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OIL & GAS

Performance standard for plug and abandonment of offshore wells

Examples and applications

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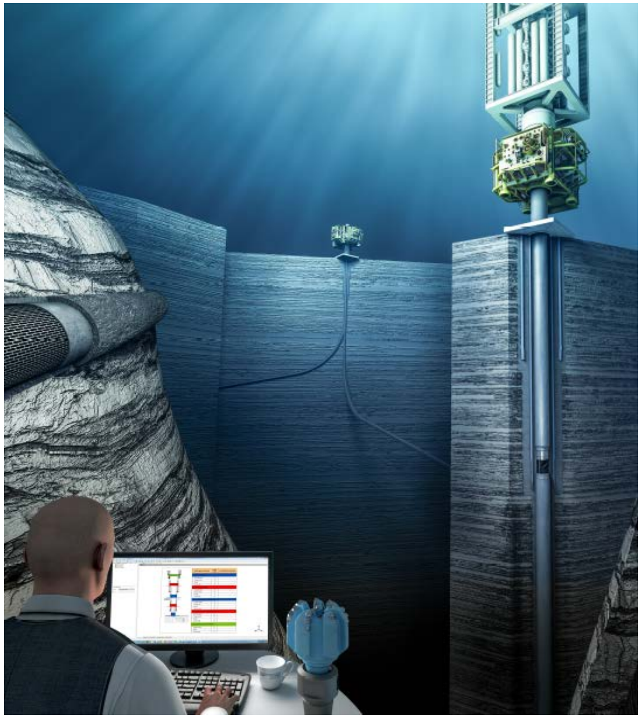
ESRA well conference, Stavanger 2017.11.15

SAFER, SMARTER, GREENER

Content

- DNV GL RP-E103 Risk based abandonment of offshore wells
- **Risk assessment method for P&A wells**
- **Performance standards for P&A**
- Case examples of alternative P&A designs

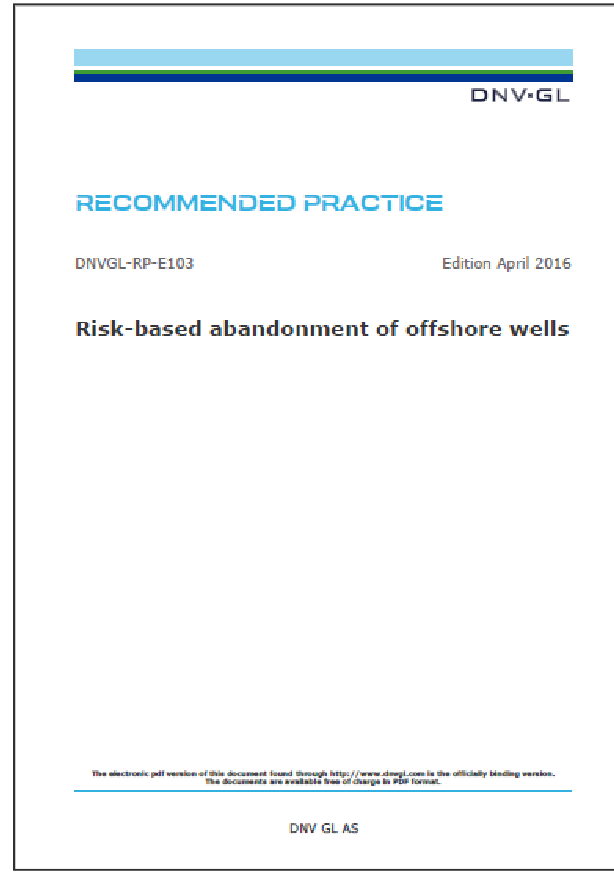


Background of Knowledge

- 2nd revision of Recommended Practice DNV GL RP-E103 to be released early 2018.

  “Risk based Abandonment of offshore wells”

- The recommended practice DNV GL RP-E103 provides a framework for application of risk based methods in the well abandonment design, when performing risk assessment and in developing performance requirements for the well barriers.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RECOMMENDED PRACTICE

DNVGL-RP-E103 Edition April 2016

Risk-based abandonment of offshore wells

The electronic pdf version of this document found through http://www.dnvgl.com is the officially binding version.
The documents are available free of charge in PDF format.

DNV GL AS

Fit-for-purpose Method

Current P&A Regulations Internationally

- There are prescriptive requirements as to the number and size of plugs required.
- The requirements are the same for all types of wells.

Alternative ways / Risk-Based Approach

- The industry is looking to differentiate between P&A requirements on a well-by-well basis.

Fit-for-purpose

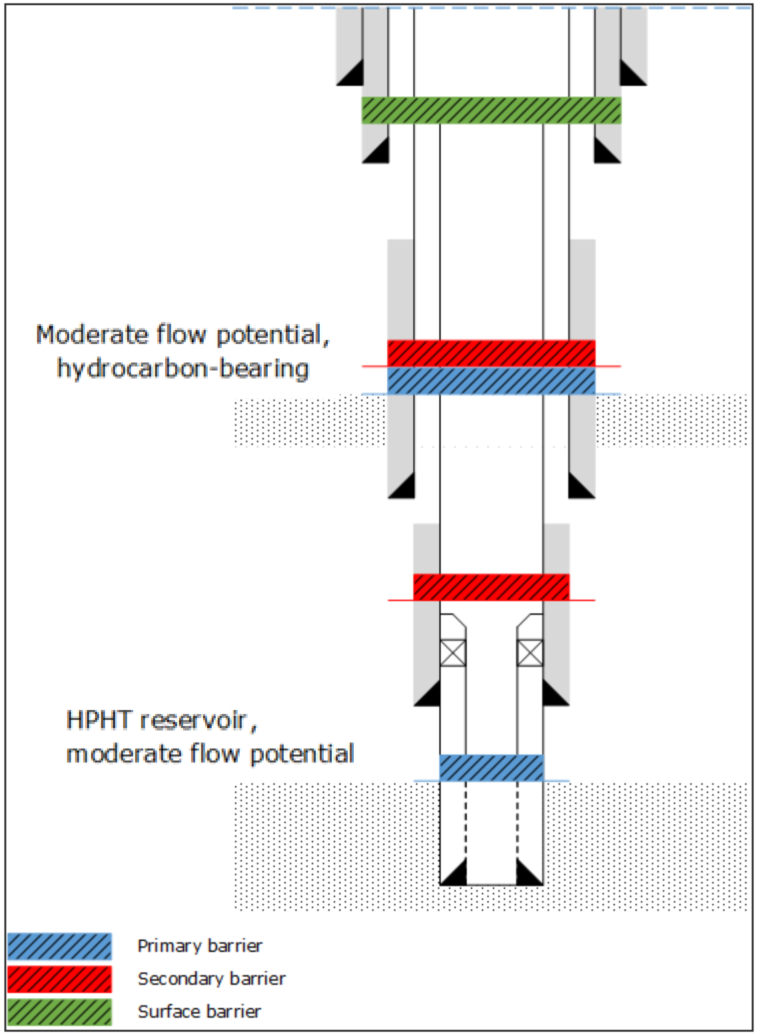
- DNV GL RP-E103 is a fit-for-purpose method, where both the risk acceptance criteria is site-specific and the abandonment well design can be well-specific.
- Well barrier specific performance requirement can be established
- New technology, methods, standards and development of best practices can be applied.

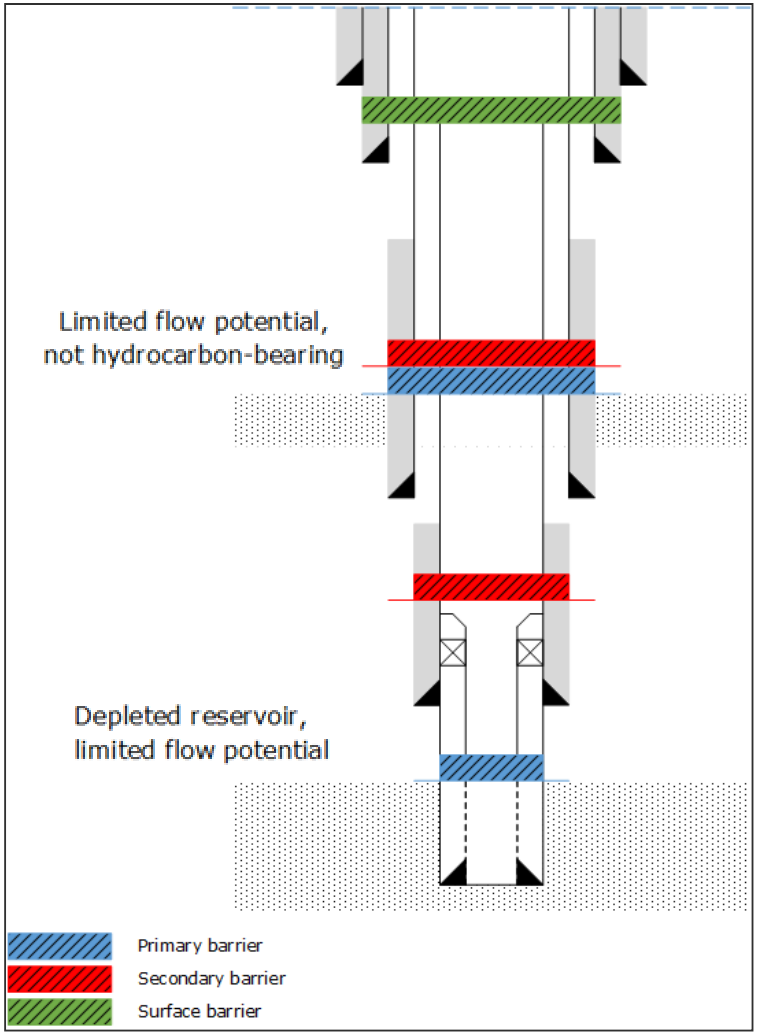
What does "performance-based" mean?

- Specific solutions can be applied to wells individually, based on the well's P&A needs.

- Adjustments to the well abandonment design could be considered and evaluated:
  - Changing the number of permanent barriers required
  - Changing the type of permanent barriers
  - Changing the properties of the permanent barriers (size, length, shape, composition, permeability)
  - Changing the position of the barriers

Well P&A design
Are all P&A wells the same?





Elements in well abandonment risk assessment

Well specific input

Geology input
Reservoir, Overburden

Natural resources

Metocean data

Well abandonment design

↓

Pressure and flow sources

↓

Well barrier failure modes

↓

Leak potential

↓

Impact analysis

↓

Performance requirement (PR)

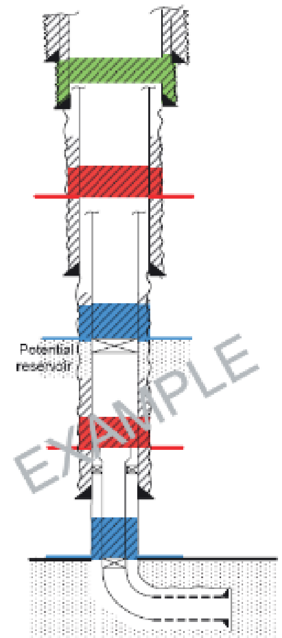
↓

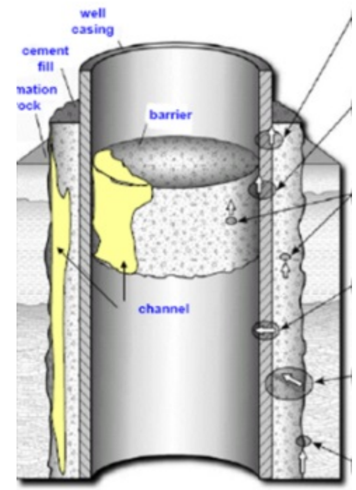
Design meets PR

No → Well abandonment design

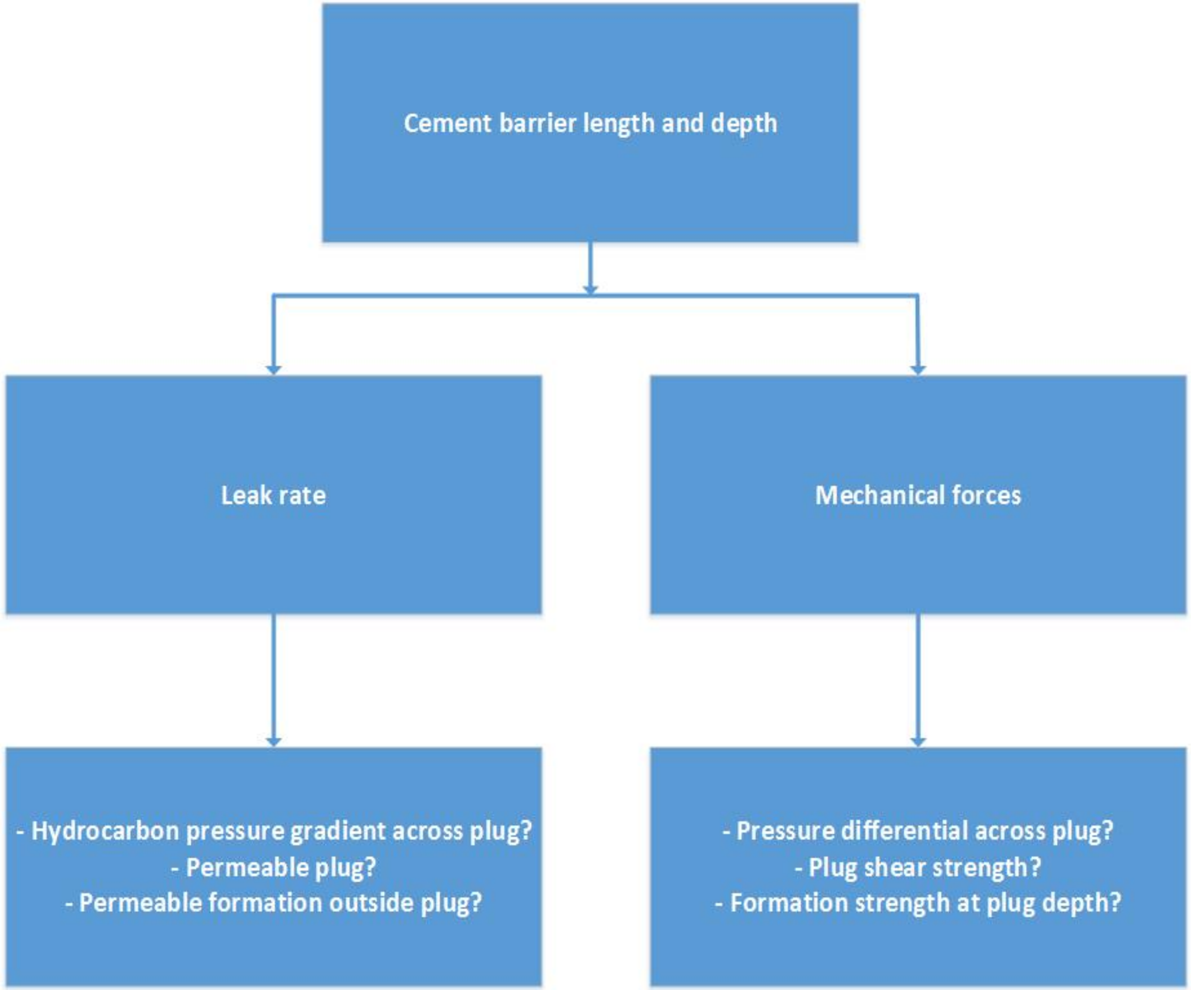
Yes ↓

Qualified well abandonment design





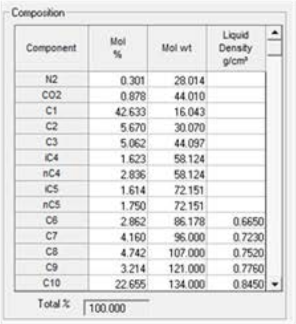
Examples of numerical analysis done
Assessment of plug length and setting depth



Annulus - Leak rate analysis

Analysis of fluid properties

PVTsim



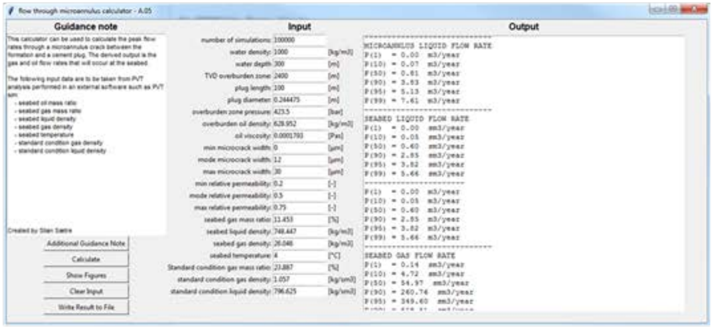
Composition

Component	Mol %	Mol wt	Liquid Density g/cm³
N2	0.301	28.014	
CO2	0.878	44.010	
C1	42.633	16.043	
C2	5.670	30.070	
C3	5.062	44.097	
iC4	1.623	58.124	
nC4	2.836	58.124	
iC5	1.614	72.151	
nC5	1.750	72.151	
C6	2.862	86.178	0.6650
C7	4.160	96.000	0.7230
C8	4.742	107.000	0.7520
C9	3.214	121.000	0.7760
C10	22.655	134.000	0.8450

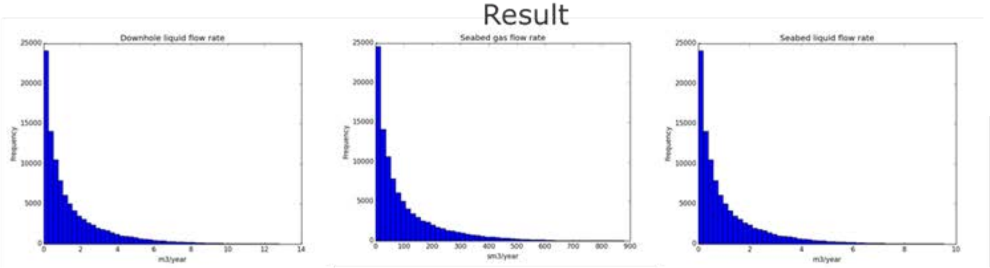
Total % 100.000

Flow potential through permeable cement

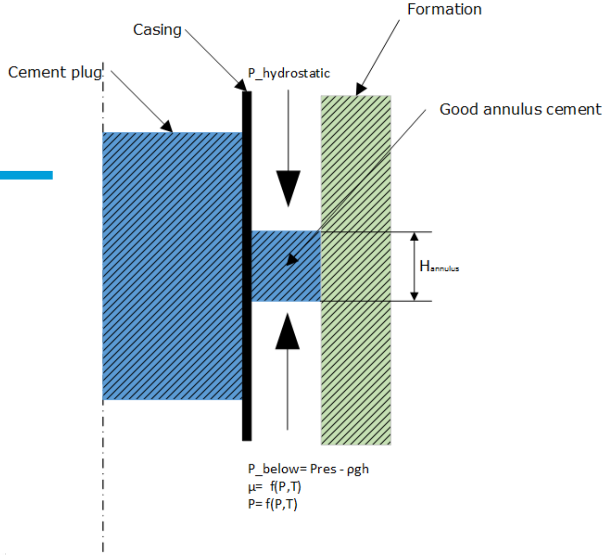
Micro annulus leakage



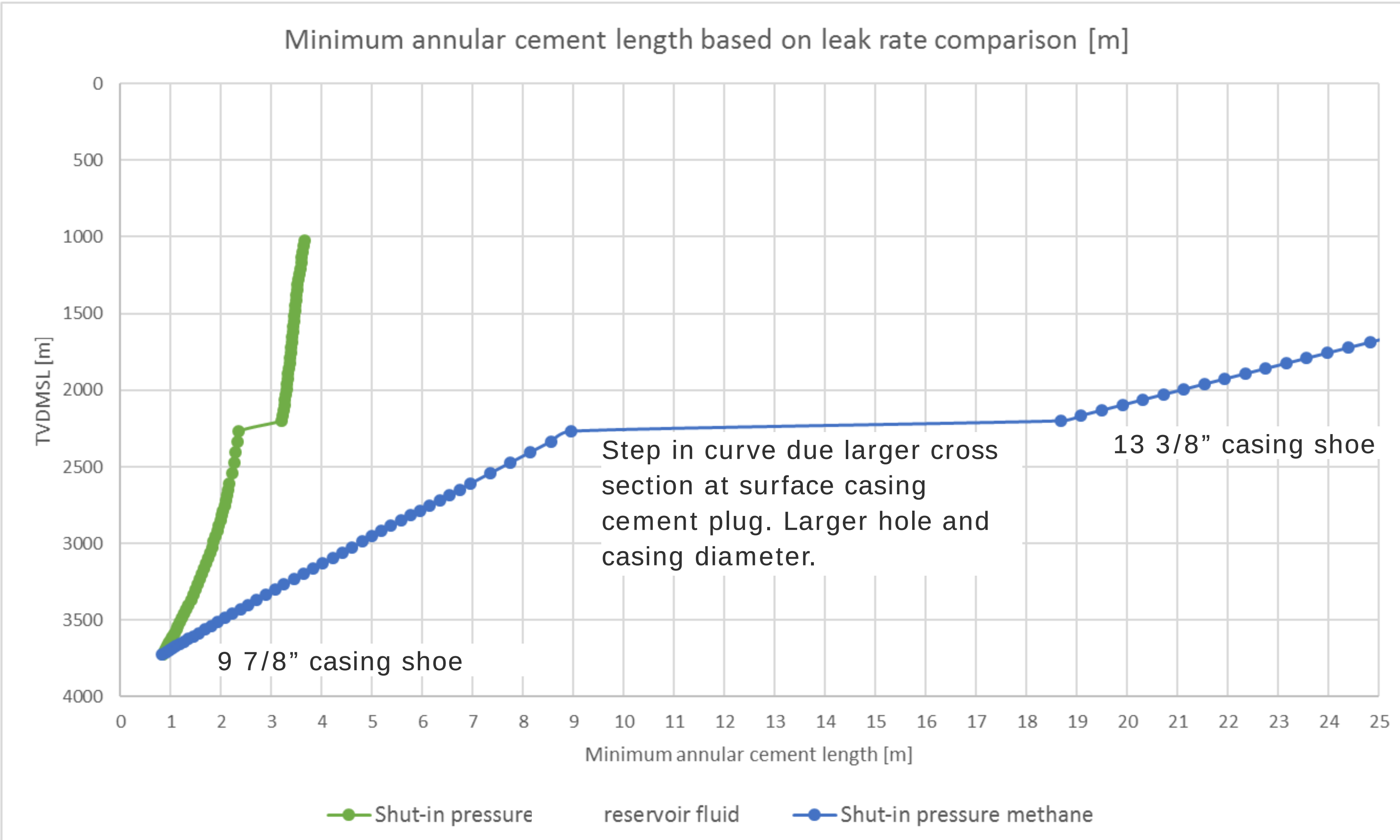
Result



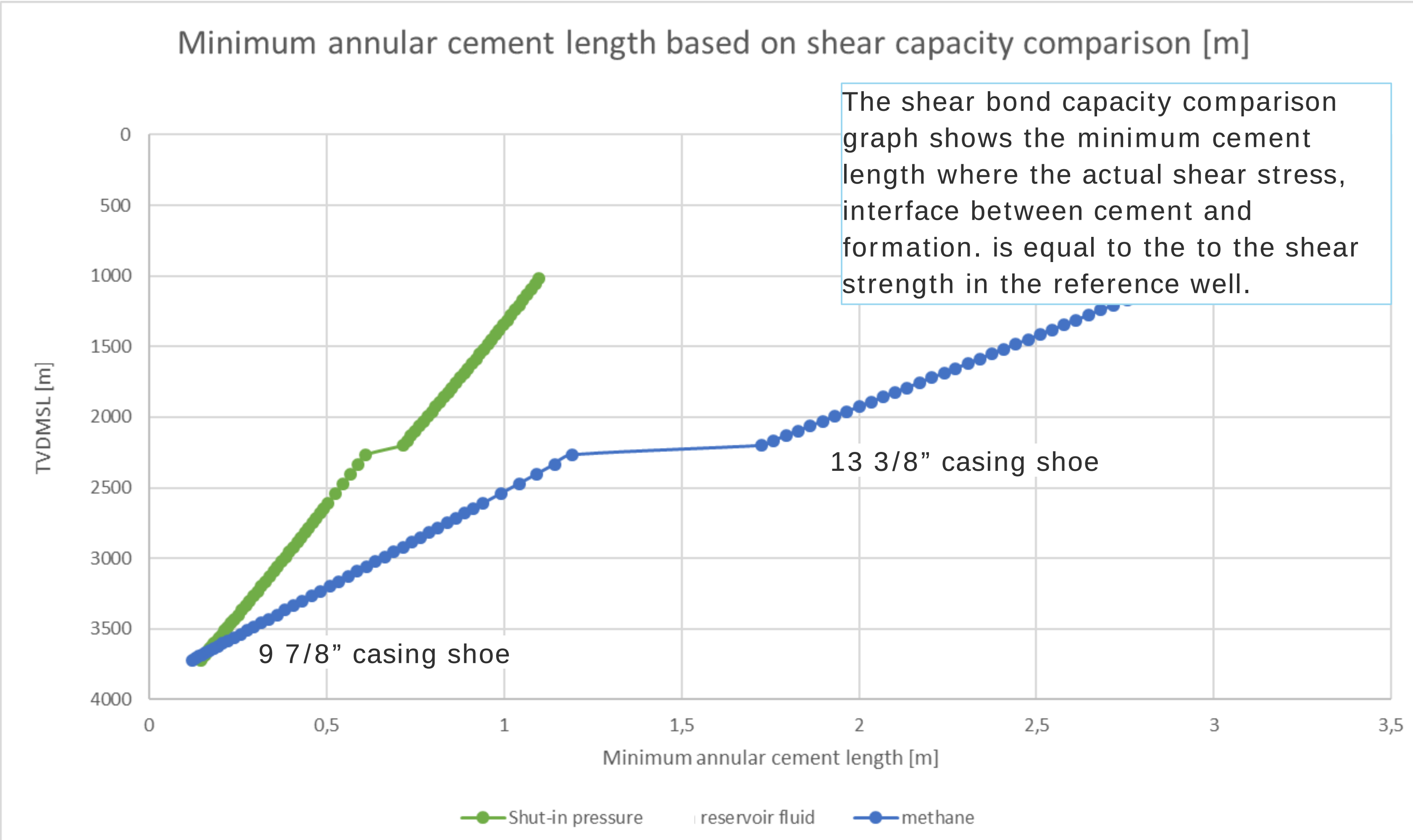
Shut-in pressure and Pressure differential across annulus plug



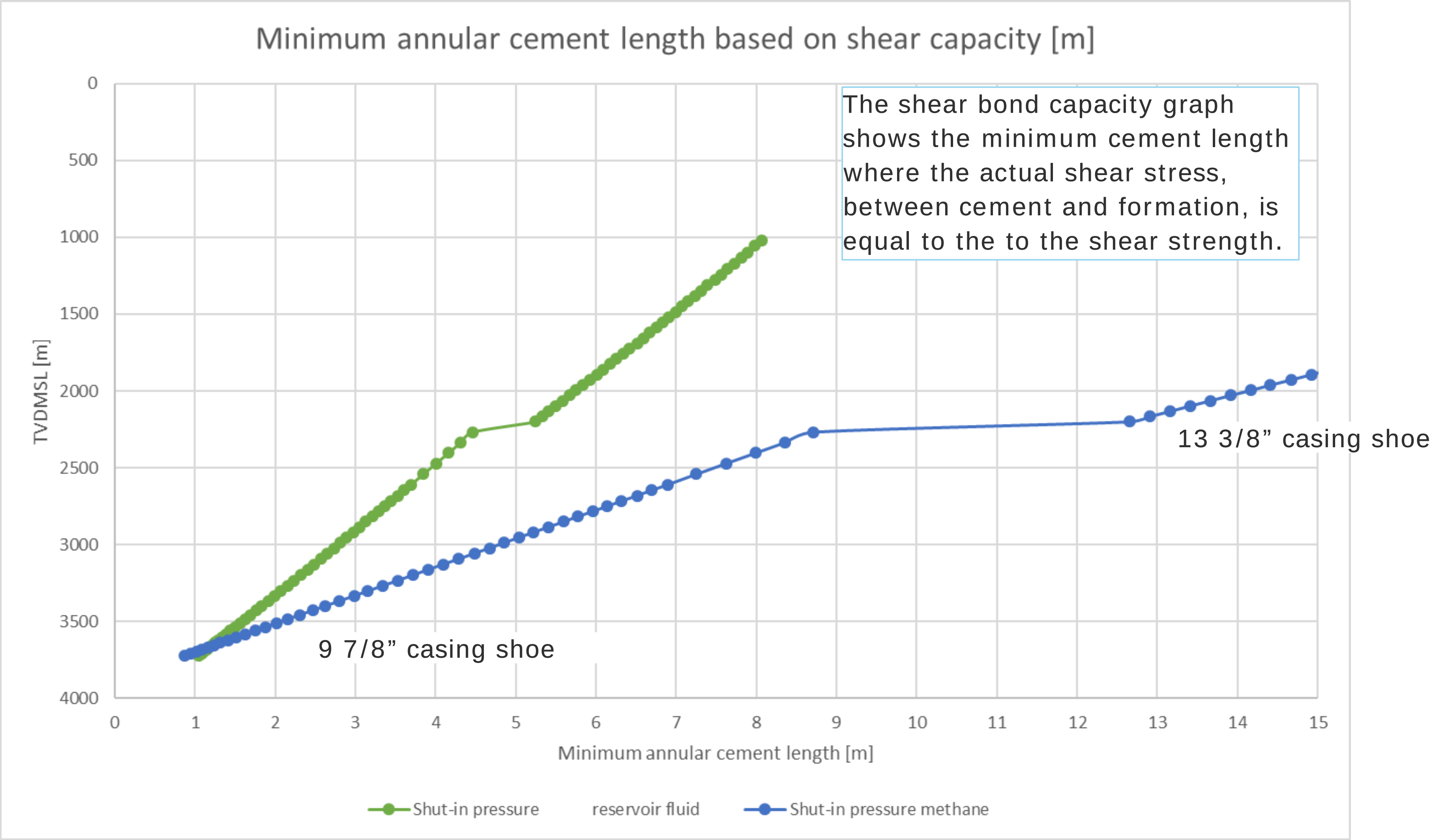
Comparative analysis
Minimum annular cement length (1/3)



Comparative analysis
Minimum annular cement length (2/3)



Comparative analysis
Minimum annular cement length (3/3)



The shear bond capacity graph shows the minimum cement length where the actual shear stress, between cement and formation, is equal to the to the shear strength.

Barrier failure modes

- Shrinking cement
- Micro annulus
- Formation strength and sealing capability
- Cap rock integrity
- Etc.

				Risk assessment			
Barrier element	Failure mode	Failure cause	Effect	Likelihood with 20 m	Likelihood with 30 m	Likelihood with 50 m	Comments
Open hole cement (rock-to-rock cement in milled window), primary barrier							
	Insufficient barrier length, less than milled window.	- Low top of barrier - barrier slippage (note: calculation table xx SF) - Density miscalculation - Poor volume calculations	Reduced structural capacity of cement. If exceeding structural capacity, then shear collapse of cement or slippage. Possible leak of sea water into well	Likelihood of structural collapse is reduced with increasing length. Ref. structural capacity calculation of cement			

Risk Evaluation Tool – Risk Matrix

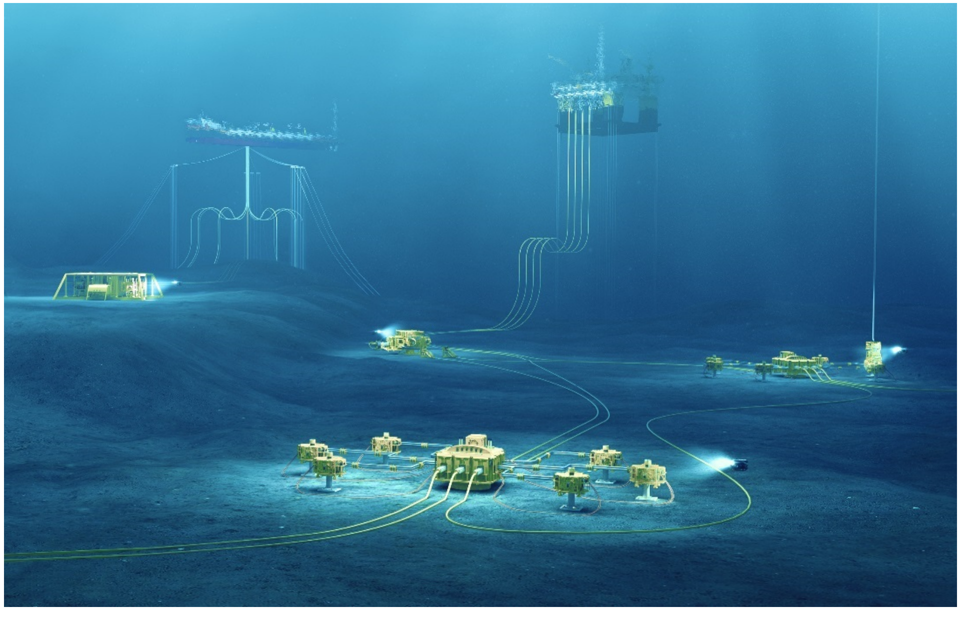
	Reputation	Platform Safety Risk	Time & Cost	Long-term Environment	Operational Risk	Increasing probability				
						$1x10^{-4}$	$1x10^{-3}$	$1x10^{-2}$	$5x10^{-2}$	$1x10^{-1}$
						P1	P2	P3	P4	P5
I5	Visible oil on surface	> 1 kg/s hydrocarbons on platform			Loss of both barriers [2]					
I4	Gas bubbles detected at surface, well site	> 0.1 kg/s hydrocarbons on platform [1]			Loss of one barrier [2]					
I3	Gas bubbles detected at seabed, well site	> 0.01 kg/s hydrocarbons on platform	Operator & Location Specific	Operator & Location Specific	Uncertain well barrier condition					
I2	Gas bubbles detected on license	Undetectable hydrocarbons on platform			Negligible well integrity situation					
I1	No impact	No hydrocarbons on platform			No impact					

- The proposed risk matrix is aligned with industry codes and operator best practice.

Examples
Case A

- Subsea Template
- Oil production reservoir
- Two overburden zones (gas, oil)

- No significant annulus leakages were observed and recorded, good annulus cement
- No migration of overburden fluids and no hydrocarbons observed in environment



Case A

- Analyses provided the required minimum permanent well barrier length.

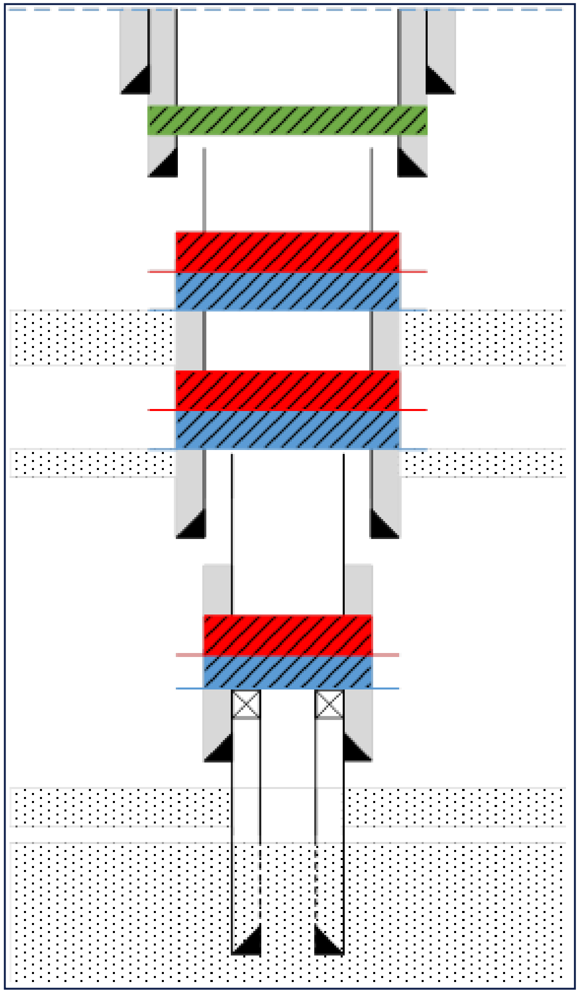
Results

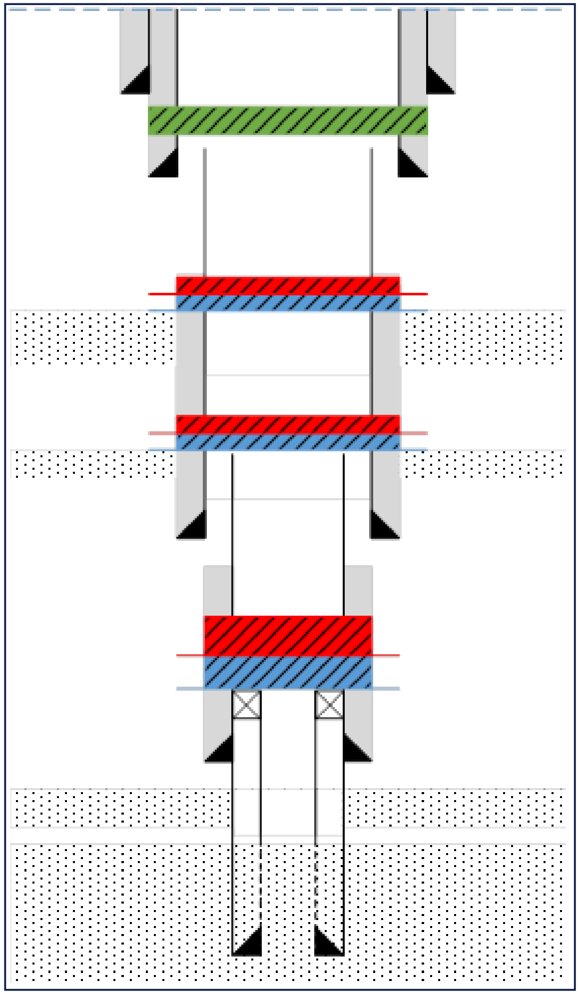
- For the deepest reservoir
  - minimum of 30m interval with acceptable bonding and casing cement verified by logging.

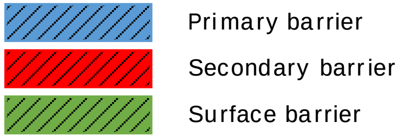
- Lower overburden zone
  - minimum of 15m interval with acceptable bonding and casing cement verified by logging.

- For the upper overburden zone
  - minimum of 18m interval with acceptable bonding and casing cement verified by logging.

Case A







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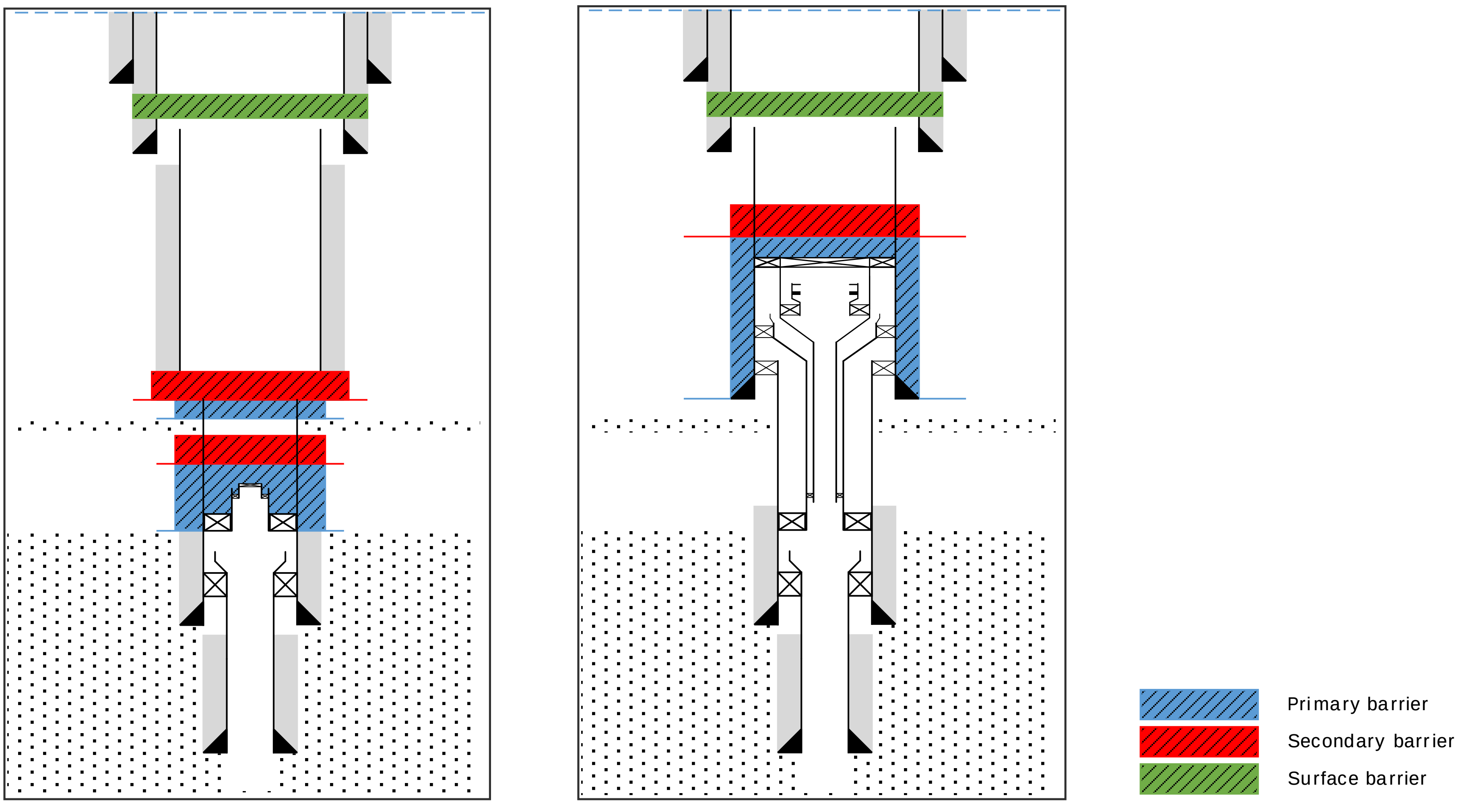
Case A

	Base Case	Alternative
Reputation	Low	Low
Platform Safety	N/A	N/A
Time & Cost	Medium	Low
Long Term Environment	Low	Low
Operational	Medium	Low

- The alternative P&A design was selected as the required permanent barrier lengths, which could be used operationally to simplify decision making and to potentially lower operational costs and well P&A time.

Case B



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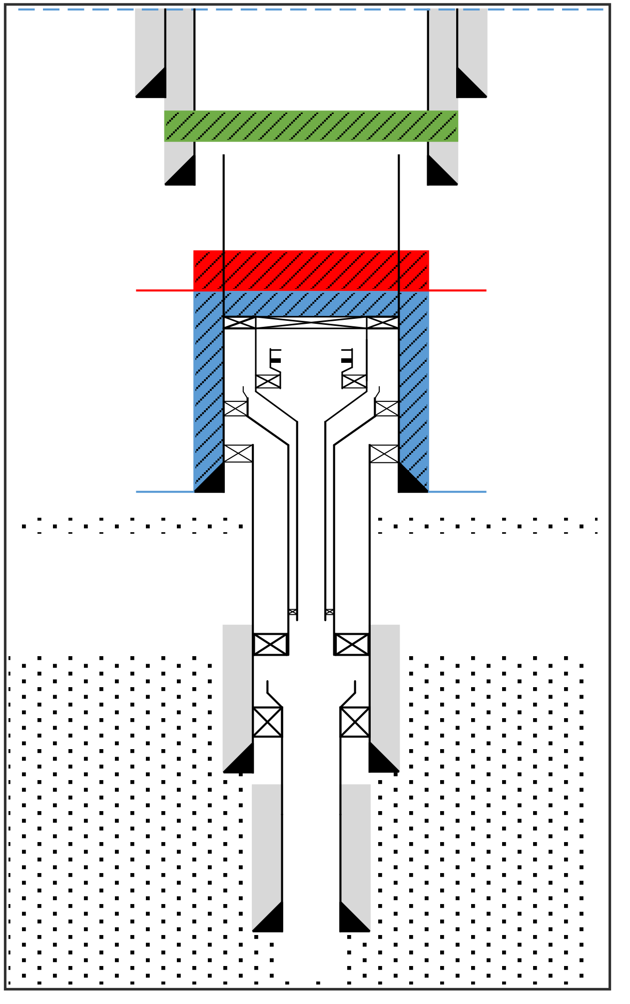
Case B

Comparison of fit-for-purpose well barriers (RP ch 2.3.2-2.4.2)

Conclusions

- Reservoir pressure is lower than hydrostatic pressure. **There is no gas flow potential across the barrier plugs.**
- Plug length of 20 m considered sufficient to withstand the anticipated combined loads.
- The plugs can withstand the anticipated environment.
- The setting depth is acceptance as long as the barriers are set within the boundaries for mechanical strength and formation strength.



Case B

Regarding the length of the reservoir barrier, compare the leak risk between 20, 30 and 50 m barrier plug in a milled window.

A length of the reservoir barrier of 20 m (cement in a milled window or annulus plug logged good > 20m) provides an acceptable risk level to withstand the expected mechanical forces on the cement plug. Increased length provides reduced vulnerability.

Activity 2	Base case	Alternative case
Reputational	Low	Low
Platform Safety	Low	Low
Time & Cost	Medium	Low
Long Term Environment	Low	Low
Operational	Medium	Low

P&A risks categories

Reputational risk
Considering the risk of visible oil at surface, or gas bobbles at surface or subsea.

Platform safety risk
Gas release rate at platform

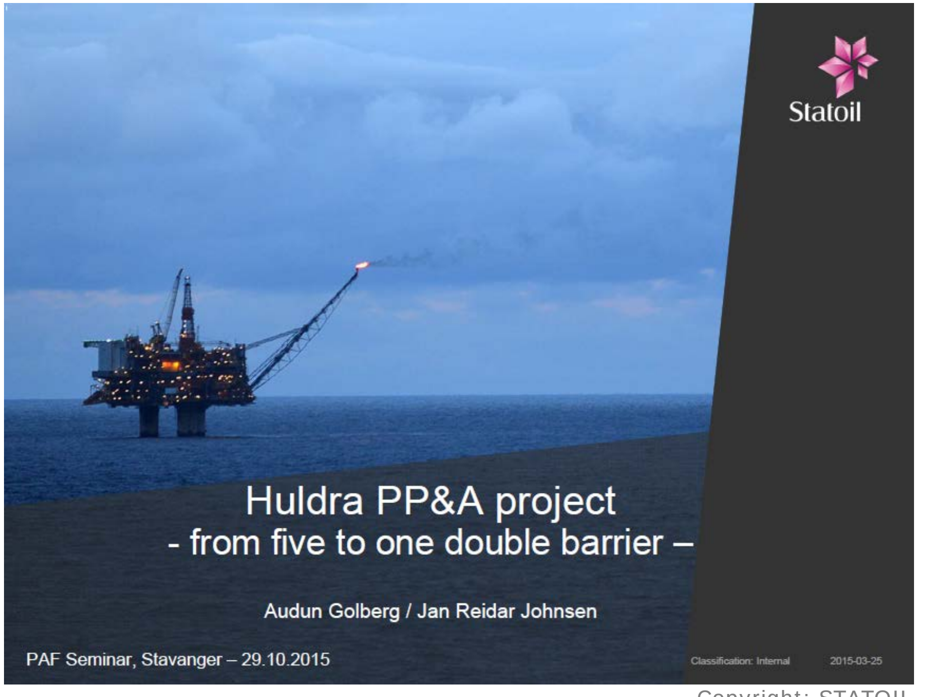
Long-term environment
Consequence for the environment, sea floor, water column, surface.

Operational risk
Loss of well barriers

Case C

- Major cost savings been implemented in well P&A in Norway on the Huldra field with the help of DNV GL.[1]

- Risk assessing the alternative well abandonment designs proved the strength of the alternative solutions.



1 – Huldra PP&A project – from five to one double barrier - PAF Seminar, Stavanger – 29. October 2015

Case C

	Base Case	Alternative
Platform Safety	Low	Low
Time & Cost	High	Low
Long Term Environment	Low	Low
Operational	Low	Low

- Cost savings claimed to be 100 MNOK per well x 5 wells.

Summary

- DNV GL provides P&A risk assessment method
- Performance requirements can be defined to P&A
- Examples show that considerable savings can be achieved
- “Fit-for-purpose” designs can be used rather than “one size fits all”

Risk-based abandonment of offshore wells, DNV GL

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