New Technology: "Single-Trip Multi-Frac"

Teknologidag Oljedirektoratet, 7. juni 2023

Statfjord field, Equinor

Marius Berge-Skillingstad, lead completion engineer

Agenda

- Introduction to Statfjord
- Low permeable reserves on Statfjord
- Motivation for use of multi-stage fracturing
- Introduction to «Single-Trip Multi-Frac» operations
- Pilot well C-7 C and experiences
- Lessons learned and way forward

Technology developing through decades

Initial oil production by pressure maintenance

IOR production

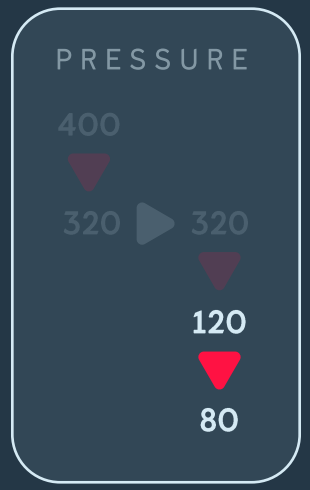
Statfjord Late Life (SFLL)

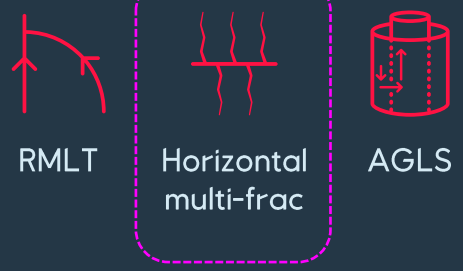
Field Lifetime eXtension (FLX)

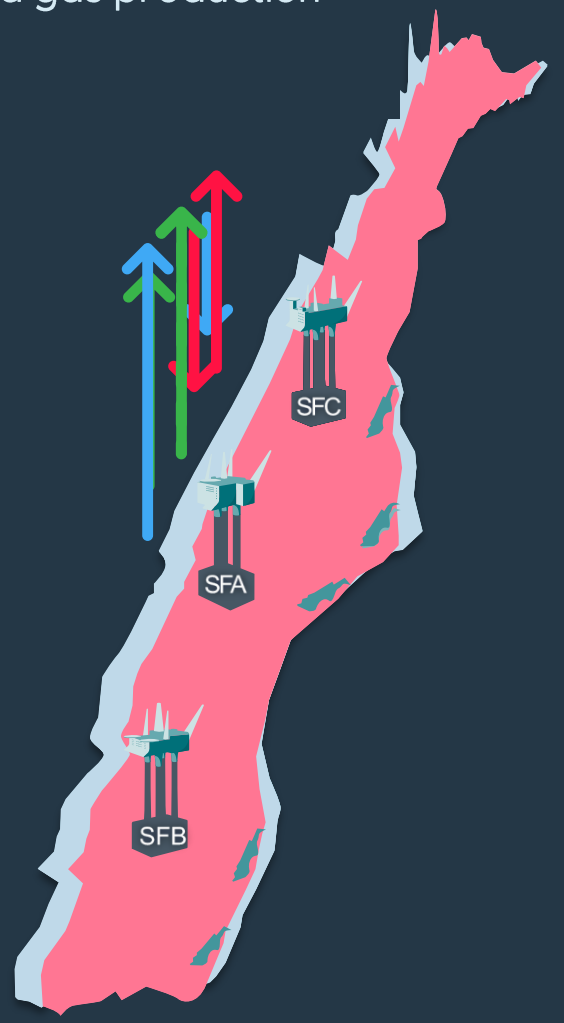
- New ways of working > continue chasing oil, gas and water
- Continue lowering pressure topside
- Deeper gas lift & AGLS
- Retrofit multilateral wells (RMLT)
- Horizontal multi-frac wells for low permeability/ tight formations (Cook)

2020 → 2040 Maximise oil and gas production

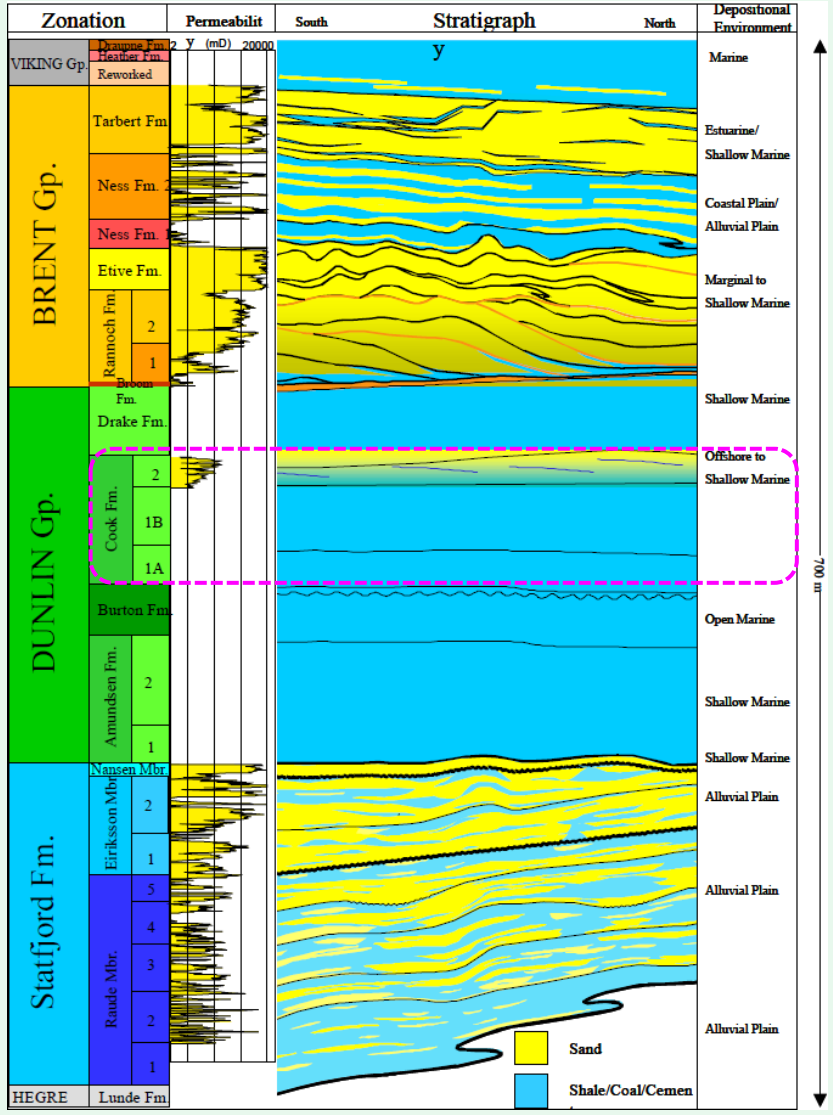
FLX: RMLT, GL, AGLS
horizontal multi-frac



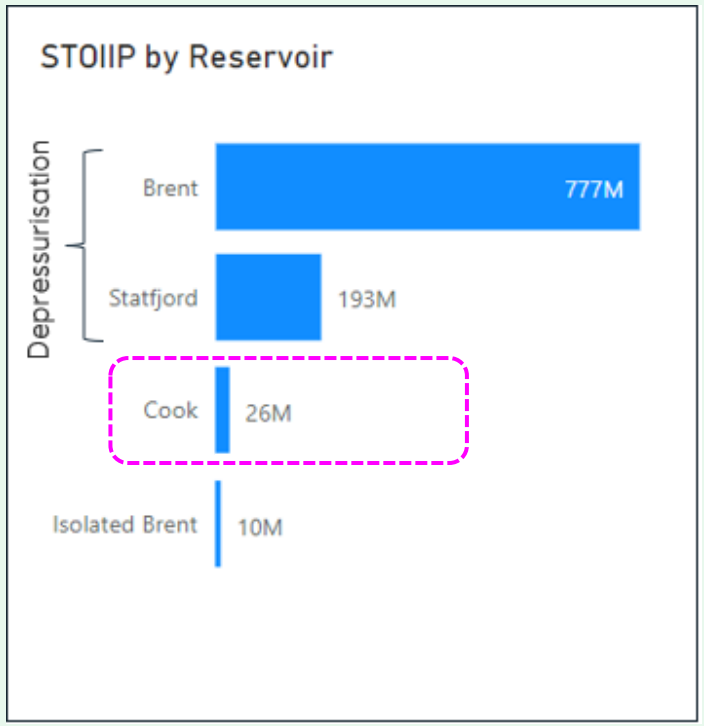




Low permeable reserves on Statfjord



Average Reservoir Properties						
Reservoir	Zone	Porosity (%)	Water Saturation (%)	Gross Thickness (m)	Net / Gross (%)	Permeability (mD)
COOK	Cook 2	22	10-20	22	45	200-1000
	Cook 1	11	50-60	40-65	5	**1-10**

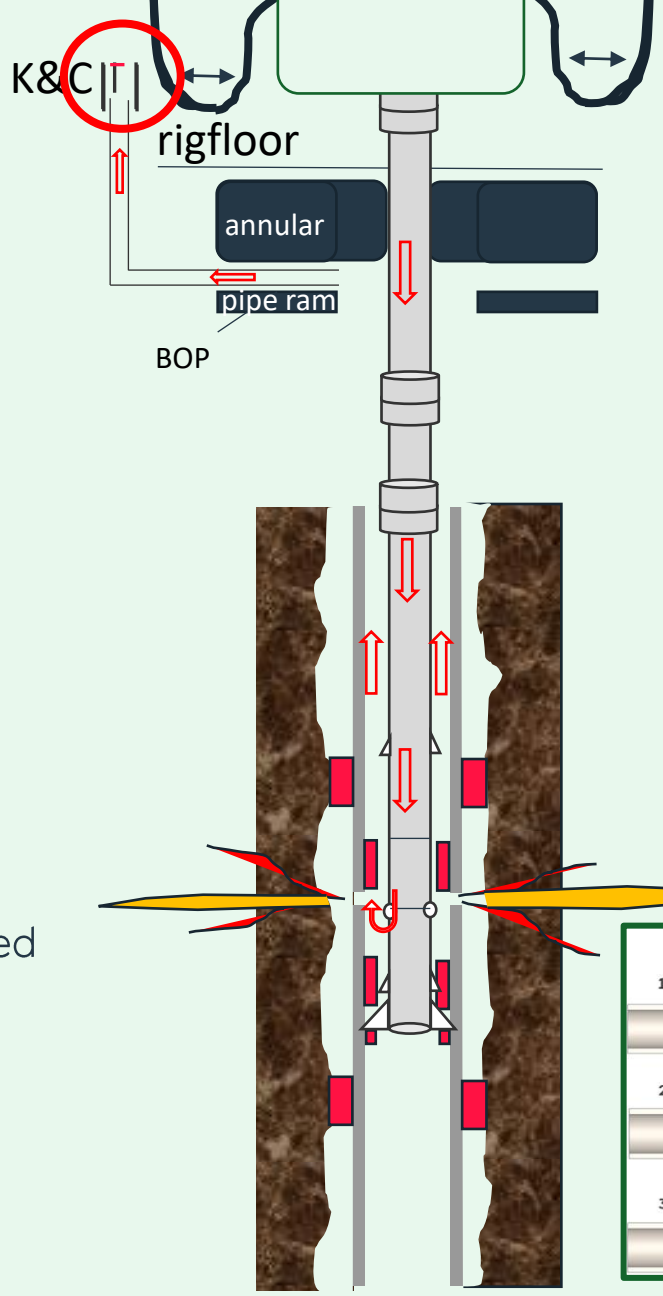


Initial Reservoir Conditions			
COOK	Datum Depth	2469.0	m TVD MSL
	Datum Pressure	383.4	BARA
	Datum Temperature	93.7	Deg. C
	Oil Water Contact	2604.4	m TVD MSL

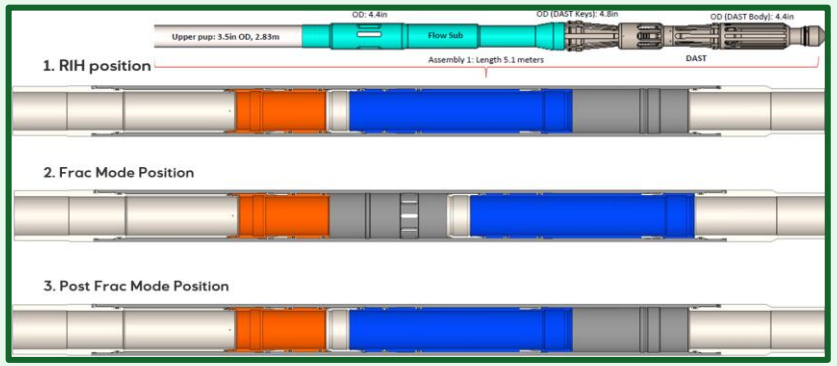
STOOIP Distribution and Oil Recovery per Rezervoir Zone			
Reservoir Zone	STOIIP (MSm3)	Oil Produced as of 1/1/2023 (MSm3)	Oil Recovery Factor (%)
Cook 2	12	5.1	43%
Cook 1	**8**	**0.2**	**2%**
Cook East Flank	6	0.0	0%
Total Dunlin Gp.	**26**	**5.3**	**20%**

"Single-Trip Multi-Frac" – What is it?

- RIH with DAST
- Open frac sleeve
- Breakdown test + Analysis
- R/U frac stand
- Connect stimulation vessel
- Flush lines / PT
- *Optional: Pump Mini-frac / SRT*
- Pump Main frac
- Close frac sleeve and reverse out underdisplaced proppant slurry with const BHP
- Leak test frac sleeve
- R/B frac stand
- POOH to next sleeve

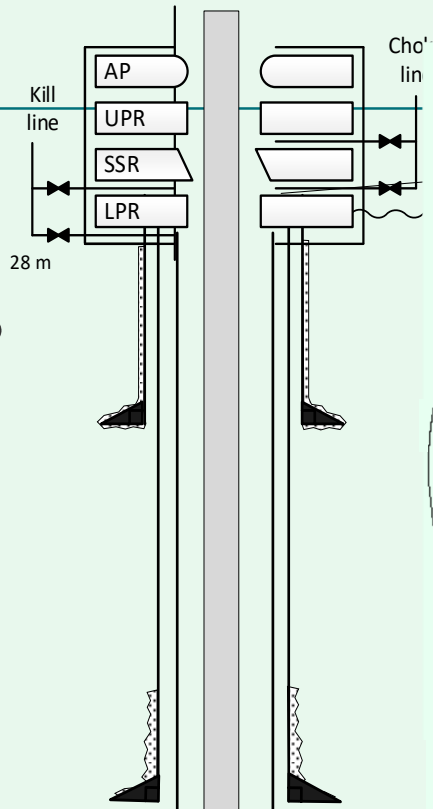


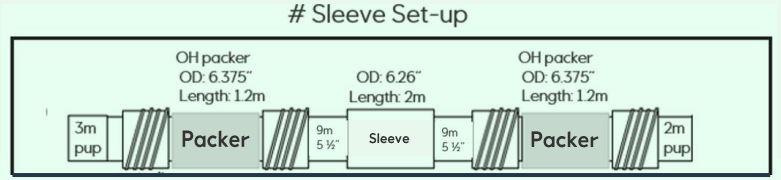
ANIMATION

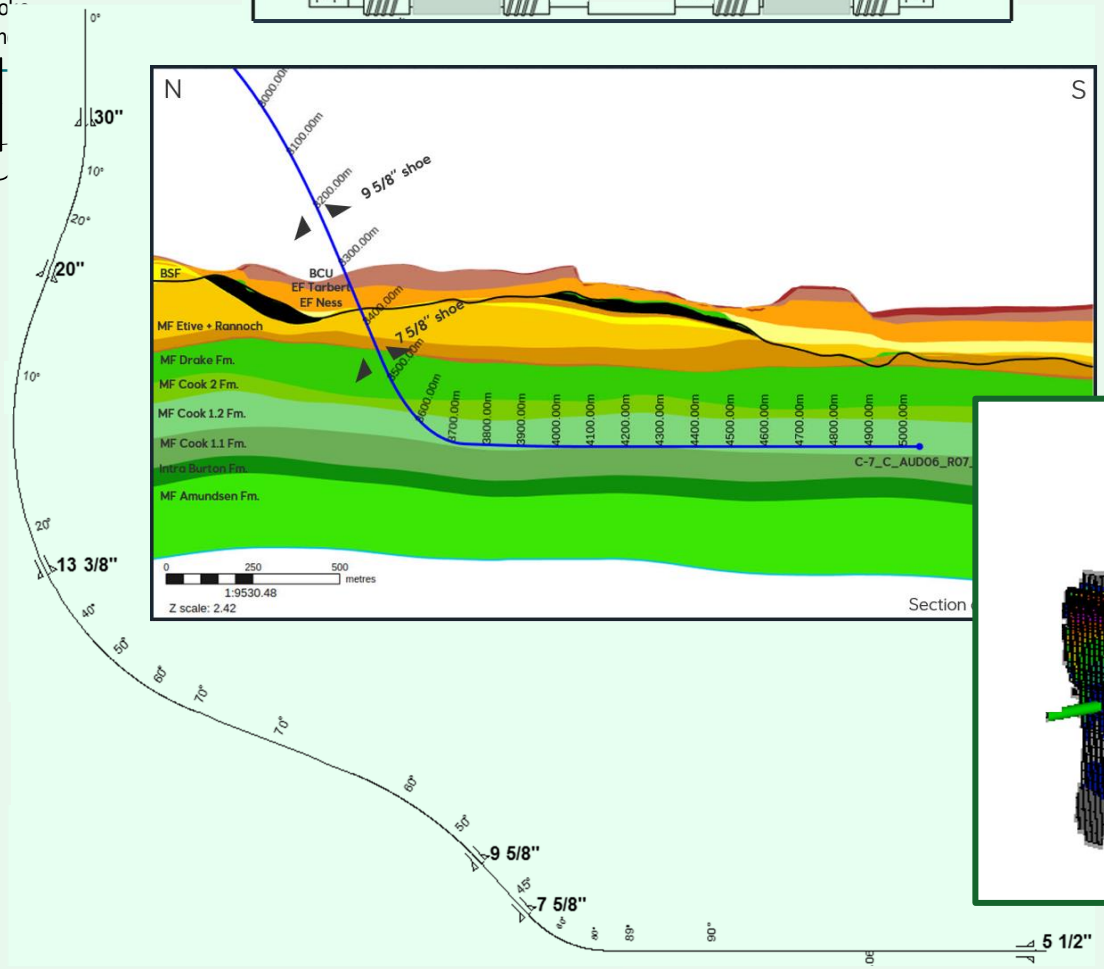


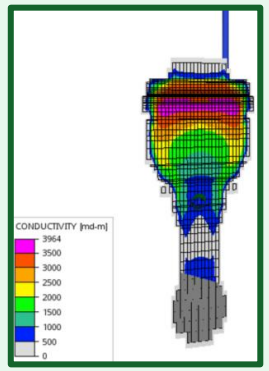
C-7 C
Well objective

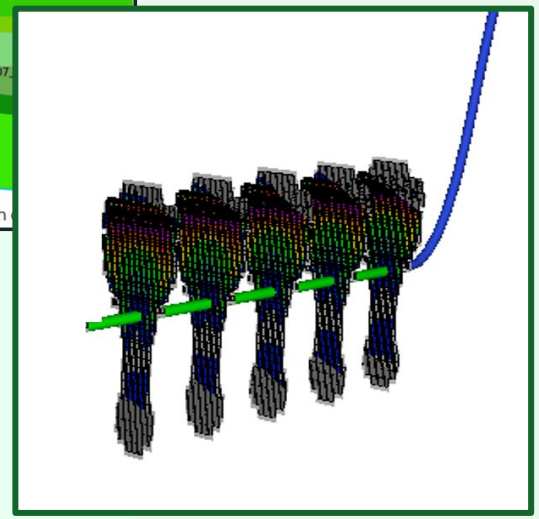
The idea is to initiate fractures from Cook 1 up to and including Cook 2. This will enable drainage of the low productive Cook 1 and at the same time get sufficient production from Cook 2 to have commercial rates.

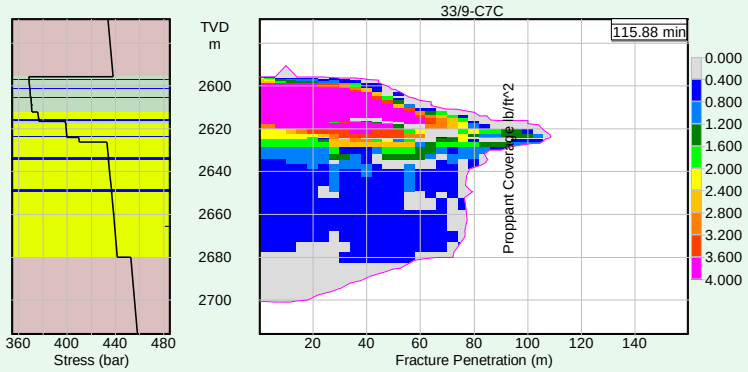


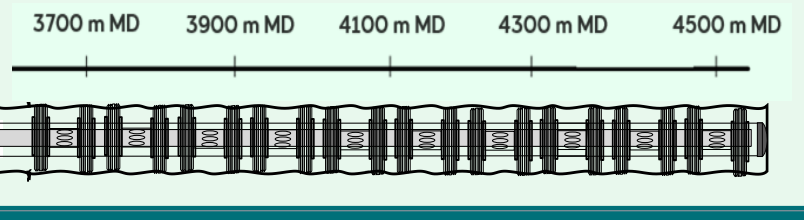












C-7 C Frac design - Timeline

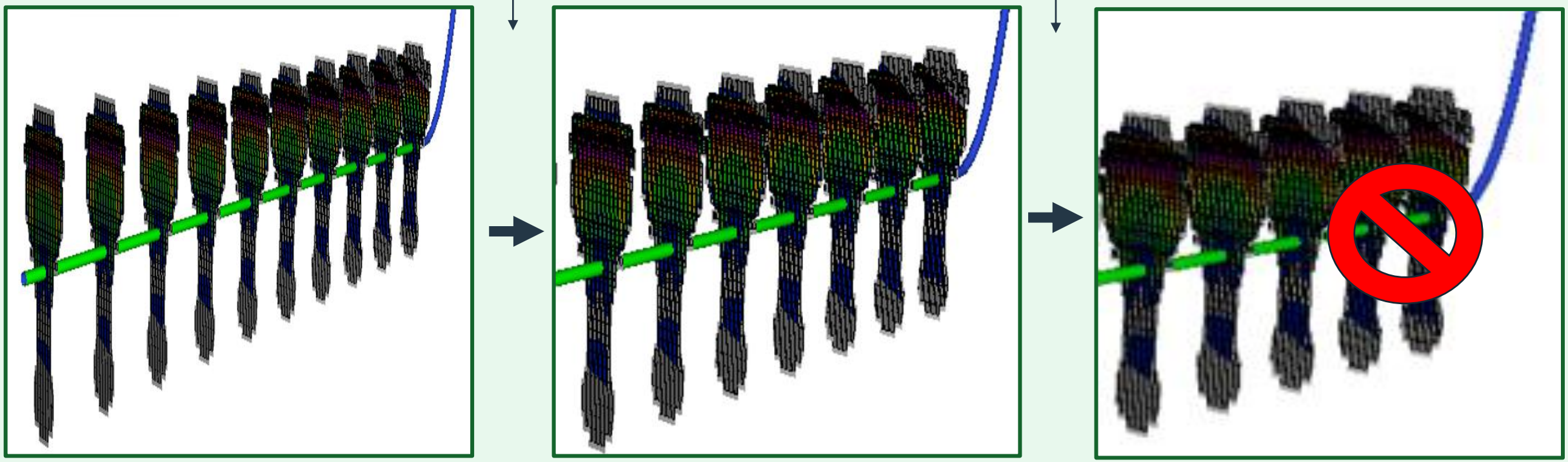
Subsurface potential
10 stages

Logistical Limitations

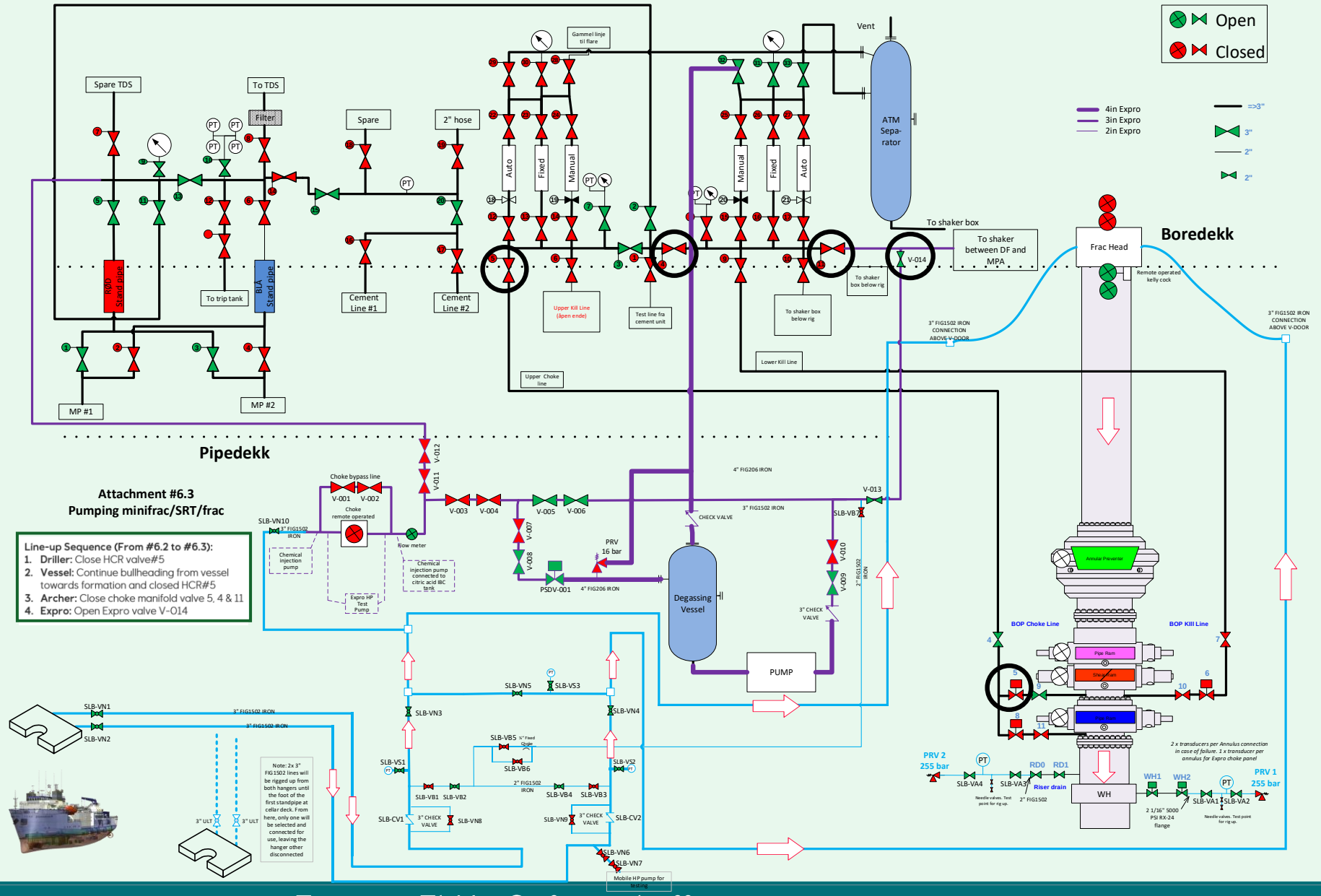
Subsurface freeze
7 stages

Technical & Time Restraints

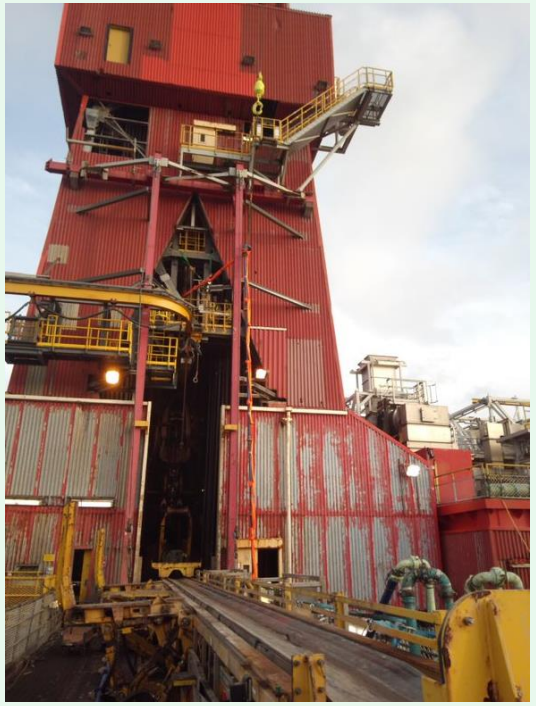
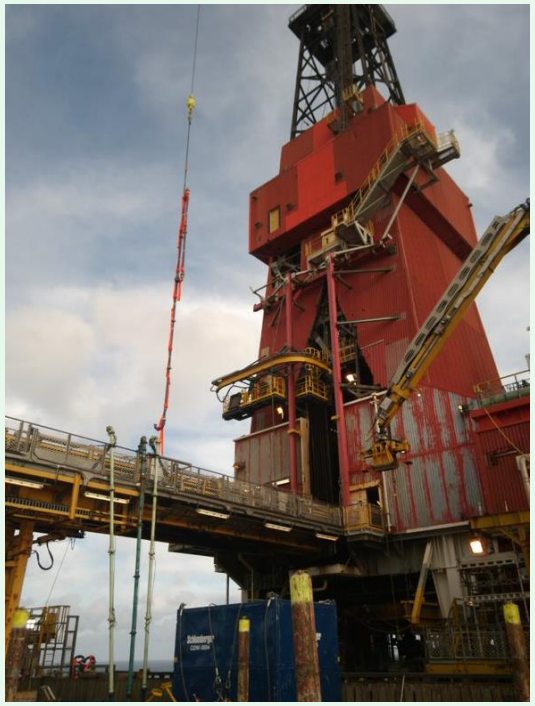
Management of change
3 of 5 stages

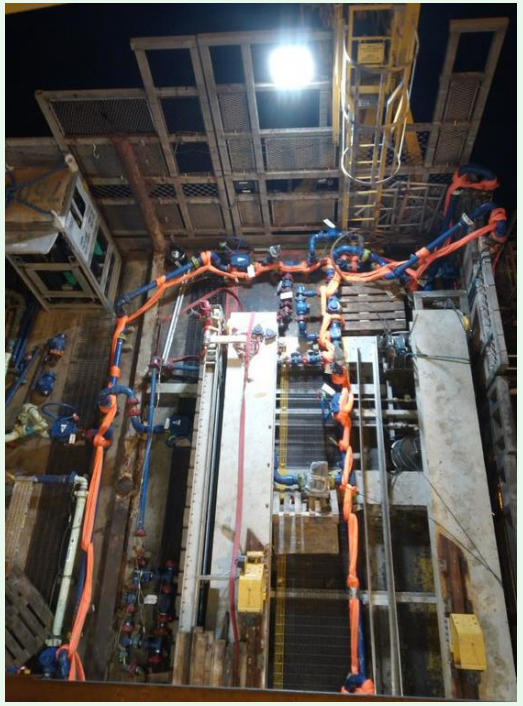
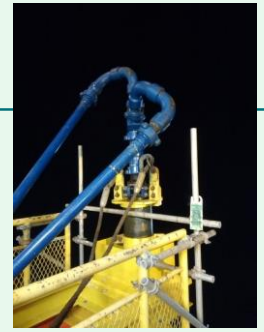


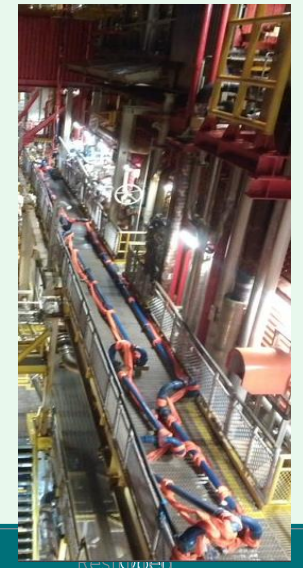
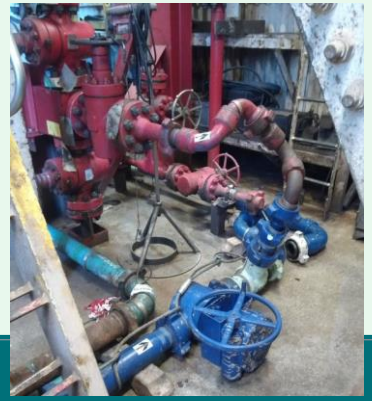
Line-up diagram

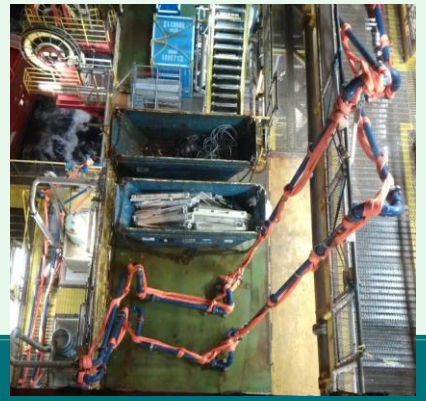


Line-up: reality

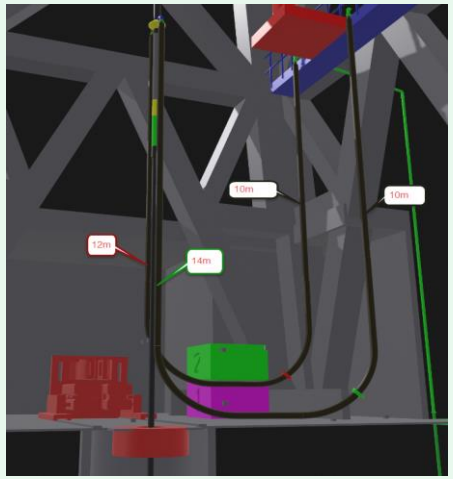



Frac stand – What is it?

- Frac head handling is typically very time consuming

- A lot of manual work required in red zone
- Rigging up/down scaffolding on drill floor
- No cherry picker available on Statfjord (limited ability working at height)

3D modelling

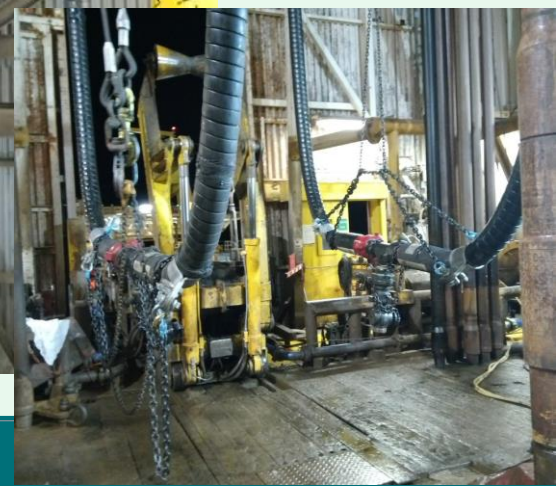


Stack-up test X-rig Ålgård →

Frac stand Statfjord C →

Rig up / Rig down

Less than > 30 min



Summary of the results

Total stage time
32 hours

Stage 1

Connect vessel. Flush and PT surface lines
Performed Breakdown test
Performed mini-frac
Performed Main frac on sleeve #1

Total stage time
8 hours

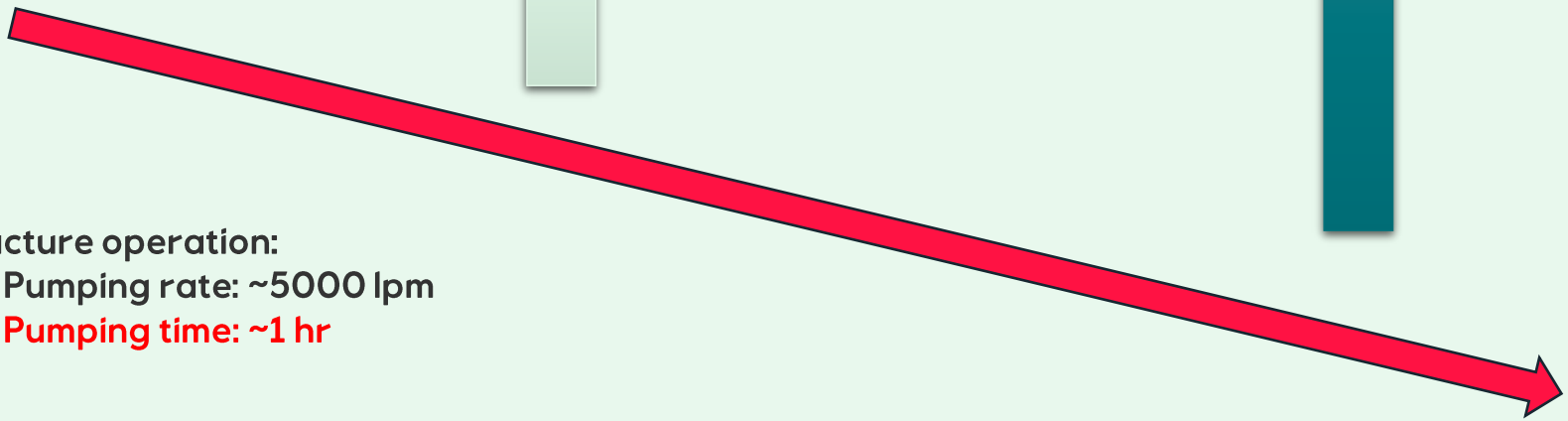
Stage 2

Performed Breakdown test
Performed Main frac on sleeve #2

Total stage time
7 hours

Stage 3

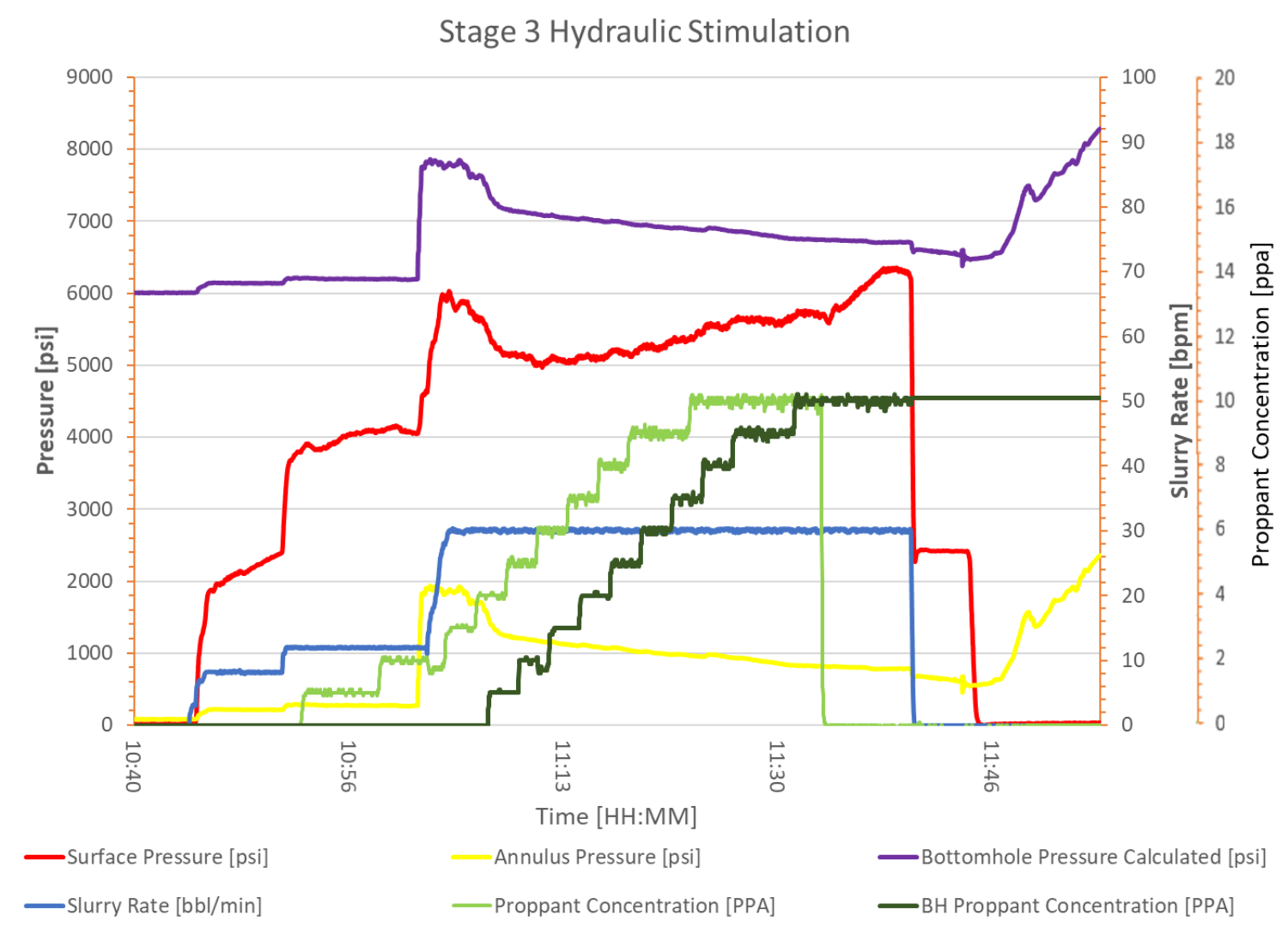
Performed Breakdown test
Performed Main frac on sleeve #3



Fracture operation:

- **Pumping rate: ~5000 lpm**
- **Pumping time: ~1 hr**

Stage 3 Hydraulic Stimulation



Equinor FLX - Safe and efficient operations

Summary of the results | Ambitions

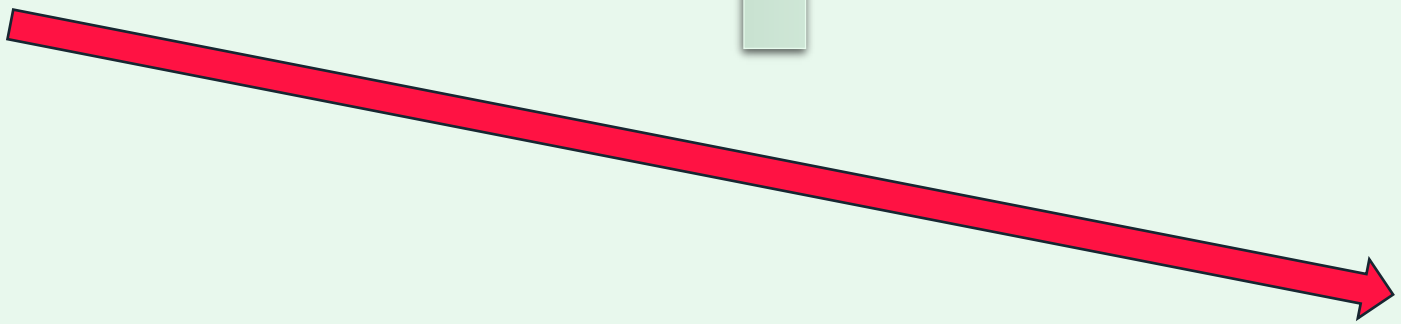
Stage 4 - Aborted

Opened sleeve #4
Performed Breakdown test
Went into losses
Closed sleeve
Losses stopped
POOH to the next sleeve

Stage 5 - Aborted

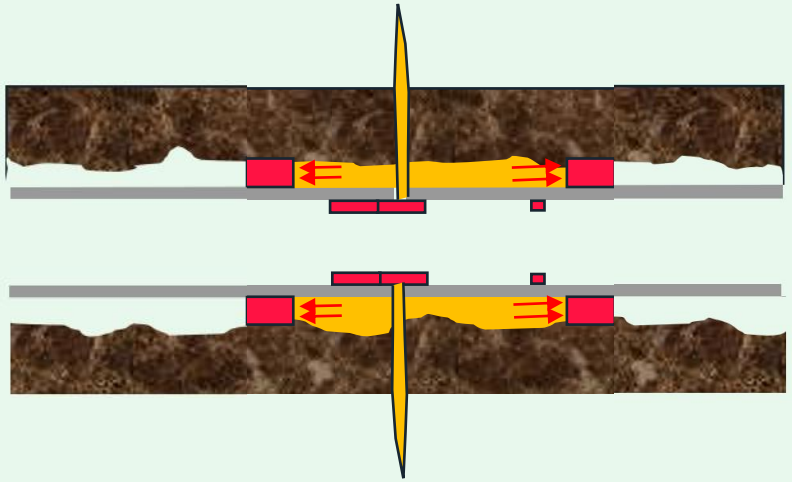
Opened sleeve #5
Went into losses
Closed sleeve
Losses stopped
Aboard ops

Losses 25-30 m3/hr

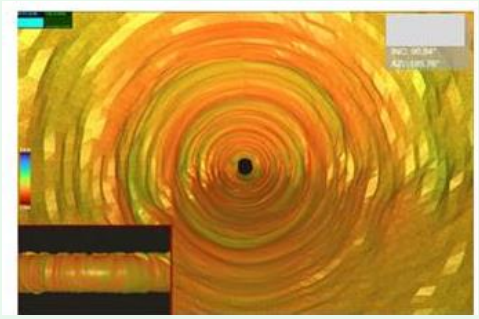


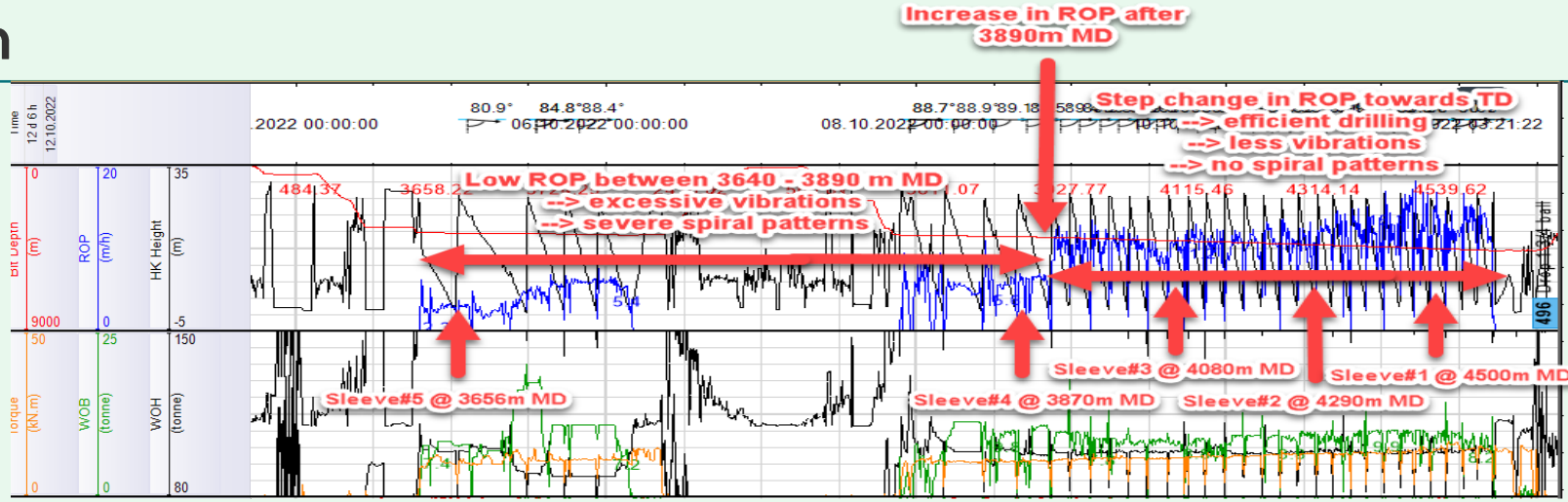
We can do a stage in 6h!

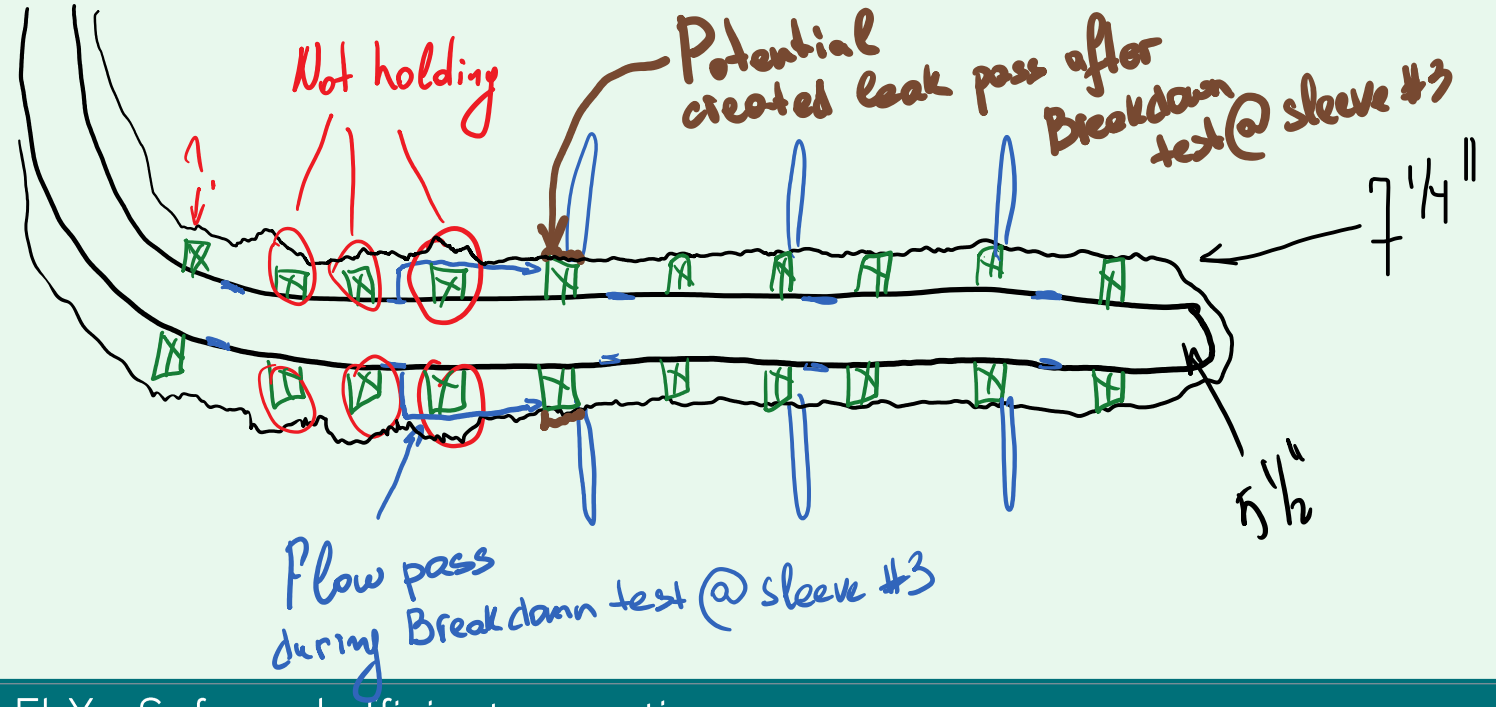
A bit of an issue / speculation



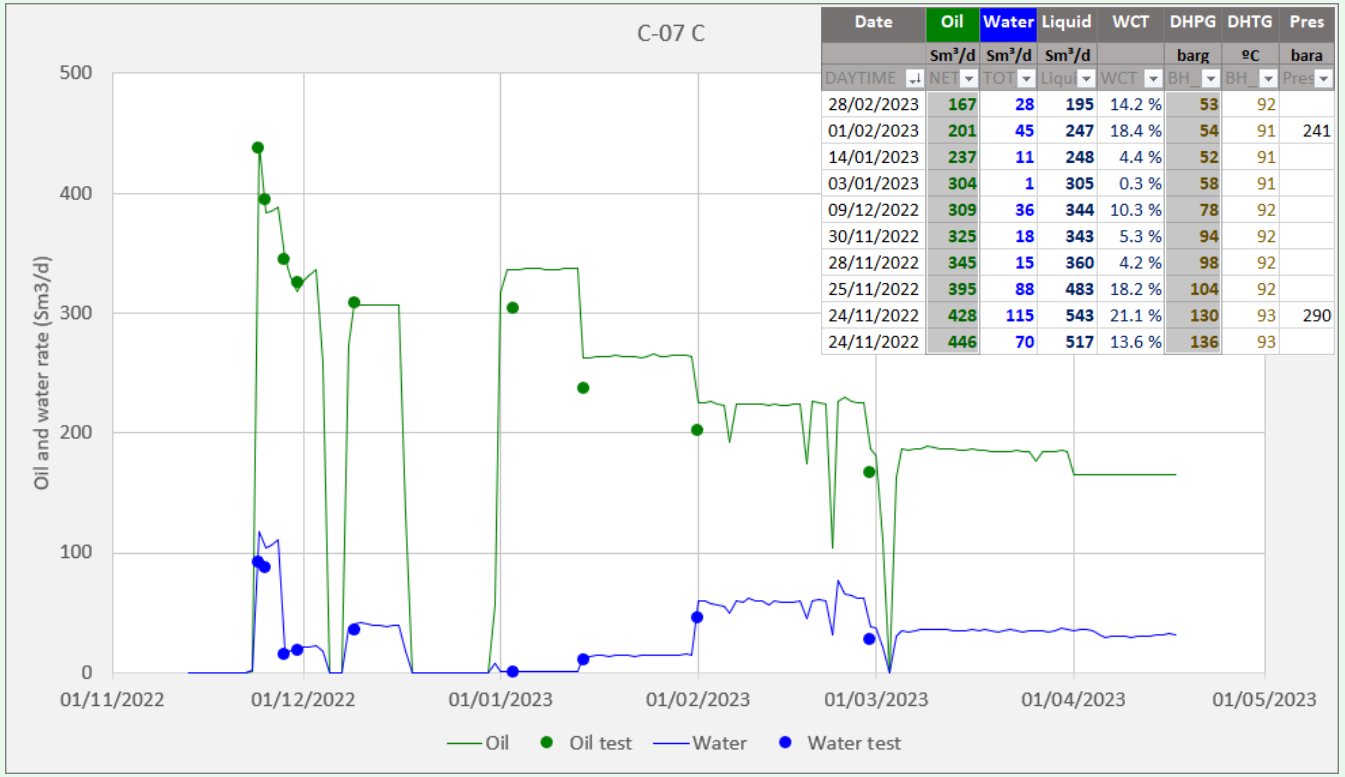
This is not from C-7 C, only illustration !







C-7 C – Well Performance



Date	Oil	Water	Liquid	WCT	DHPG	DHTG	Pres
	Sm³/d	Sm³/d	Sm³/d		barg	ºC	bara
DAYTIME	NET	TOT	Liqui	WCT	BH_	BH_	Pres
28/02/2023	167	28	195	14.2 %	53	92	
01/02/2023	201	45	247	18.4 %	54	91	241
14/01/2023	237	11	248	4.4 %	52	91	
03/01/2023	304	1	305	0.3 %	58	91	
09/12/2022	309	36	344	10.3 %	78	92	
30/11/2022	325	18	343	5.3 %	94	92	
28/11/2022	345	15	360	4.2 %	98	92	
25/11/2022	395	88	483	18.2 %	104	92	
24/11/2022	428	115	543	21.1 %	130	93	290
24/11/2022	446	70	517	13.6 %	136	93	

- Signs of transient behavior typical of low-permeability reservoirs
- Gradual reduction of both the liquid rate and flowing bottomhole pressure
- **Potential for future production improvements for next wells**

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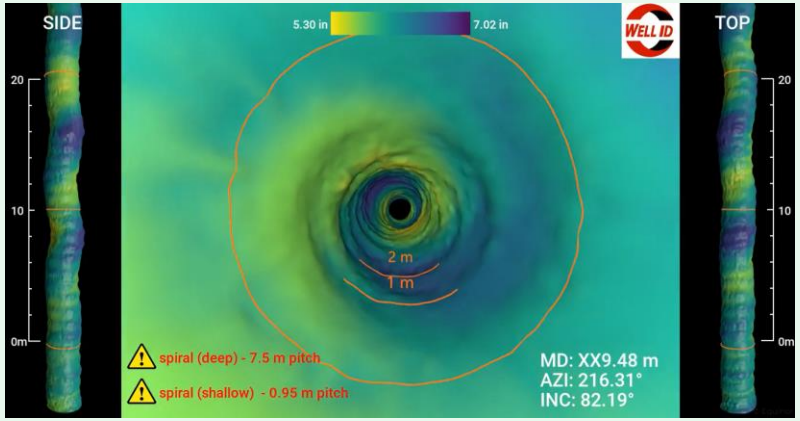
C-7 C – Lessons Learned and Way Forward

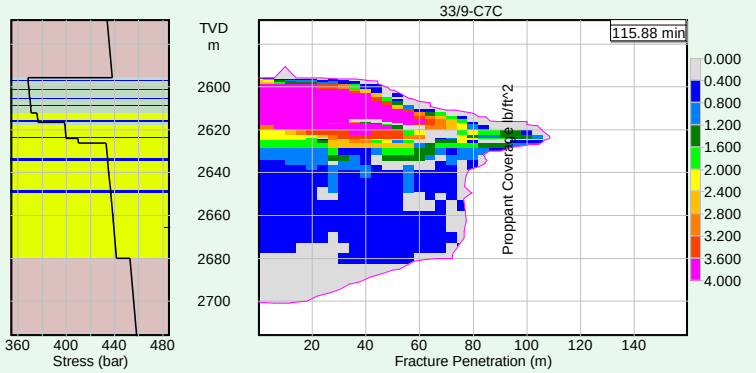
Completion design changes:

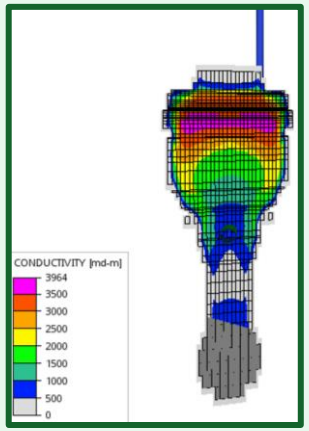
1) Removing underreamer
2) Redesigned WLP packer for 6 ¾'' hole
3) WellID 4D caliper

Frac design changes:

1) Wellpath will be landed shallower to reduce vertical distance to Cook 2.
2) Final concentration of proppant will be increased.







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Marius Berge-Skillingstad, lead completion engineer

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