Persistence pays off with subsea water shut off on Kinnoull Field

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Kinnoull Field Introduction

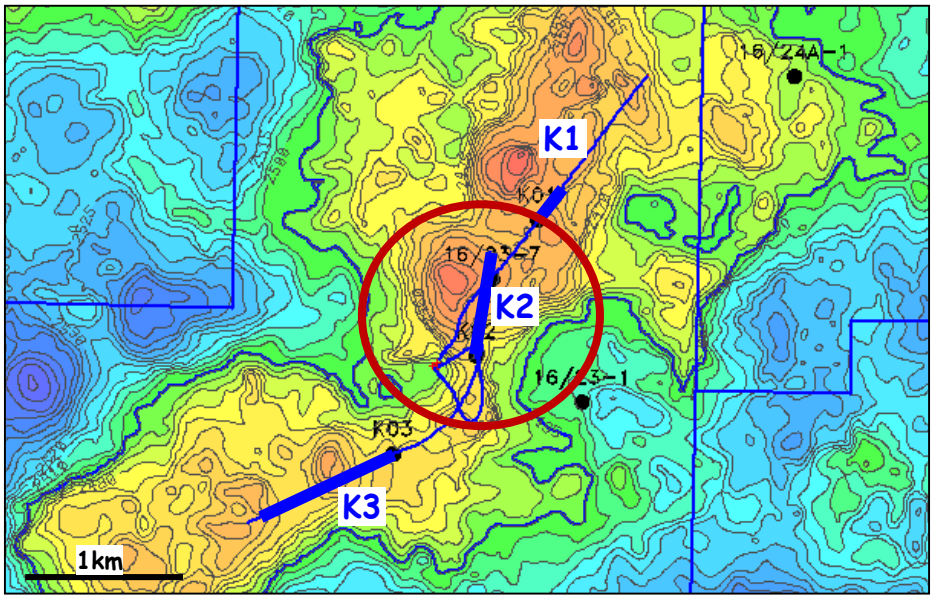
A three well subsea tieback to the Andrew Platform via 28 km pipeline.

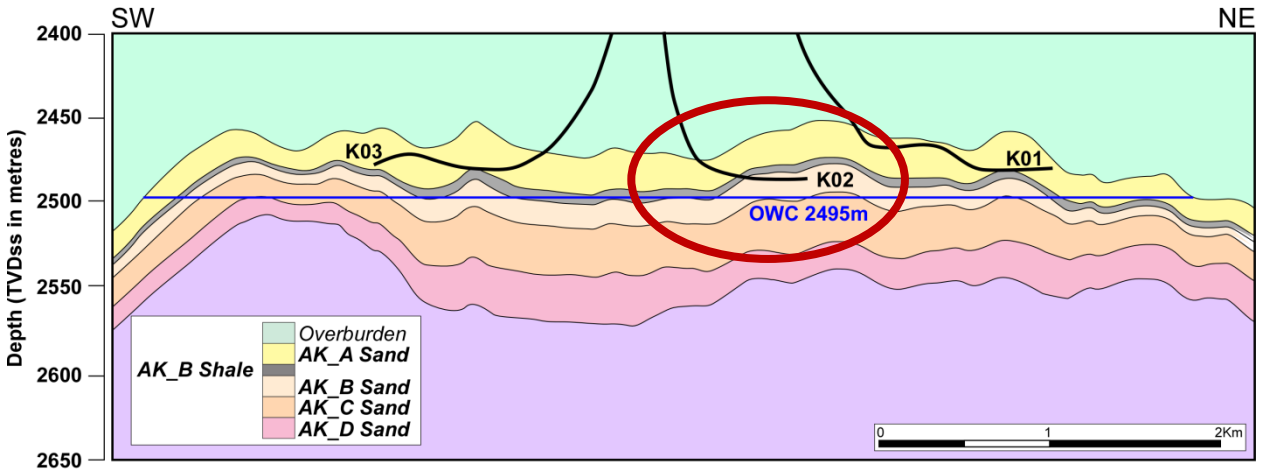
80mmbls of under saturated oil in place.

Discovered by 16/28-7 in 2008. First oil late 2014.

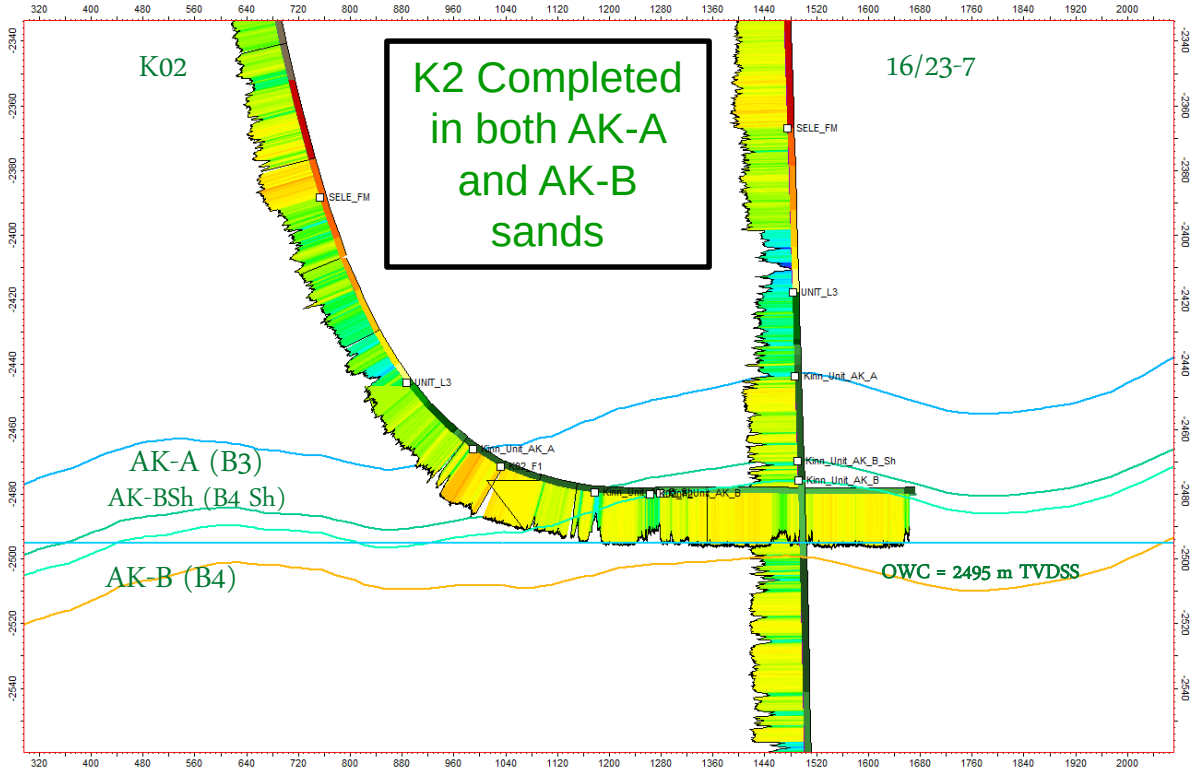
Joint venture between BP (77%) and JX Nippon (23%)

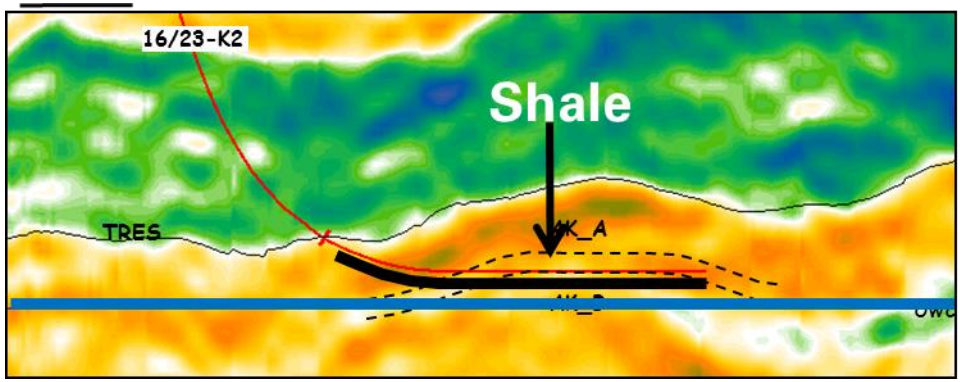
ISSUE: K2 started cutting water earlier than expected, in June 2015.





K2 Static





Reservoir is made up of two laterally extensive Lista sands; AK-A and AK-B. Separated by a barrier formation, the AK-B Shale.

The AK-A and AK-B are good quality, clean, porous (~25%) and permeable (~500mD)

K2 is the only well to be completed in the AK-B along the crest of the field where the sand rises above the oil water contact (OWC)

K2 completed 15m above the OWC to prevent early water breakthrough.

K2 – Petrophysical logs

K2 Water Cut and GAP Model

A sharp increase in K2 water cut was measured 250 days after start up.

The high water cut had a significant backing out effect on the other two Kinnoull wells.

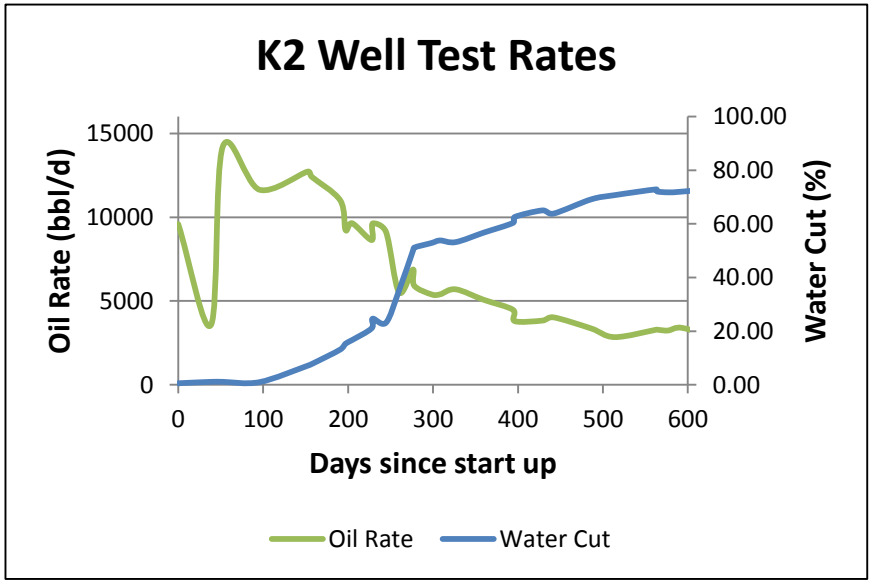
Investigation and modelling work was completed through a close working relationship between the Kinnoull JV partners, BP and JX

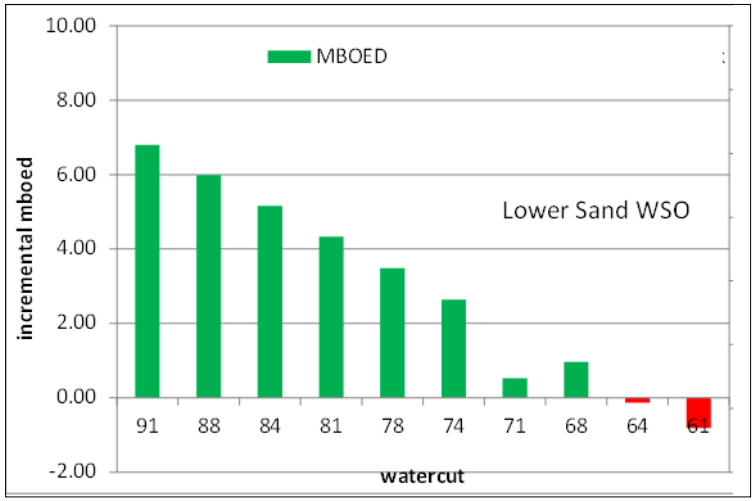
Simulation modelling (JX) and Well GAP modelling (BP) were completed to appraise the forward options.

<u>GAP Model (BP)</u>

Log permeability was used define the PI split between AK-A and AK- B sands

The GAP model indicated significant incremental oil with a lower sand water shut off (WSO). Final results would depend on the water cut split between the two sands.





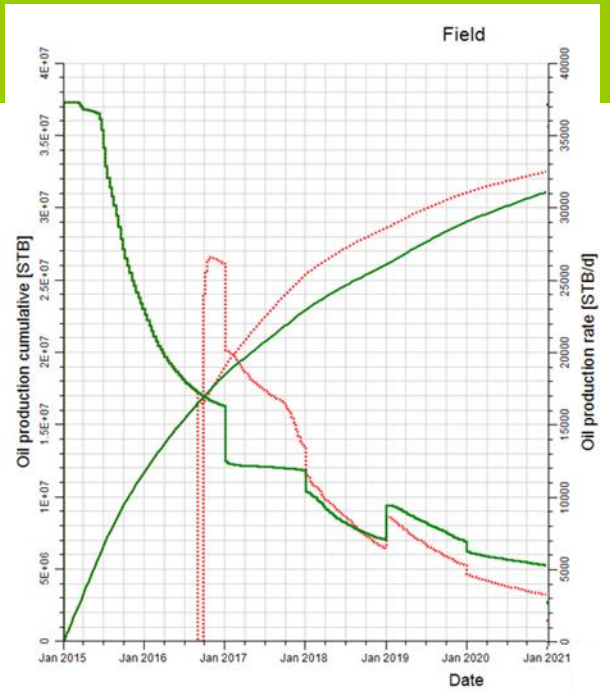
K2 Simulation results

Full field simulation model built and matched by JX.

A good simulation match is achieved with water production primarily from the AK-B sand and the AK-B shale acting as a seal.

The AK-B WSO was appraised to 2021 and yields a positive incremental oil rate.

The value is primarily achieved through the acceleration of oil production.



Year	Do Nothing		AK-B WSO		Incremental	
	Oil (mbd)	Gas (mmscfd)	Oil (mbd)	Gas (mmscfd)	Oil (mbd)	Gas (mmscfd)
2016	18.4	14.7	19.9	15.9	1.5	1.2
2017	12.1	9.7	17.3	13.8	5.2	4.2
2018	8.4	6.7	8.7	6.9	0.3	0.2
2019	8.2	6.6	6.8	5.4	-1.4	-1.1
2020	5.7	4.6	3.9	3.1	-1.8	-1.4
2021	5.2	4.2	3.0	2.4	-2.3	-1.8
mmboe					0.62	

K2 Forward plan.

Full field simulation and GAP modelling agree that there is value in a WSO.

Modelling enabled the cross functional subsurface team to demonstrate value in an expensive subsea intervention.

Geological understanding and drilling data highlighted the risk of other water sources – Fault/fracture channelling of water into the AK-A.

Array production logging was required to confirm the source of water prior to setting a plug.

An AK-A isolation option (Straddle) was discounted during the planning stage due to low probability of occurrence and high front end loading (cost/time).

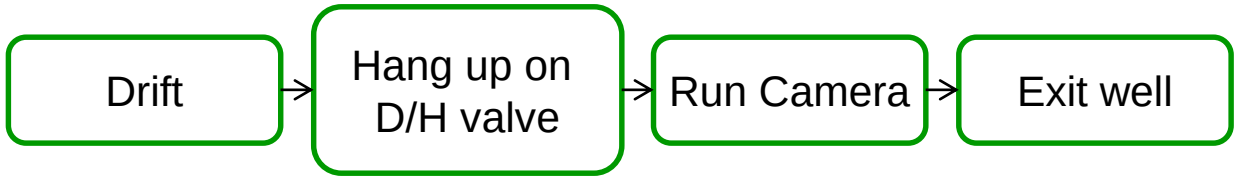
Array production logging tools

SAT – Spinner array tool

RAT – Resistance array tool

K2 Intervention

An interventions vessel was mobilised to enter the well.
The drift run identified an unexpected restriction…



- Not prepared for wireline milling offshore. Best practice to return with fully planned contingencies
- Well behaviour didn't indicate a partially closed fluid loss valve (No DP loss)

Lesson learned

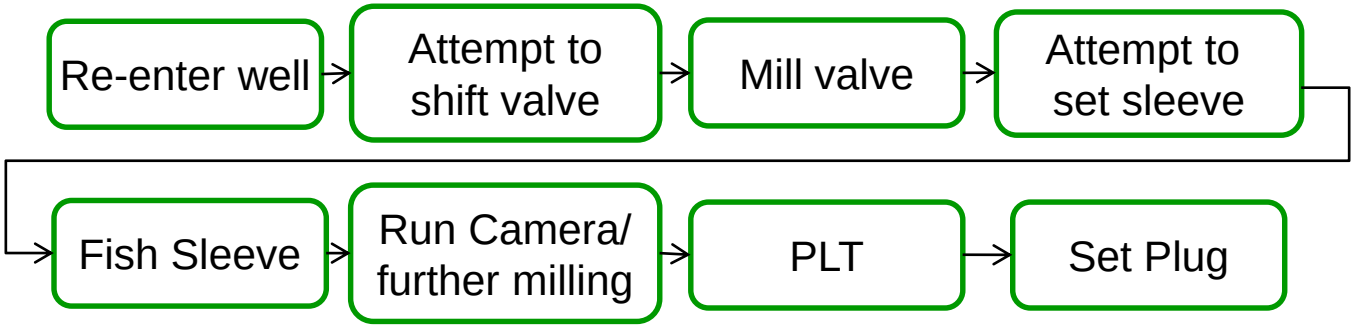
- **Partially opened D/H valve risk not identified during well planning.** Contingency options for shifting/milling the valve were not available offshore.

Second Intervention

There was clear value case from the modelling to return to the well and gain access.

Two solutions were planned; Shifting and Milling. Once the D/H valve was opened we would then set a sleeve across the valve to maintain access.

There were issues setting the sleeve, which resulted in fishing operations. Further milling/dressing of the valve was preferred to re-running the sleeve.



Lesson learned

- **Square edges tools in high angle wells.** Sleeve running tool became stuck below WEG, specialist tools were machined for fishing.

PLT Analysis

It was a Multi-discipline, Multi-company discussion to decide the forward plan and plug location.

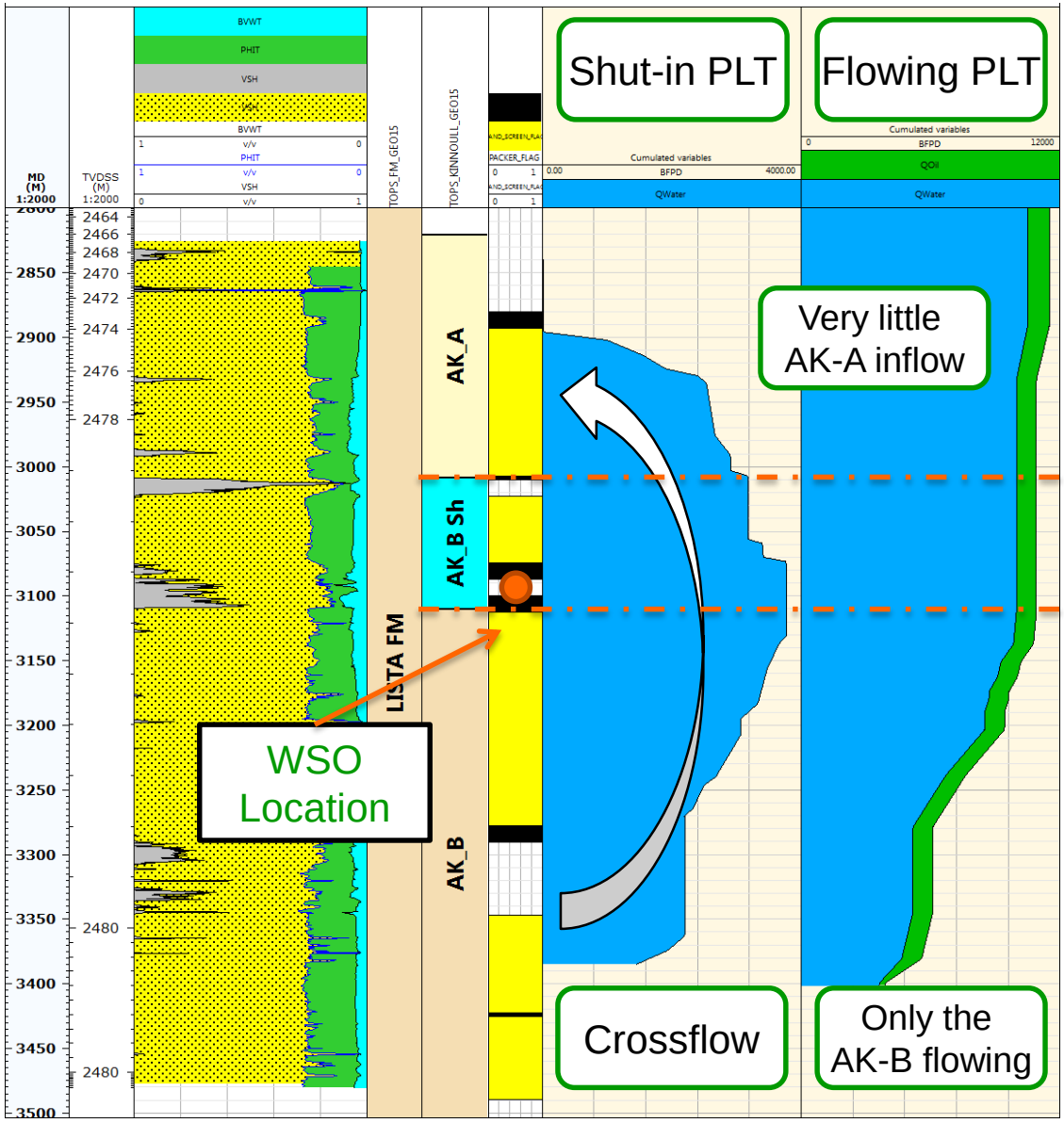
Did crossflow make sense?

Why was the AK-A not producing?

LESSON: Behaviour more extreme then expectations – **High PI sands coupled with low drawdowns.**

IPR calculations indicate **only** 100 psi drawdown on the AK-B at full rate production, this was equal to the reservoir pressure differential. **The AK-A couldn't flow.**

A plug was set to isolate the AK-B



Conclusion

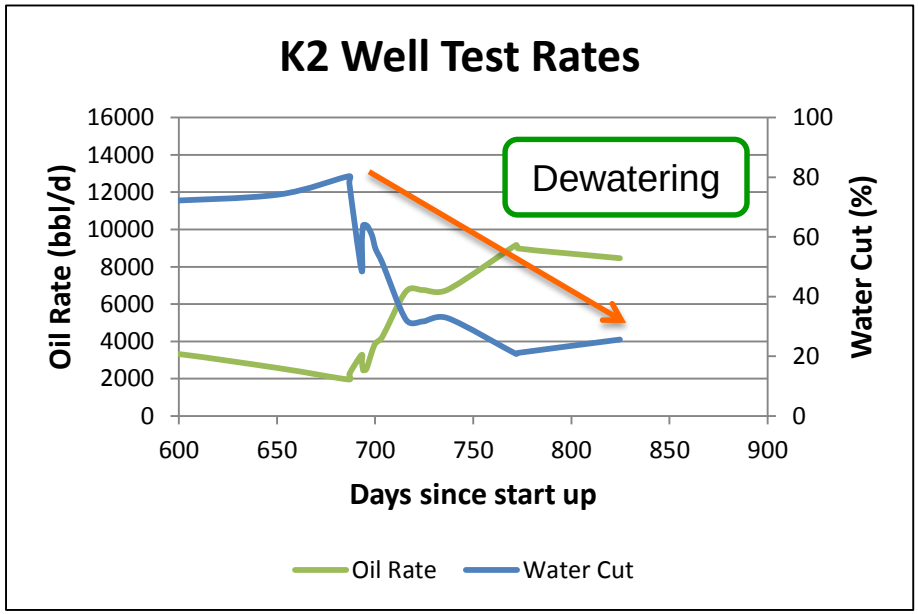
Good collaboration across functions and across the JV gave us the confidence needed to undertake this job, even when the job became more challenging than first thought.

Ultimately perseverance paid off and K2 was returned back to production with gain ~5 mbd once well had cleaned up.

Further WSO opportunity is being evaluated for K3 from 2018

Key Lessons Learned on this job:

- **Watch square edge tools in high angle wells – these can be difficult to recover into Wireline entry guide (WEG)**
- **D/H valves could restrict reservoir access even though they appeared to be open based on well behaviour.**



Any Questions?

BP would like to thank JX for their technical input into the K2 project and their permission to present today.