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Will the Current Approach to Hydrocarbon Well Plug and Abandonment be Effective 'In Perpetuity'?

Professor Brian Smart
Richard Stark

Agenda

Introduction to P&A in the context of the Decommissioning Challenge

- Aims and intent of decommissioning?
- What do we have to decommission?
- Current Approach to Well P&A – regulatory and technical

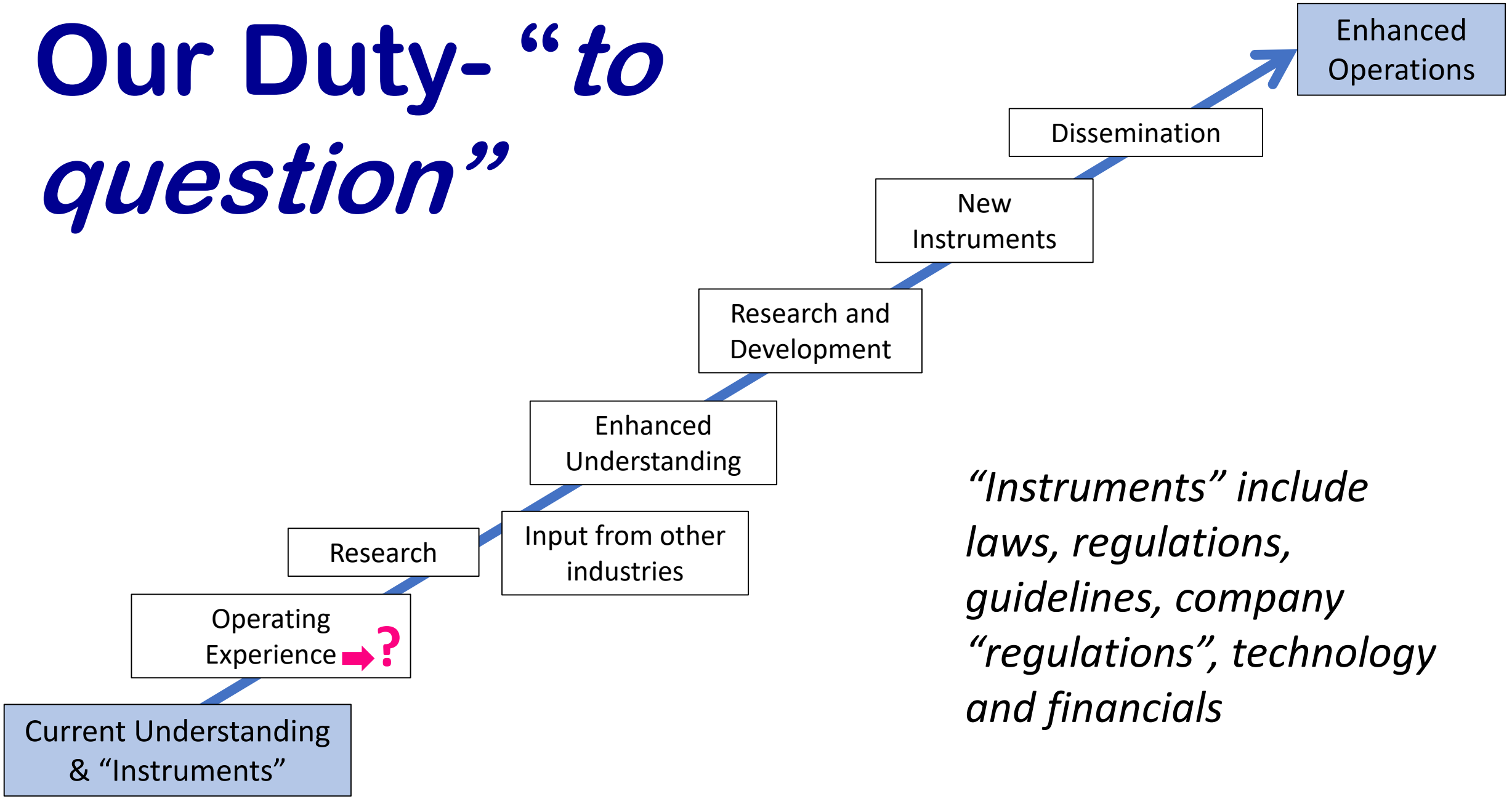
Do abandoned wells leak and does it matter?

- Current perceived failure mechanisms of cement plugs
- The impact of geo-mechanical shear on plug material
- What is ‘natural’ and do we need to plug the wells?
- Perpetual decommissioning

Conclusions

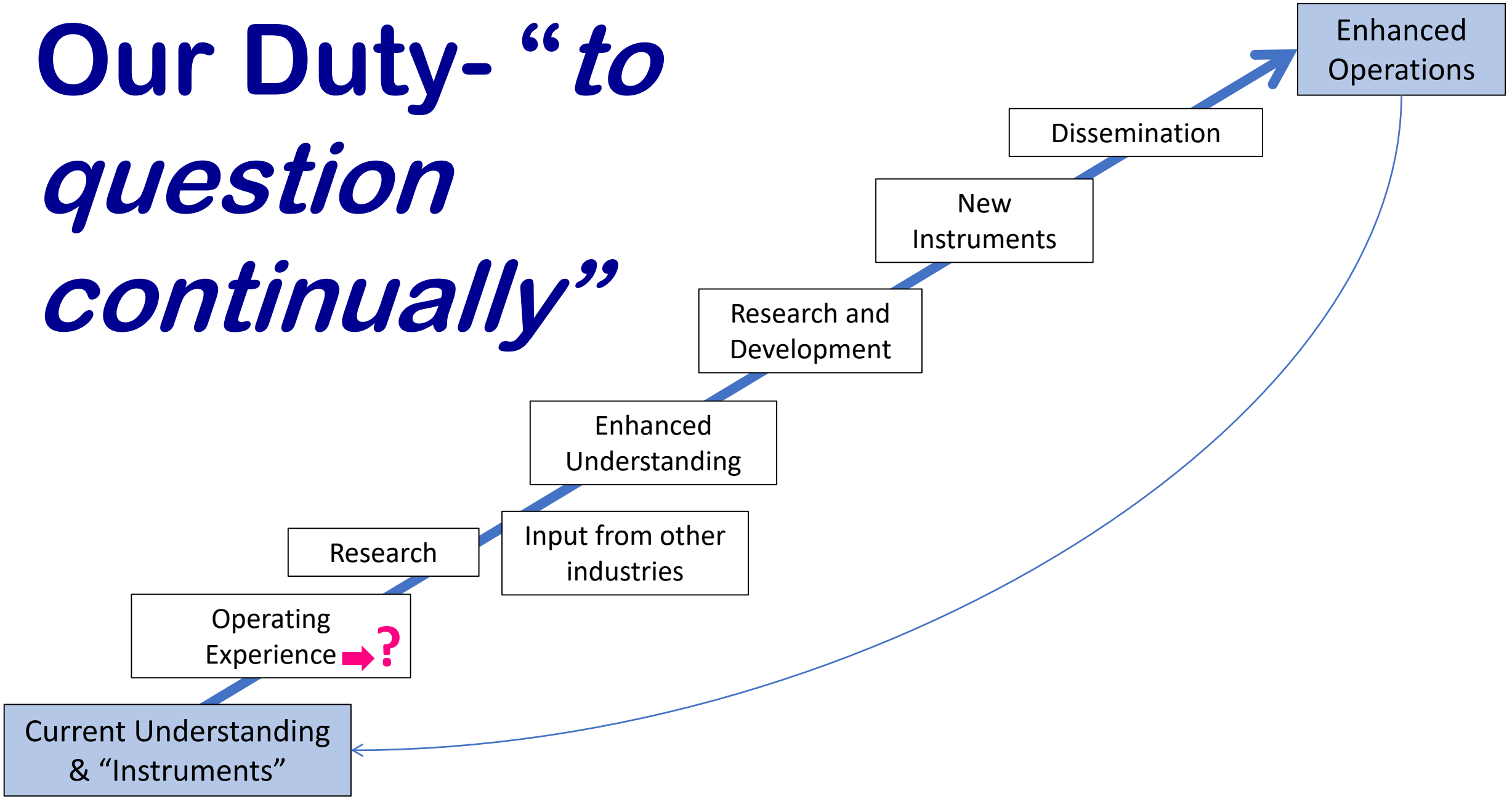
- Is the status quo a workable solution?
- Whose problem is it really?

Our Duty- "*to question*"



"Instruments" include laws, regulations, guidelines, company "regulations", technology and financials

Our Duty- "*to question continually*"



Our Duty - the question examined here

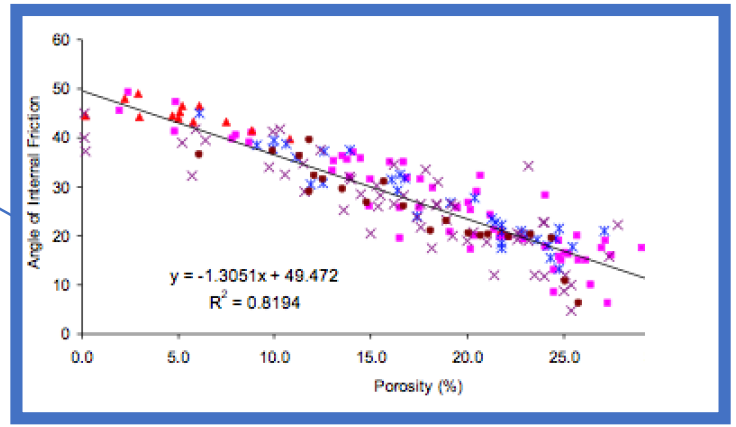
Enhanced Operations

Dissemination

CPD: Cross-discipline and facilitated

New Instruments

Research and Development



Enhanced Understanding

Input from other industries

Research

Operating Experience ➡ ?

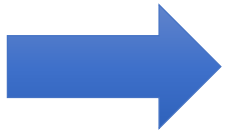
Current Understanding & "Instruments"

P&A effective <u>in perpetuity?</u> <u>Really?</u>

Our Duty- "*to question*"

Answering questions could lead to new P&B Instruments:

- Enhanced guidelines
- New technology/materials
- Alternative financing



<u>Enhanced Operations</u>

i.e. P&A more liable to be effective in perpetuity

Decommissioning and Abandonment

- ***Oil and gas decommissioning:***
  - "involves the plugging and abandonment of the wells, cleaning of the installations and pipelines and their removal. The process also includes clear up of the seabed and the long-term monitoring of anything left in situ"

- ***Well Plug and Abandonment:***
  - The well plugging and abandonment procedure aims at preventing fluid leakages along the well so that all the fluids will remain permanently confined in the separate strata containing them before plugging. (Mainguy et al, 2007)

- ***Decommissioning:***
  - "taking equipment out of use" (Cambridge dictionary)
  - "withdrawl of something from service" (Oxford dictionary)

- ***Abandonment:***
  - "cease to support" (Oxford dictionary)
  - "Leave in place, usually forever" (Cambridge dictionary)

- **Well P&A presents the longest and least accessible technical challenge**
- **Should wells be 'abandoned' or 'decommissioned'?**
- **Is well decommissioning a perpetual task**

The Intent of Decommissioning

Field Owners' intent (?)

- Leave the basin once production operations are complete
- Avoid or limit on going liability (risk / commitments)

State / Government's intent (Guidance Notes: Decommissioning of Offshore Oil and Gas Installations and Pipelines)

- Meet international obligations
  - precautionary principle
  - polluter pays principle
- Maximise economic return as a contribution to UK energy security
- Ensure field owners take responsibility for decommissioning
- Protect the tax payer from the risk of funding [additional] decommissioning liabilities

- **Are these short – medium term goals, 0 – 30 – 40 – 50 years?**
- **This presentation aims to consider time scales of 50 – 100 – 500 year and perpetuity**
- **Who should pay for the inadvertent effects of development?**

Well Plug and Abandonment Challenges (P&A)

Number of Wells

Well Status	No of Wells	%
Completed (operating)	2,128	47% (3,739)
Completed (shut in)	696	
Plugged	267	
Abandoned Phase 1 / 2	648	
Abandoned (Phase 3)	4,135	53%
TOTAL	**7,874**	

From Well Insight Report, OGA 2018

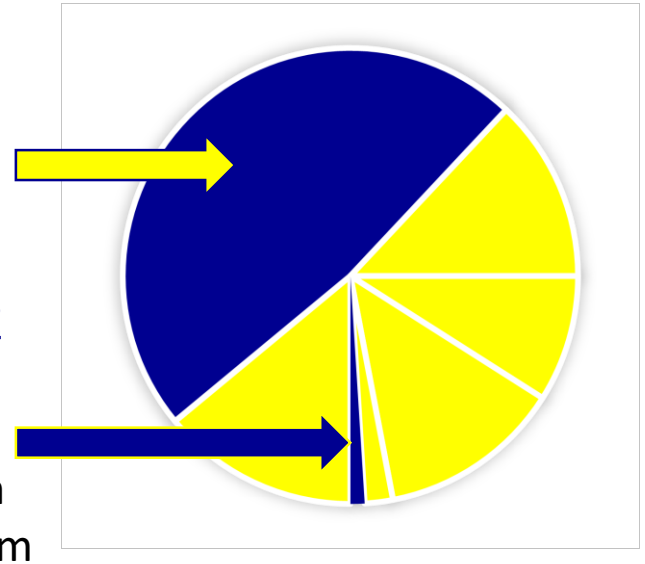
Cost of P&A

Well P&A

- 48%
- £26.7Bn
  - O&G = £13Bn
  - HMRC = £13Bn

Post-Decommissioning

- <1% of estimate
- <£560m
  - O&G = <£290m
  - HMRC = <£290m



From UKCS Decommissioning: 2018 Cost Estimate Report, OGA 2018

- **Almost 50% of wells have already been plugged using current materials and methods**
- **How permanent are 'permanent barriers'?**
- **Is <£580 million sufficient to remediate anything which occurs in the future?**

Who is liable for what?

The Petroleum Licensing (Production) (Seaward Areas) Regulations 2008

- All casings and fixtures forming part of a well and left in position…..shall be the property of the OGA (Clause 19 (14))

Decommissioning Programme

- Production of a Decommissioning Programme is a statutory requirement (Petroleum Act 1998)
- Wells must be identified within the Programme

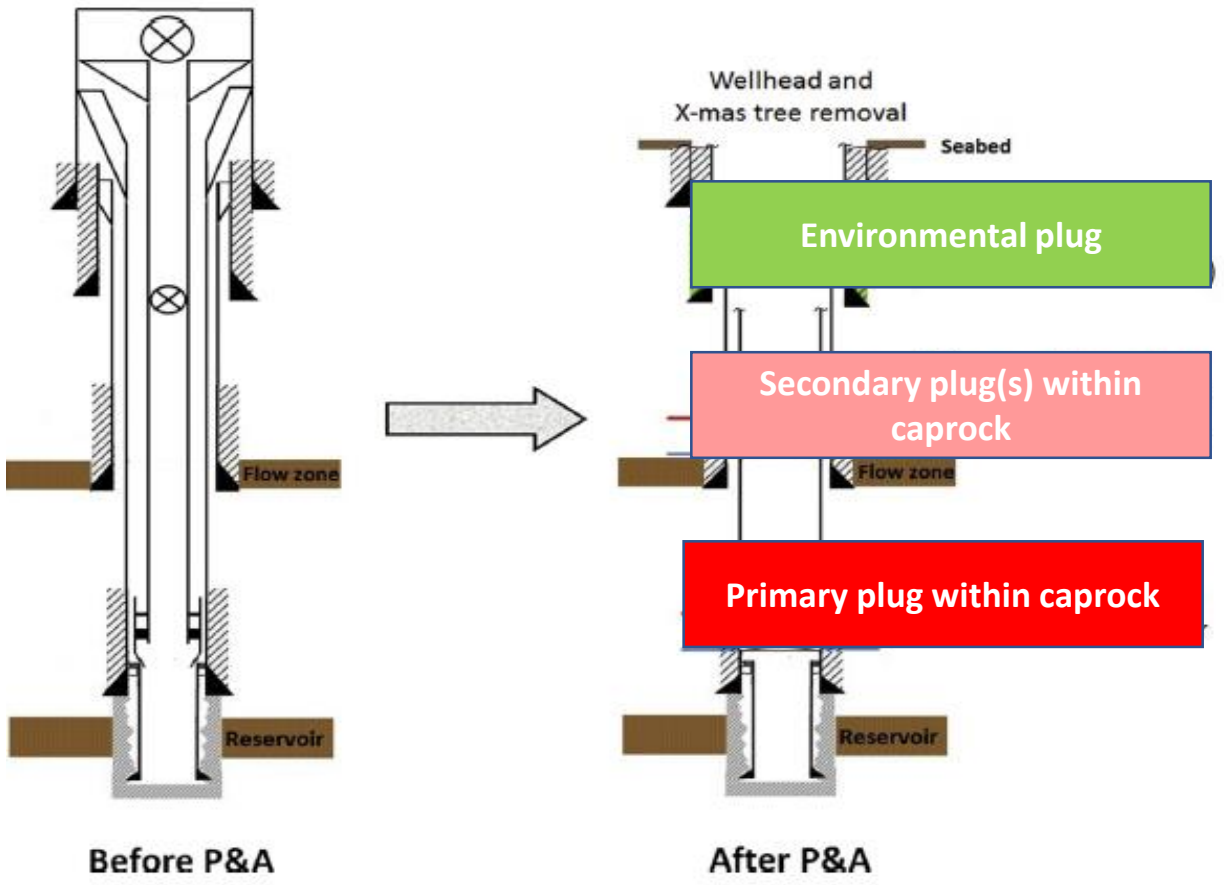
Decommissioning Guidelines (BEIS)

- Provides guidance on what and how field owners should decommission
- Doesn't discuss wells – P&A the responsibility of OGA
- Provides the basis for owners' perpetual liability
- 'Soft law' instrument enforced by statutory requirement to produce an approved DP
  - "Do what I say or you have to continue operating"

Questions:

- ***Who is liable for the wells and for how long?***
- ***What is a perpetual liability, how much will it cost and how long will it take to discharge?***
- ***Can insurance cover a perpetual liability?***

Current Best Practice - Approach

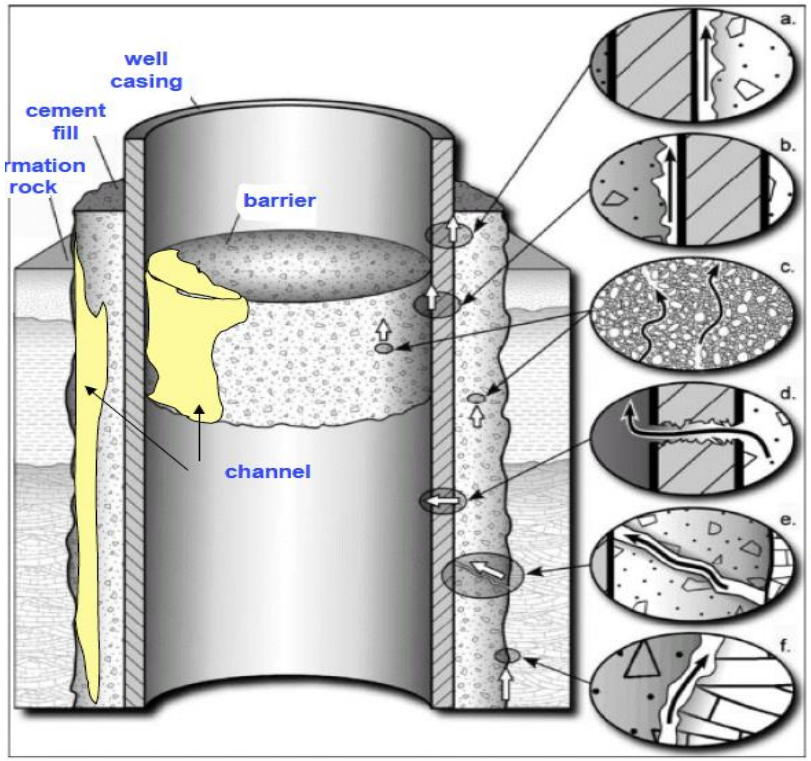


Guidelines for the Abandonment of Wells (OGUK, 2015, issue 5)

- Phase 1 – Reservoir Abandonment
  - Pull tubing, install primary and secondary permanent plugs
- Phase 2 – Intermediate Abandonment
  - Permanent environmental plug (cement)
- Phase 3 – Remove Well Head
  - Cut and remove casing 10 feet below seabed
- Aim to "restore the cap rock" and never have to re-enter the well (permanent)

- Plugs located according to the position of the reservoir and known or suspected flow zones
- Plug length standardised
- Intent not to go back!

Causes of Cement Plug Failure



https://blog.wellcem.com/plug-and-abandonment-of-oil-and-gas-wells-different-materials

- **The possible causes of plug failure are presented from a largely static appreciation**
- **Add the additional challenge due to movement of ground and casing?**
- **Movement caused by effective stress changes due to pore pressure and temperature changes as the reservoir equilibrates**

Consider the impact of Reservoir/Field Geomechanics causing ground movement

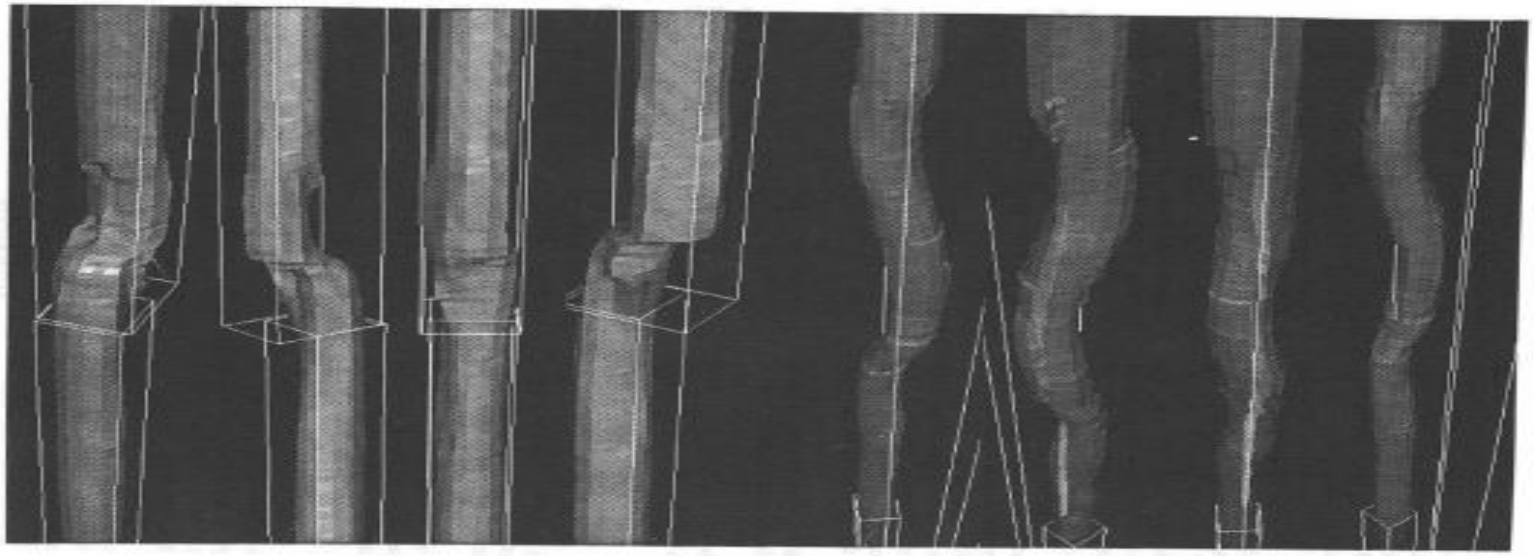
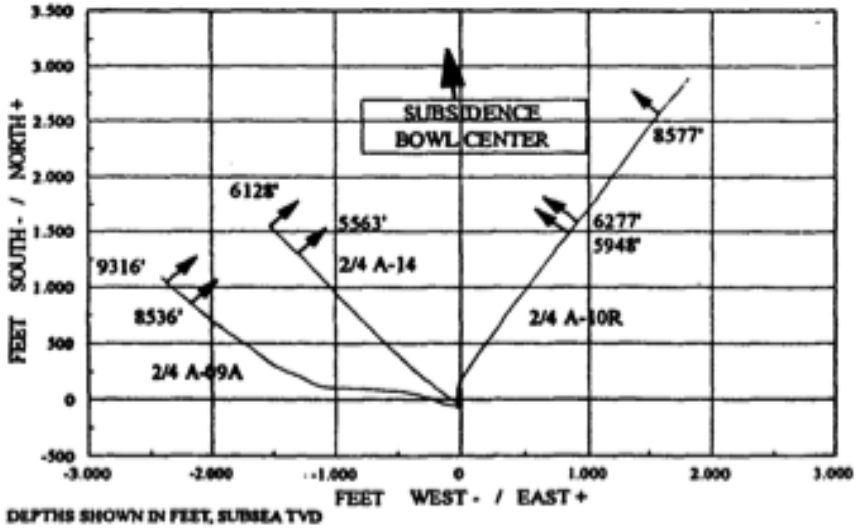


FIGURE 7. 3D REPRESENTATION OF OVERBURDEN DEFORMATION - 4 VIEWS
WELL: 2/4 B-10 JOINT 289 11603'-11610' MD
TOTAL LENGTH SHOWN: 7.2 FEET TUBING ID: 3.958"



DEPTHS SHOWN IN FEET, SUBSEA TVD

FIGURE 6. 2/4 ALPHA DIRECTION OF MOVEMENT
PLAN VIEW - JUNE 1992 DIRECTIONAL SURVEYS

FIGURE 8. 3D REPRESENTATION OF RESERVOIR DEFORMATION - 4 VIEW
WELL: 2/4 A-20 LINER JOINT 47 12530'-12542' MD
TOTAL LENGTH SHOWN: Appx. 12 FEET LINER ID: 5.4"

SPE 28091 ***Subsidence Induced casing deformation mechanisms in the Ekofisk Field***
SPE G.H Schwall & C.A.Denney
Phillips Petroleum Co, Norway 1994

- **Evidence of casing buckling/shear in Ekofisk – extreme but not isolated case in oil and gas**
- **Follows the fundamentals revealed in mining subsidence basins**

Some More Geomechanics

Static and Dynamic Considerations in Rock Engineering Brummer (ed.) © Balkema, Rotterdam. ISBN 90 6191 1532
An investigation of shear debris comminution as a mechanism of strain energy release for frictional sliding on dominant parting planes
B.G. D. Smart & B. R. Crawford
Heriot-Watt University
1990

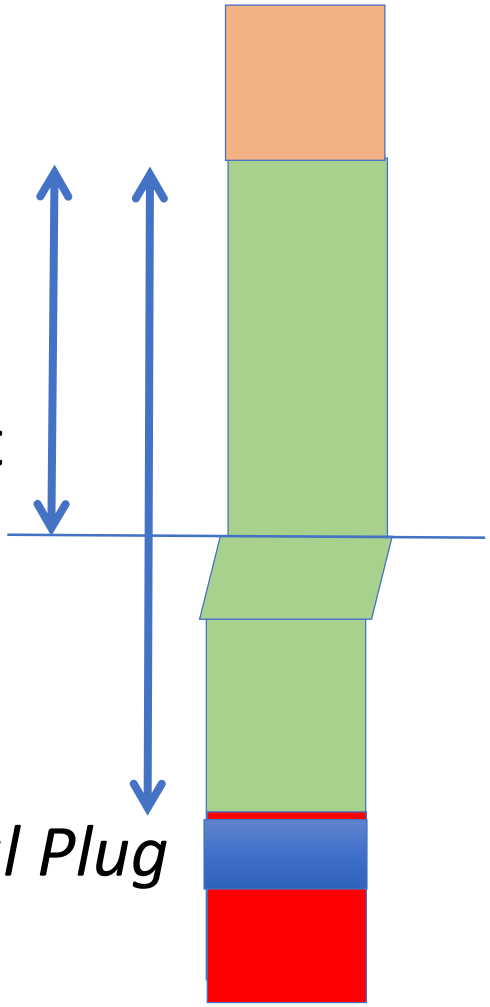
SPE 48864
Casing Shear: Causes, Cases, Cures
Maurice B. Dusseault, Uni of Waterloo et al
1998,

Rock Mechanics, Balkema, Rotterdam ISBN 90 5410 045 1
Subsidence-induced failures above oil and gas reservoirs
J. M. Hamilton, A.V. Mailer & M.D. Prins
Exxon Production Research Company Houston
1994

Existing Cement

Cement Plug to at least 100 ft above shear zone

Mechanical Plug



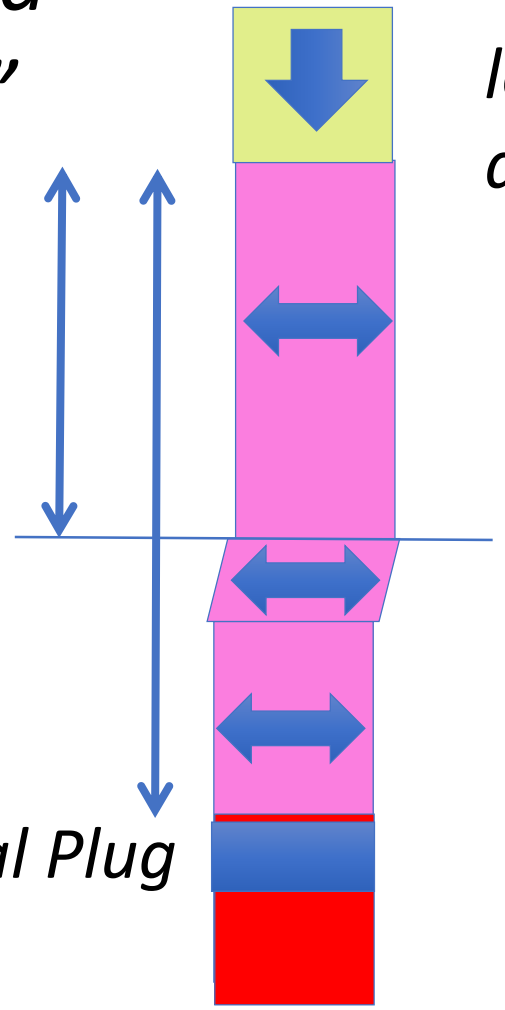
Proposed "Plastic"

"Live" loading + drillability

Plastic Plug to at least 100 ft ? above shear zone

Mechanical Plug

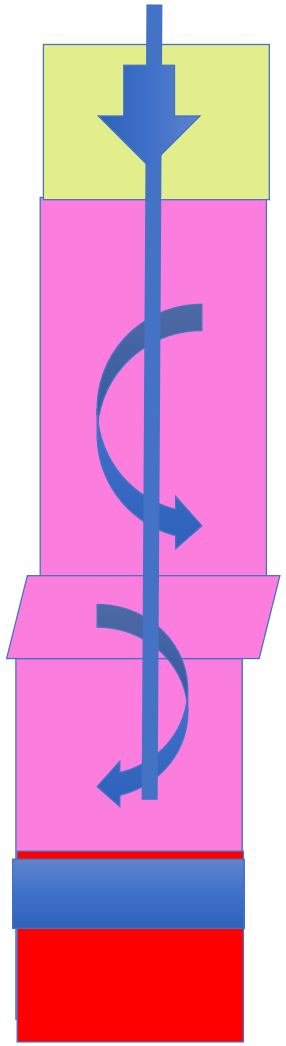
Flow zone



GUIDELINES 8.17 Overburden competence due to reservoir compaction/subsidence

Some geological environments are prone to formation compaction and/or subsidence of the seabed. The related geological movements could affect flow potential, formation pressures, rock strength/stresses, mechanical well access (wellbore distortion), and should be risk assessed when selecting the position and properties of permanent barriers.

Proposed:
Plastic + Access +
Thixotropic:
Stir it up to re-squeeze



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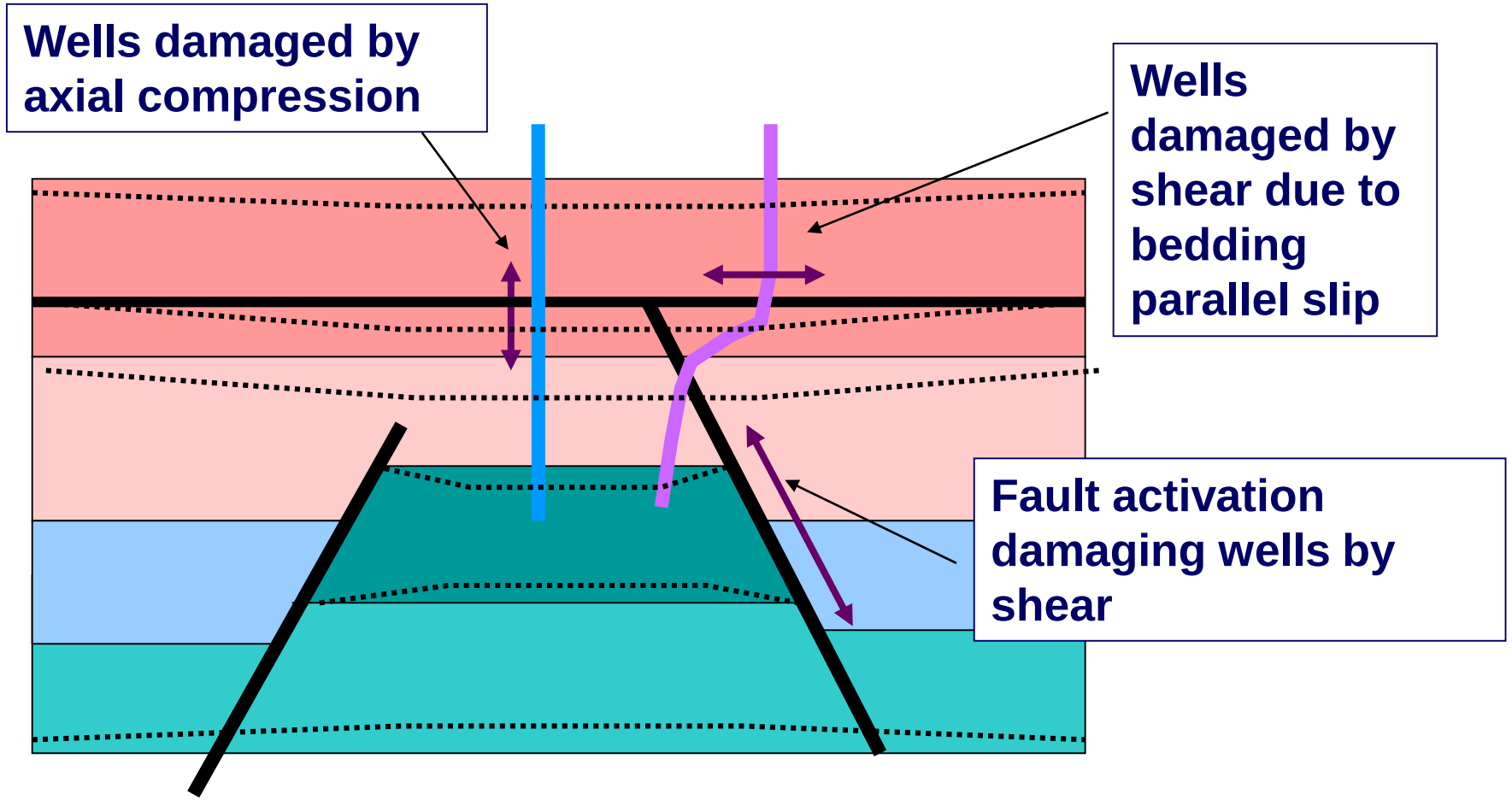
Reservoir/Field Geomechanics



- The ground truth – activated during production, reactivated (reversed) during recharge
- Implications for plug material, lengths and locations ?

Just to make the point, imagine you are a sculptor…….

Up to life size, marble, no problem

>>> life size, limestone, problems because of bedding

The enigma of the sphinx's face? Bed thickness and bedding planes!

The enigma of the sphinx's face?
Influenced by bed thickness and bedding planes location!

Still a lot of questions, but some technical/guideline suggestions:

- Recognise that post abandonment the ground will move as/if reservoir recharge occurs
- Most damage will be done to the well and casing on the horizons where bedding-parallel shear is concentrated, or on faults and fractures
- These shear zones will be known or predictable – reservoirs and the “overburden” can be calibrated from low to high risk
- If such a shear zone will intersect a plug placed according to the current reservoir/flow zone criteria, then the plug should be extended above the shear zone
- But what if the shear zone offers a leakage pathway for fluids?
- Consideration should be given to using plug materials that remain plastic, combined if possible with a hydrostatic completion – R&D being done on barite, bentonite, unconsolidated sand slurries, quick clay,
- A permanently thixotropic plug material offers another type of intervention

Do Oil and Gas Wells Leak?

Quantitative

Location	Leakage	Reference
Onshore British Columbia	29%	From a study which included 62 abandoned or suspended wells
Gulf of Mexico	50%	Bruffatto et al (2003) determined that in offshore wells half of the well casing considered began to leak after 50 years.
Norway CS	1%	Vinges (2011) reported that of 193 abandoned wells studied 38 had integrity issues including 2 which could flow to surface
Onshore Canada	1%	Sustained annular pressure in less than 1% of wells flows to surface. Generally gas detected but sometimes oil or salt water flows to surface

Qualitative

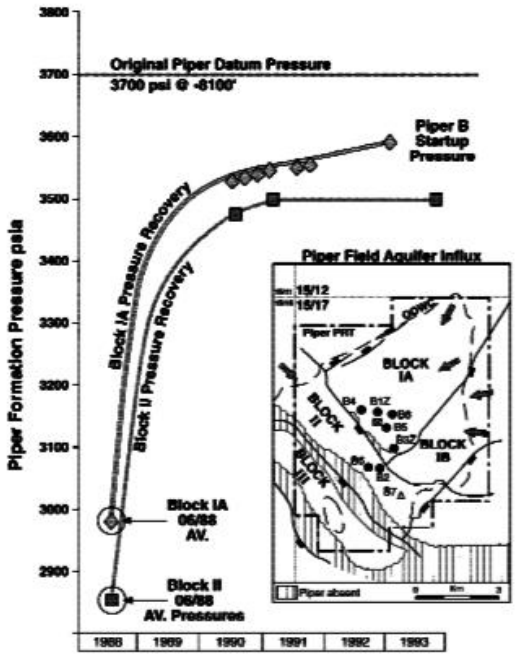
"…overtime it is expected that the condition of abandoned wells will deteriorate" (Miyazaki, 2009)

"…because of deterioration of well casings and cement over time, it is necessary to ensure that [abandoned] wells are inspected and repaired over time" (Bishop, 2013)

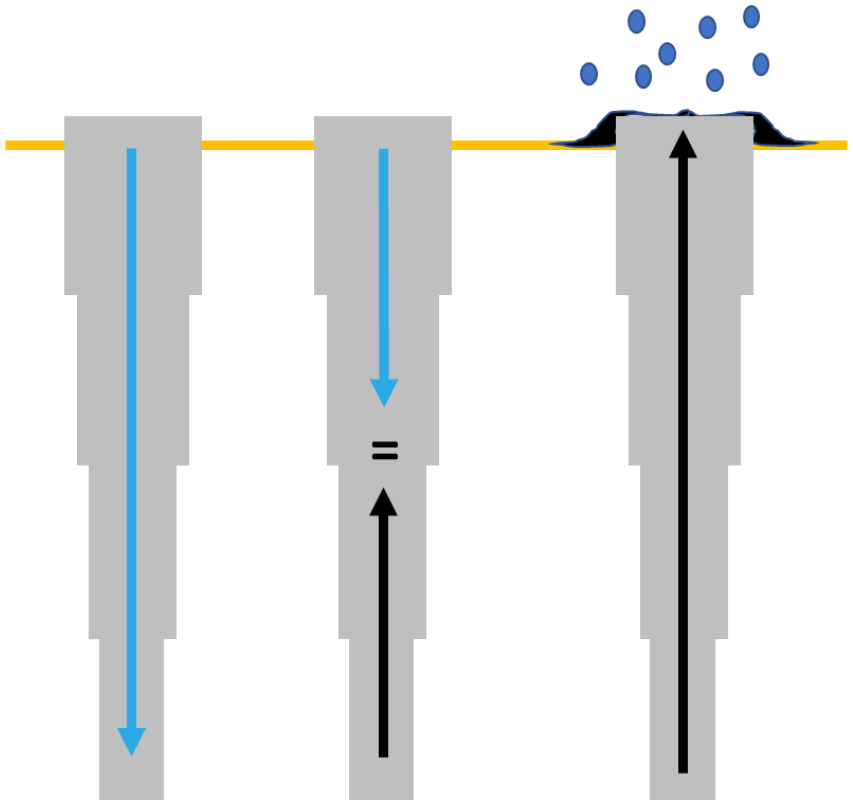
- ***Do abandoned wells leak – yes – but there is limited data?***
- ***What do we need to do about it – over 50% of wells have already been abandoned? (short term)***
- ***Are leaking wells a problem in 50 – 100 – 500 years and do we care? (long term)***
- ***What scale of financial provision or insurance is required?***

Will all wells leak? Can we control rather than contain pressure?

The Piper field recharged to 97% of virgin pressure within 5 years but will all reservoirs?



Piper field pressure recovery 1988 – 1993
From Harker (1988)



< hydrostatic pressure **= hydrostatic pressure** **> hydrostatic pressure**

- **Will most wells will recharge to pressures in excess of hydrostatic pressure?**
- **Are there alternative approaches which may provide a more insurable well 'decommissioning' option?**
- **Should well 'decommissioning' be considered on a case-by-case approach?**

What is 'natural'?

Natural seeps:

- 600,000 tonnes / annually (~20% of Macondo)
- UKCS methane seepage: 120,000 – 3,500,000 tonnes per year
- Global annual oil spills 116,000 tonnes
- "..seepage is inferred to have a fertilizing effect on both the seafloor and the water column, which may be of broad ecological and biological significance" (Hovland. M, Sigmund, J. 2012)
- Dilution and currents: "it is a big ocean" (Tony Hayward, 2011)

What are the oceans' carrying capacities? (Environmental)

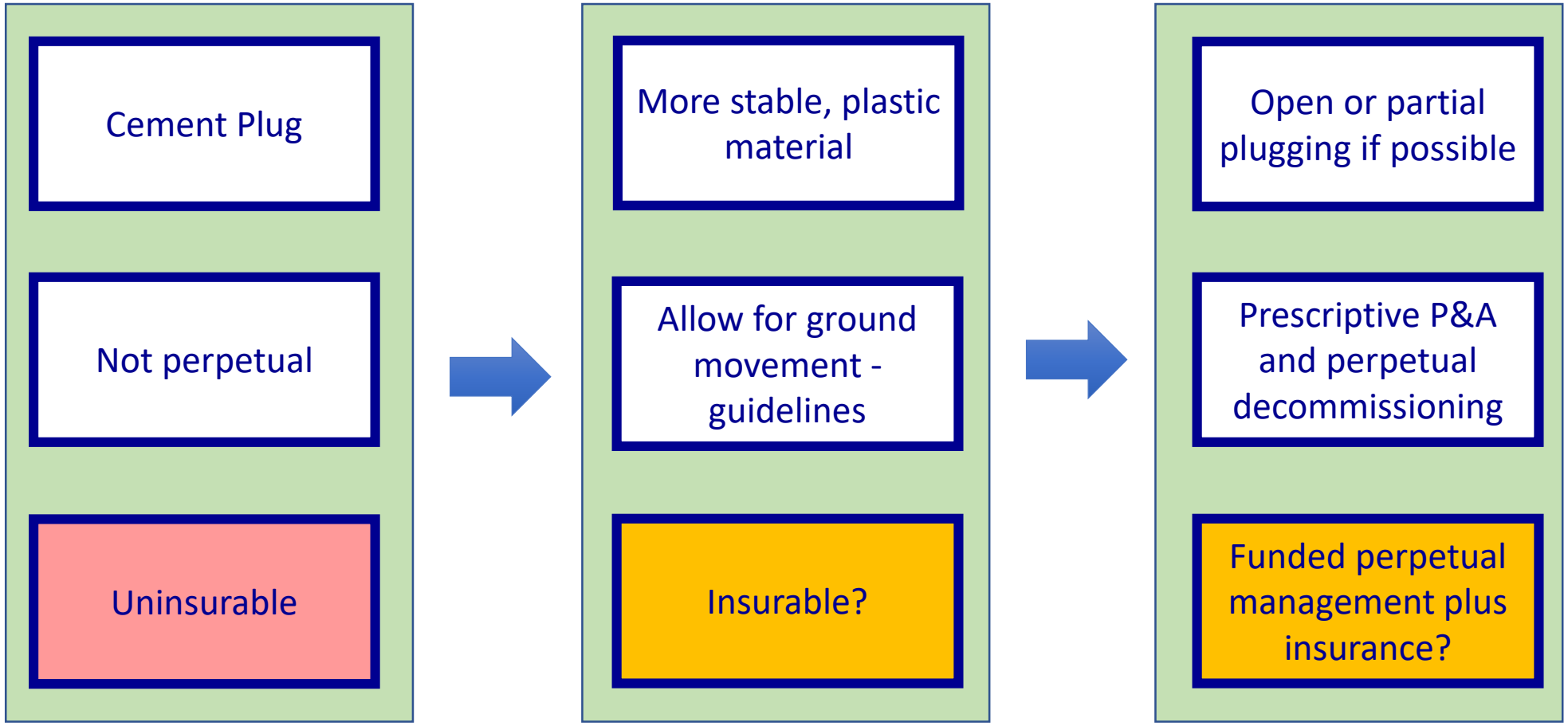
- 30 ppm on UKCS

Wells P&A	100%	90%	75%
No of Wells	3,739	3365	2804
Cost to P&A wells	£27 Bn	£24 Bn	£21 Bn
Savings	£0	£2.6 Bn	£6.7 Bn
Invested at 7% for 50 years	£0	£73 Bn	£138 Bn

https://www.youtube.com/watch?v=a_HWlFzgQiM

- **Oil occurs in the 'natural' environment, when does it become a problem?**
- **Could liquid leakage from some P&A wells be considered to be non-threatening?**
- **Could case-by-case savings provide funding for perpetual well decommissioning?**

The possible evolution of P&A instruments



Concluding Questions?

- Is cement ‘permanent’ – is there a problem with the 4,135 wells already plugged?
- Is ~£500 million sufficient to discharge a perpetual liability or insure it?
- What do we do with the 3,739 wells still to be abandoned?
- Will the State ultimately assume responsibility as the stakeholder of last resort?

- Can a suitable (natural) plug material be found?
- Would natural plugs be more insurable?
- Encompass ICOE currently working with universities on proposals based on natural materials

- How much oil is ‘bad’ for the environment?
- In moderation, can oil be beneficial to the environment?
- Response to call for evidence includes proposal to conduct North Sea ecosystem Environmental and Societal Impact Assessment

- Does decommissioning require a perpetual P&A management plan?
- How would this be paid for in line with the polluter pays principle?
- PhD seeking mechanisms to account for the ‘full cost of development within the energy industry’

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Thankyou

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