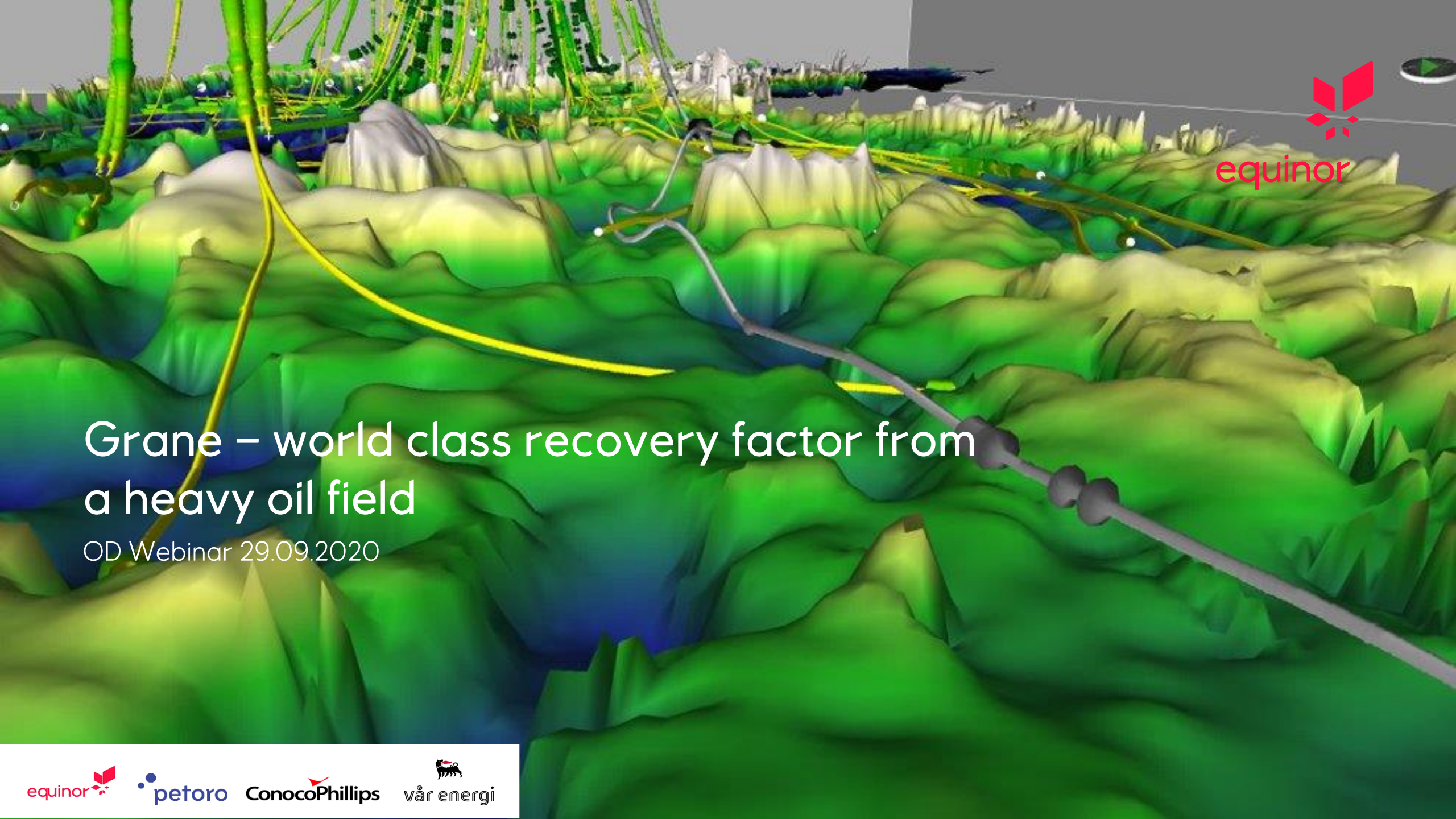
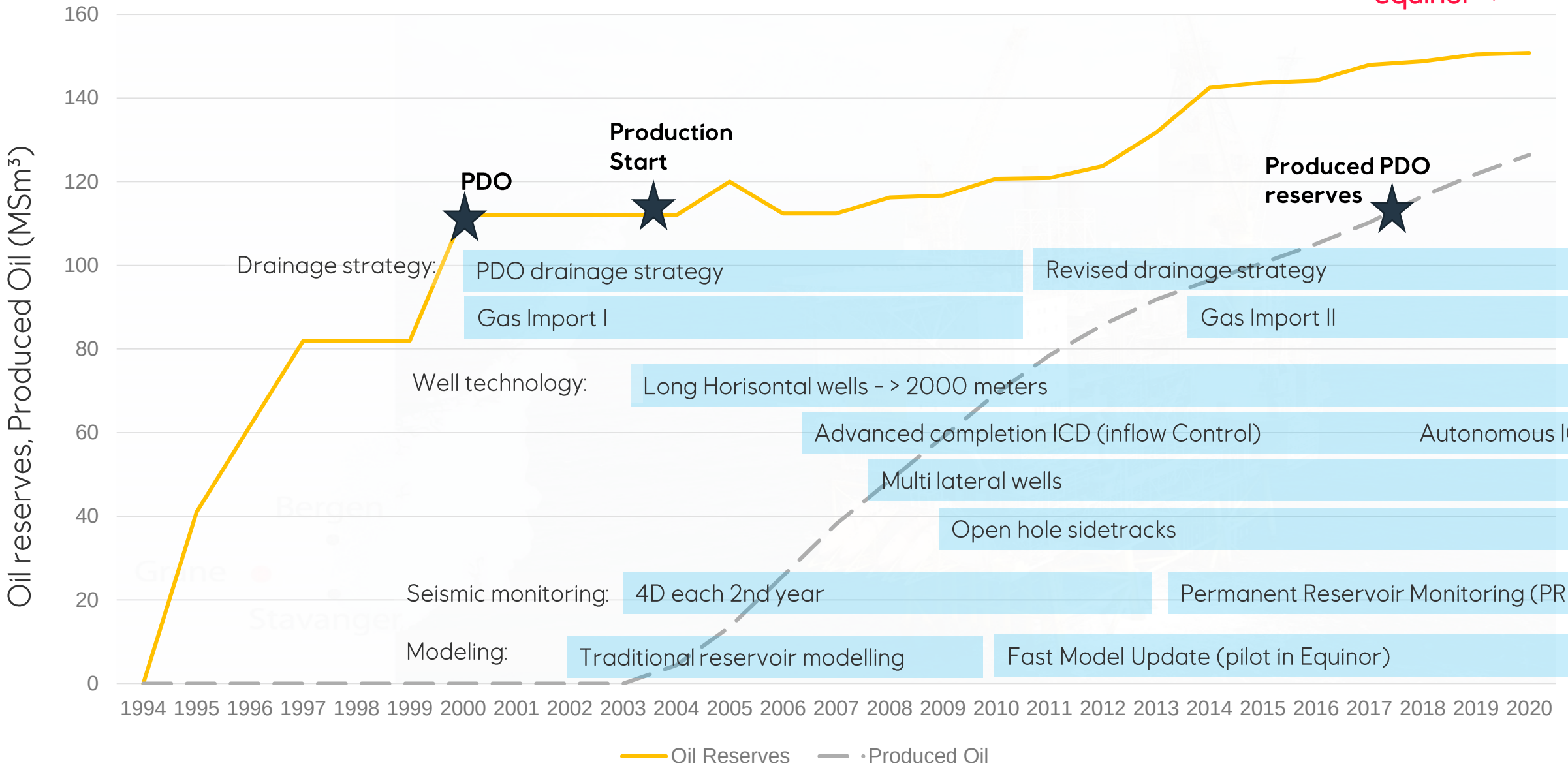


Grane – world class recovery factor from a heavy oil field

OD Webinar 29.09.2020

equinor petoro ConocoPhillips vår energi

Oil Reserves Development Grane



Grane: Key facts and initial drainage strategy

Geological setting

- Water depth 120-130 m TVD MSL
- Paleocene Heimdal fm
- Excellent properties, 7D permeability
- Reservoir depth 1680 m TVD MSL
- Hydrostatic pressure

Heavy Oil Reservoir

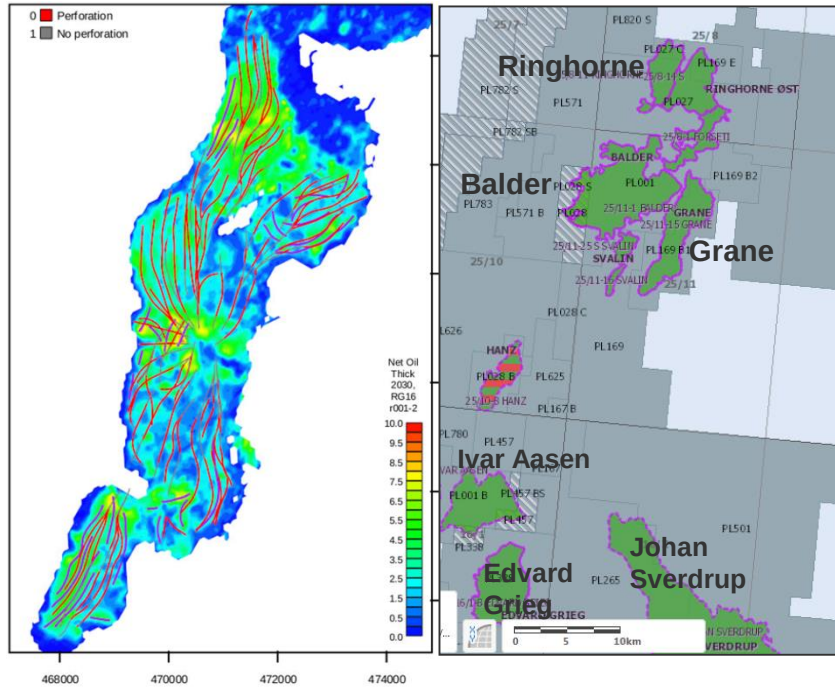
- 220 MSm³ STOOIP, no initial gas cap
- Oil viscosity 10 – 12 cP
- Coning challenges due to heavy oil:
  - Gas 750 times more mobile
  - Water 33 times more mobile

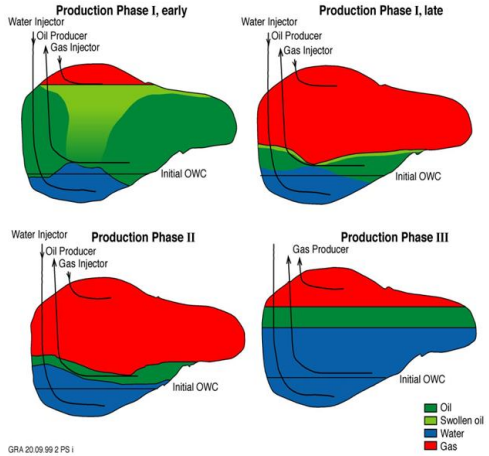
Primary drive mechanism PDO

- 3 alternatives evaluated
  - Water injection
  - CO2 injection
  - Gas injection
- Gas injection chosen, gravity stable

Drainage strategy in PDO

- Phase I: oil production, gas import, limited water injection
- Phase II: oil production, no gas import, increased water injection
- Phase III: gas export





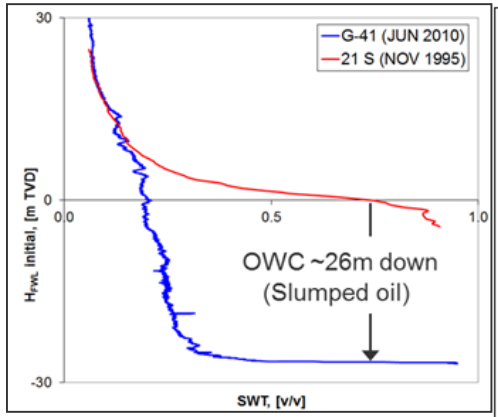
Revised drainage strategy

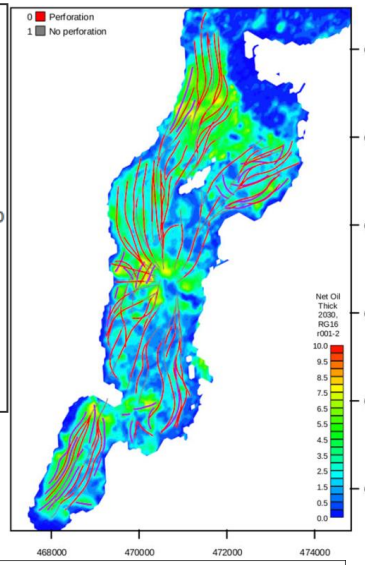
PDO Drainage strategy Phase II

- Initiated in 2010
- Increased water injection (WI)
  - Drill water injector(s) 2010
- Stopped gas import 2011

Observations

- Oil had slumped to base when drilling first water injector
- Massive water influx in North when stopping gas import



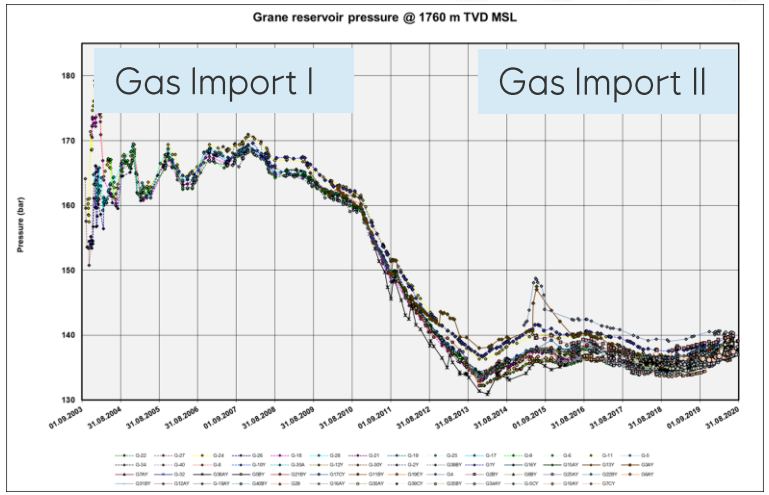


Mitigating actions

- Abandon increased WI as late phase IOR strategy
- Drill deep producers in central area
- Reopen gas import

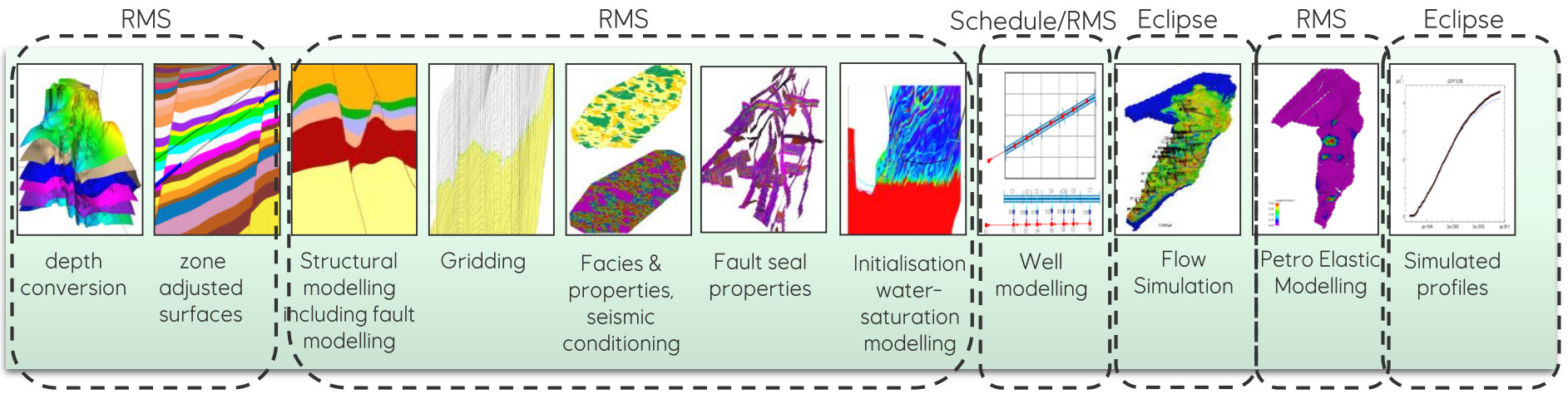
Revised Drainage Strategy

- Phase I: oil production, gas import until 2022(?)
- Phase II: oil production, no gas import, infill drilling ends when no more attractive targets
- Phase III: gas export



FMU concept - platform for cross-disciplinary collaboration

- Automation and integration of all the modelling steps: consistent, repeatable, updateable and can be run in batch.
- Grane was an early adaptor of the FMU workflow
  - Research Project started in 2009
  - First implementation in Asset 2010-2011
- Continuous improvement of functionality in workflow, modelling software, Visualization tools and Reporting tools



Grane PRM – world class seismic data

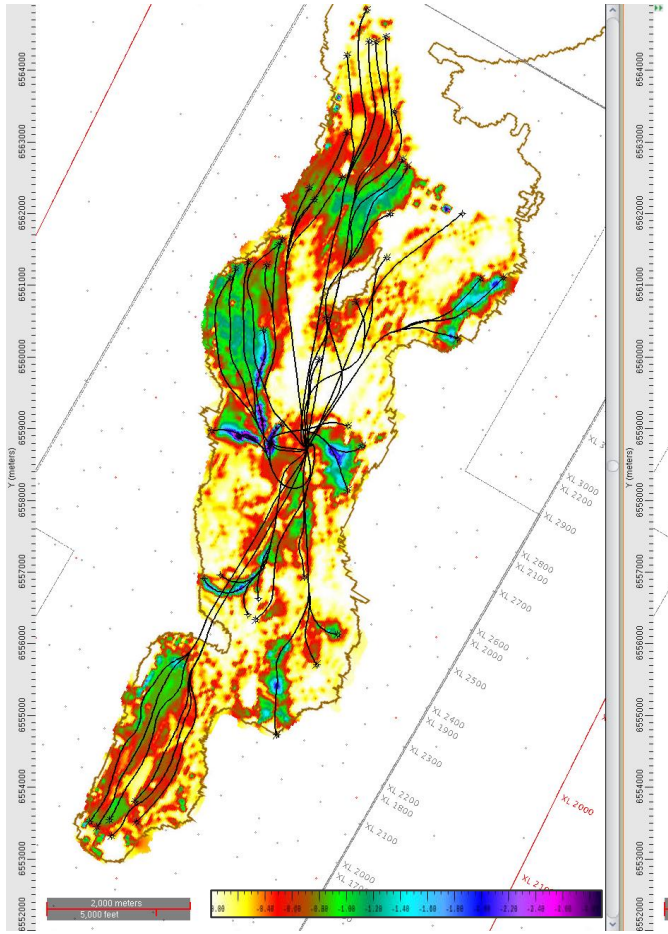
- First acquisition in 2014 – bi-annual acquisitions
- Frequent and high-resolution imaging of the dynamics in the reservoir
- Used as input to a sand probability cube (modelling)

- Ambitious seismic data acquisition:

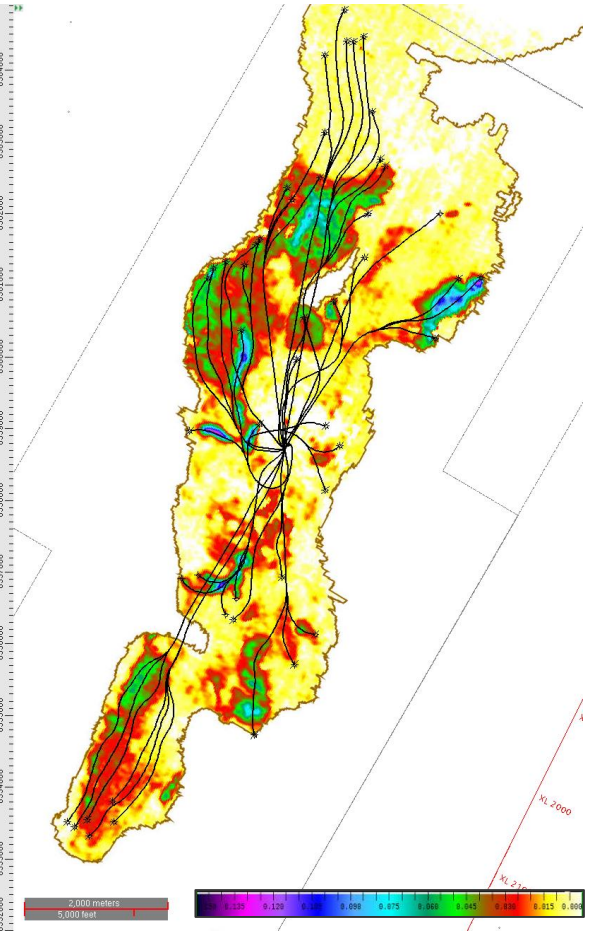
Survey	Area Covered	Objective	Comment
NH9301	Sub regional	Structural Imaging and 4D base	Reprocessed -97, 07, 15
NH0304 (OBC)	Southern part	Structural Imaging	Reprocessed 06/07, 12/15, 16
NH0501	Full field	4D streamer monitor 1	WG (Q-marine) acquired and processed by WG
NH0704	Full field	streamer monitor 2	WG (Q-marine) acquired and processed by CGG
ST09002	Full field	er monitor 3	PGS acquired and processed by Geokinetics
ST11007	Full field	or 4	WG (Q-marine) acquired and processed by WG
ST13007	Full field		Dolphin Geo acquired and processed by WG
ST14221 (PRM0)	PRM area	PRM ba	WGP acquired and processed by CGG
ST15221 (PRM1)	PRM area	PRM monitor 1	WGP acquired and processed by CGG
ST15222 (PRM2)	PRM area	PRM monitor 2	quired and processed by CGG
ST16221 (PRM3)	PRM area	PRM monitor 3	and processed by CGG
ST16222 (PRM4)	PRM area	PRM monitor 4	cessed by CGG
ST17221 (PRM5)	PRM area	PRM monitor 5	WGP by CGG
ST17222 (PRM6)	PRM area	PRM monitor 6	WGP acquir d by CGG
ST18221 (PRM7)	PRM area	PRM monitor 7	WGP acquired and ssed by CGG
EQ18222 (PRM8)	PRM area	PRM monitor 8	WGP acquired and processed by CGG
EQ19221 (PRM9)	PRM area	PRM monitor 9	WGP acquired and processed by CGG
EQ19222 (PRM10)	PRM area	PRM monitor 10	WGP acquired and processed by CGG
EQ20221 (PRM11)	PRM area	PRM monitor 11	WGP acquired and processed by CGG
EQ20222 (PRM12)	PRM area	PRM monitor 12	Ongoing: WGP acquired and processed by CGG

18 surveys since 2005

Reservoir simulation model:
Change in gross gas column thickness



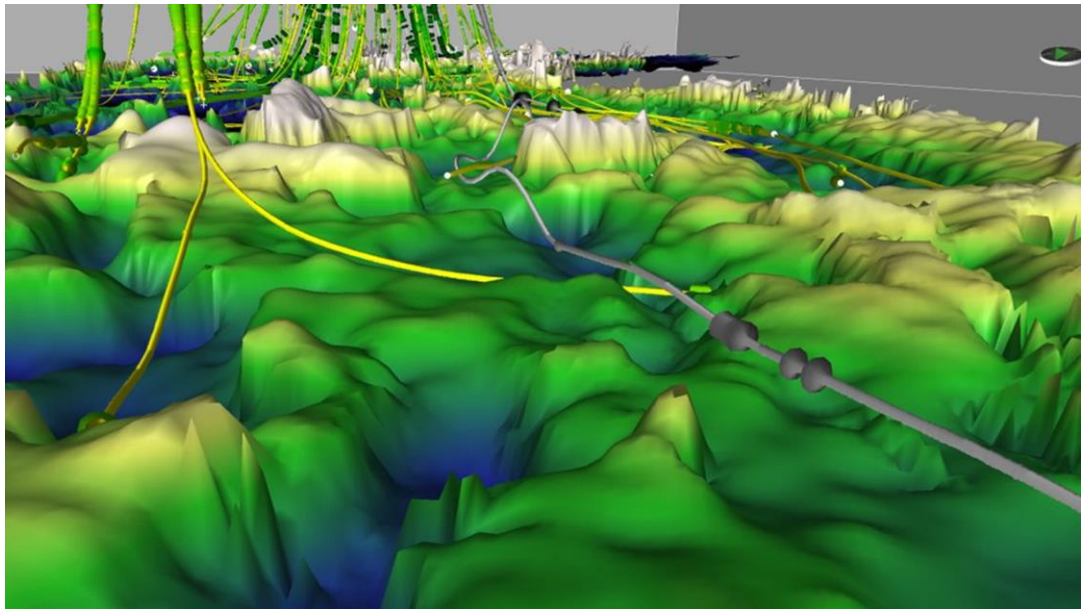
Seismic data:
MaxPos attribute

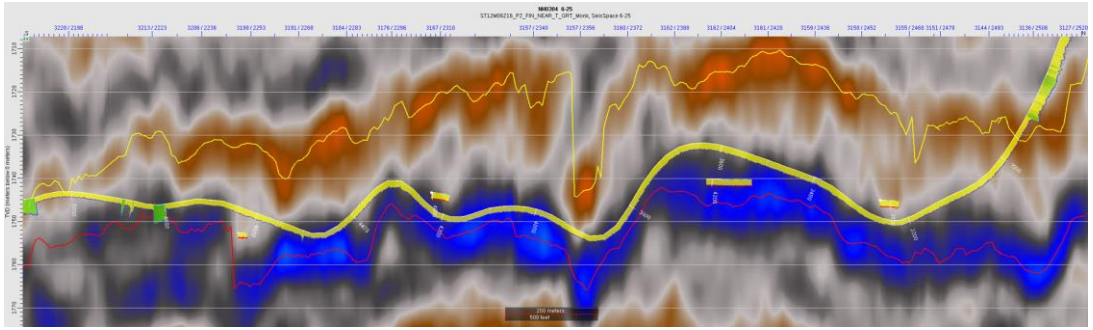


High quality seismic data and models allow tailor shredded wells …

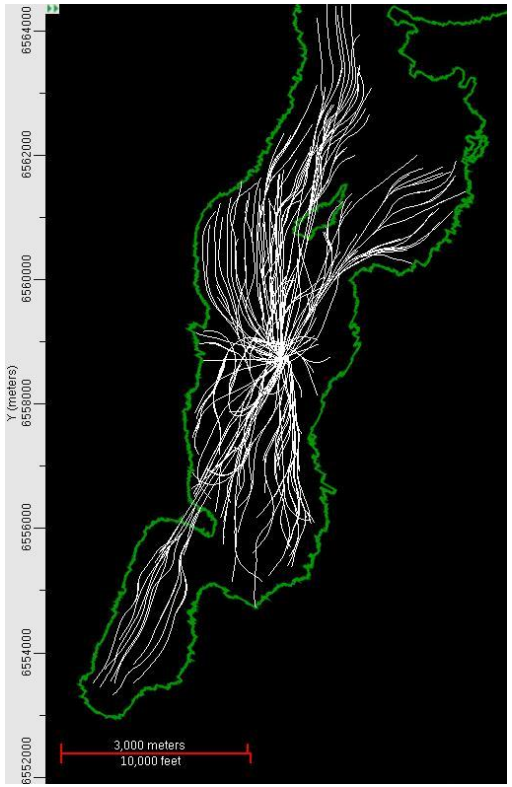
- Heimdal Fm. Sandstone (Paleocene) reservoir
  - Encased within potentially unstable Lista Fm. shale
  - Assumed originally massive turbidite sands
  - Porosity ~33% (30-38), permeability ~7D (3-12)
  - Rugose top/base reservoir due to geological remobilization and sand injection

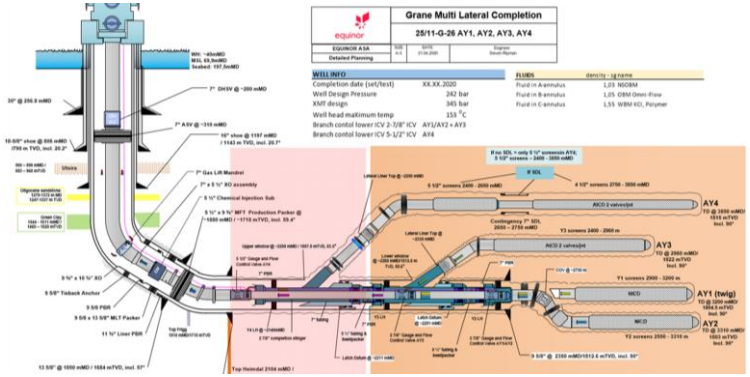
- Target wells as deep as possible to drain slumped oil
  - Requires high precision in seismic imaging





IOR Enabler – advanced drilling and well technology





- 2003-2004: single laterals, no inflow control
- 2004: G-6 first well with ICD
- 2005: G-10 first MLT well (with ICD)
- 2007: G-39 BY first well with ICV (2 x ICV)
- 2008: started to use open-hole side-tracks to avoid unstable shale
- 2009: G-18 pilot testing of RCP valve
- 2011: G-38 AY first well with TWIG (branch with open-hole junction in the reservoir)
- 2012: G-5BY first re-drilling of existing well slot
- 2017: G-16 AY with Tendeka TR7 (RCP valves)
- 2018: G-35 BY, first user Weatherford Floreg WR7 (RCP valve)
- 2019: G-5 CY, first MIC system with 3 x ICV

Dense Well Pattern

Currently drilled 116 producing/injecting well tracks (31 well tracks planned in the PDO)

Additional 50 more well tracks to be drilled (RC1-5)

Typical Well Design today

3 branched well

lateral reservoir sections between 1000 and 2500 m

individual branch control & AICD

Advanced geosteering a necessity

Technology development in collaboration with vendors

Multilateral wells: Halliburton

Geosteering: Baker

Autonomous inflow control devices

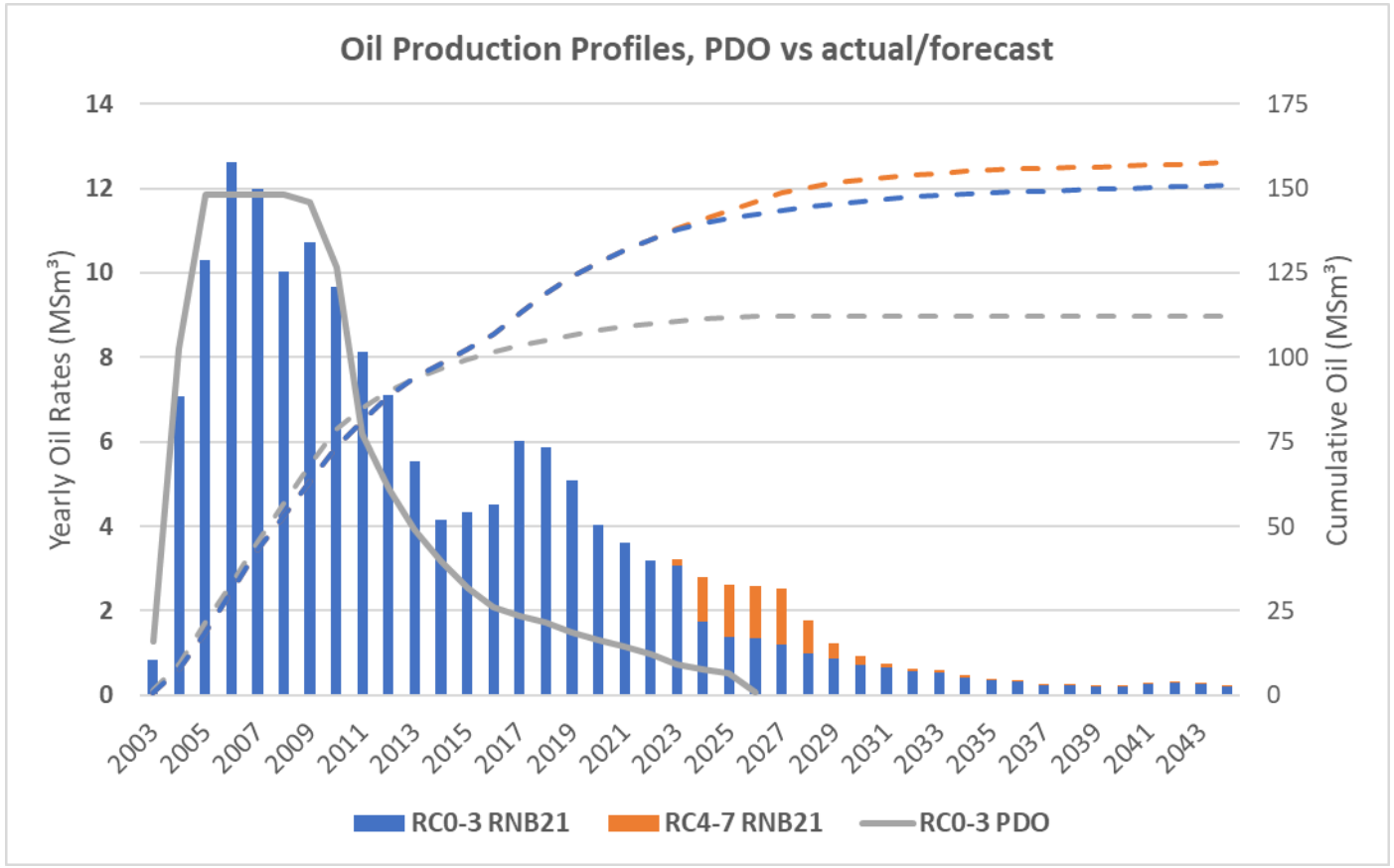
-Tendeka and Weatherford Floreg (RCP)

Bold decisions made early in the Grane license- enabled world class recovery

- Recovery factor from the Grane field is today 57 %

- PDO* Recovery Factor = 55%
- RNB2021** Recovery Factor = 69%
- Ambition Recovery Factor = 72%

- Increased well density together with advanced drilling and well technology will be the main future IOR enabler to achieve the recovery ambition



*) *STOOIP PDO 205 MSm³, revised STOOIP estimate 220 MSm³*
**) *RNB 2021 expected reserves*

NPD IOR webinar 29.09.2020

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Acknowledgements to the Grane licence partners: