Introducing OXAND

- **Independent international engineering consultancy firm specialised in industrial life cycle asset management**
- **5 Business Units (Europe, North America) , +120 consultants to support investors, owners and managers to make the right decisions**
- **Advanced skills and expertise in ageing, risk and financial modelling to support decision making**

- ~ 850 projects
- > **€ 1,250bn** OF CAPEX

CAPITALISED IN ***SIMEO™***

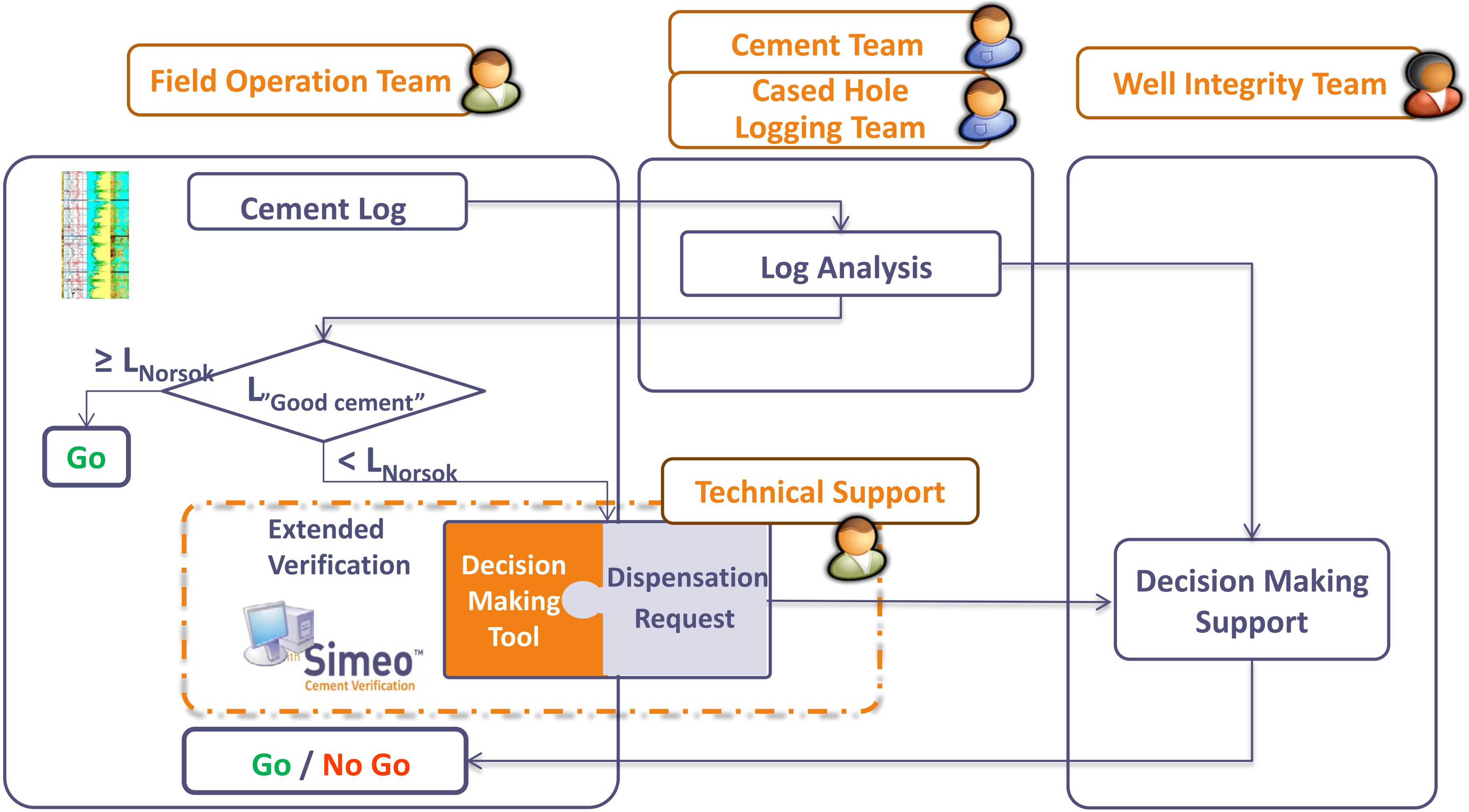
OIL & GAS **NUCLEAR** **LARGE ASSETS** (Hydro, Roads, Railways, Ports, Real estate ...)



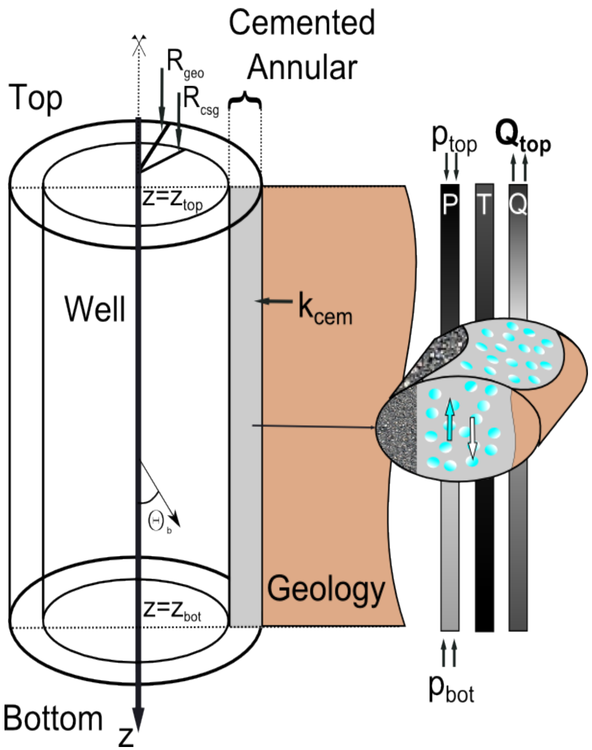



SIMEO WellCem: Help for Decision-Making

OXAND provides STATOIL with a dedicated IT Tool supporting its decision-making process for the assessment of primary cement jobs



Numerical 1D model



Synthetic representation of the well given each input data

Main assumptions:

1-phase model (gas or liquid)

- Darcy's Law
- Compressible newtonian fluid, laminar flow, steady state
- Unidirectional flow along the well

Boundary conditions at the top and bottom:

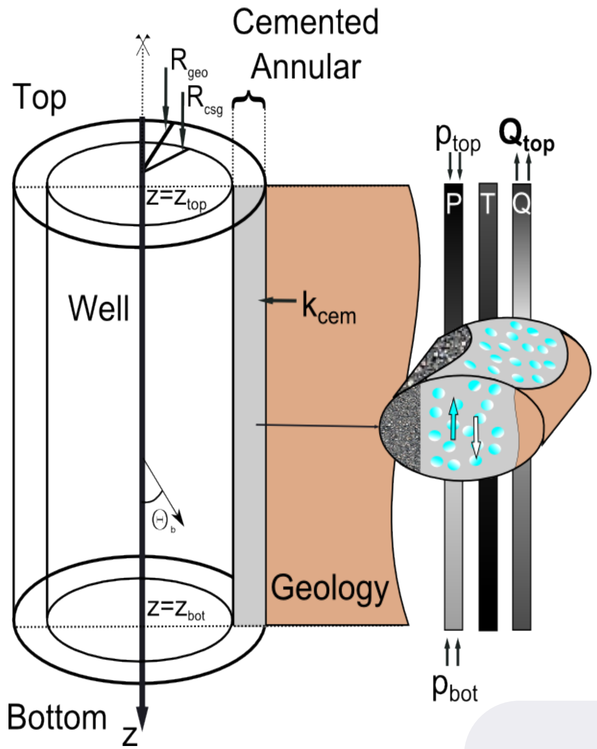
$$\begin{cases} \dfrac{d(\rho_\alpha * v_\alpha)}{dz} = 0 \\ \text{at } (z = z_{top}, x = 0) \quad p_\alpha = p_{top} \\ \text{at } (z = z_{bot}\ x = L) \quad p_\alpha = p_{bot} \end{cases}$$

Equation of the mass flow rate $Q_{m,\alpha}$ for phase α:

$$Q_{m,\alpha} = -A_{tot} * \frac{p_{bot} - \left(p_{top} + \int_0^L \rho_\alpha g \cos(\theta_b) dz_{MD}\right)}{\int_0^L \frac{\mu_\alpha}{\rho_\alpha * k_\alpha} dz_{MD}}$$

Numerical 1D model

2-phase model



Main assumptions:

Same as 1-phase model plus:
- No interaction between fluids
- Continuity of the "wetting" fluid phase
- Intrinsic permeability of the cement is independent of the fluid

Boundary conditions at the top and bottom:

$$\begin{cases} A * s_{nw} * \rho_{nw} * v_{nw} = Q_{m,nw} = cte \\ v_{nw} = \frac{k\rho_{nw}g}{\mu_{nw}}\left(\cos(\theta) - \frac{1}{\rho_{nw}g}\frac{dp_{nw}}{dz_{MD}}\right) \end{cases}$$

Wetting phase equations (a)

$$\begin{cases} A * s_{w} * \rho_{w} * v_{w} = Q_{m,w} = cte \\ v_{w} = \frac{k\rho_{w}g}{\mu_{w}}\left(\cos(\theta) - \frac{1}{\rho_{w}g}\frac{dp_{w}}{dz_{MD}}\right) \end{cases}$$

Non Wetting phase equations (b)

$$p_{nw} = p_w + p_c$$

Equilibrium equation (c)

Equation of the mass flow rate $Q_{m,nw}$ for the non-wetting phase (gas) :

$$Q_{m,nw} = s_{nw} * k * \frac{A_{tot}\rho_{nw}}{\mu_{nw}} * \left((\rho_w - \rho_{nw}) * g * \cos(\theta_b) + \frac{p_{res} - p_{top} - \int_0^{L_{tot}} \rho_w g \cos(\theta_b)dx - p_{c,bot}}{\frac{\rho_w * k}{\mu_w}\int_0^{L_{tot}} \frac{\mu_w}{\rho_w * k}dx} + \frac{dp_c}{dz_{MD}} \right)$$

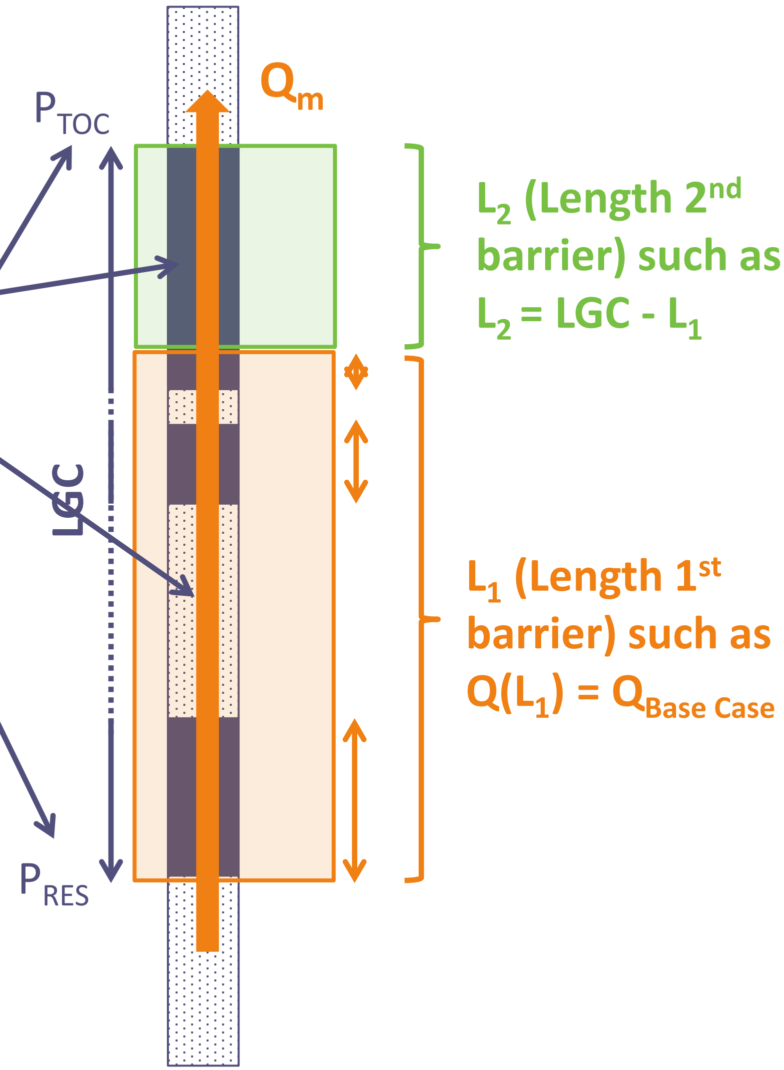
Numerical 1D model

→ Gaz mass flow rate calculation

- Input parameters

Name	Label
Well parameters	
Length of cement	L
Intrinsic Cement Permeability	k_{cem}
Intrinsic Defect Permeability	k_{cem}*
Pressure at top of cemented annular	P_{bot}
Pressure at bottom of cemented annular	P_{top}
Depth at top of cemented annular	z_{top}
Depth at bottom of cemented annular	z_{bot}
Inclination borehole	θ_b
Temperature	T(z)
Properties fluids	
Viscosity	μ(T,p)
Density	ρ(T,p)

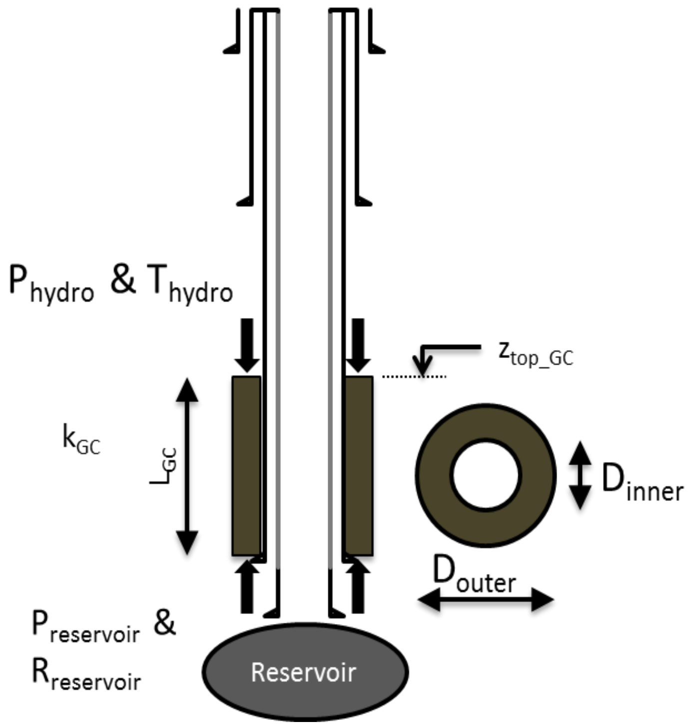
Cemented annulus



Base Case Mass Flow Rate

→ Base Case: well following Norsok's requirements under severe conditions (HPHT)

Characteristics and units	HPHT Case study
Inner diameter (m)	0.250
Outer diameter (m)	0.332
Cement length (mMD)	30
Well Deviation (°)	55
TOC position (mTVD)	4370
Temperature at TOC (°C)	170
Reservoir Pressure (at top of the reservoir) (bar)	900
Reservoir Temperature (at top of the reservoir) (°C)	171
Fluid type	Methane
Cement permeability (µD)	0.1

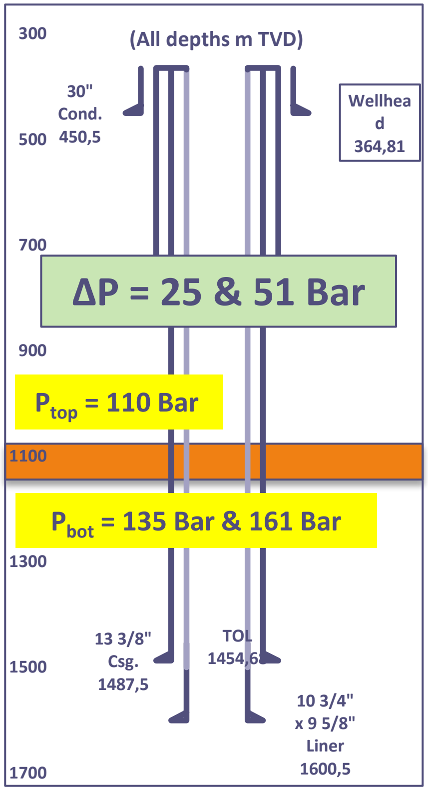


Synthetic representation of the well with the required parameters by constitutive component

➡ Upper Acceptable Gas Mass Flow Rate (Threshold)

Simulation of different scenario

Different scenario can be simulated:

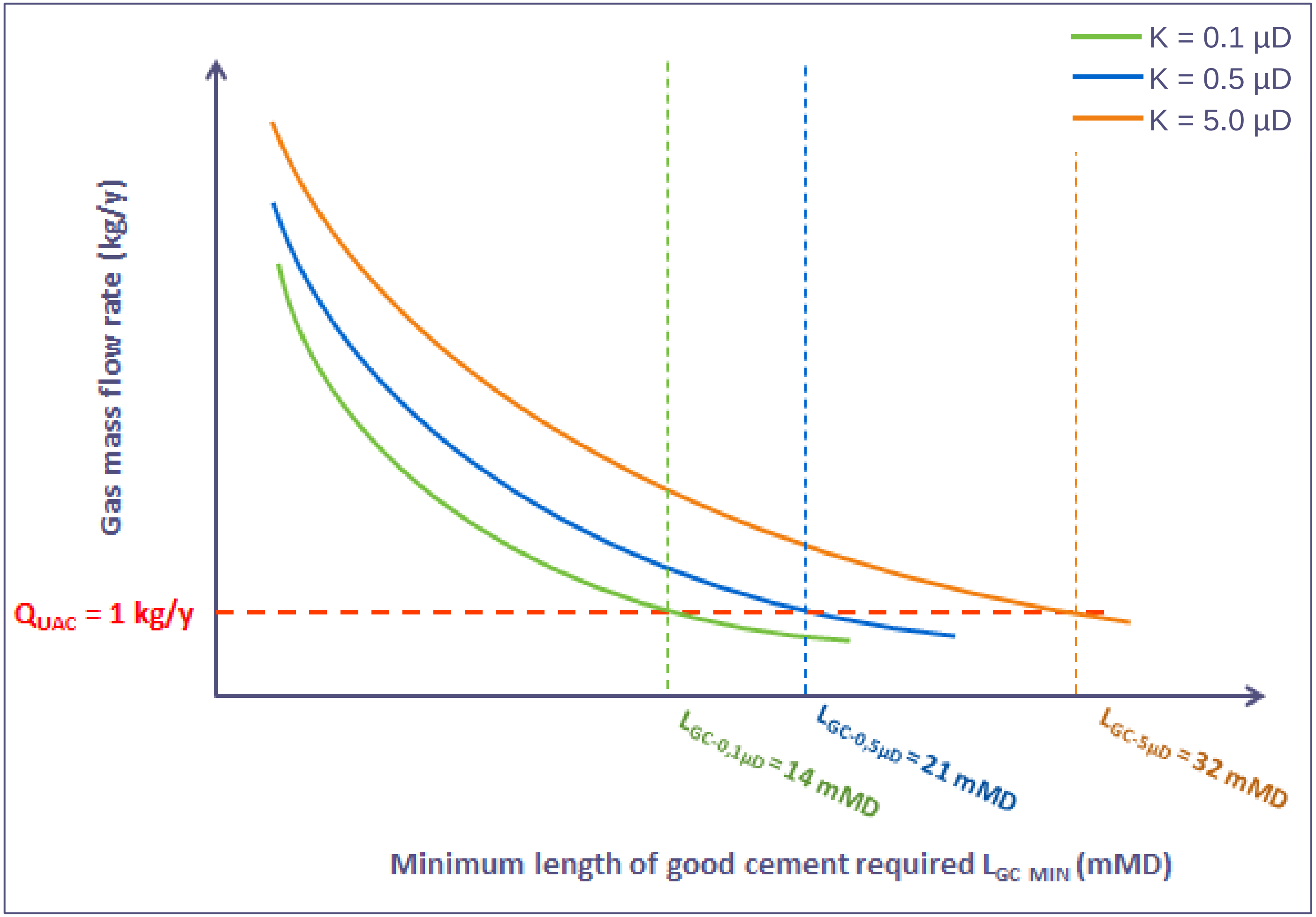


Scenario with current and long terms reservoir pressures

ITEM	VALUE / RANGE	UNIT
Z_{top}	-1100	mTVD
L_{good_cement}	8 - 16 - 30	mMD
z_{bottom}	Function to L_{good_cement}	mTVD
Inclination	60	°
T_{top}	44	°C
T_{bottom}	63	°C
P_{top}	110	Bar
P_{bottom}	135 – 161	Bar
Cement permeability	[0.1 - 10] GC	µD
$\varnothing_{OuterDiameter}$	$17\ ^{1/2}{}'' \Rightarrow 0.44$	m
$\varnothing_{InnerDiameter}$	$13\ ^{3/8}{}'' \Rightarrow 0.35$	m
Phase 1 : Gas	Methane	Nature
Phase 2: Liquid	Water	Nature

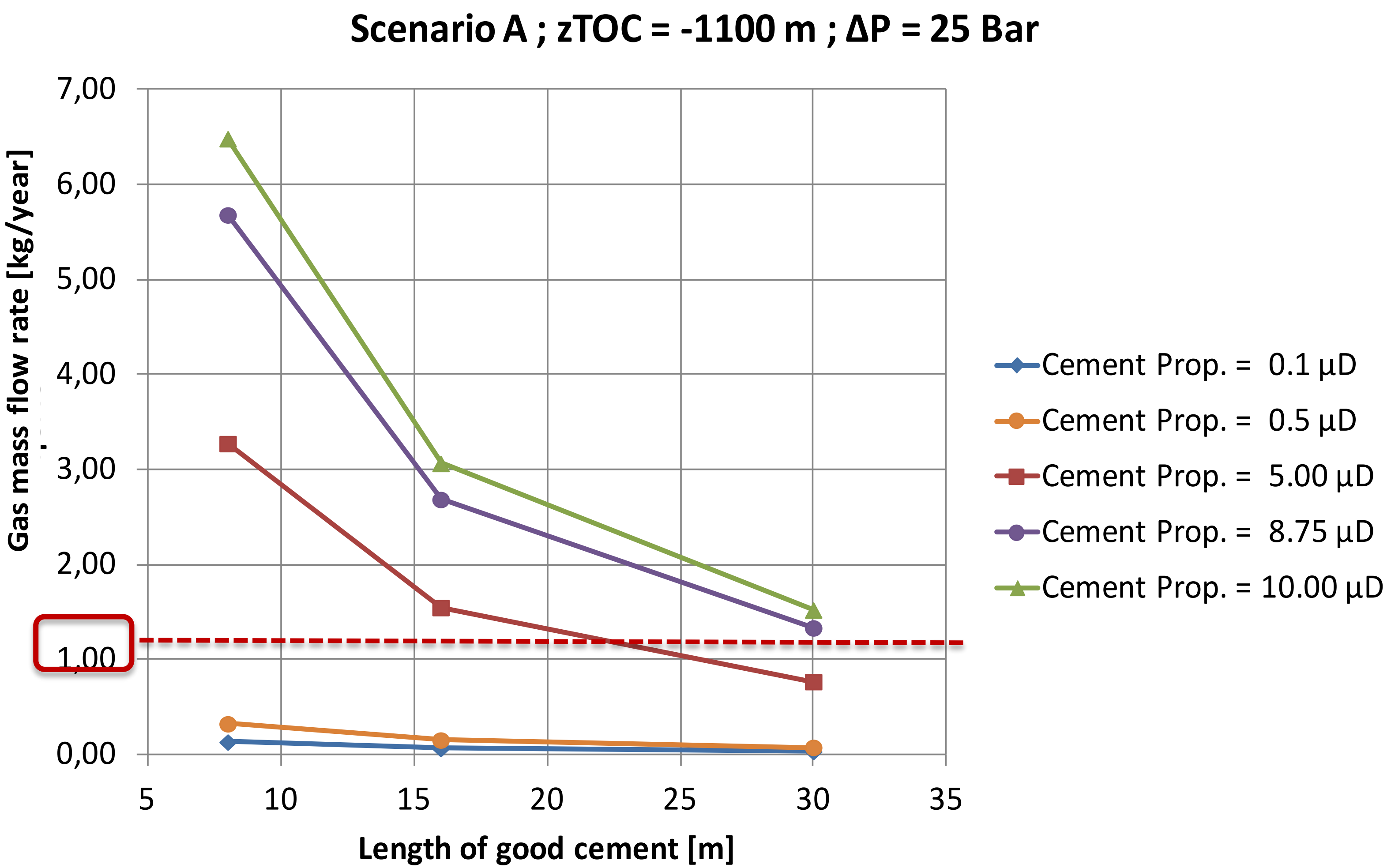
Results from simulations

Assessment of a required length of good cement to ensure a given mass flow rate:



Results from simulations

Example of a low pressure well:



Simeo™ WELLCEM Workflow

Mass flow simulation

- Well geometry
- Boundary conditions (pressure, temperature)
- Reference flow rate
- Cement properties

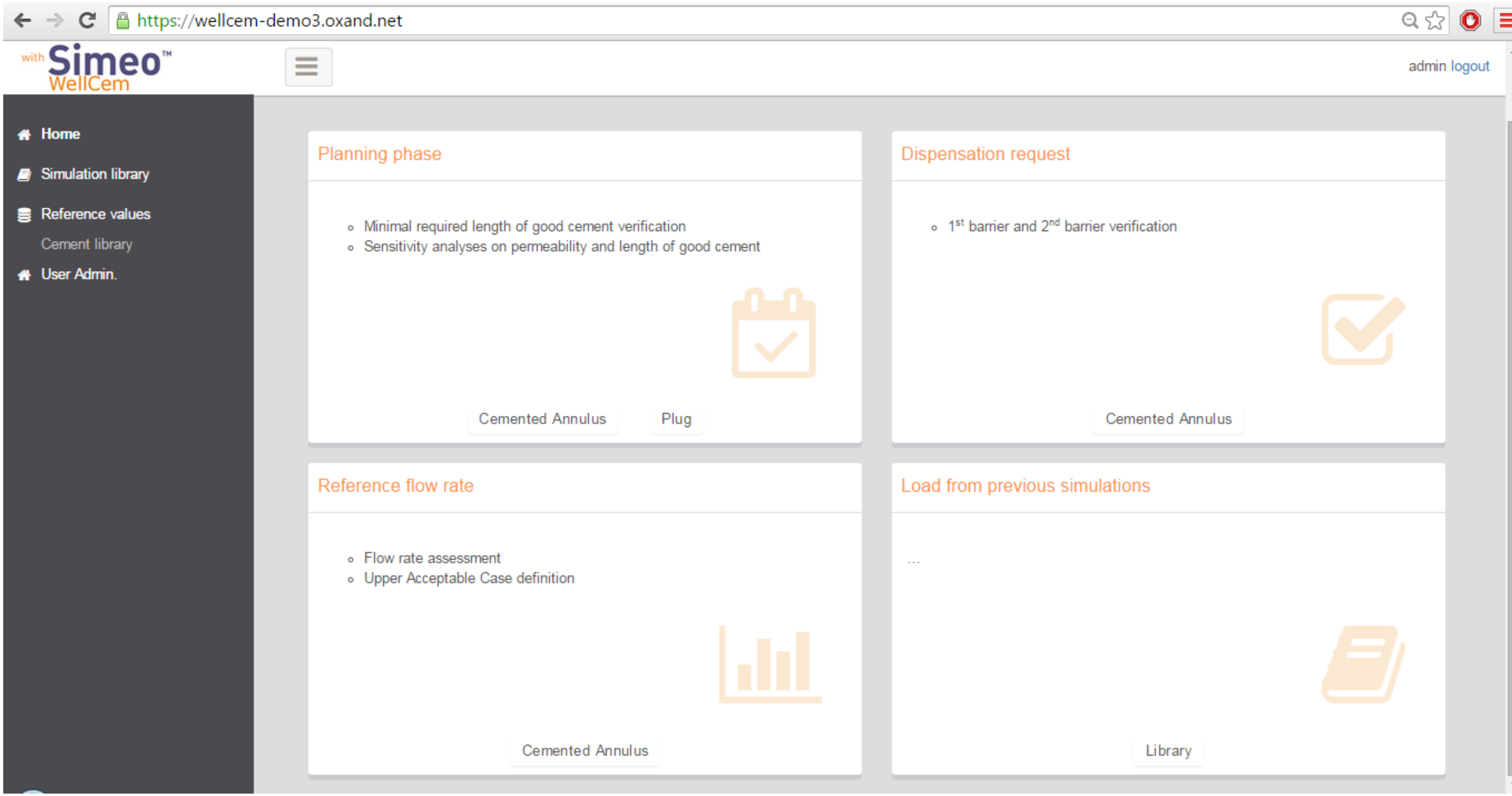
FLOW RATE CALCULATION

1. Support for dispensation request
   - 1st barrier and 2nd barrier identification and caracterization (length, flow rate)

2. Support during cement investigations planning phase
   - Minimal required length of good cement
   - Sensitivity analyses on well characteristics

Oxand
Asset, Ageing & Risk Management

Screenshots



► **Full-web tool**

Screenshots

- **Automatic generation of reports**

Statoil — with Simeo™ WellCem

Cement integrity on annulus report for dispensation request

Country	country2	**Date**	October 28th 2015
Field	field21	**Author**	admin
Well	well211	**Mail**	admin@admin.admin
Simulation			

well211_DRannulus_UAC1kg/y_102815_1105

well211 geometry and flow characteristics

Data	value
Cazing size (inch)	7 3/8
OH diameter (inch)	9.8
$P_{top\ reservoir}$ (bar)	900
$T_{top\ reservoir}$ (°C)	150
P_{TOC} (bar)	430
T_{TOC} (°C)	135
Permeability of cement k (µD)	0.5
Number of annulus intervals	3

Results from the simulation

The 1st barrier satisfies the cement integrity in comparison with the Upper Acceptable Case's conditions.
The 2nd barrier assessment assumes a deficient 1st barrier; the flow rate is calculated considering the reservoir pressure applied at the bottom of the 2nd barrier.

	1st barrier	2nd barrier
L_{GC} (mMD)	30	0
Q (kg/y)	3.93	0

Extended Evaluation of Primary Cement Jobs: a value-added approach

Objectivity

- Systematic approach
- Quantitative and objective indicators for decision-making support

Time and cost saving

- Time for decision-making reduction
- Elements to justify the relevance of any additional action

with Simeo™ WellCem

Knowledge improvement

- Well portfolio regarding the cement integrity
- One common platform for the operational teams
- Increased confidence in the cement integrity assessment

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Takk.

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