Astrimar

Long term well plug integrity assurance

A probabilistic modelling approach

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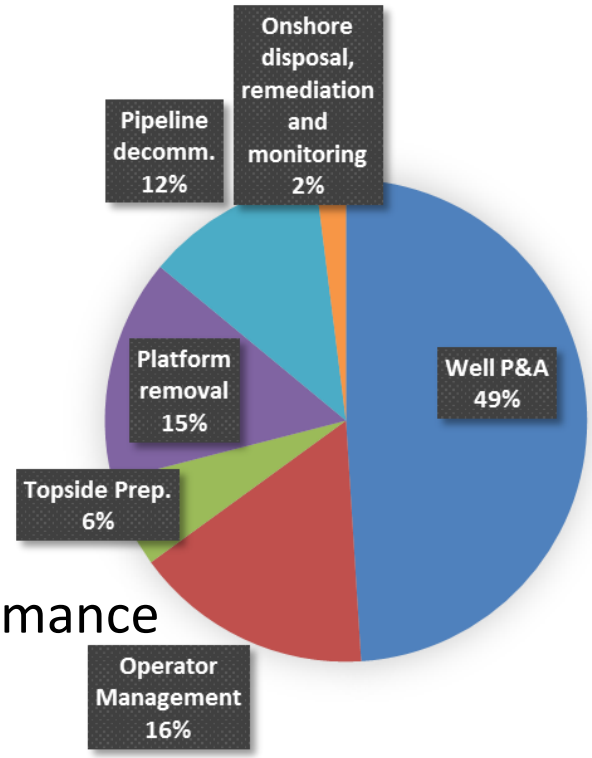
Background

Well P&A required to protect **people** and **environment**, prescribed by **regulations** and remains responsibility of operator in **perpetuity**

- Across the North Sea between 2017 and 2025
  - 349 fields to be decommissioned (214 on UKCS)
  - 2500 wells for P&A
- £1.8bn for decommissioning on UKCS (2017)
  - 49% spent on P&A
- P_{50} estimates of £60bn to be spent up to 2025
  - Target to reduce to £39bn



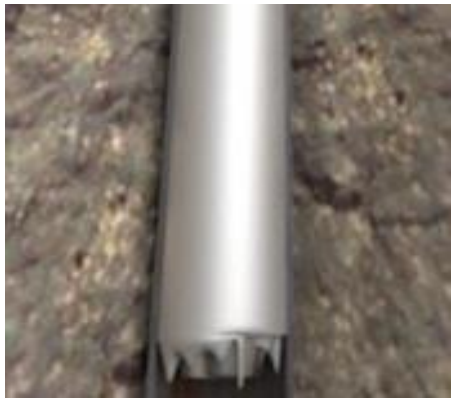
HOW?

- New technology → step change in costs & performance
- Risk based approach to P&A design

[1] Guidelines on Qualification of Materials for the Abandonment of Wells, Oil & Gas UK, 2015
[2] Decommissioning Insights 2017 , Oil & Gas UK, 2017
[3] Reducing the bill for well abandonment. Jahre-Nilsen, P., DNV GL, 2016

Challenges: Current practice & guidelines

- Cement: the de facto barrier material
- Well data varies with age and region
- Most P&A jobs require rigs
- Regulations and guidance differ between regions
- Prescriptive guidelines: a barrier to introduction of new technology
  - New materials: resins and Bismuth alloys
- UK Regulator imposes eternal responsibility
- Verification test: life assurance limitations



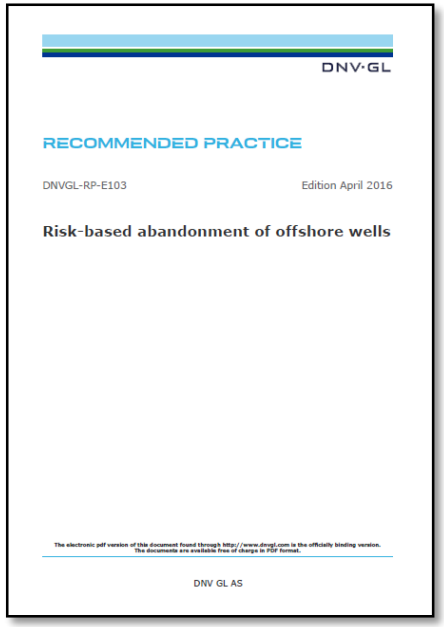
[4] Muchison decommissioning, Neves, G. CNRI, 2014
[5] A case study: Rigless plug and abandonment on unmanned installations in North Sea, Halliburton, 2012
[6] Decommissioning case study pack, Claxton

Objectives

- Develop models and tools to support high integrity seal reliability prediction
  - Casing plugs
  - Annulus plugs
  - All well barrier elements
- Support technology qualification of new materials for P&A
- Prediction of plug life and overall well P&A integrity
- Supporting risk based approach to P&A design
- Supporting development of Bismuth alloys for P&A with a statistical plug life exceeding 3000 years

Benefits of a risk based approach to P&A

- Risk based P&A
  - Minimise environmental and safety risks
  - Optimise business risk
- Well specific P&A solutions
  - Simpler designs for lower risk wells
  - Increased focus on high risk wells
- Well barrier failure modes and failure mechanisms formally assessed
- Assess impact of new technology on risk
  - New plugging and sealing materials
  - New deployment technology


DNV·GL

RECOMMENDED PRACTICE

DNVGL-RP-E103 Edition April 2016

Risk-based abandonment of offshore wells

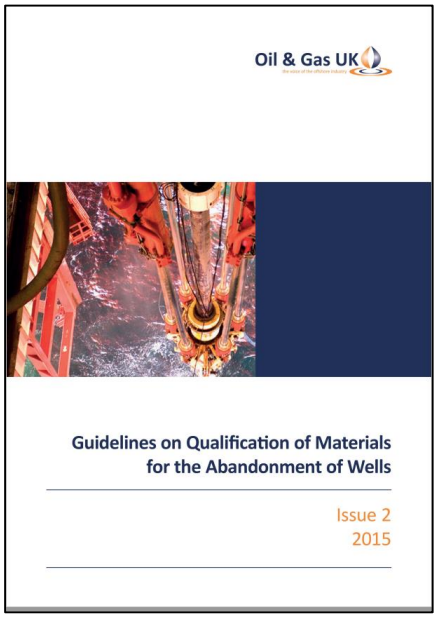
The electronic pdf version of this document found through http://www.dnvgl.com is the officially binding version. The documents are available free of charge in PDF format.

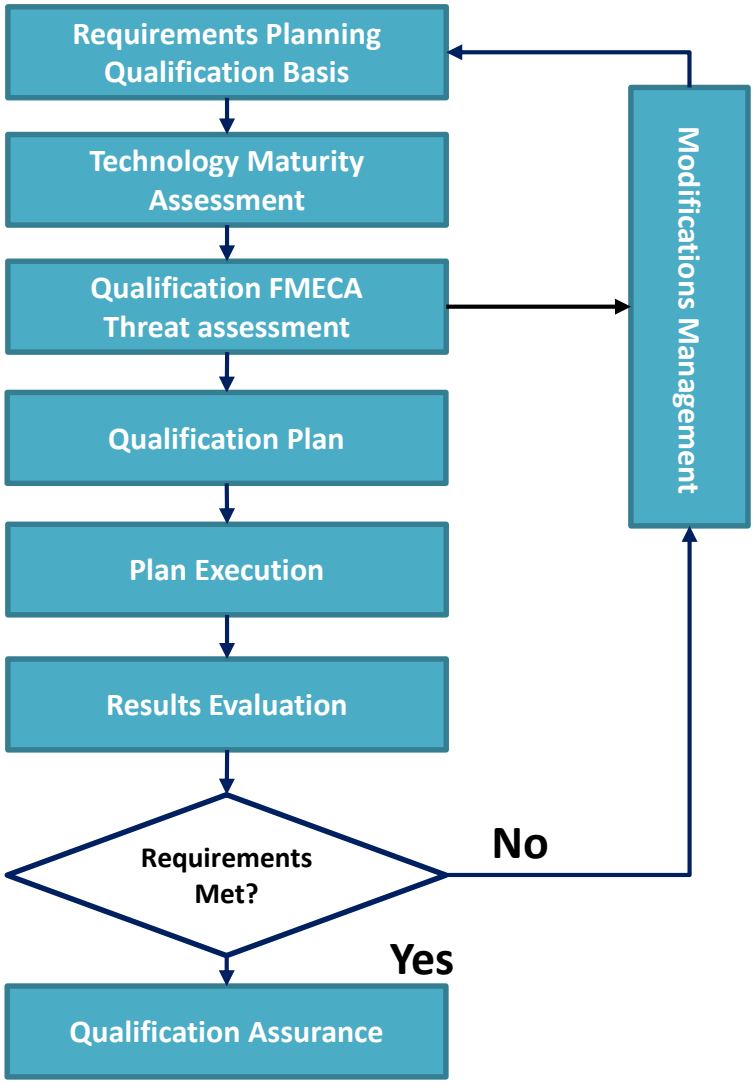
DNV GL AS

Risk based approached combined with new technology expected to deliver 30-50% reduction in costs

Plug technology qualification guidance

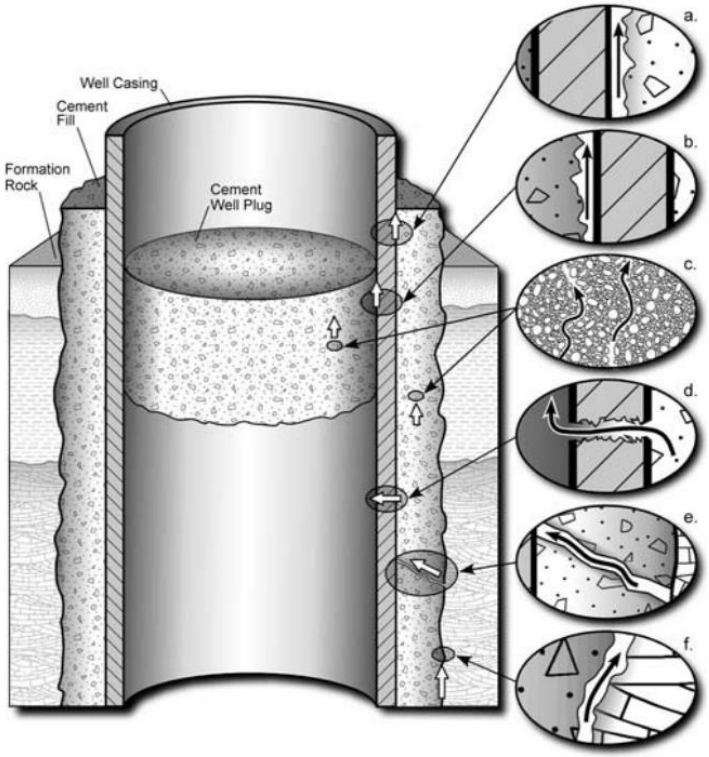
- New technology for P&A
- Technical Qualification Guidance
  - Oil and Gas UK: Materials and plug deployment focus
- TQP process guidance
  - DNVGL RP A203 or API RP 17Q
- TQP supports integrity assurance





Well barrier elements can fail

- Loss of barrier integrity a significant problem
  - Chance for hydrocarbon leakage to environment
  - Potentially irreparable for abandoned wells



a) Casing/annular cement micro-annulus

b) Cement plug micro-annulus

c) Bulk permeability

d) Damaged/corroded casing string

e) Fracture in annular cement

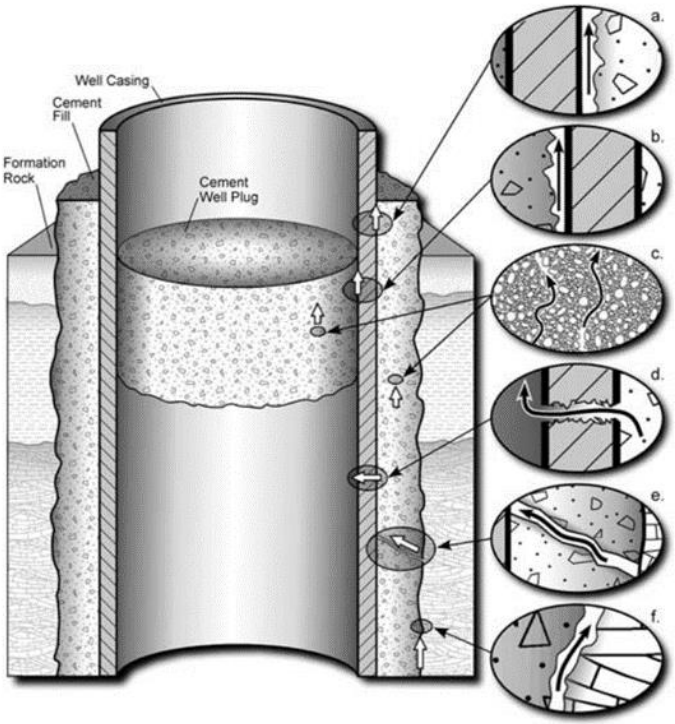
f) Annular cement/formation micro-annulus

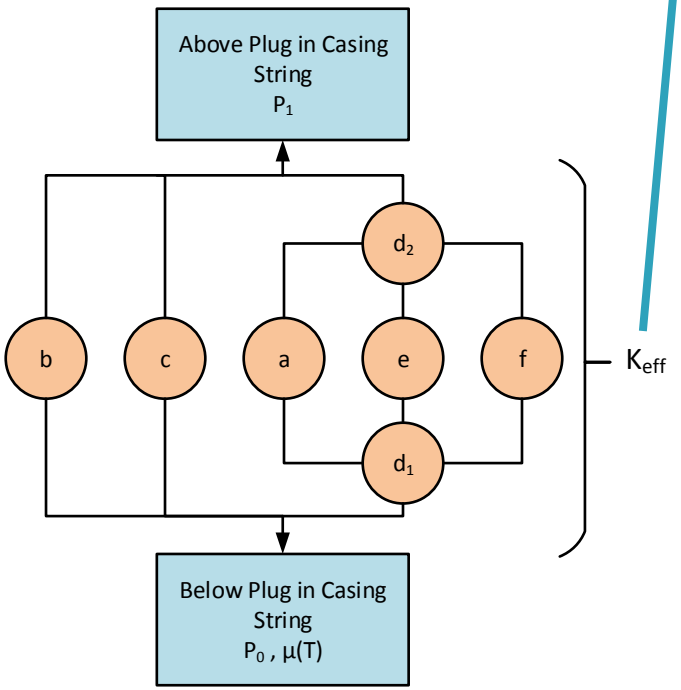
[7] Quantitative estimation of CO2 leakage from geological storageAnalytical models, numerical models, and data needs, Celia et al, 2004

Leak potential for a well barrier

- Leak needs failed barrier element with pressure differential
- Darcy's equation used to assess flow potential for each path between isolated zones
- Plug failure logic represented as flow path block diagram

$$Q_{WB} = \mathrm{K_{eff}} \frac{1}{\mu} \Delta P$$





Each mechanism has likelihood and consequence

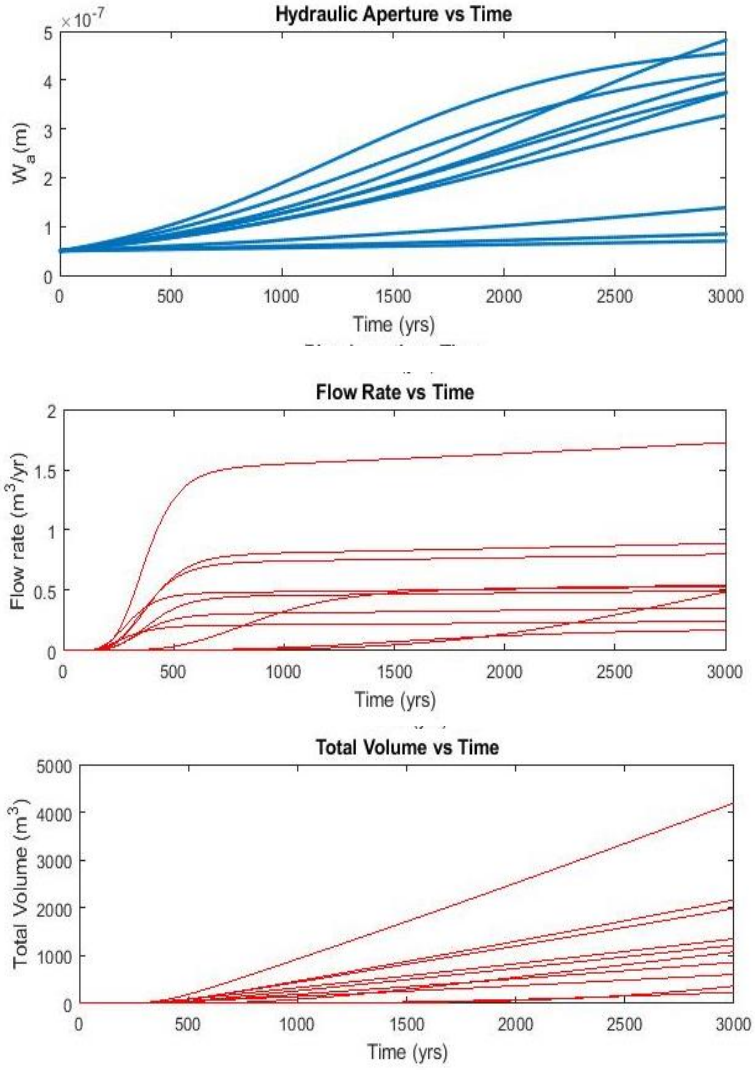
[7] Quantitative estimation of CO2 leakage from geological storageAnalytical models, numerical models, and data needs, Celia et al, 2004

Impact of uncertainty on long term WB performance

- Well barrier element parameters
  - Sampled distributions reflect degree of confidence / uncertainty
- Model parameters are dynamic
  - Time and environment dependent
  - Requires construction of material specific degradation models
- Leak rates and volumes
  - MCS approach
  - Demonstrates sensitivity of output to input parameters

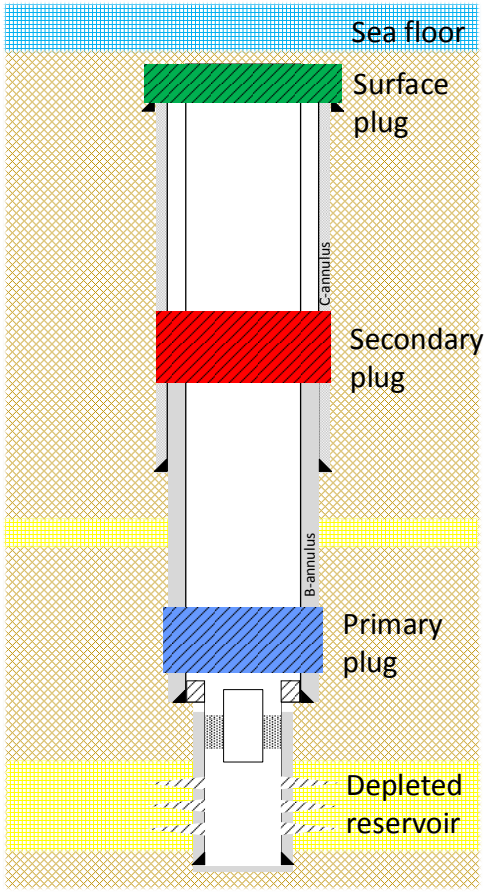
Multiple barriers will improve reliability performance

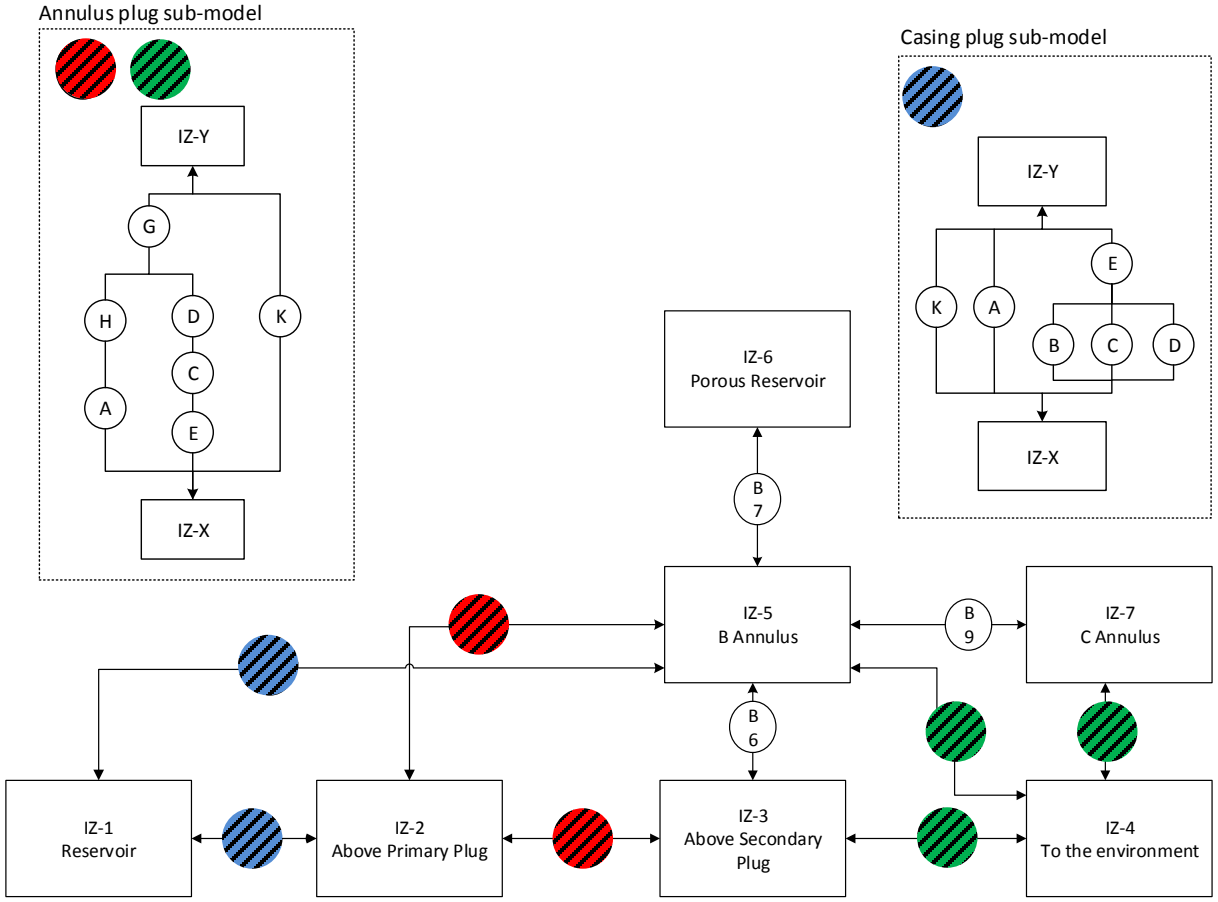
Requires a system model



System model for well P&A: STEM-flow

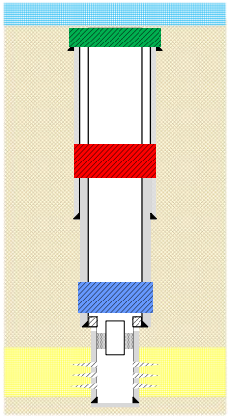
- Multiple plugs, barriers and zones to be isolated
- Requires system model - **S**eal **T**echnology **E**valuation **M**odel (STEM-flow)

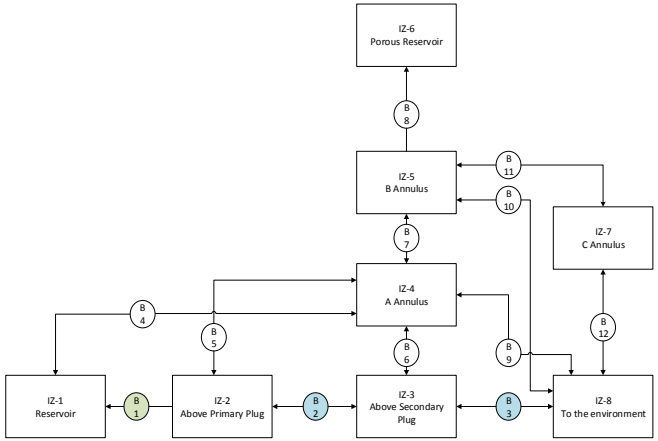




Well P&A integrity system model

Well condition data
Well design
Drilling logs
Cementing logs
Pressure monitoring
Fluid compositions
Well surveys





Well barrier models
Casing plug
Annulus plug
Additional barrier

System model

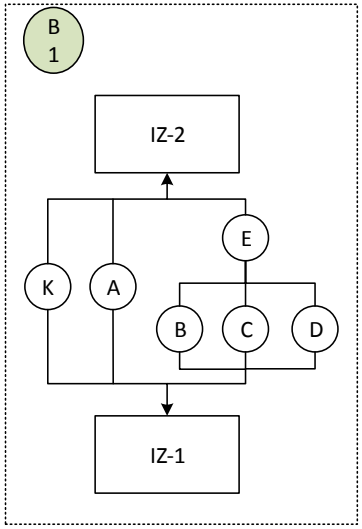
Parameter uncertainties

STEM-flow

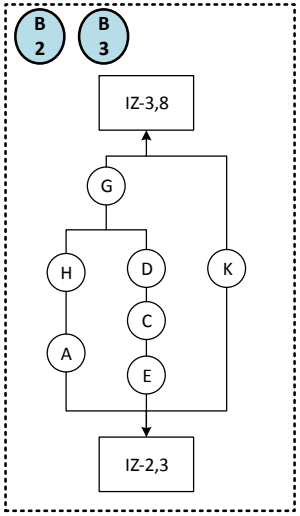
Output

Barrier data
Barrier materials
Deployment method
Casing inspections
Cement bond logs
Barrier position

Casing plug sub-model



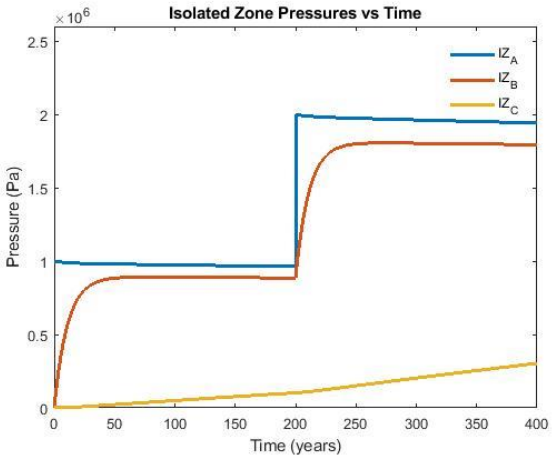
Annulus plug sub-model



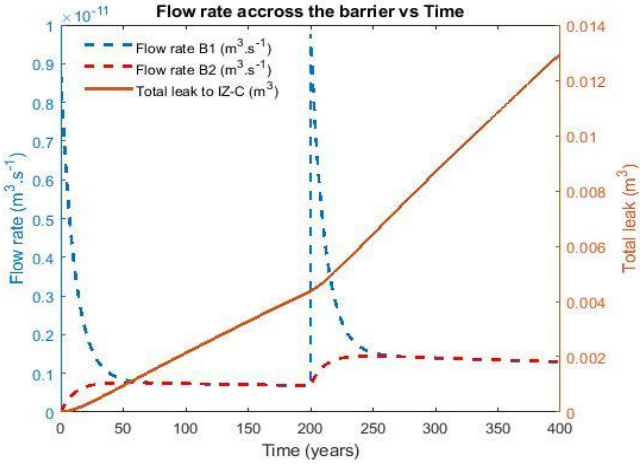
Well P&A integrity modelling output

Output

Pressures

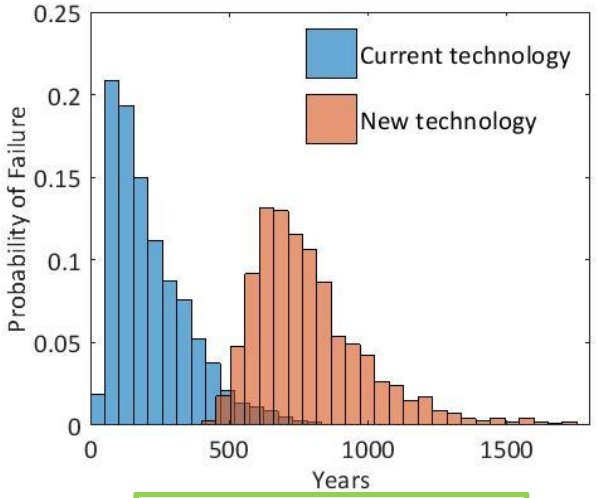


Leak rates & volumes

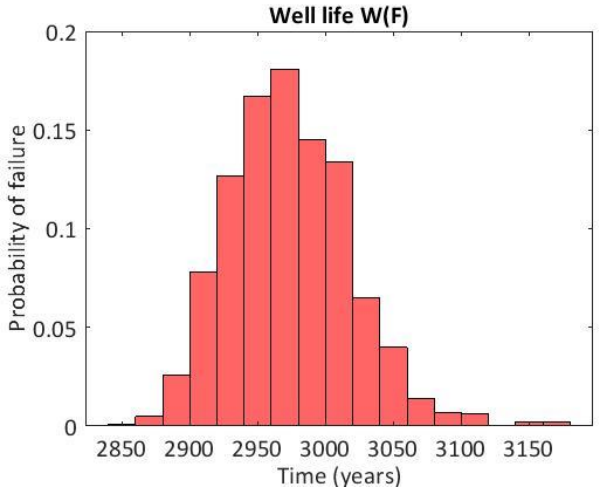


Leak acceptance criteria

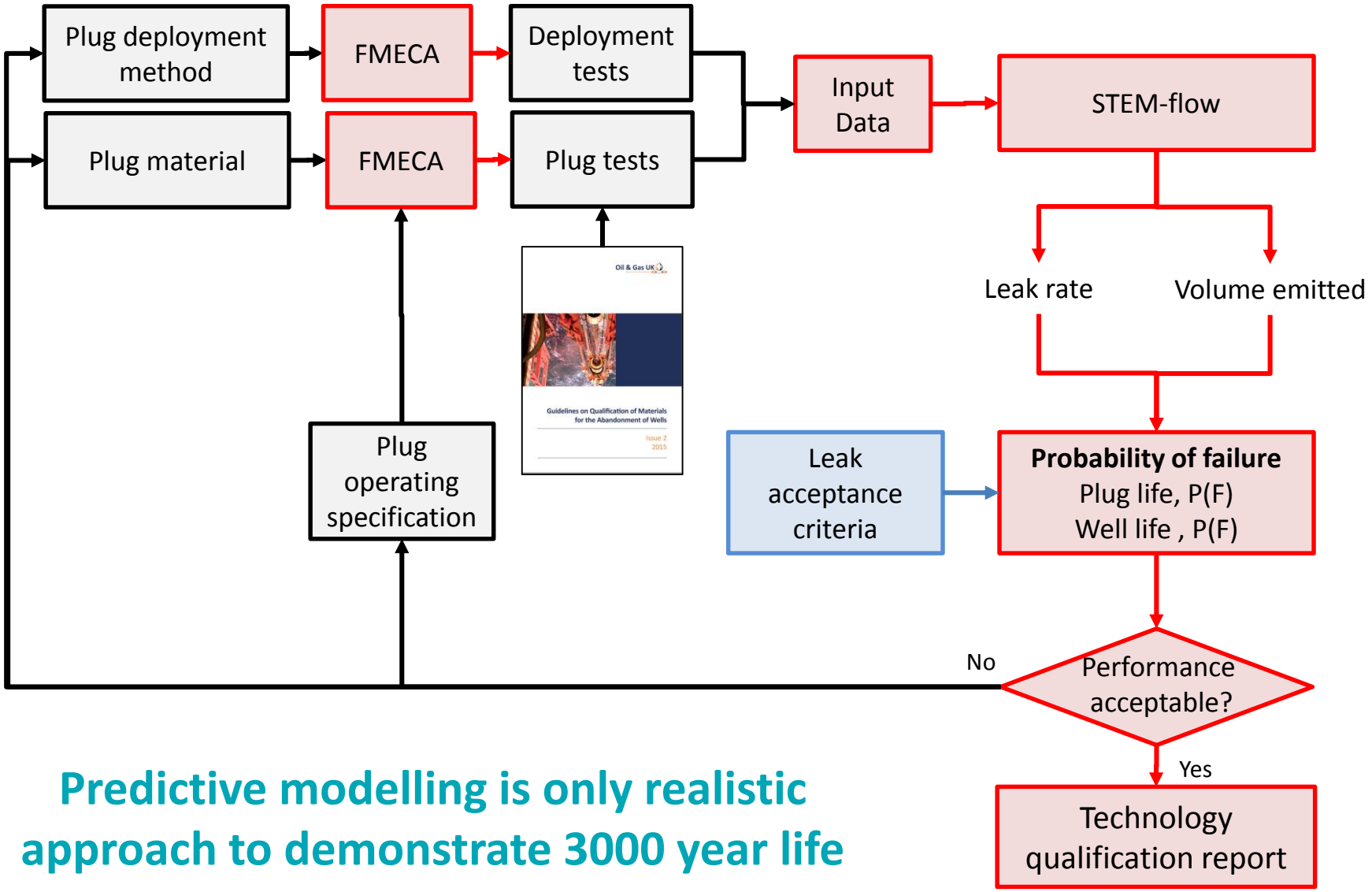
Statistical life of plug



Statistical life of well

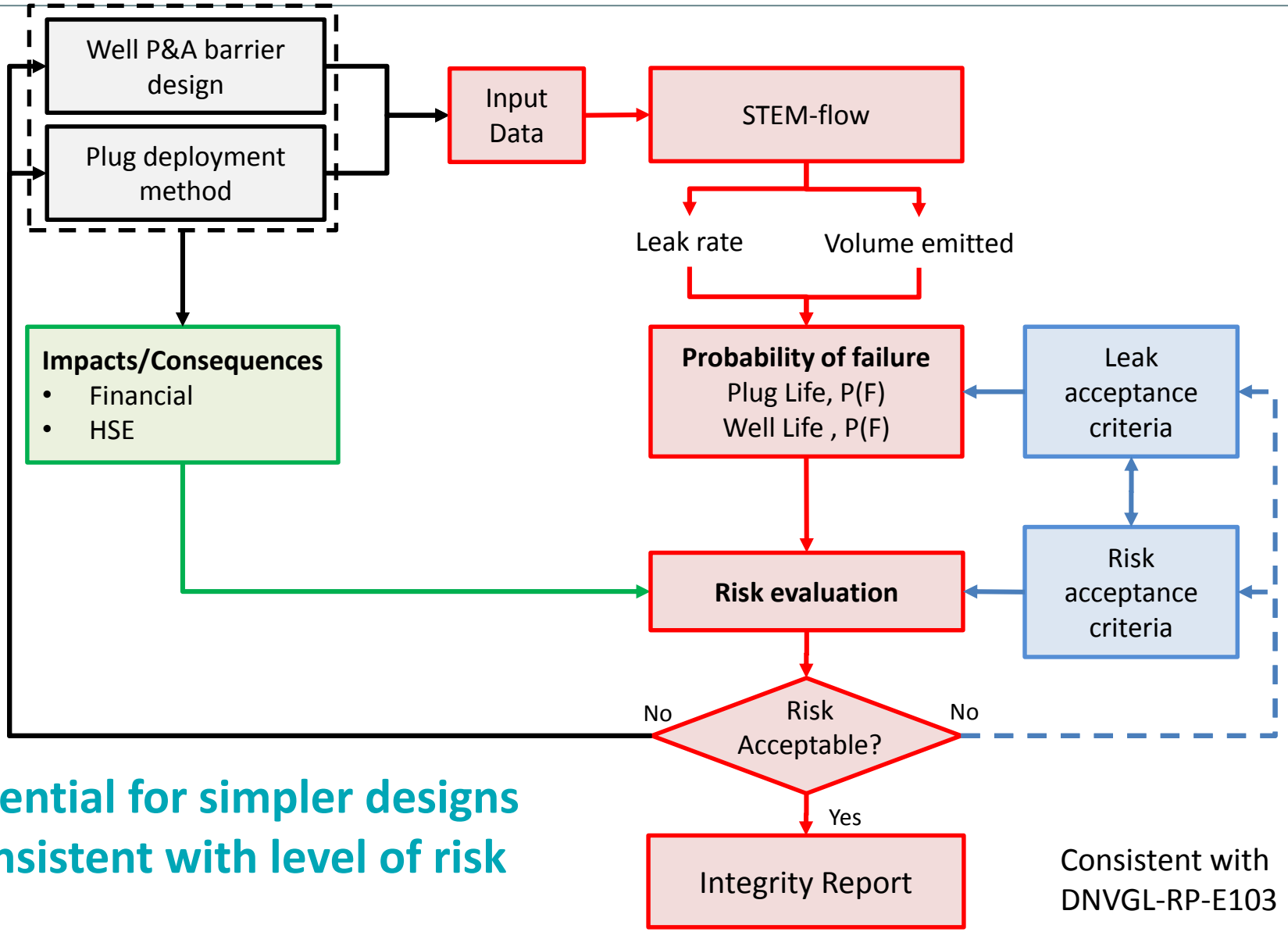


Support for seal technology qualification



Predictive modelling is only realistic approach to demonstrate 3000 year life

Support for risk based well P&A integrity modelling



Potential for simpler designs consistent with level of risk

Consistent with DNVGL-RP-E103

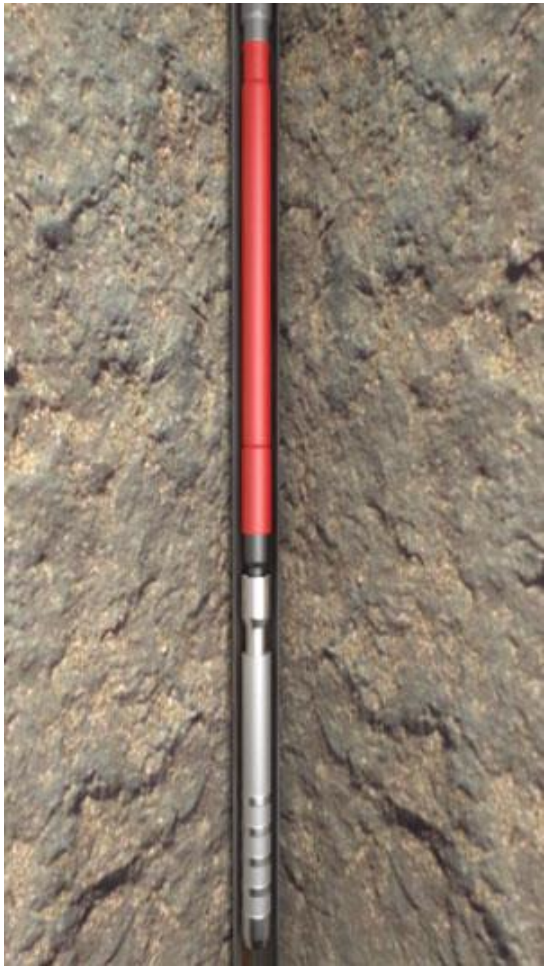
Summary of STEM-flow applications

Application

- Predictive STEM-flow tool
  - Individual & multiple plugs
  - Statistical life and well integrity risks

STEM-flow provides support for

- New P&A technology development
  - Technology qualification / risk assessments
    - New plug / sealing materials and technology
    - Novel deployments
- Operator integrity assurance
  - Assessment of plugging / sealing technology
    - Existing technology
    - New technology
  - Quantitative evidence to support P&A well integrity assurance



Rawwater Bismuth alloy plug installation

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Thank you for listening

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