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Plugging Practices Update - Methodologies/Emerging Issues

Matteo Loizzo & Steven Canny

October 15, 2024

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Truly Permanent P&A?

Matteo Loizzo
October 15, 2024

Not all leaks are created equal

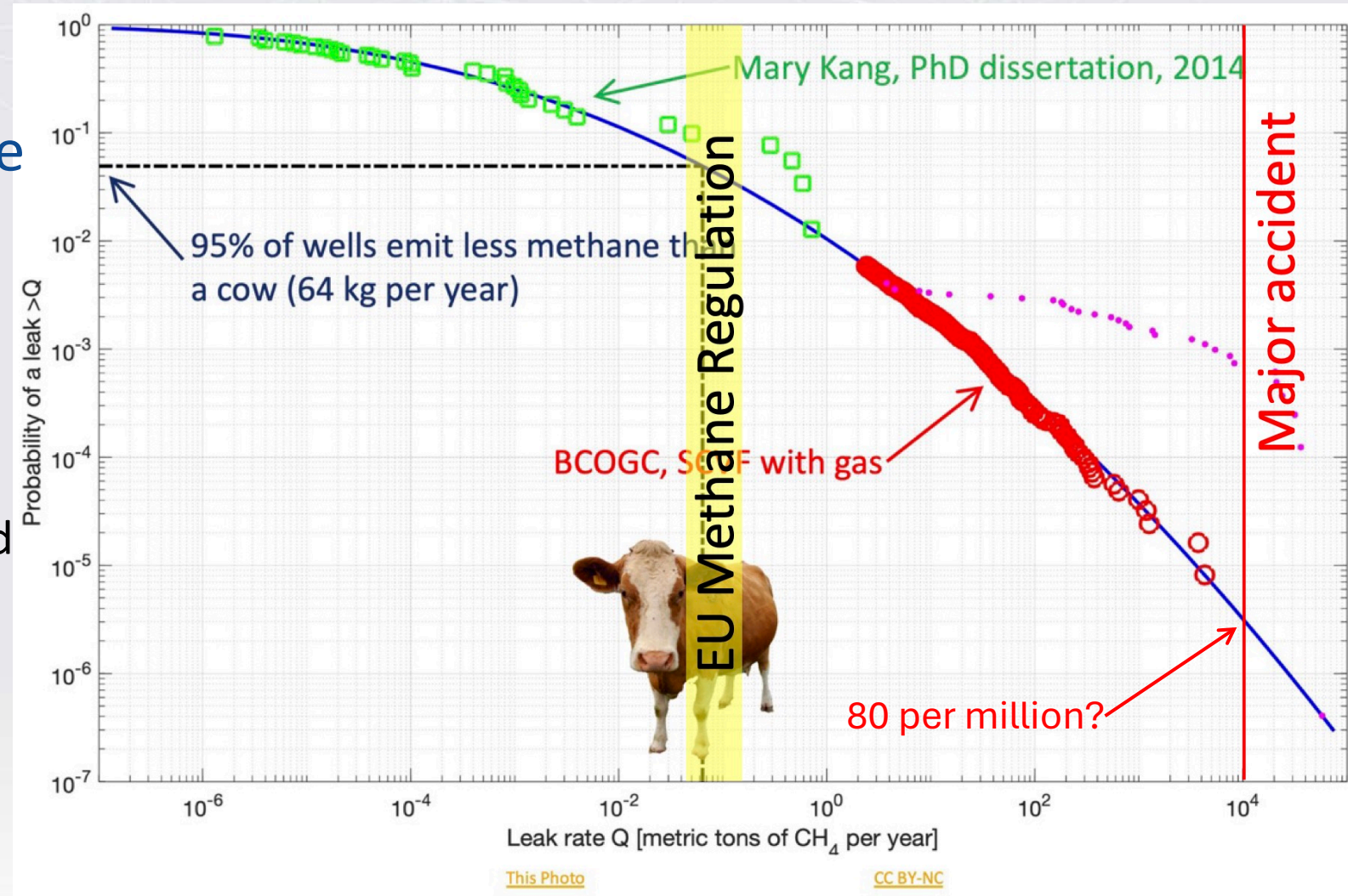


Major accident vs. nuisance

Methane leaks concentrated

- Super-Pareto $\rightarrow$ 98/2
- Not only $\text{CH}_4 \rightarrow$ VOC, brine, oil
- 2024 EU CH_4 Regulation LDAR
 - 5 g h^{-1} (0.044 t y^{-1}) dry wellhead
 - 17 g h^{-1} (0.15 t y^{-1}) subsea
 - 0.7 and 2.3 cows

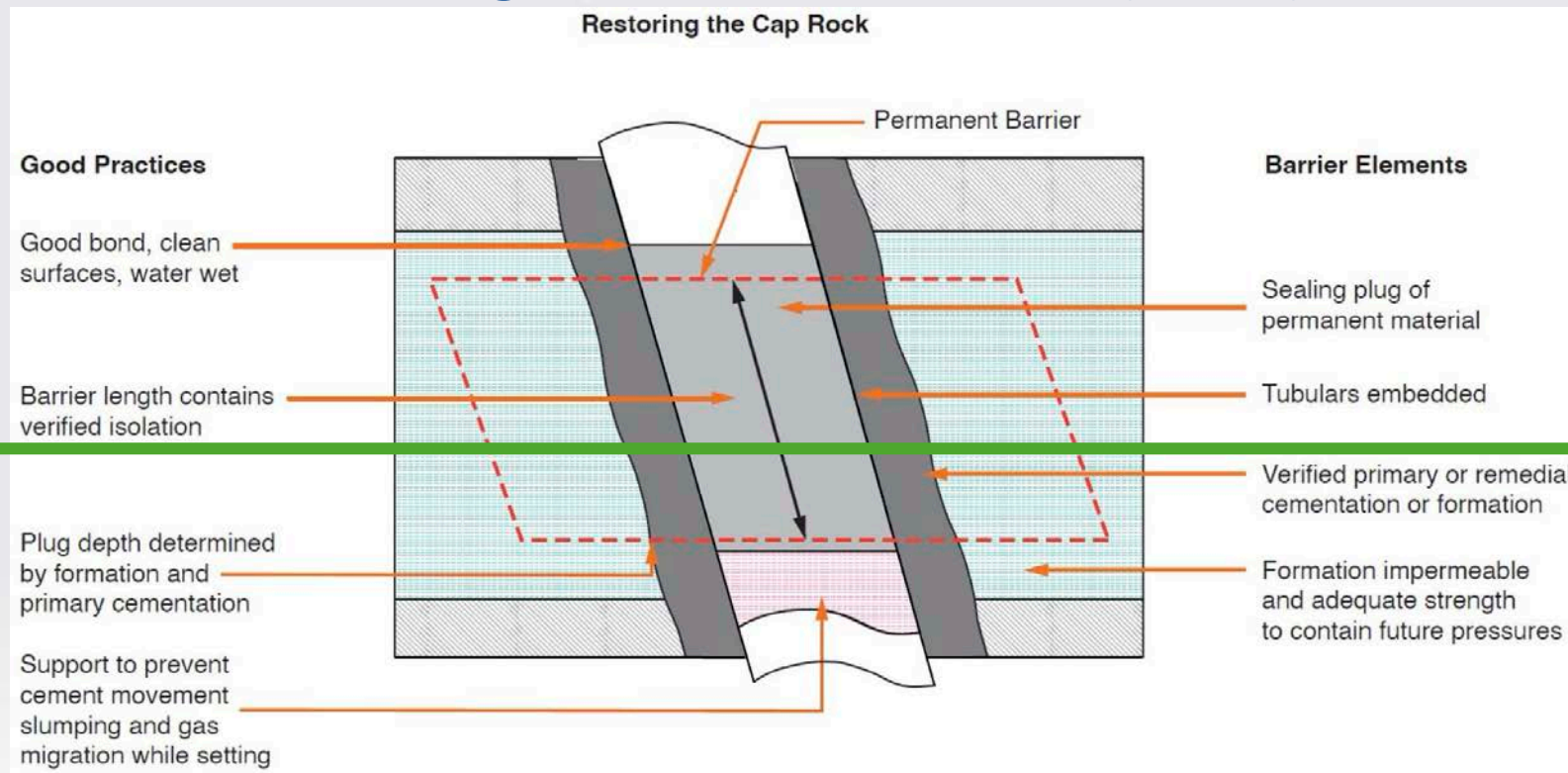
Major accident $>10,000 \text{ t y}^{-1}$



Restoring the caprock



OEUK Well Decommissioning Guidelines, Issue 7 (2022)



Infinity to the left...

... to infinity to the right

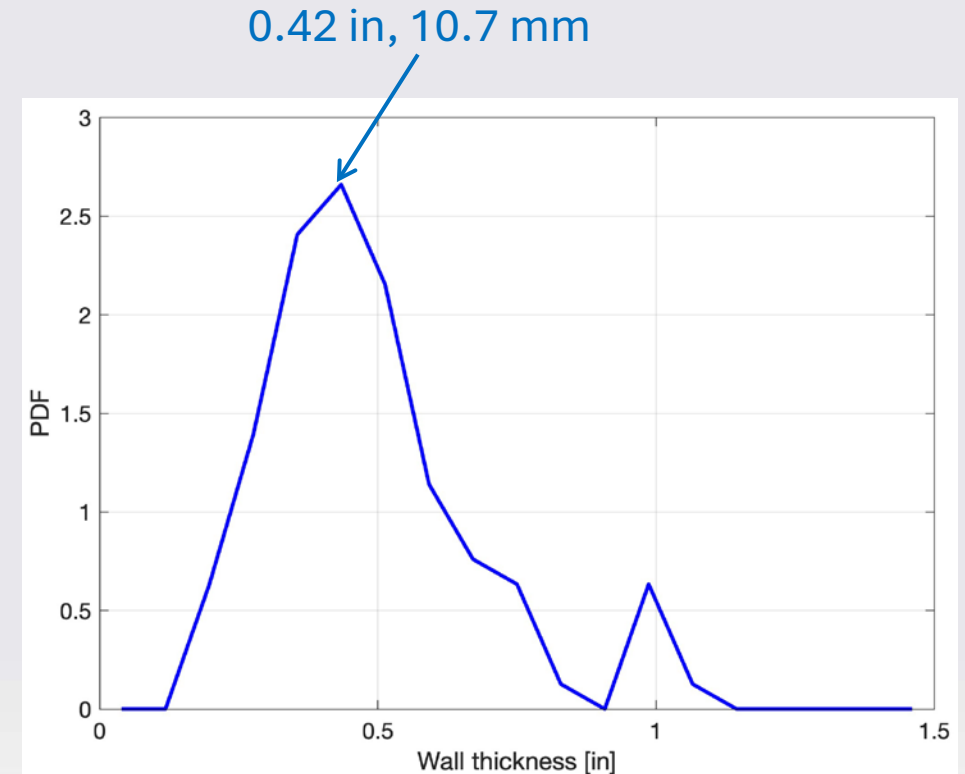
Third not given

Temporary vs. permanent abandonment

Want to abandon a well forever?

- Easy: draw the line only through rock and cement
- Steel won't do → corrosion
- Microbiologically influenced corrosion (MIC)
 - 0.3 mm y^{-1} after 7 years induction period
- Saltwater
 - 0.18 mm y^{-1} (no oxygen) to 0.5 mm y^{-1} (with O_2)
 - Clear fluids always move → natural convection

Casing pierced in 20-60 years



What if we rely on steel?



Well in Weld County (US-CO)

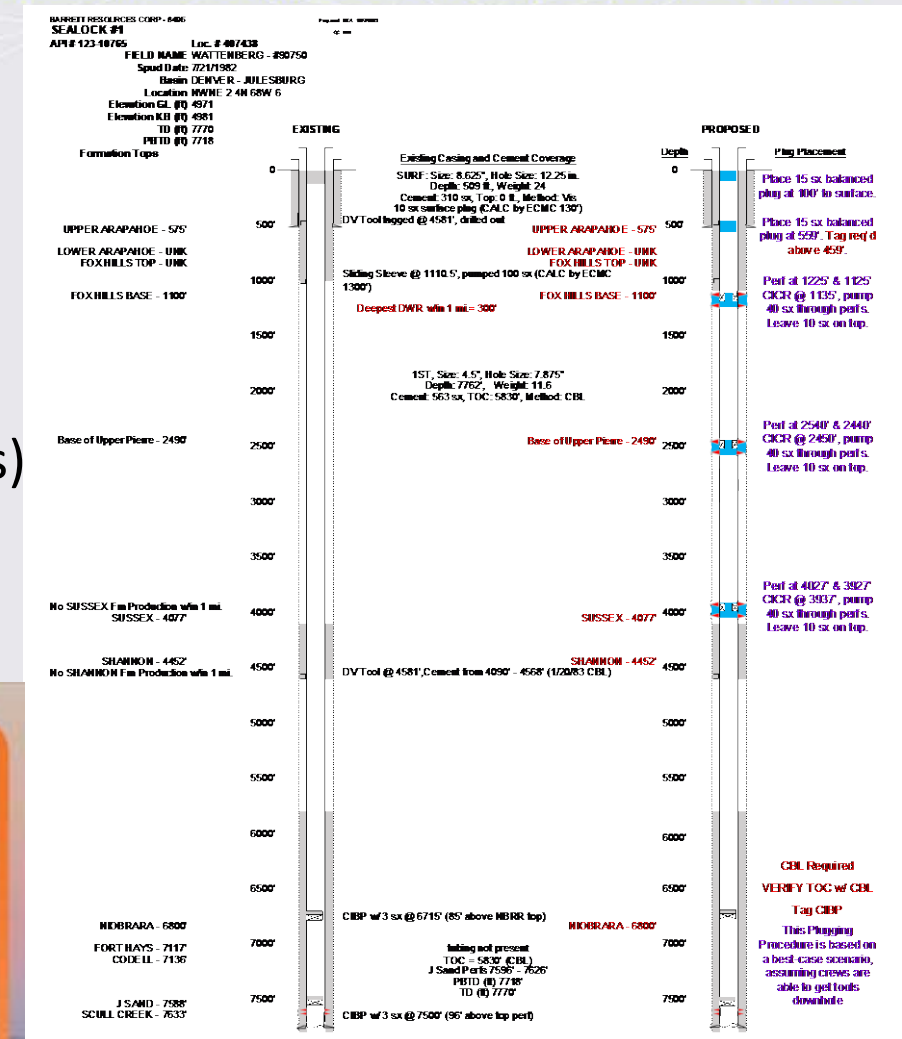
Temporarily abandoned on 1993 Oct 29

- Steel part of the barrier system
- 4½" 11.6 ppf casing → 6.35 mm wall thickness (13-35 years)

Large pathway → major accident



Source: 9News



Source: 9News – YouTube; COGIS - WELL SCOUT CARD

Creeping rocks – the silent helpers

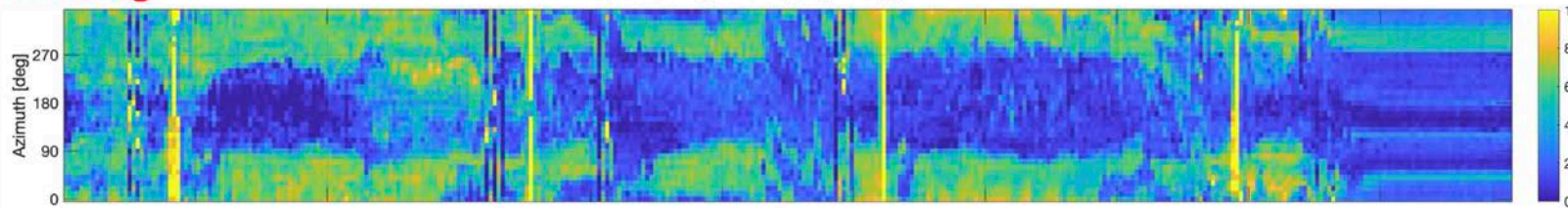
Shales (and salt) fix most large defects

Free pipe and mud channels get filled

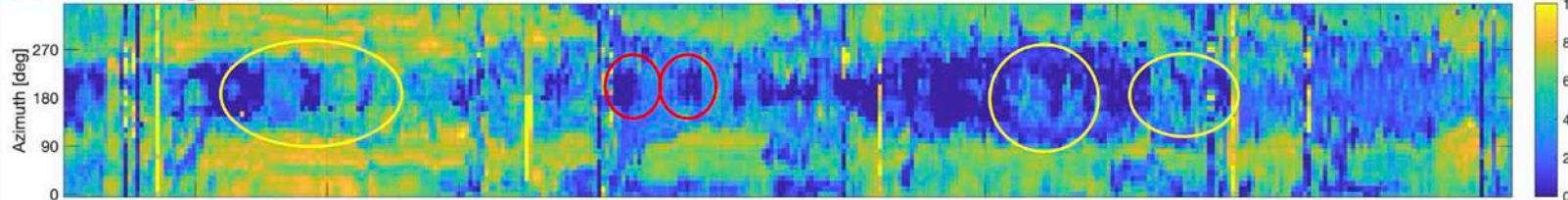
- Still need a plug to restore the caprock

First log

Acoustic impedance, Z [MRayl]



Second log, 6 months later



How do we get rid of zombie wells?

Draw the line

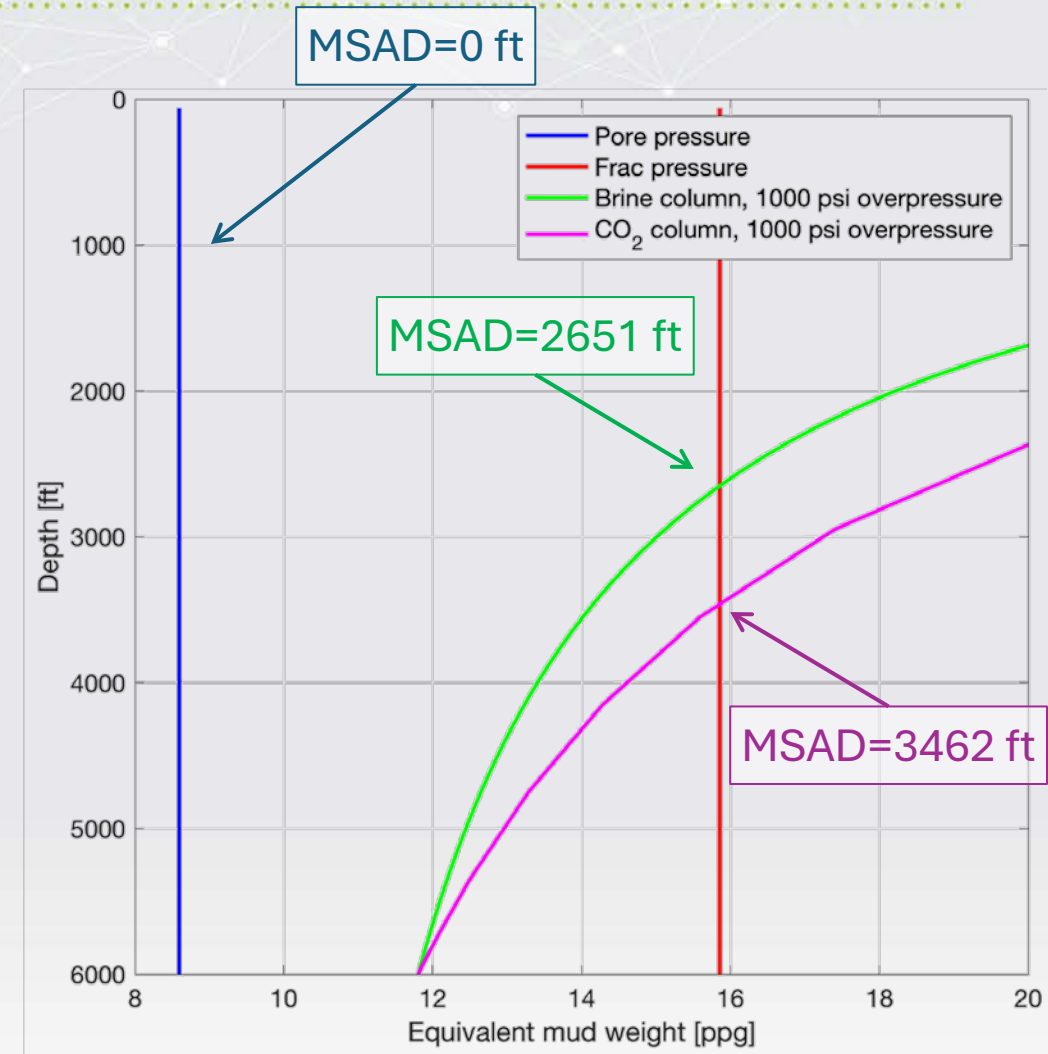
Set a plug across competent caprock

- Below MSAD → Minimum Safe Abandonment Depth
- Where a column of reservoir fluid meets frac pressure
 - Watch out for increased pressure (PWRI) and lighter fluids (CCUS)

If possible, find a creeping caprock

- Do you need to log at all?

Prevent major accidents – but how about cow-size leaks?



Keeping gas at bay



Get rid of (water-filled) microannuli

Two creeping rocks' failure modes

1. Fracturing
2. Debonding and microannulus

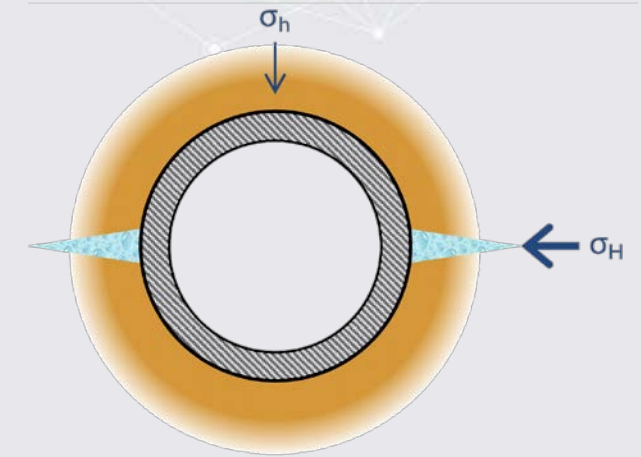
Water gets stuck in microannuli $\rightarrow$ too thin to flow fast

- Gas flows as bubbles through $\sim 100 \mu\text{m}$ water film
- Leaks around $0.1\text{-}1 \text{ t y}^{-1}$

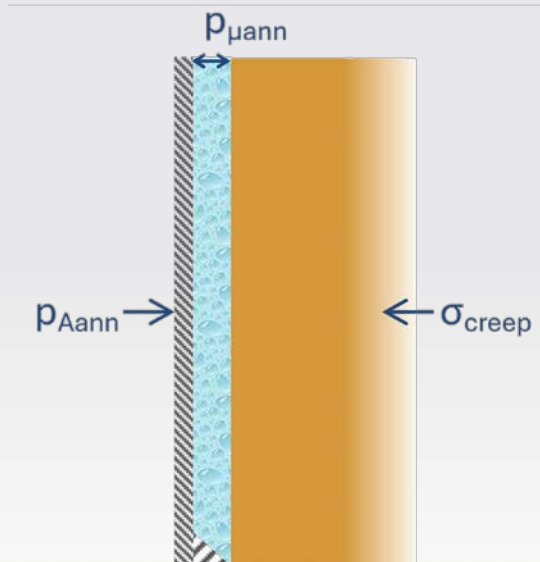
Drain the microannulus, then use creep to keep it shut

- Is this how PWC works in some cases?

1



2



Optimizing Subsurface Isolation in PP&A

Steven Allan Canny

October 15, 2024

Looking Back...to look forward

PP&A a Decade ago

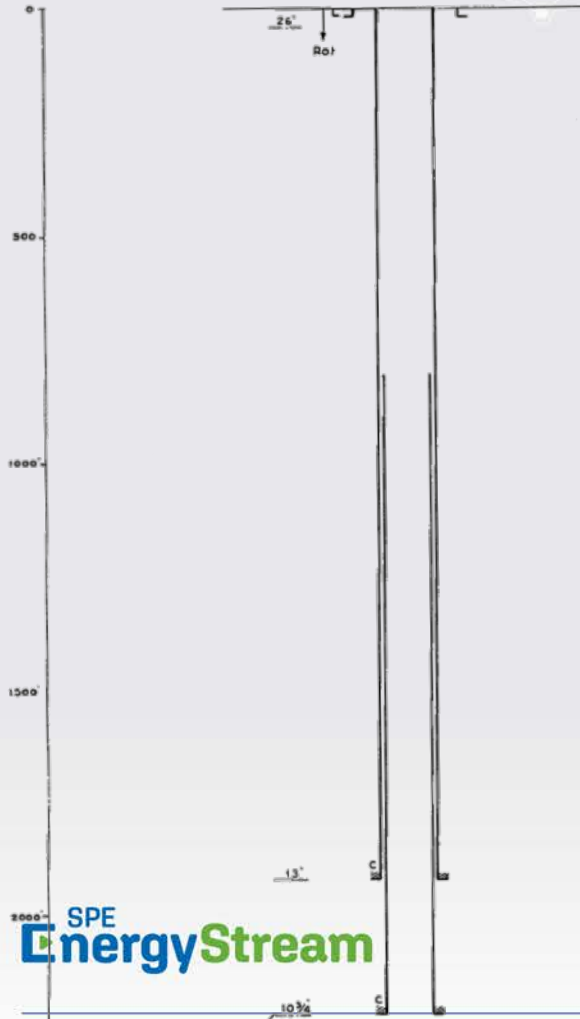


Status:-

Abandoned 1920's.

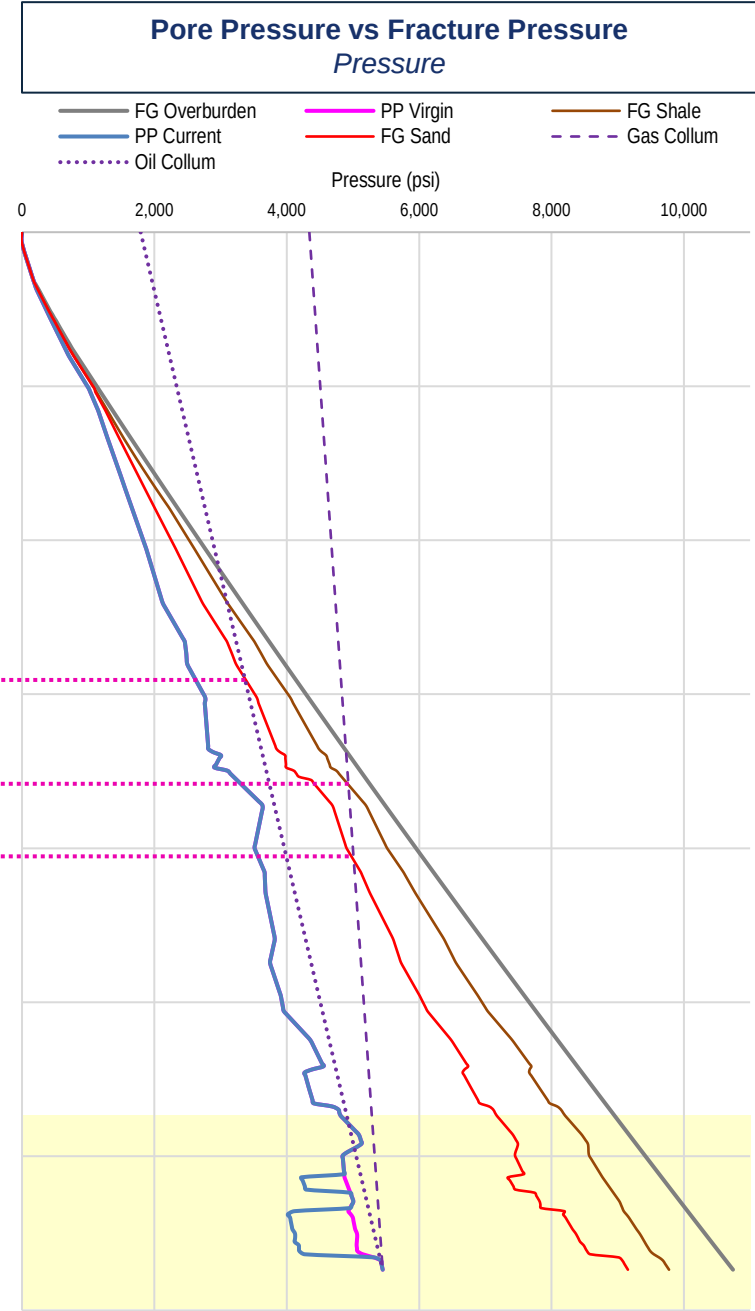
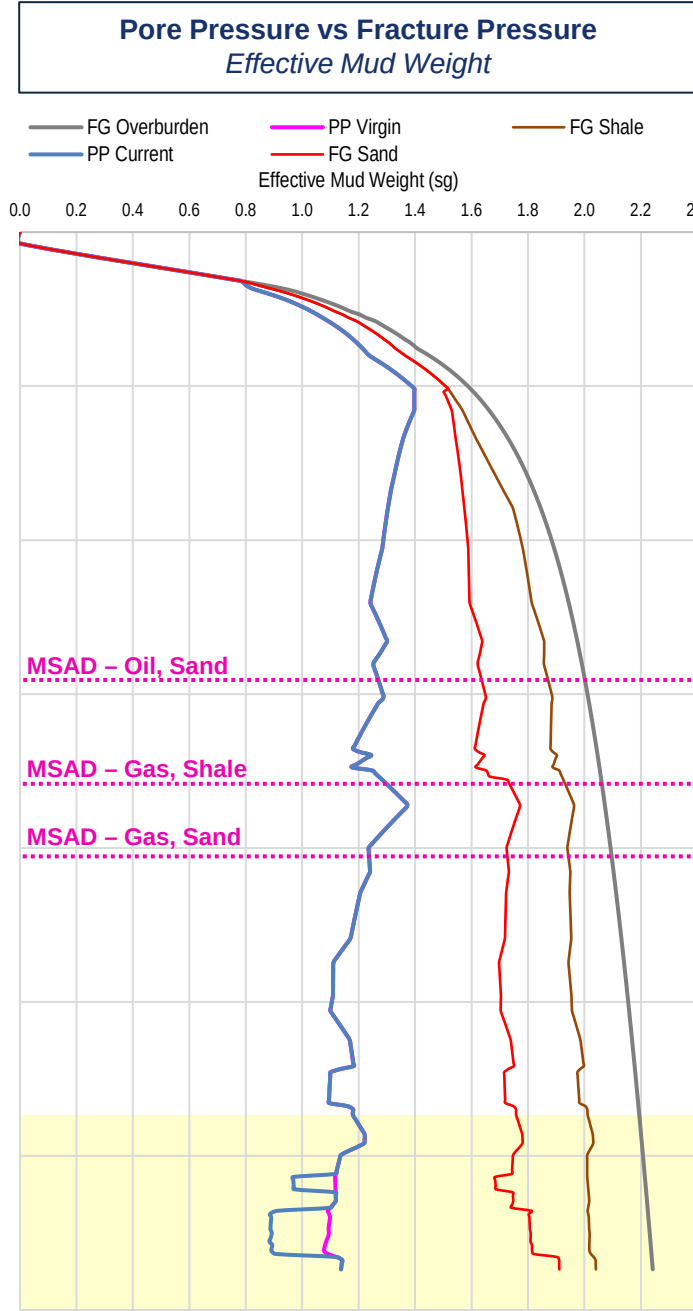
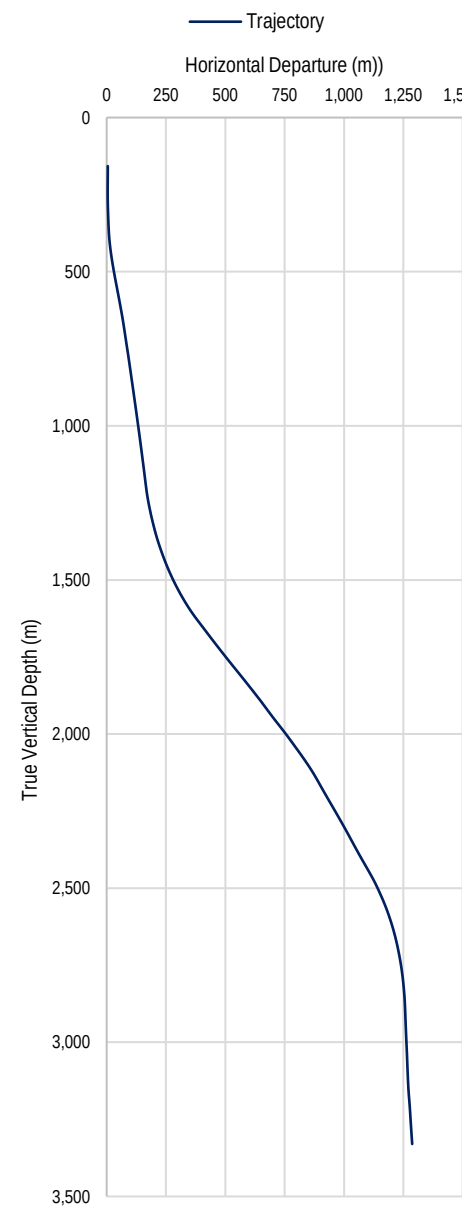
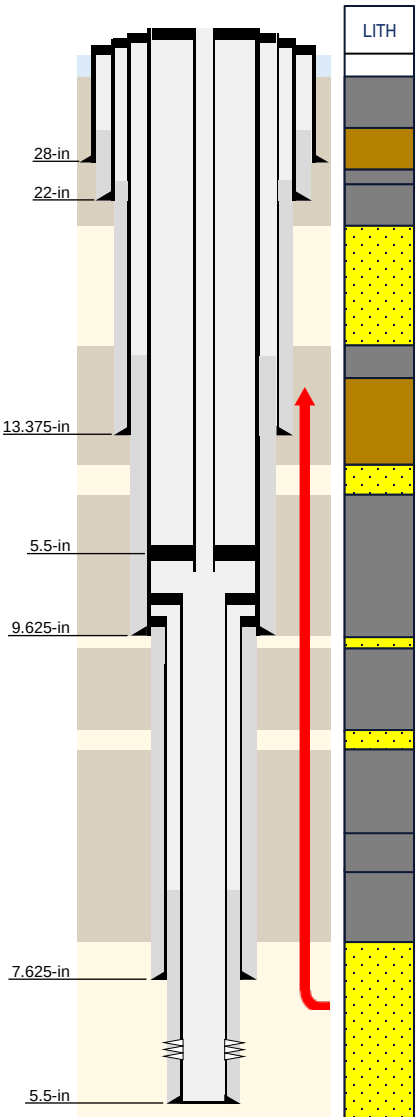
Procedure:-

1. Mix and drop 20 sacks construction cement on top of fish at 2102'.
2. Drop iron cylinder od Diameter 11" to 11 $\frac{1}{2}$ "; Length +/- 2' to lodge above 10- $\frac{3}{4}$ " casing stump at 791'.
3. Drop 5 cu.ft. earth on top of this bridge.
4. Mix and drop 20 sacks construction cement on top of clay plug at +/- 791'.
5. Place temporary plug at +/- 15'.
6. Mix and place 10 sacks cement surface plug.
7. Cut off 13" casing slightly below ground level.
8. Weld on cover plate to 26".



Permeable Zones

Target Reservoirs



Overburden Assessment

Target Seals and Permeable Zones

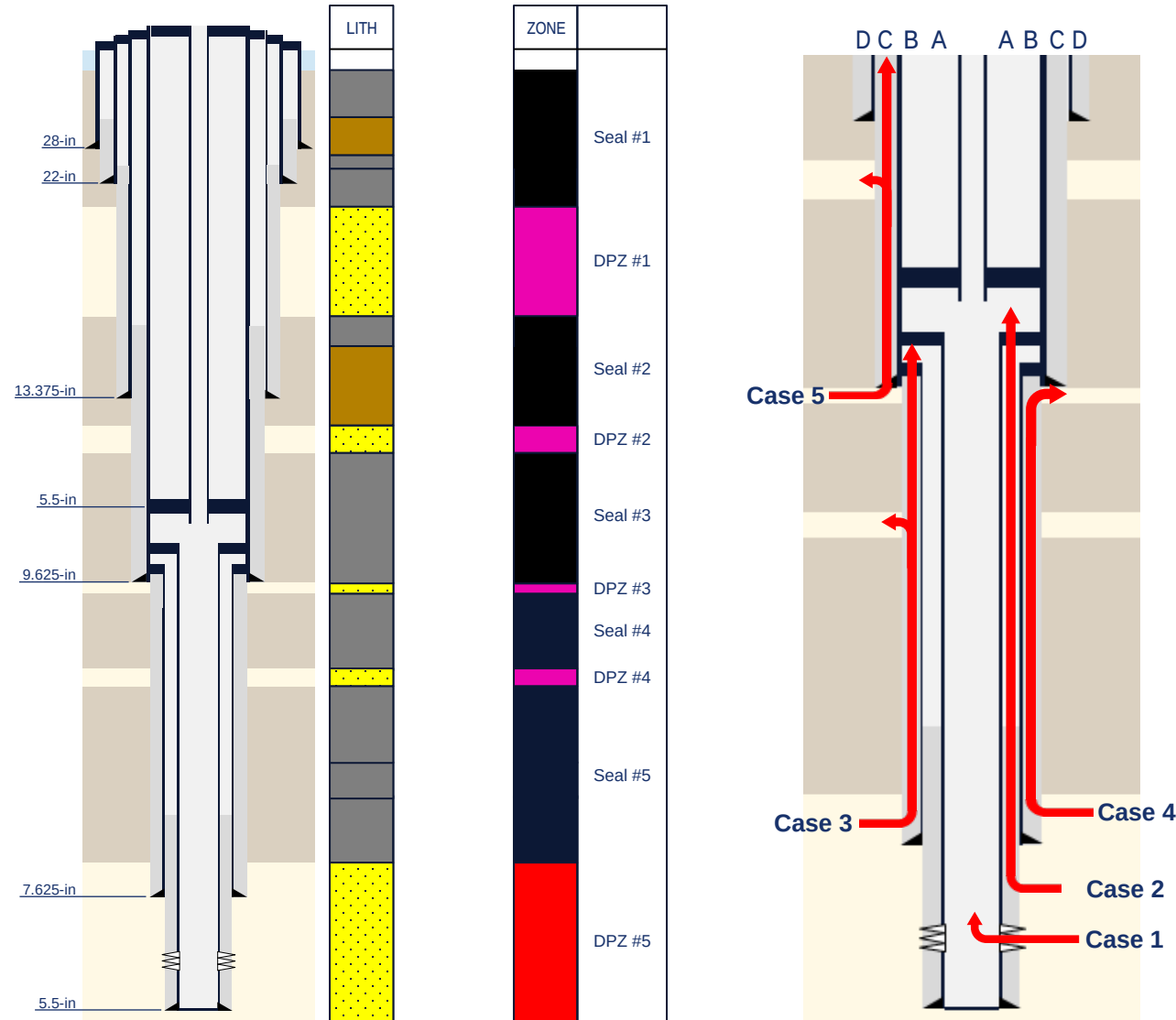


Table 1: Isolation Targets

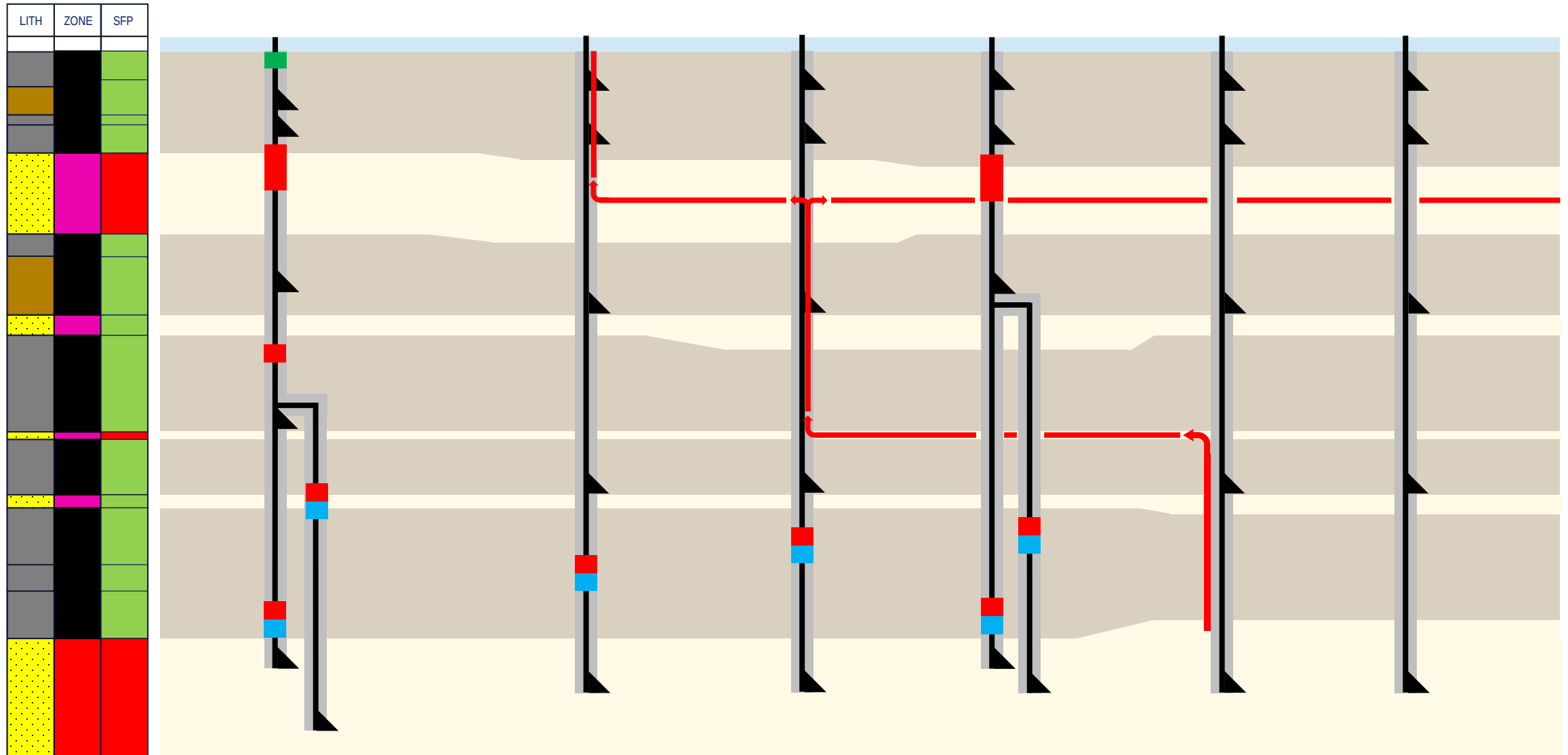
Zone	Target Type	Top Formation (mTVD)	Bottom Formation (mTVD)	Formation Thickness (mTVD)	Min Barrier Length (m)	Planned Length (m)	Comments
Seal #1	Contingency	75	575	500	30	100	Risk assess to ALARP
Seal #2	Contingency	930	1331	401	30	100	Single Barrier if DPZ #2 has SFP
Seal #3	Contingency	1403	1890	487	30	100	Single Barrier if DPZ #3 has SFP
Seal #4	Contingency	1923	2234	311	30	100	Single Barrier if DPZ #4 has SFP
Seal #5	Planned	2296	2943	647	30	100	Single Barrier. Combination Barrier Possible if DPZ #04, #03, #02 & #01 have no SFP

Table 2: Inflow Assessment

Risk Case	Inflow Mobility Potential	Zone(s)	Failure Mode	Well Barrier Verification	Mitigation
1	DPZ #05 to wellbore	DPZ #5	Underbalanced wellbore and flow into well, and migration through completion.	<u>Overbalanced Fluid</u> Maintain 50 psi overbalance of abandonment fluid	Set temporary barrier in 5.5-in liner and qualift to 500 psi above reservoir pressure. VO inflatable barrier
2	DPZ #05 to Wellbore	DPZ #5	Flow through B-annulus cement. Migration into B-Annulus behind liner and casing. Flow through liner top packer into wellbore.	<u>Annular Cement</u> Qualify cement - assess formation & casing bond. <u>Liner & Casing</u> Confirm tubular integrity. <u>Liner Top Packer</u> Qualify liner top packer seals.	Additional measurement with passive acoustic log to confirm there is no fluid flow behind the liner & casing.
3	DPZ #05 to DPZ #04 and crossflow communication	DPZ #5 & DPZ #4	Flow through C-annulus cement behind liner. Migration into DP #04.	<u>Annular Cement</u> Qualify cement - assess formation & casing bond. <u>Liner & Casing</u> Confirm tubular integrity.	Perforate and test the Liner. Additional measurement with passive acoustic log to confirm there is no fluid flow behind the liner & casing.
4	DPZ #05 to DPZ #04, DPZ #03 & and crossflow communication	DPZ #5 & DPZ #4	Flow through C-annulus cement behind liner. Migration into DP #04 and DPZ #03.	<u>Annular Cement</u> Qualify cement - assess formation & casing bond.	Additional measurement with passive acoustic log to confirm there is no fluid flow behind the liner & casing.
5	DPZ #03 & DPZ #02 and communication in D-Annulus	DPZ #03 & DPZ #02	Charging of DPZ #03 and flow to DPZ #02 or into D-Annulus.	<u>Annular Cement</u> Qualify cement - assess formation & casing bond. <u>Liner & Casing</u> Confirm tubular integrity.	Additional measurement with passive acoustic log to confirm there is no fluid flow behind the liner & casing.

Crossflow in Formations

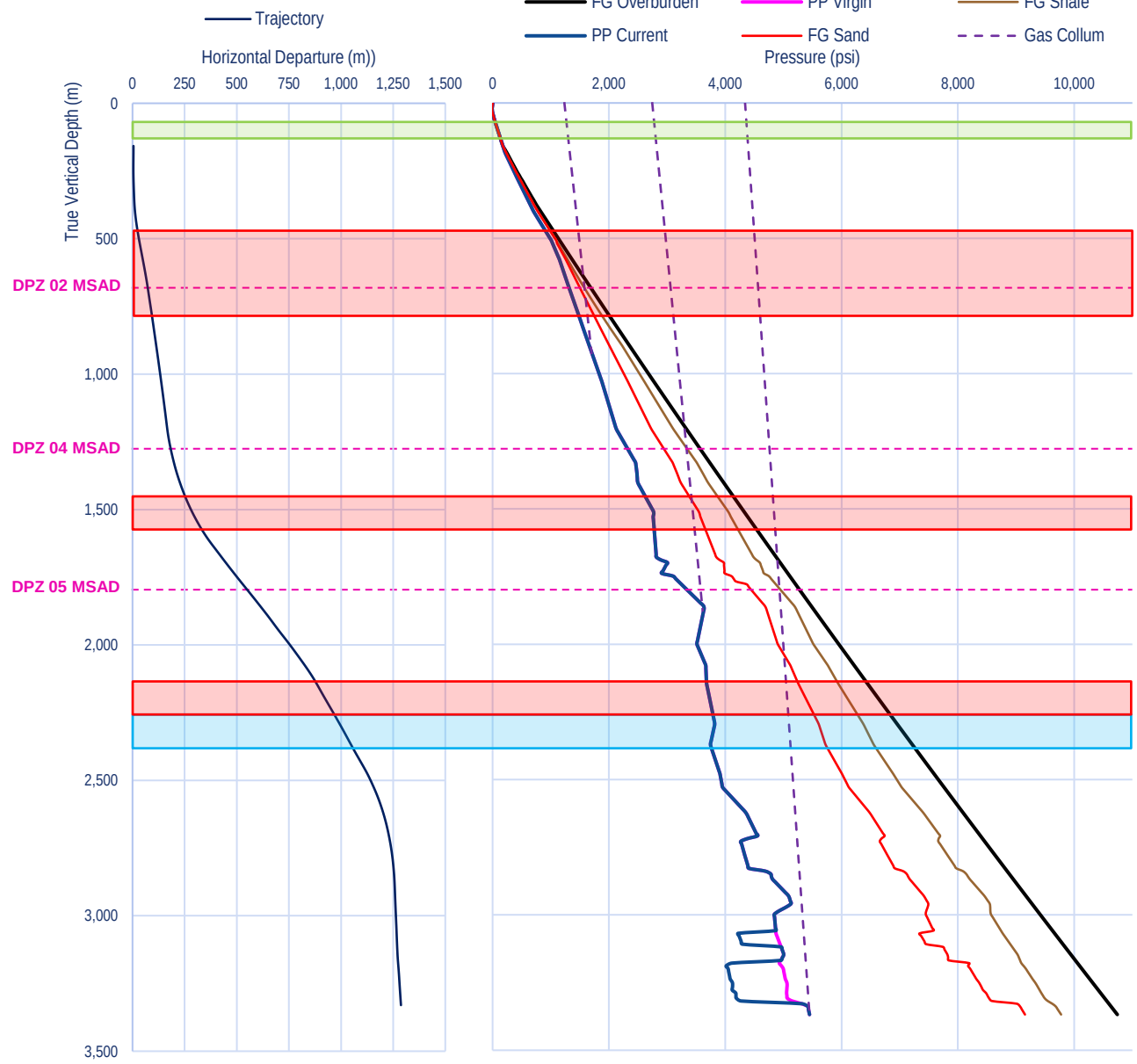
Hydrocarbon Migration | Sustained Potential Flow





Pore Pressure vs Fracture Pressure
Pressure

FG Overburden PP Virgin FG Shale
PP Current FG Sand Gas Collum



Environmental Plug
Single Plug
Plug 5 – Isolating wellbore fluids to the environment

Isolation 3
Single Barrier
Plug 4 – Isolating DPZ 02 SFP from surface

Isolation 2
Single Barrier
Plug 3 – Isolating DPZ 04 SFP from surface

Isolation 1
Combined barrier
Plug 1 & 2 – Isolating DPZ 05 SFP from surface.

Lithology

- Claystone
- Limestone
- Sandstone
- Siltstone

Zones

- Caprock
- Permeable Zone
- Hydrocarbons w/ SFP

Permeability

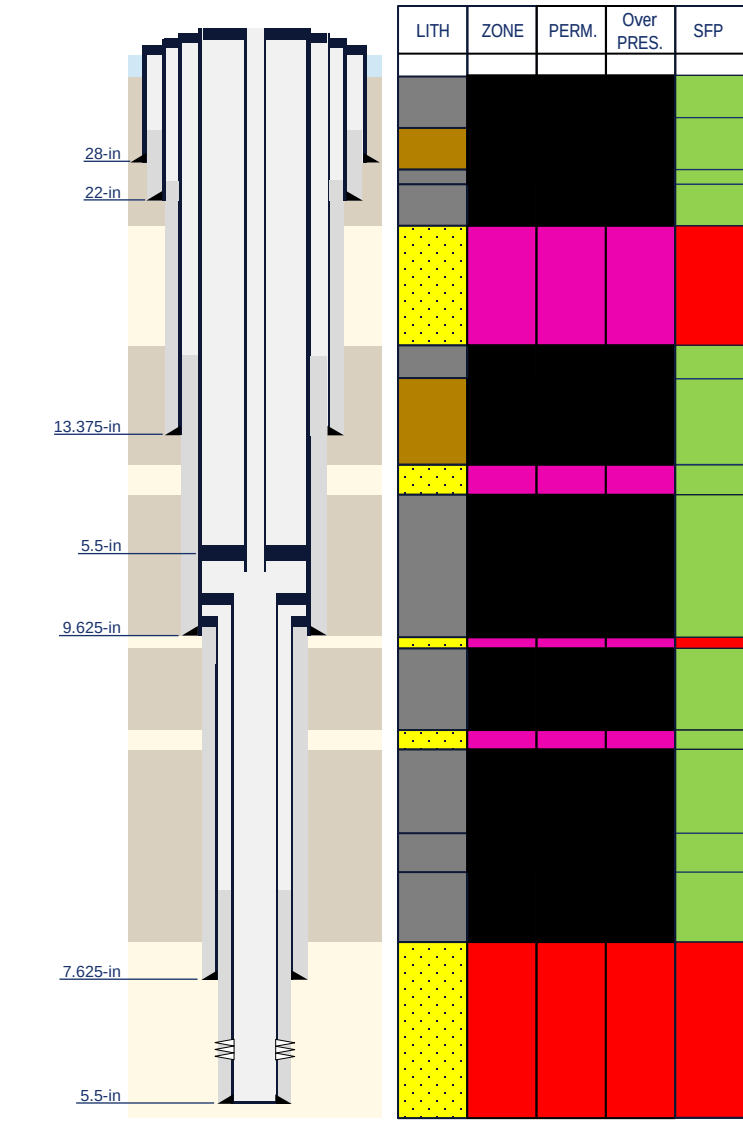
- Permeable
- Non-permeable

Over Pressurised

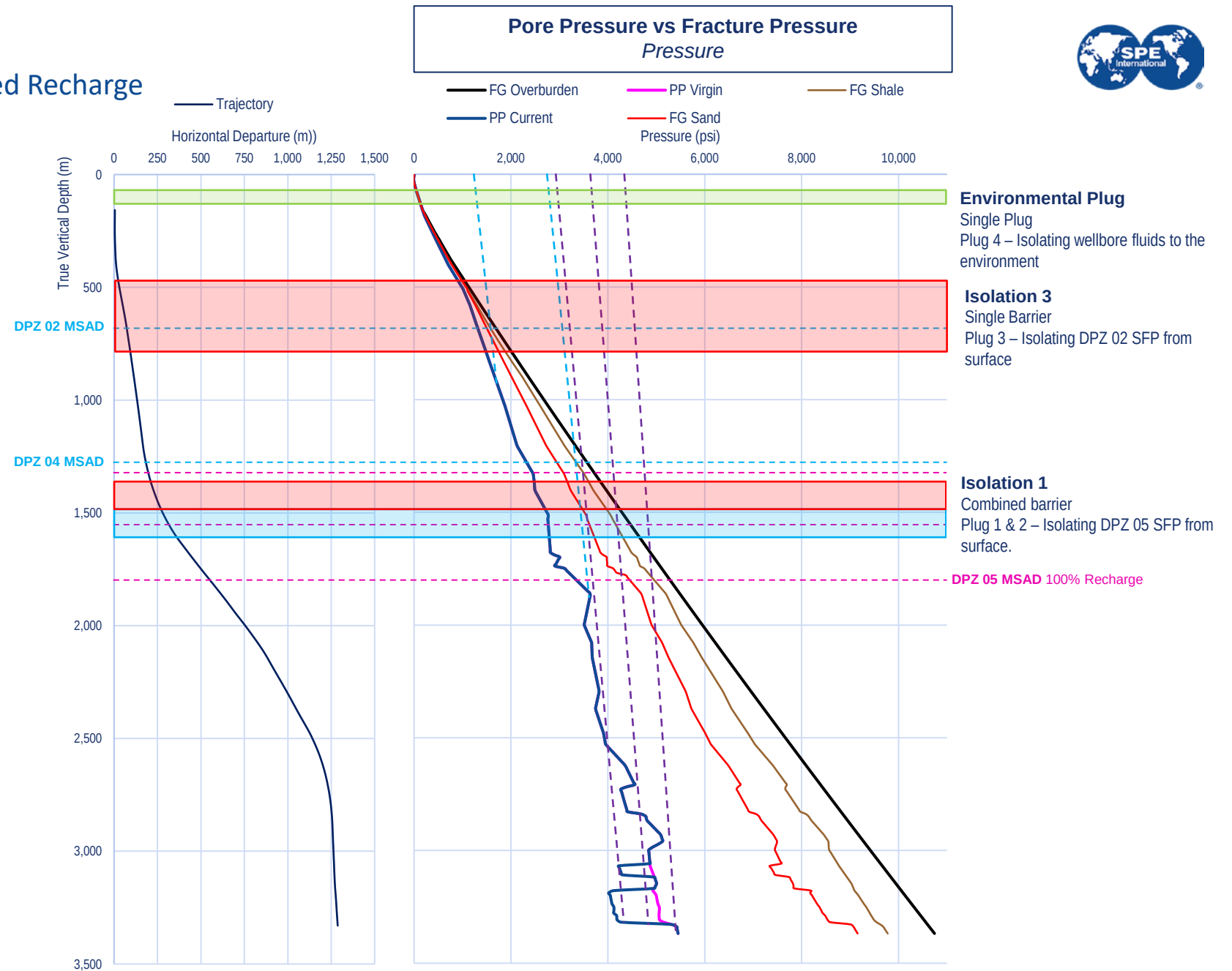
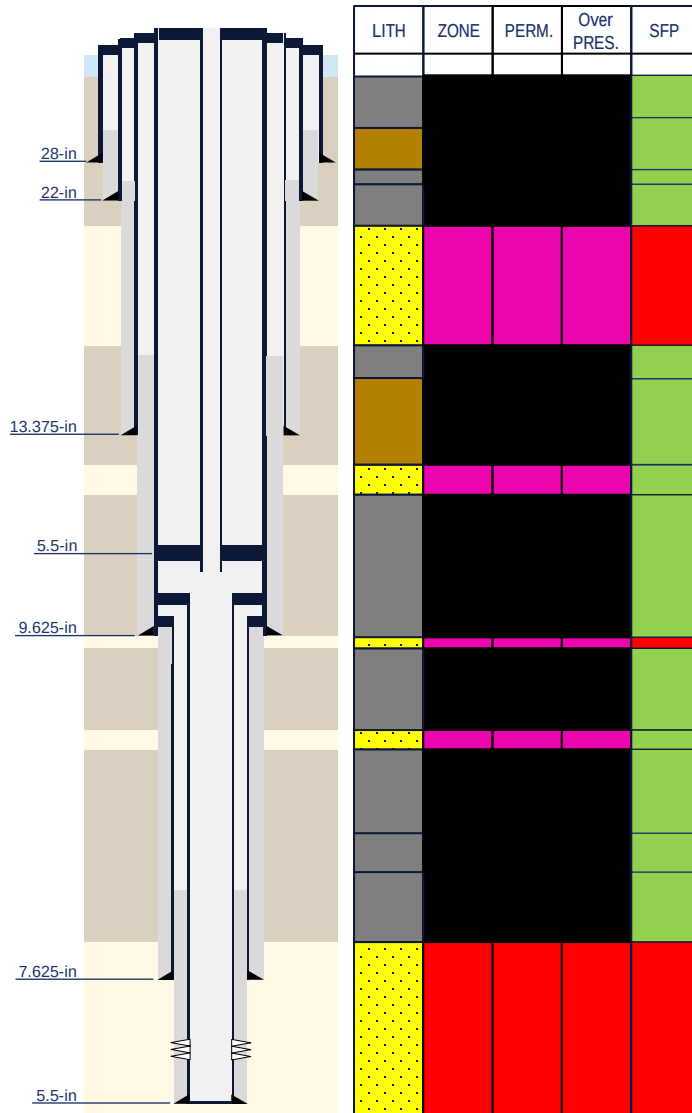
- Over Pressurised
- Normally Pressurised

Sustained Flow Potential

- No
- Yes



Virgin Pressure , Depleted or with Limited Recharge





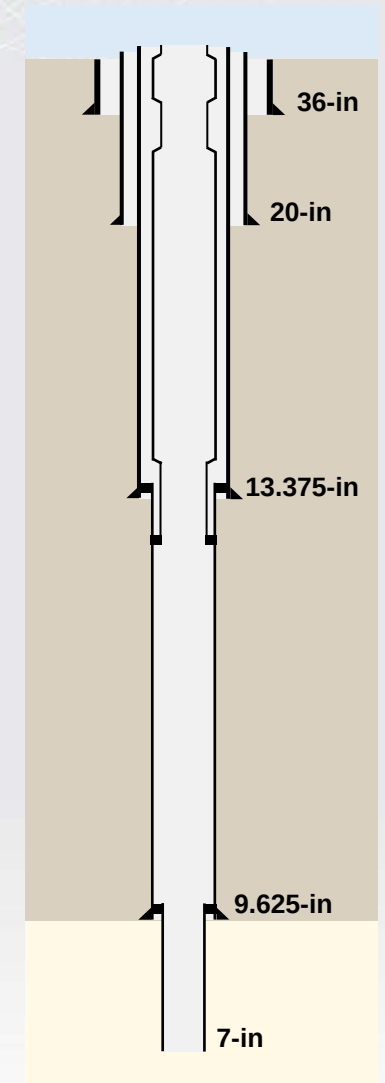
Optimizing Barrier Placement

Assessing the Subsurface to ALARP

What can we Learn from the Offshore Sector

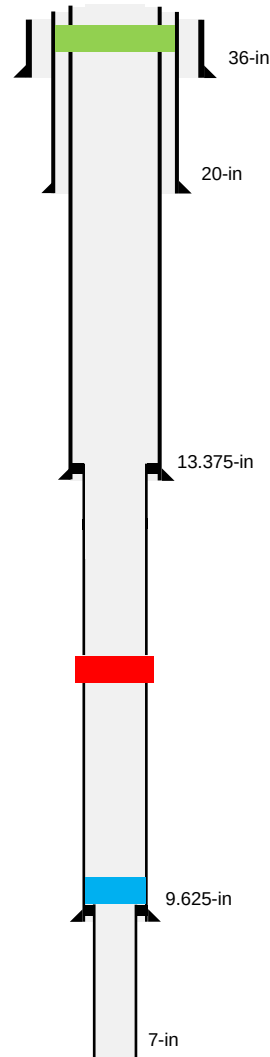
- High cost base environment
- Up to ~800ft water depth
- 4 string well design
- Swaged Intermediate completion with permanent production packer
- Gravel pack completion inside wrapped screens
- One production unit
- Overburden with permeable zones without flow potential

How can we approach the subsurface isolation to manage risk to ALARP?

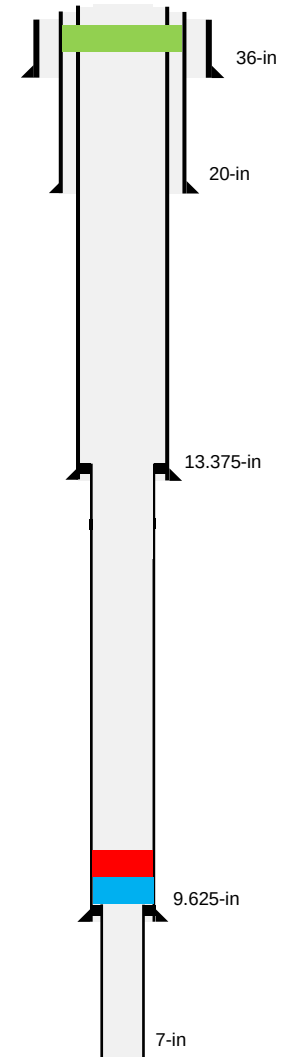
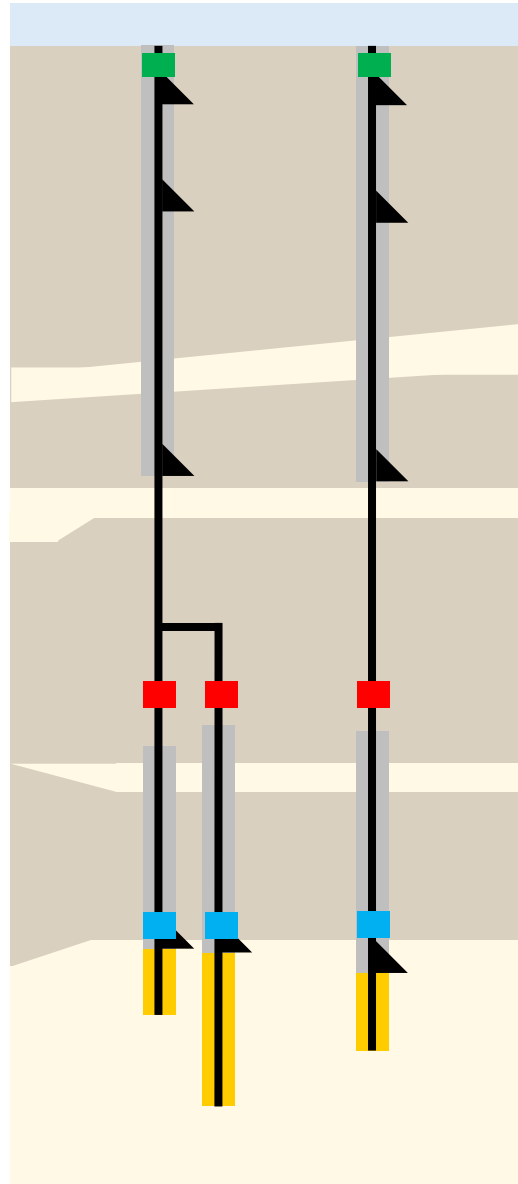


Expandable Barrier Placement Techniques

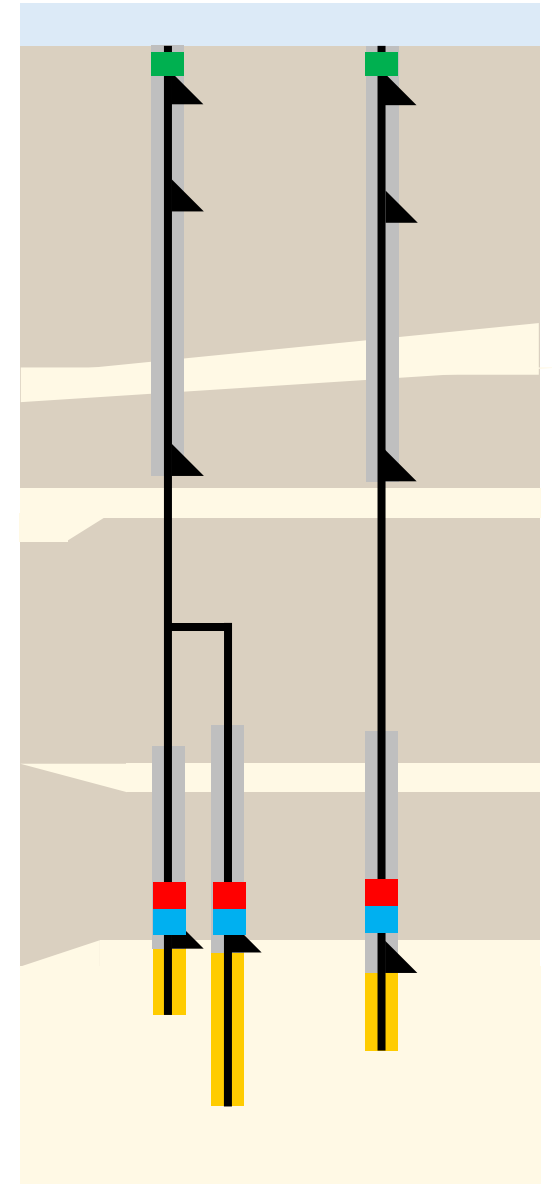
Can you avoid deconstructing the wellbore?



Case 1
Conventional Approach



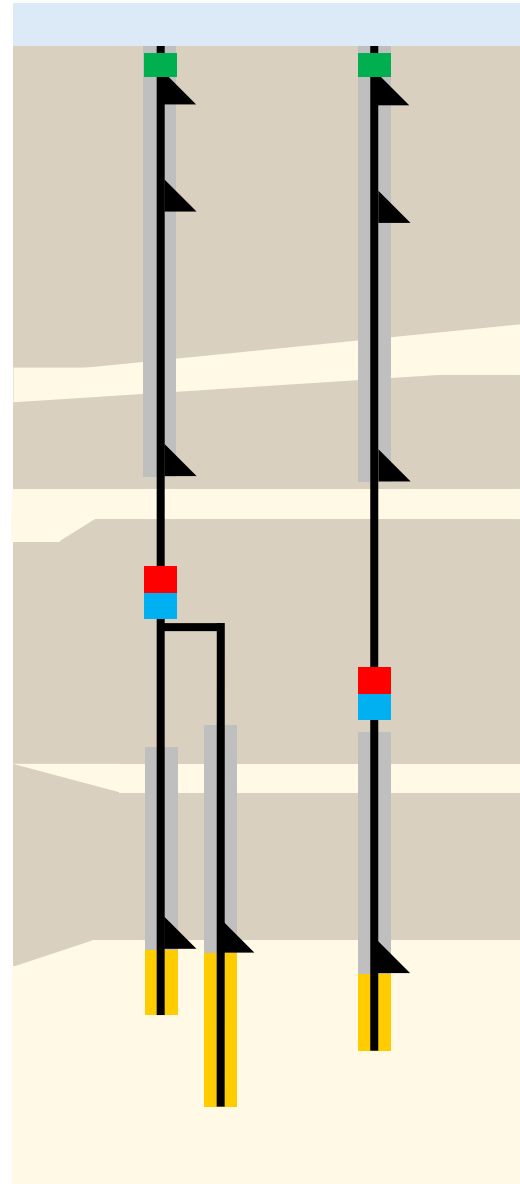
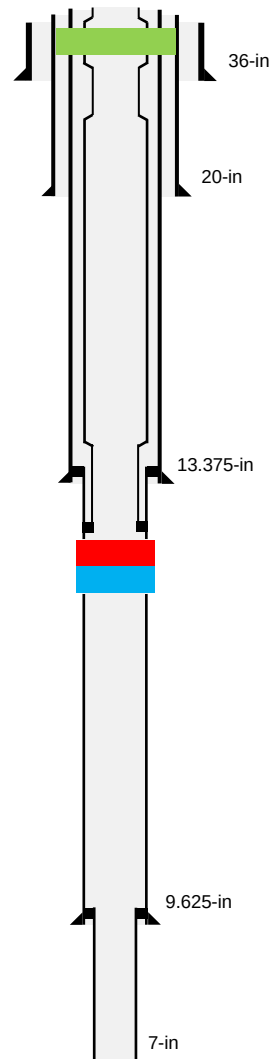
Case 2
Optimized Combination Barrier Approach





Expandable Barrier Placement Techniques

Can you avoid deconstructing the wellbore?



Discussions

The Optimized Placement Approach is risk assessed to ALARP, with the follow qualifications:

- The reservoir has depletion by 2045 and a 50% recharge pressure design case is considered
- The MSAD is above the sidetrack junction
- Ultrasonic logging string can drift through the SCSSV and centralise inside the 9.625-in casing
- TCP & and placement tool can drift through the SCSSV
- Verification is performed via inflow test & soft tagging

Operational Simplification:

- Reduce risk by establishing V0 temporary suspension
- Benefit of leaving the intermediate completion in situ
- Benefit of avoiding deep section milling
- Benefit of isolating above the casing exit junction in Well #01

Case 3

Optimized Placement Approach



THANK YOU

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