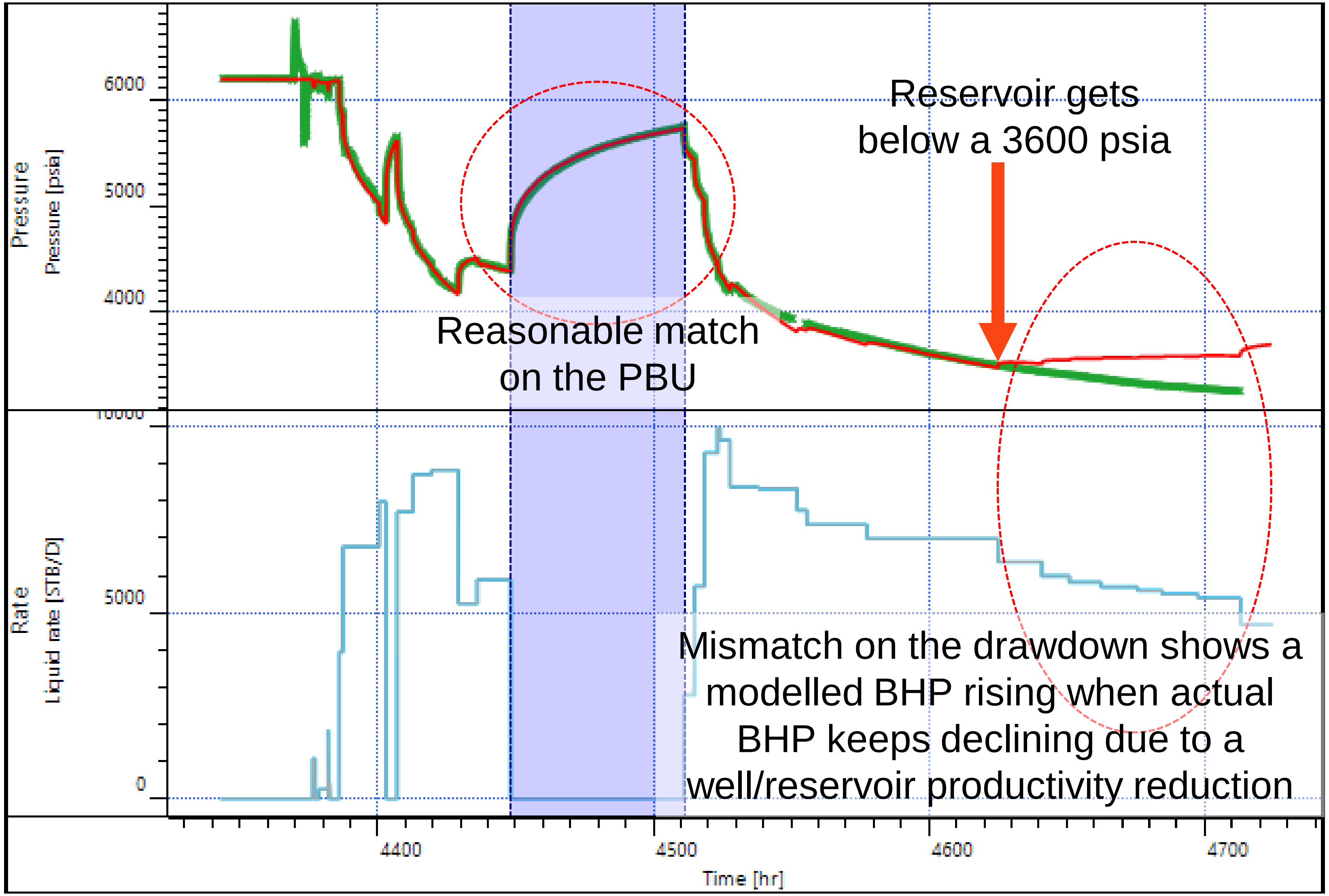


- S10 is the Paleocene well with the highest effective near-well kh
  - x3 than P11 kh, x7 than P14 kh, x6 than M2z kh
- Ultra Deep Resistivity technology enabled to improve the well placement in the reservoir and increase the well in-zone length, hence maximising the well productivity



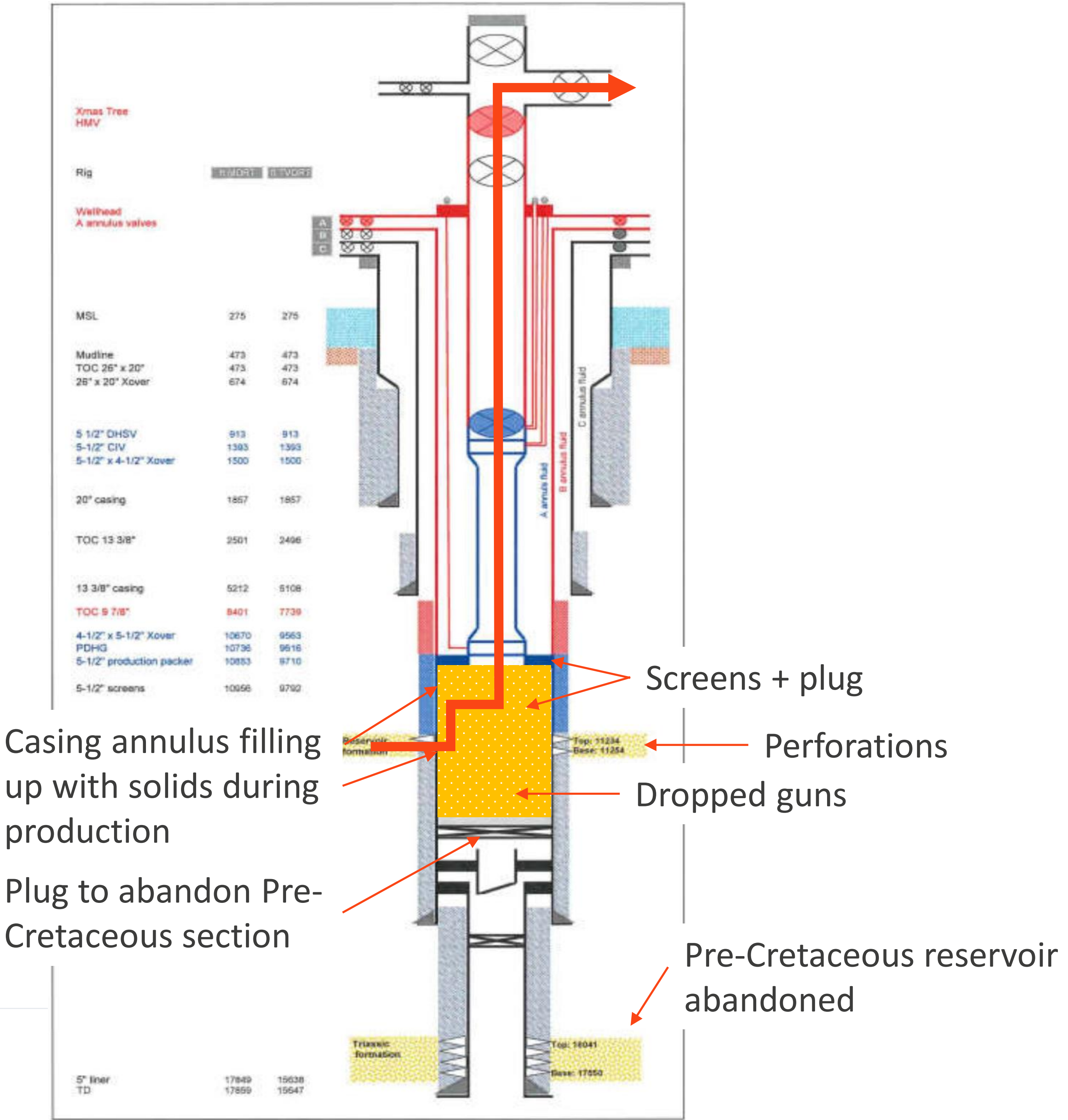
Joanne North S13y: significant gas blocking mechanism impairs well productivity

- When the reservoir pressure goes below the Bubble Point:
  - Gas blocking appears
  - Well skin increases
  - Reservoir productivity (vs. time) decreases
  - Actual drawdown increases artificially
- The high critical gas saturation appears to maintain gas within the reservoir:
  - A slight decline in GOR is observed bellow the Bubble Point
  - The trapped gas significantly impacts the effective reservoir permeability and the well productivity

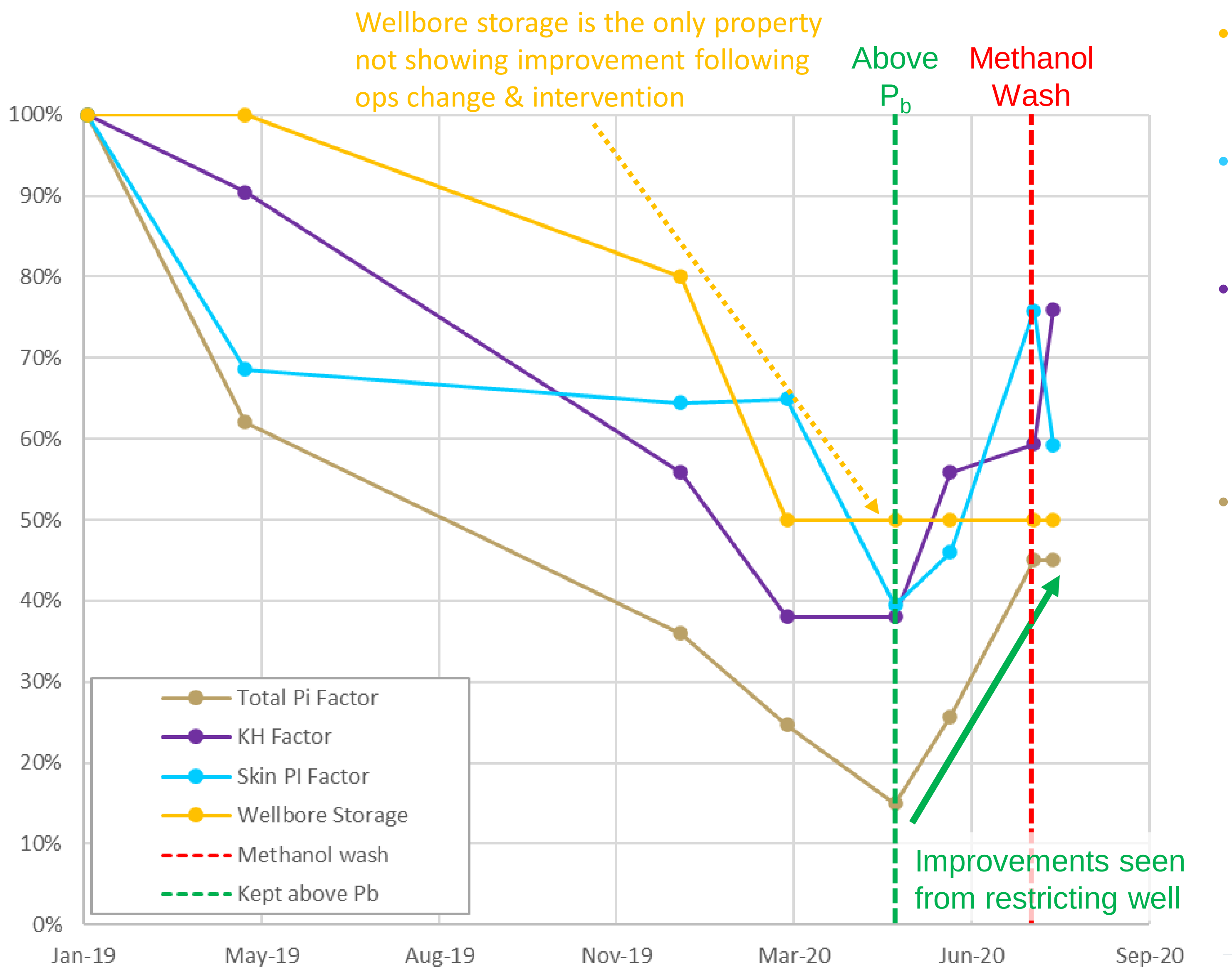


S7 Completion Diagram

- S7 old Triassic (deeper reservoir) well, used as a donor well to access L2 Sandstone
- Well recompletion justified as a data acquisition which should pay for itself
  - Objective: improve the Saddle area understanding to assess future development wells attractiveness
- The well has greatly enhanced our understanding of the Paleocene reservoir by breaking down the various impairment contributions



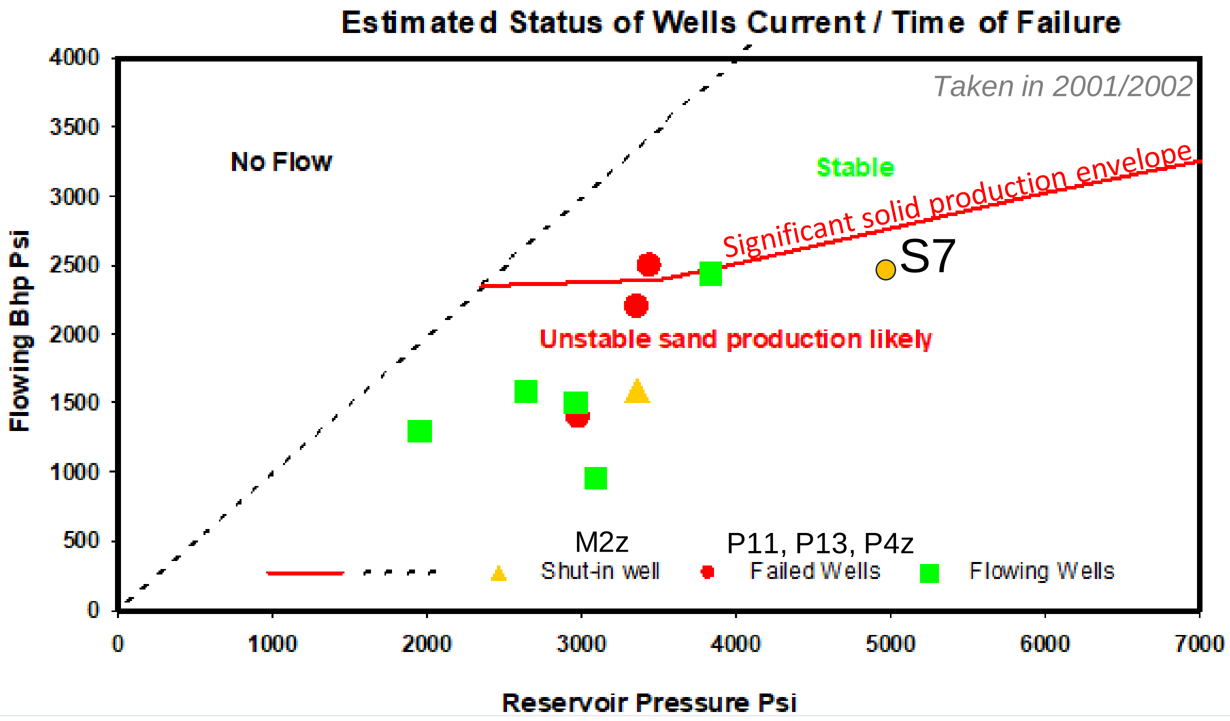
S7 Pressure/Test Data: 3 sources of well and reservoir impairment

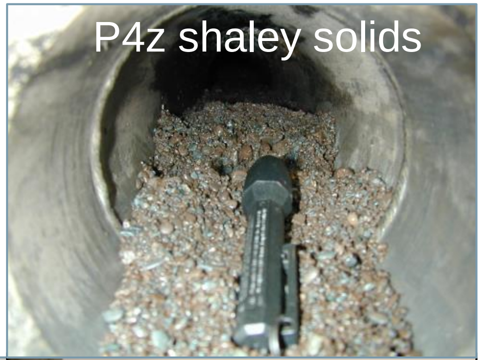


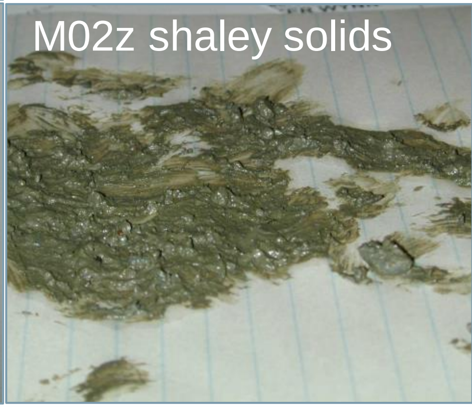
- **Wellbore storage:**
  - Impacted by casing filling up with sands and fines and liquids compressibility
- **Skin PI:**
  - Impacted by gas out of solution + likely fines appearance + scale formation
- **KH/reservoir productivity:**
  - Impacted by a combination of water and gas rel perm effect (gas rel perm effect when $P_{res}<P_b$) + fines/sands/scale appearance leading to a reservoir impairment
- **Total productivity:**
  - Although the productivity was not fully recovered due to the remaining water production and the presence of fines/sands/scales, some productivity was recovered by producing the reservoir above the saturation pressure + Methanol wash (though Methanol wash impact sustainability is uncertain)

Sand production in Paleocene wells: *producing wells below ~2500psia are likely to encounter significant sand production*

- It is probable that drawing down hard on S7 has caused solids to come into the well (as seen in previous cased and perforated Pal. Wells) & has hindered production
- Prior to the loss of productivity S7 was flowing with a BHP ~2300-2400 psi
- Historically wells with water production start producing solids







Summary & take-away

- Before and during the Phase 1 CRINE (Cost Reduction Initiative for the New Era) development:
  - Paleocene well and reservoir impairments were not anticipated due to limited offset data
  - Limited early time data combined with multiple potential impairment mechanisms made diagnostics challenging
- Based on the Phase 1 and Phase 2 wells performance, the following learnings were gained:
  - Well placement with the deep resistivity tool support enabled to increase significantly the well contacted reservoir and maximise the well productivity
  - Long horizontal wells benefited from screens to prevent solids production and catastrophic sand face collapse leading to the loss of the well
  - Vertical well recompletions in thin reservoirs:
    - Should be fitted with erosion-resistant screens to prevent integrity breach and
    - Should be managed through regular (methanol or other) back flushes to remove the solids build-up
  - When economically possible, well offtake should be reduced to manage reservoir relative permeability impairments and solids production, allowing reliable long term production from the wells
  - Reservoir surveillance and wells monitoring, including non-producing wells, are key to field understanding and value optimisation

Special mention and thanks to those involved:

Any Questions?

- Reservoir Engineers: Ted Smith & Virginie Barrand
- Geologists: Carl Elliott, Sophie Lafon & Philip Whiteley
- Geophysicist: Simon Robinson & Ben Hull-Bailey
- Petrophysicist: Peter Henderson
- Subsurface Team Lead: Yann Jehanno

- Schlumberger well placement team
- Halliburton well placement team

- J-Area partner ENI UK Limited