FLOWPRO Dynamics

New methods for modeling and upscaling inflow performance of advanced well completions

Presented at the Annual ICT meeting in Houston 27/9/2024 by K. Brekke, PhD and K. Langaas, PhD

Outline

- ICT modeling history (from personal archive)
- The Insight ICT analysis and upscaling method
- Method validation (comparison with Ansys Fluent)
- Example reservoir modelling using the Insight work process (SPE-222361-MS at ADIPEC)

ICT Modeling History

1991
First ICD hand calculations on Troll West

1992
First ICD patent and prototype developed for Troll West

First steady state ICD network simulations

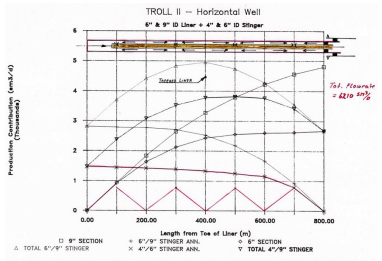
1993
First coupled reservoir and detailed wellbore simulations

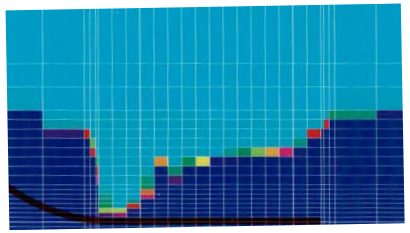
1994-1996
Theory for neTOOL type wellbore modeling being developed

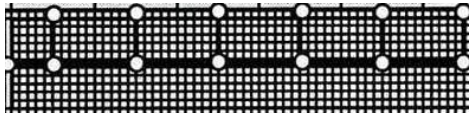
2019-2024
Autonomous valve technology emerging

Implementation of wellbore network models in reservoir simulators.

Flowpro Insight, a CFD based ICT completion analysis and upscaling software

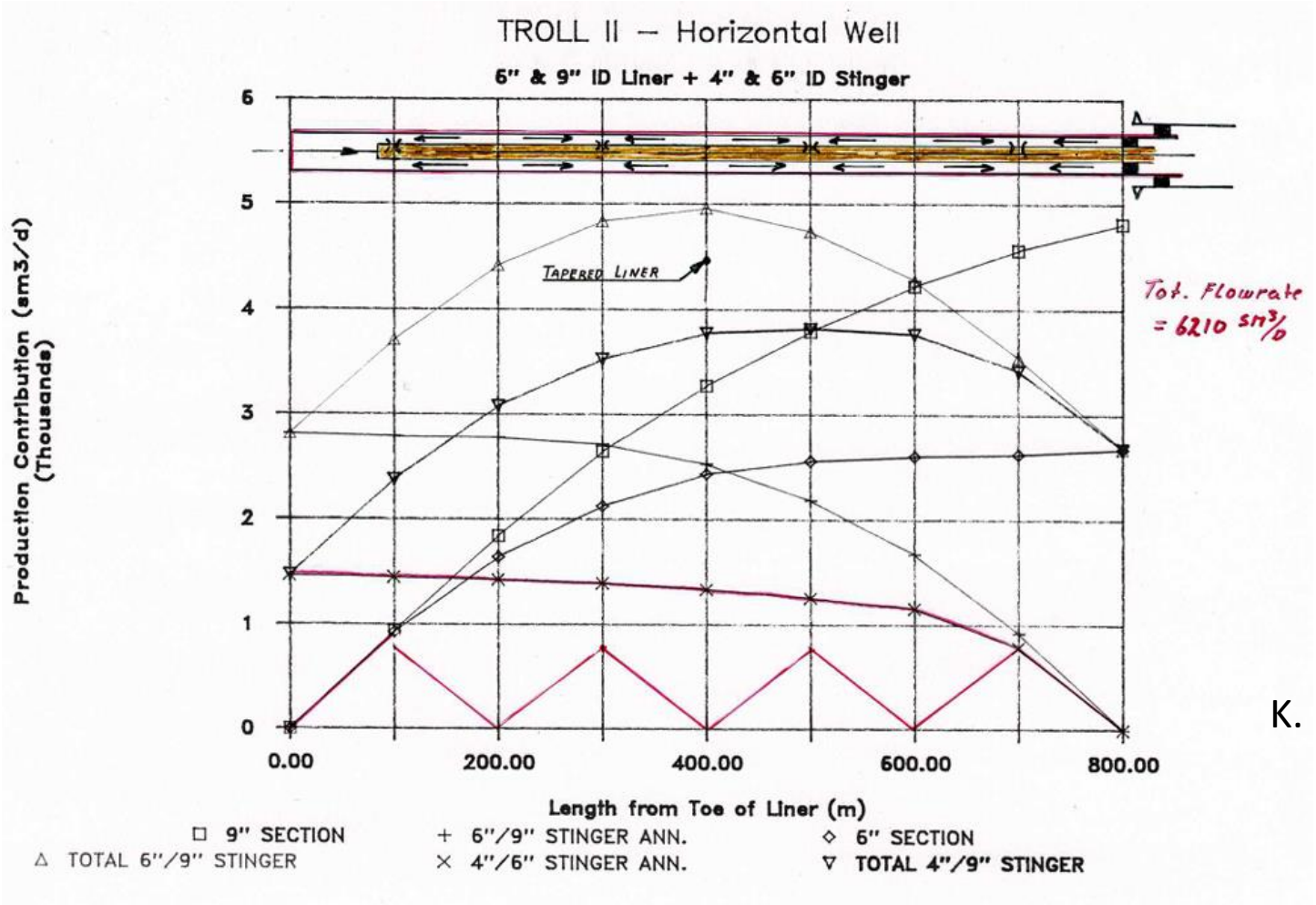






ICT Simulation Memorabilia (Norsk Hydro 1991)

Drawings of hand calculated production performance in base pipe and annulus of Troll West well with ICT



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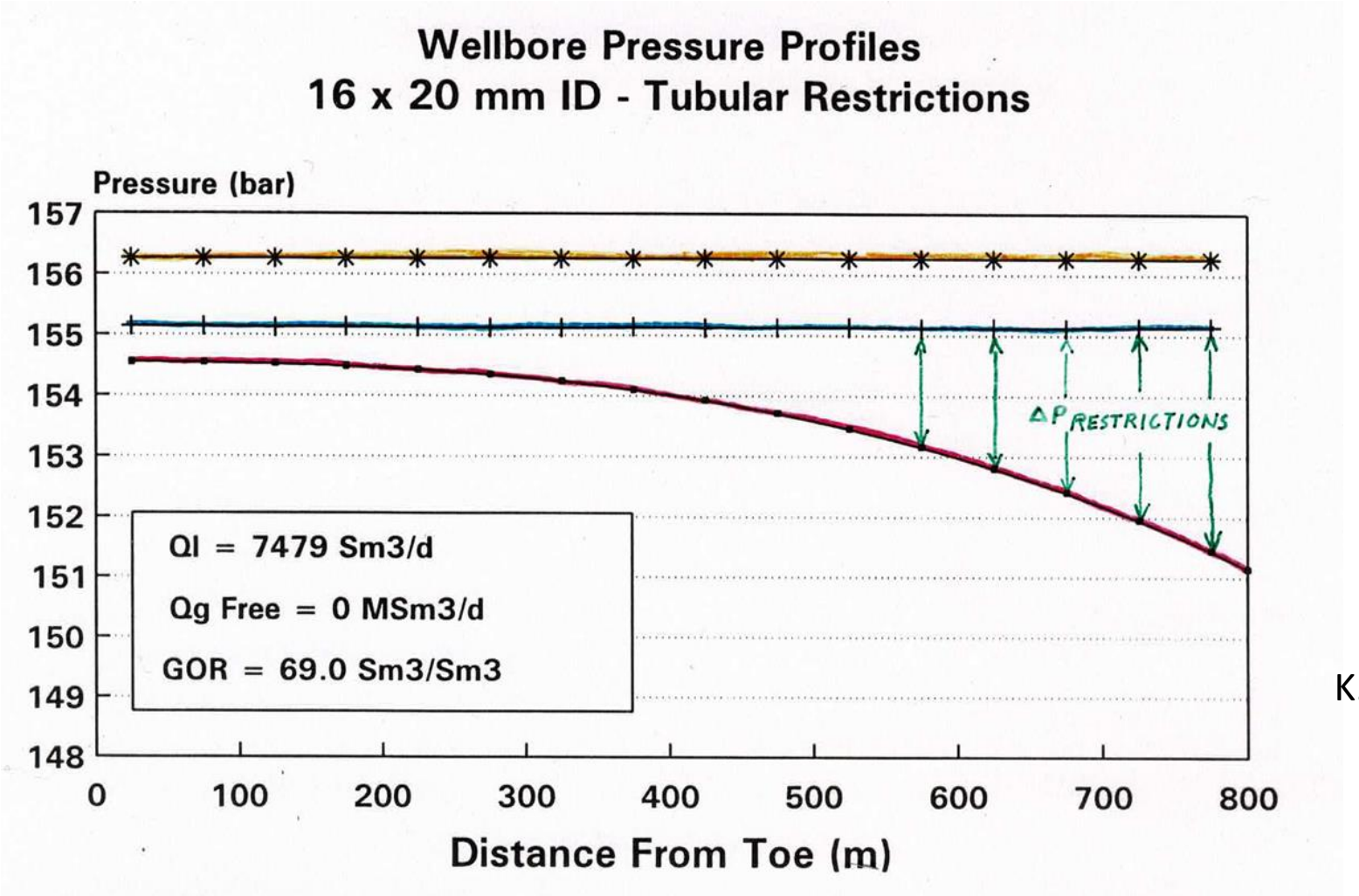
ICT Simulation Memorabilia (Norsk Hydro 1992)

HOSIM – First internal Norsk Hydro network model developed for HW ICT simulation
(Recycled gas flowline network simulator)



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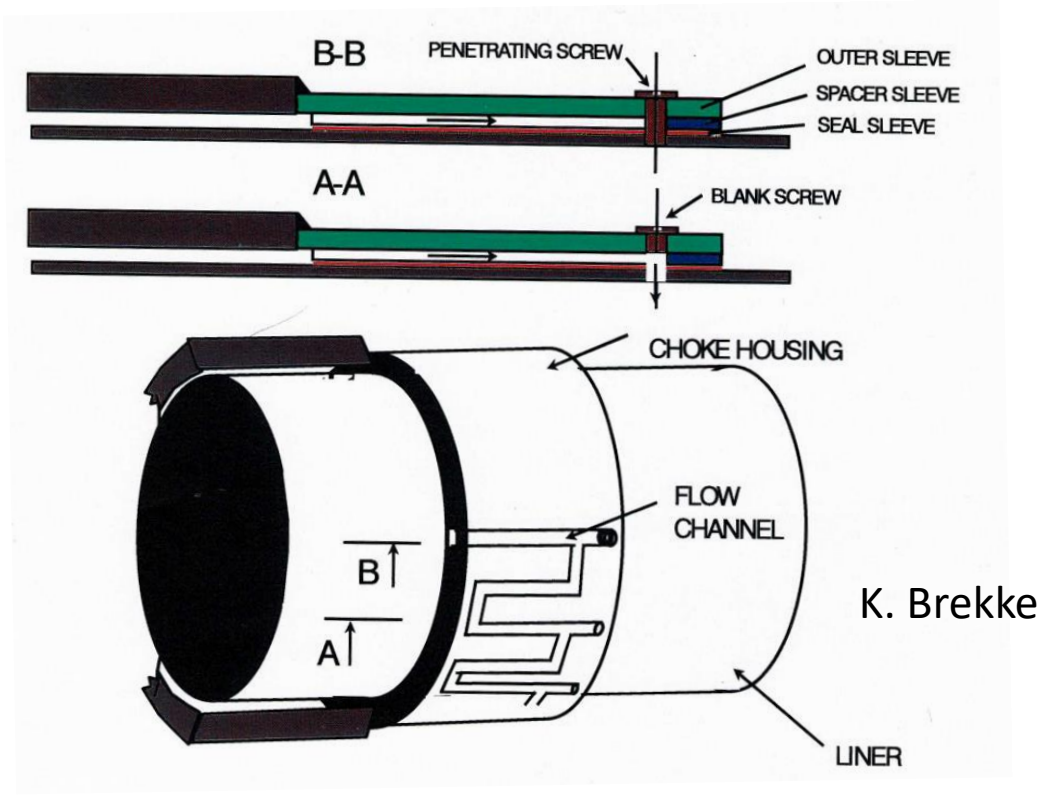
ICT Memorabilia (Norsk Hydro 1992)

First ICD white paper

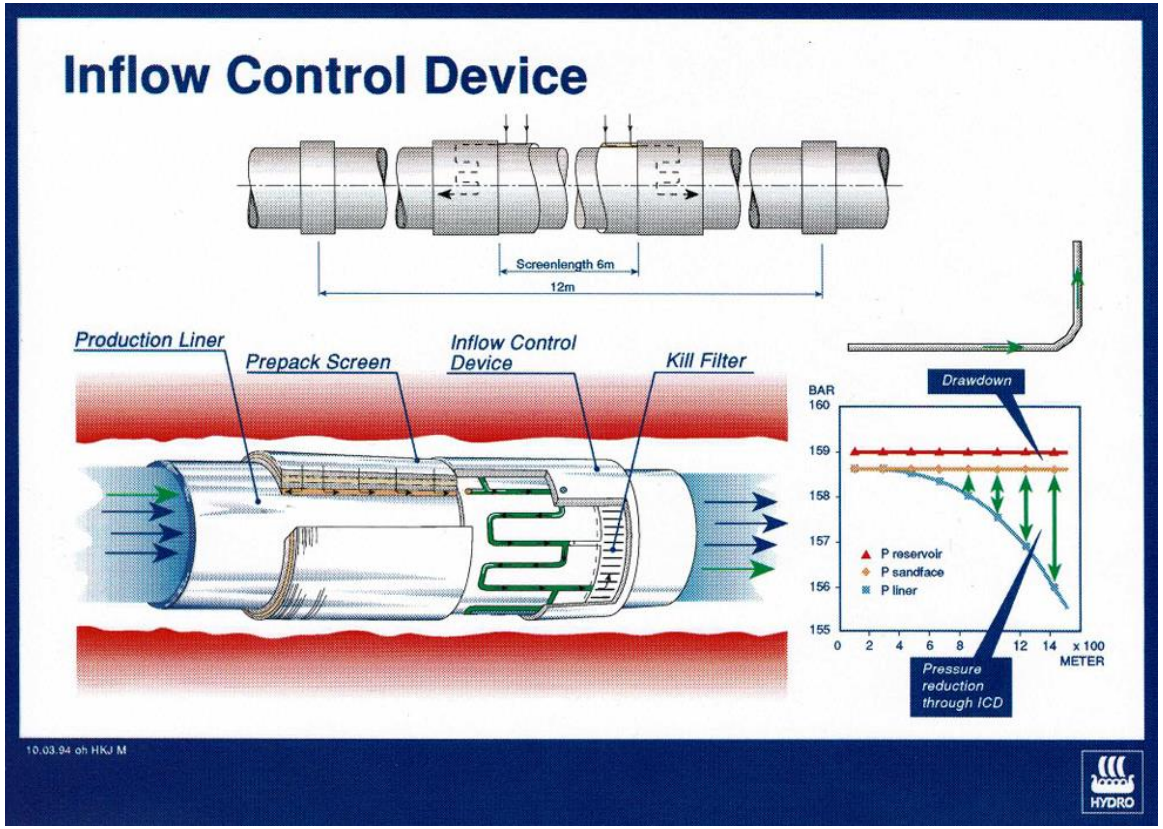
New, Simple Completion Methods for Horizontal Wells Improve Production Performance in High-Permeability Thin Oil Zones
Kristian Brekke and S.C. Lien, SPE 24762, 1992 ATCE

First ICD drawing (for prototype and patent)



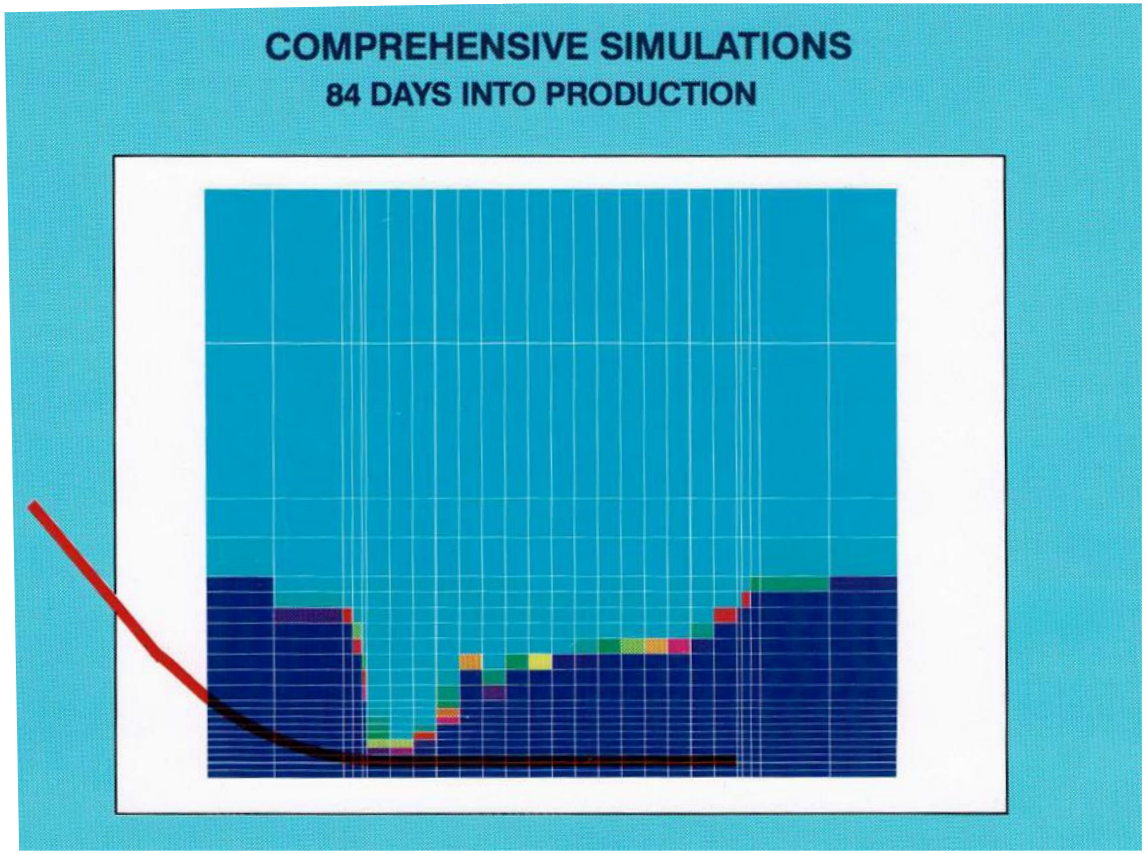
K. Brekke

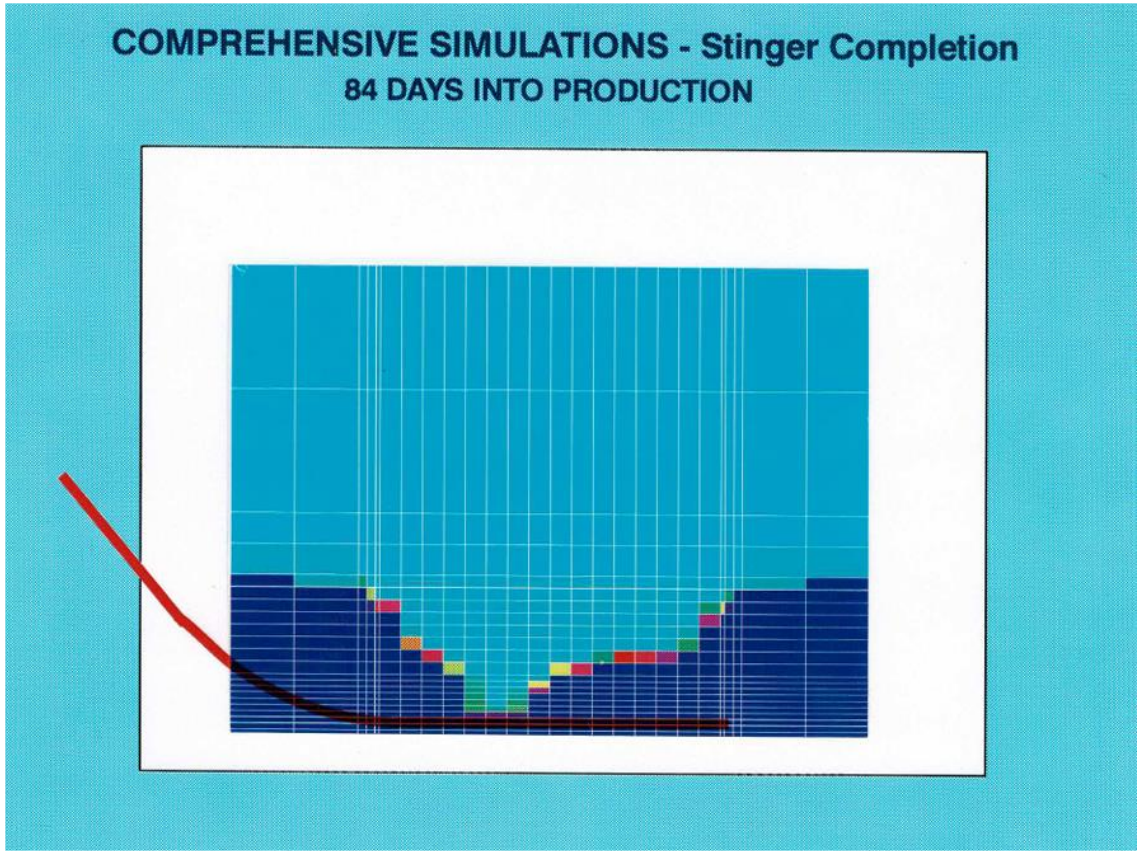
First ICD poster



ICT Simulation Memorabilia (Norsk Hydro 1993)

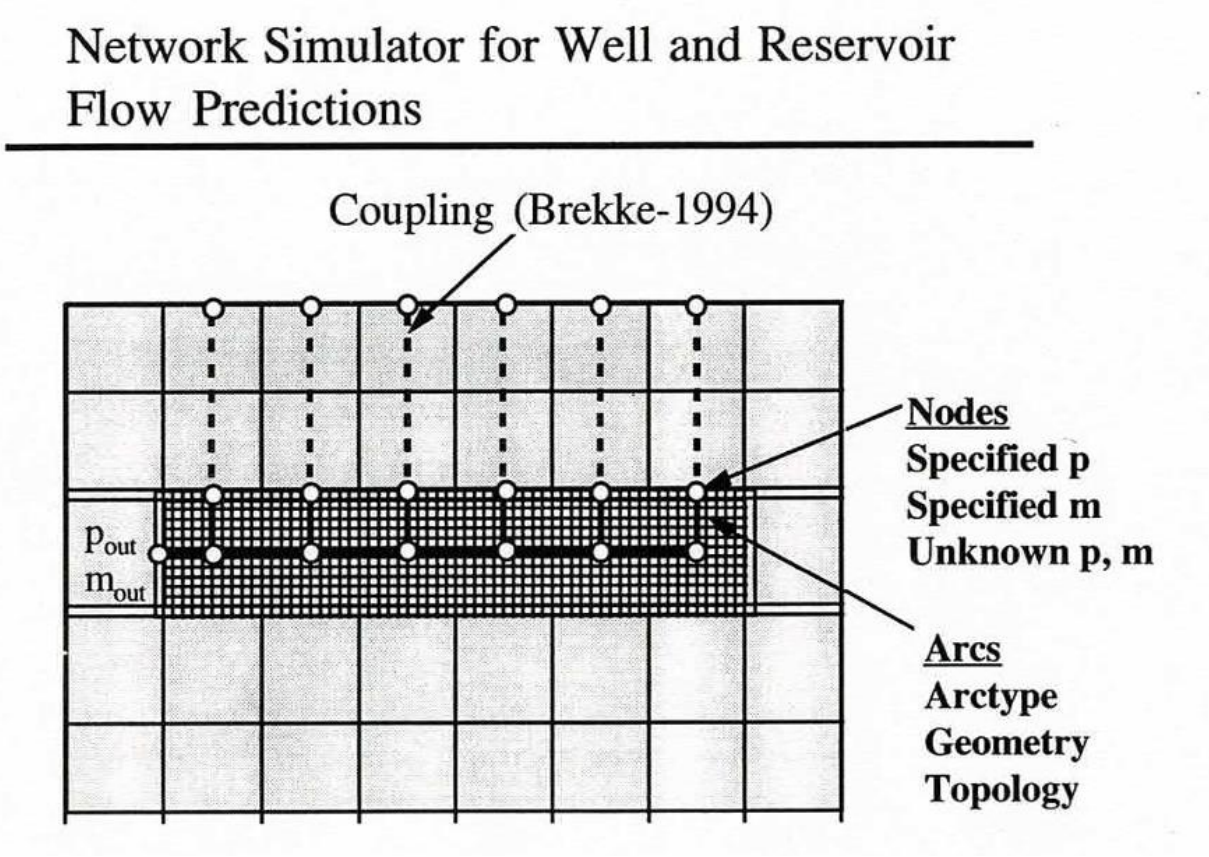
Coupled HW wellbore and reservoir simulation (HOSIM/Frontsim)
SPE 26518 “A New Modular Approach to Comprehensive Simulation of Horizontal Wells.”: K Brekke

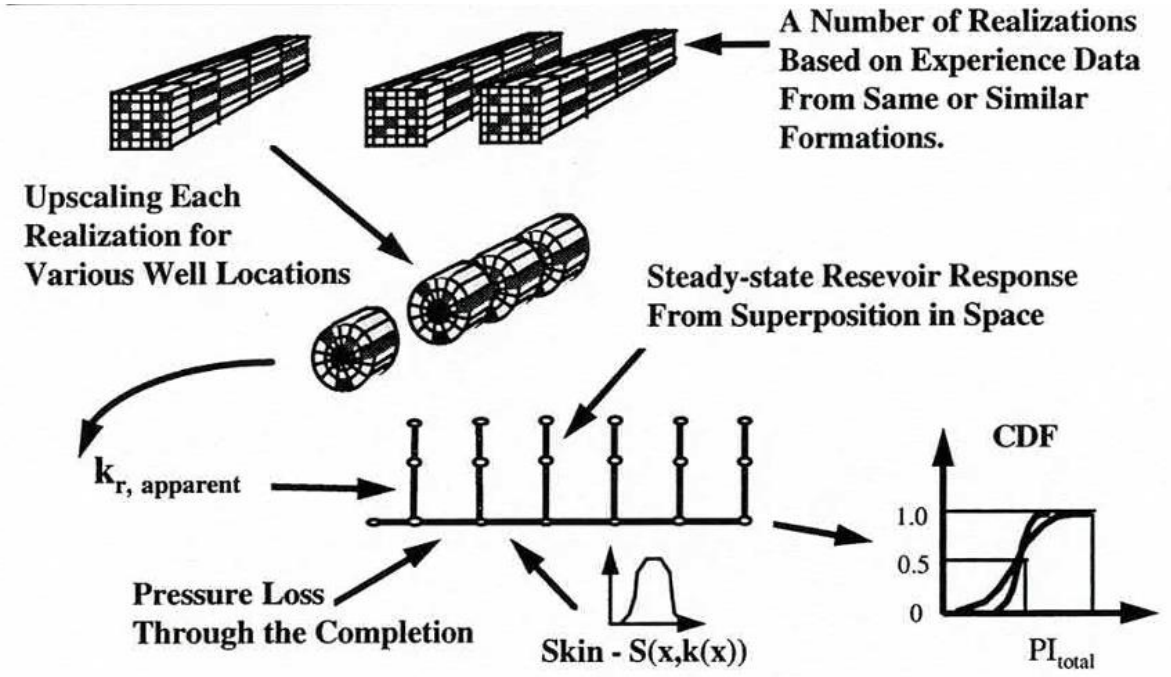




ICT Simulation Memorabilia (The University of Tulsa 1994-1996)

SPE36578 ”Horizontal Well Productivity and Risk Assessment”: K. Brekke – theory behind neTOOL





FLOWPRO Dynamics

Motivation for Flowpro Insight

- To simulate <u>all types</u> of inflow control technology correctly by including.
  - **Annulus phase segregation**.
  - **Valve interaction.**

- To efficiently include physically correct ICT performance in dynamic reservoir simulations.

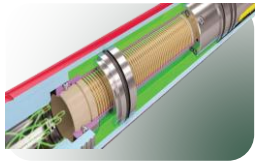
Inflow Control Devices

ICD

AICV

AICD

ICV

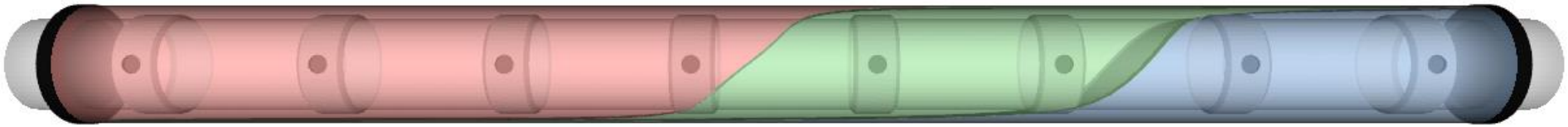


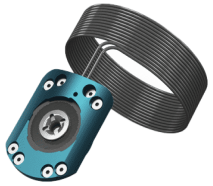
DAR / D-AICD

FLOWPRO Dynamics

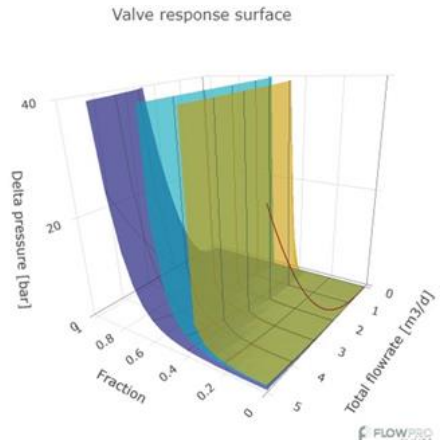
Insight Main Features

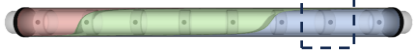
- Developed over 5 years in close collaboration with major operators.
  - Lundin, AkerBP, Vår Energi (Neptune), OMV
- Insight captures the physics of annulus phase segregation and valve interaction.
- Custom CFD – 3 million times faster than Ansys Fluent for a typical zone.
- Integrates upscaled zone inflow performance in reservoir simulators through the RCP equation or VFP tables.
- Automatic design of multi zone inflow control completions.
  - Type of ICT
  - Number and size of valves
  - Distribution of valves
- User friendly software with library of instructional videos



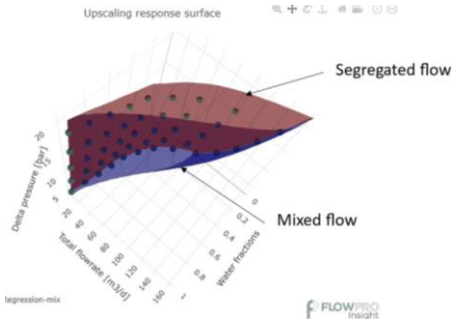


Valve

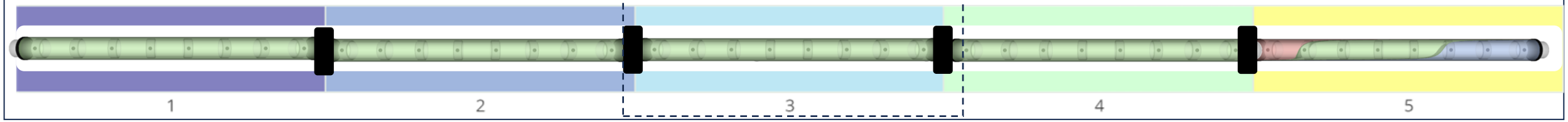




Zone



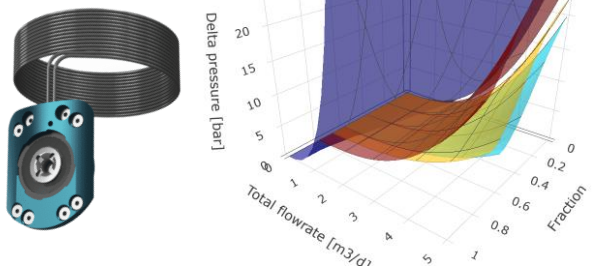
Well



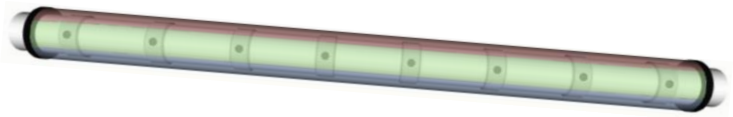
From Lab Data to Production Profiles

FLOWPRO Dynamics

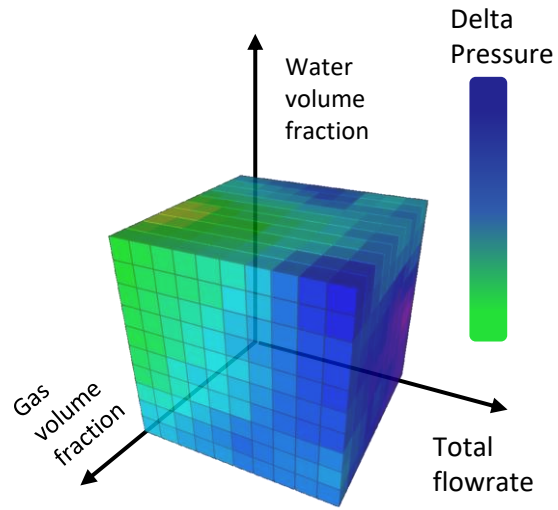
Single valve performance from lab data



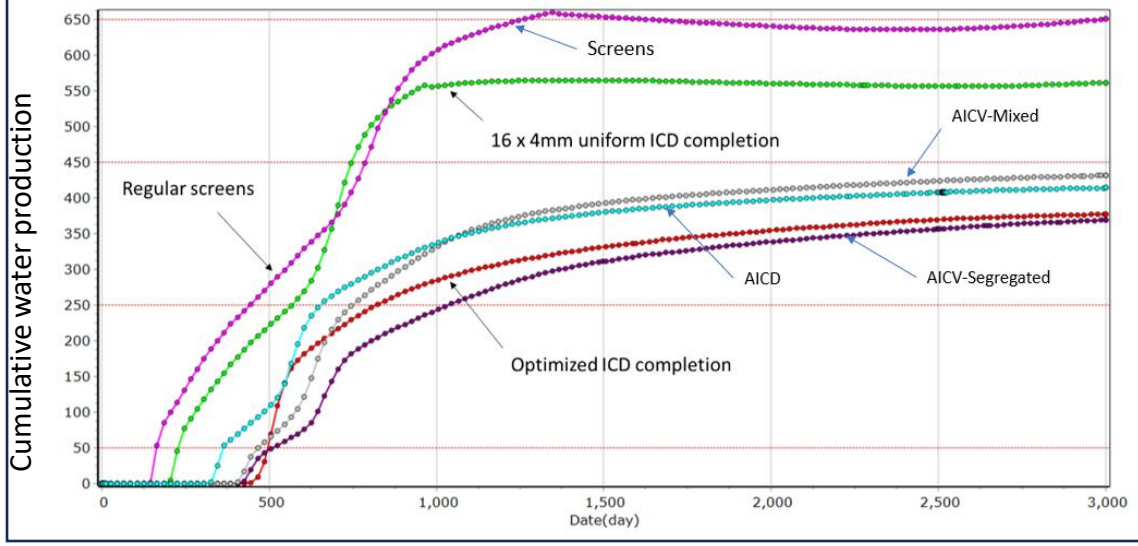
Detailed dynamic zone simulations



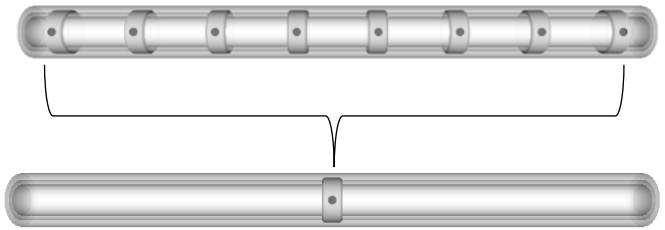
Zone inflow control sensitivity



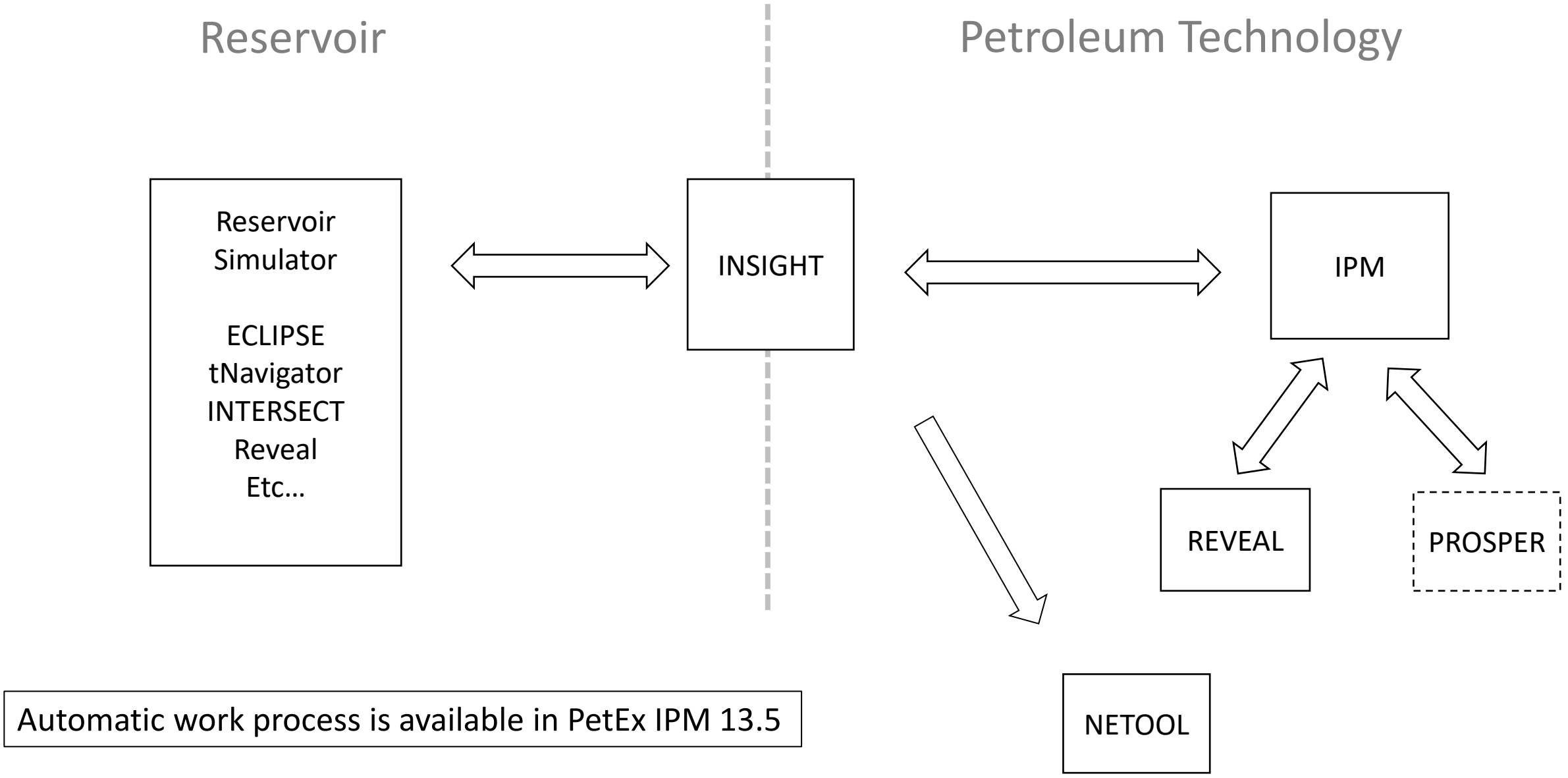
Reservoir Simulations



Upscaling through the RCP equation or VFP tables



Insight Software Environment



Automatic work process is available in PetEx IPM 13.5

Insight - Single Zone Detailed Simulation - AICV

50% oil
50% water

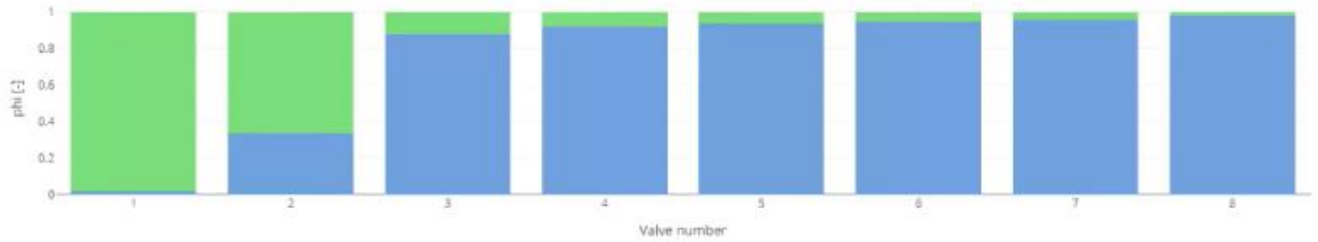
∠ 2 degrees
100m

zone status

CHOKING

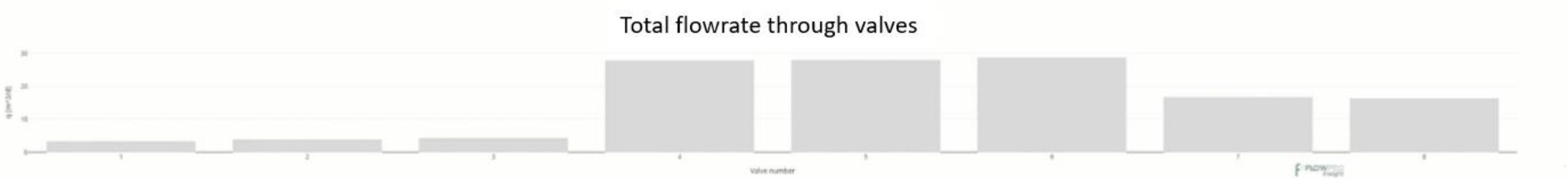
FLOWPRO Dynamics

phase fraction



valve flowrate

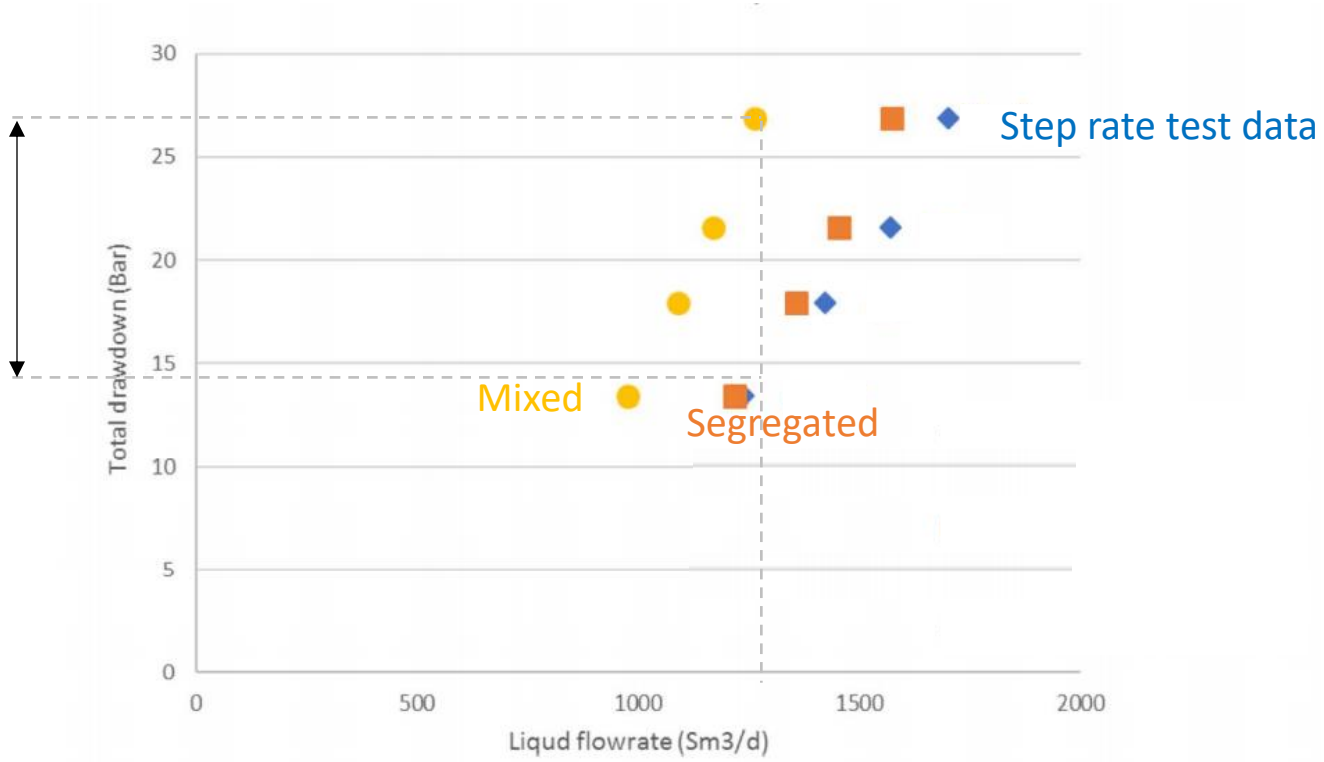
Insight - Single Zone Detailed Simulation - AICV



AICD (RCP) Segregated vs. Mixed Flow - SPE195617-MS

Step rate tests showed that pressure loss indicates segregation of liquid and gas in annulus
Oseberg H-8 Y1Y2

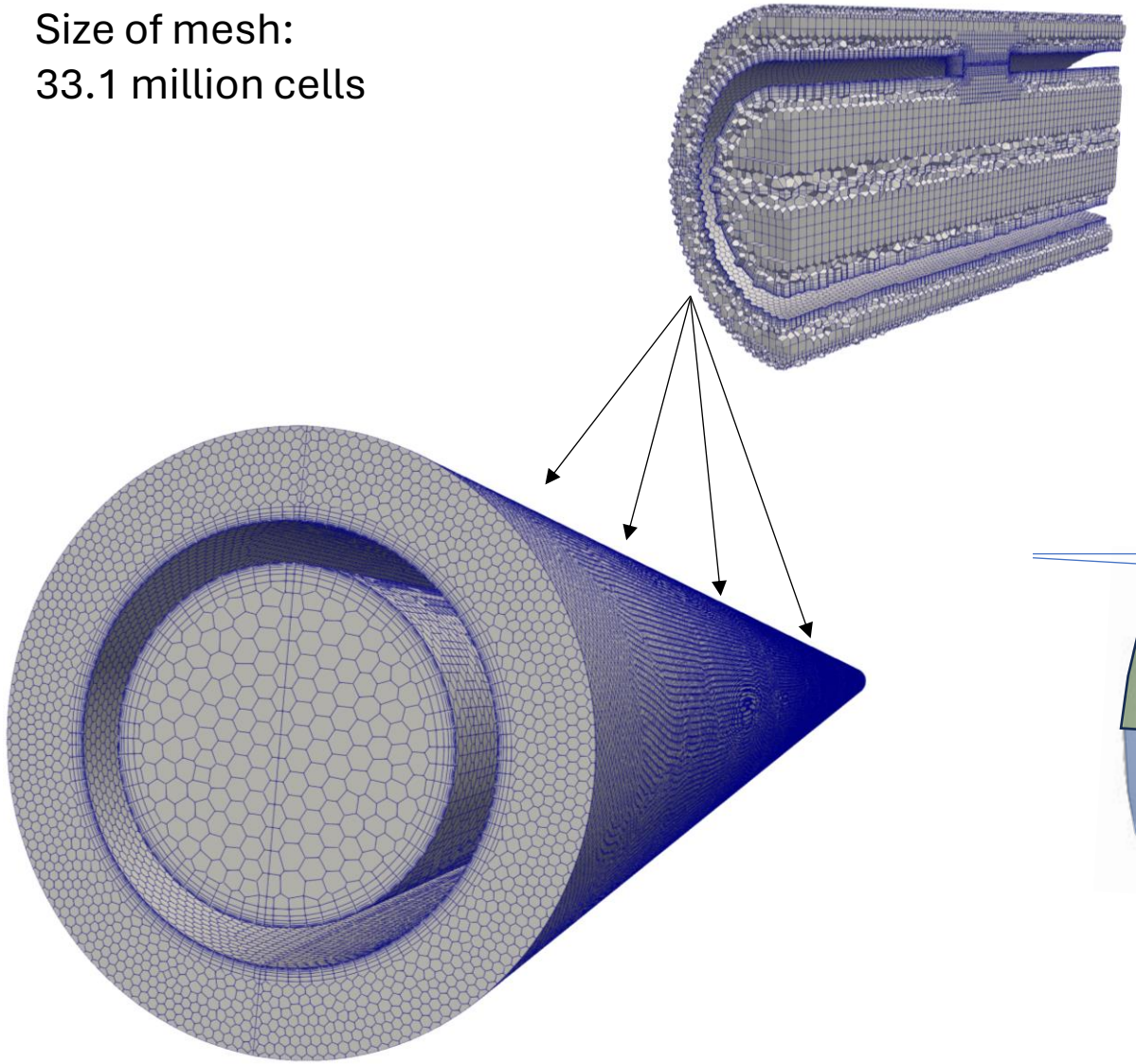
Difference in simulated drawdown by omitting or including phase segregation in annulus



SPE-195617-MS, AICD Implementation on Oseberg H Vestflanken 2
Andreas Lien, Øyvind Midttveit, Atle Johnsen Gyllensten, and Martin Halvorsen, Equinor ASA

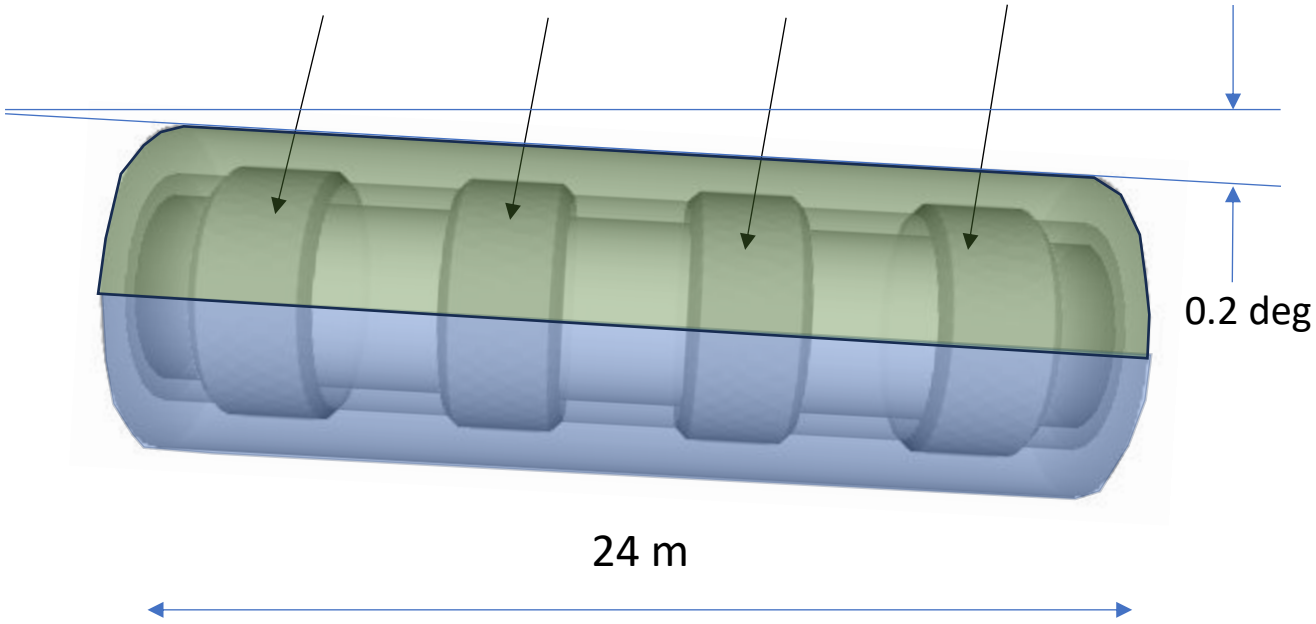
Ansys Fluent Validation Model

Size of mesh:
33.1 million cells

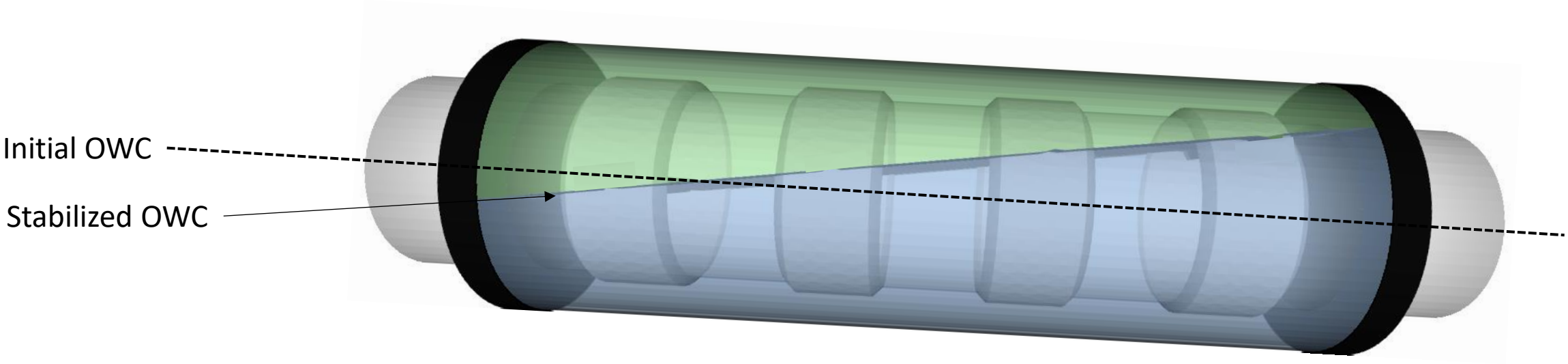


50% water and 50% oil
Oil - density: 700 kg/m3 - viscosity: 0.5 cP
Water - density: 1000 kg/m3 - viscosity": 0.4 cP
Flowrate from reservoir = 48 m3/d
Wellbore diameter: 8.5 in.
Liner/screen OD: 6 in.
Liner/screen ID: 4.92 in.
0.2 deg. deviation from horizontal

4 evenly distributed static inflow control devices (ICD)



Flowpro Insight vs. Ansys Fluent Validation Model



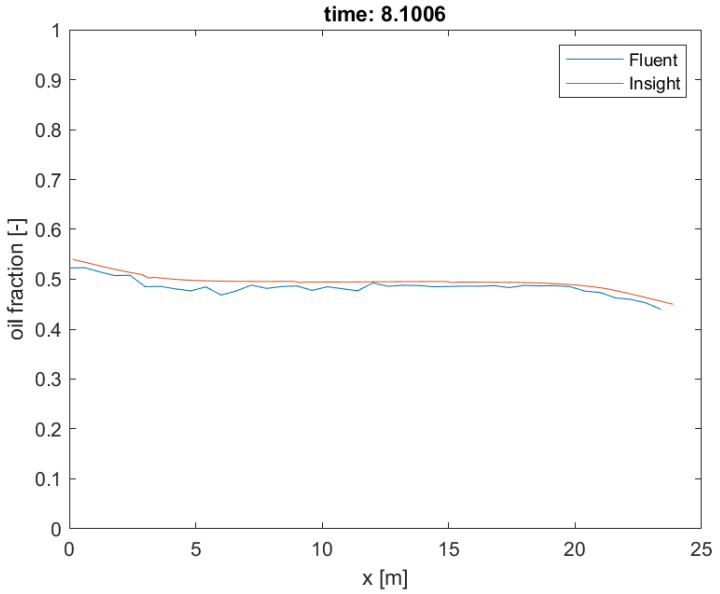
	Number of Cores [-]	Computation time [h]	Simulation start time [s]	Simulation end time [s]	Resource coefficient (cores * computation time [h] / simulation time [s])
Fluent	160	22.25	3.407	91.46	40.429
Insight	1	1.185e-3 (4.26 s)	0	91.46	1.296e-5

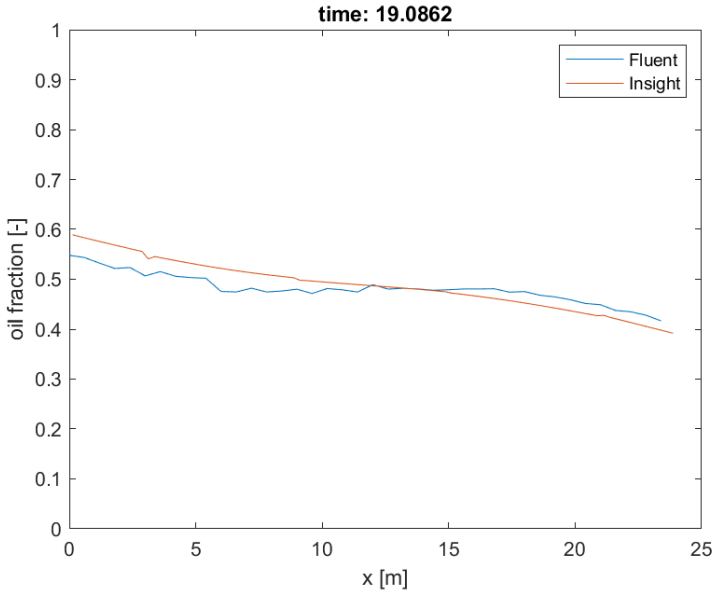
Ratio of resource coefficients: 3 119 559

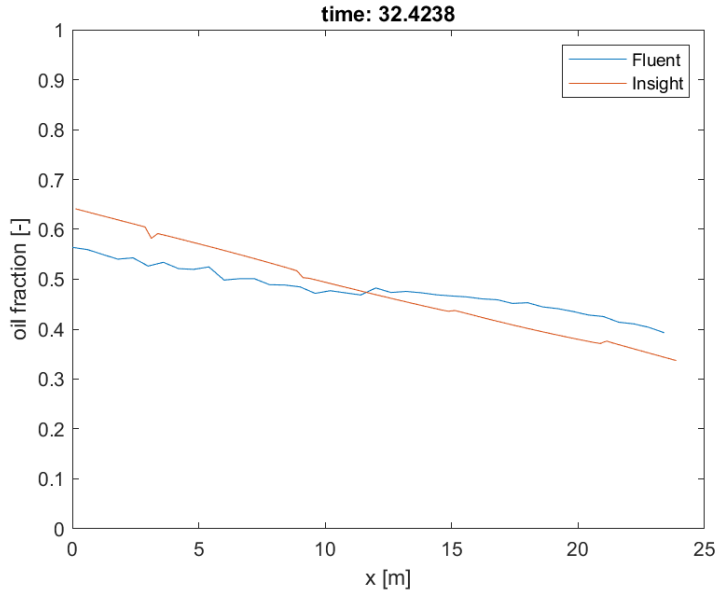
For this specific problem, **Insight is 3 million times faster than Ansys Fluent.**

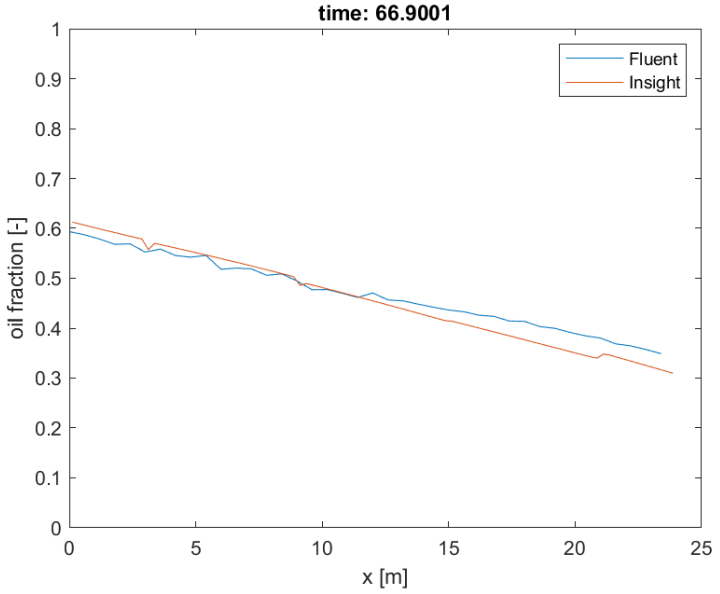
Case with 0.2 deg. deviation from horizontal

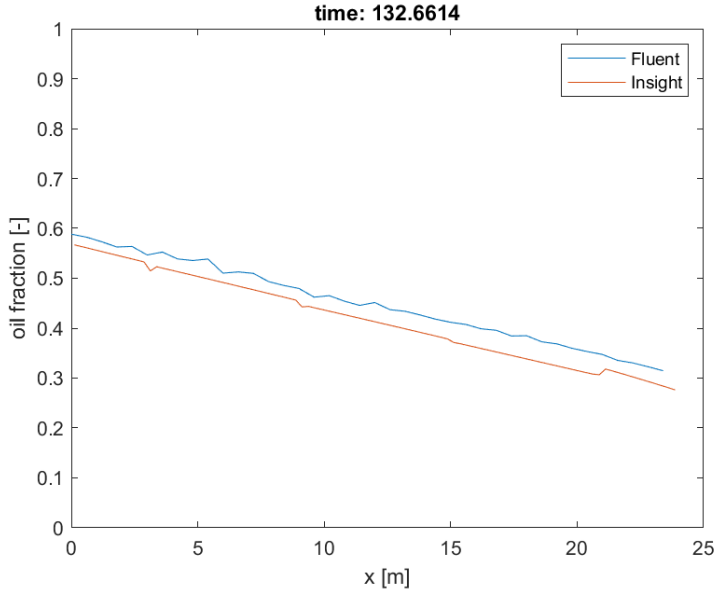
Oil volume fraction along the annulus





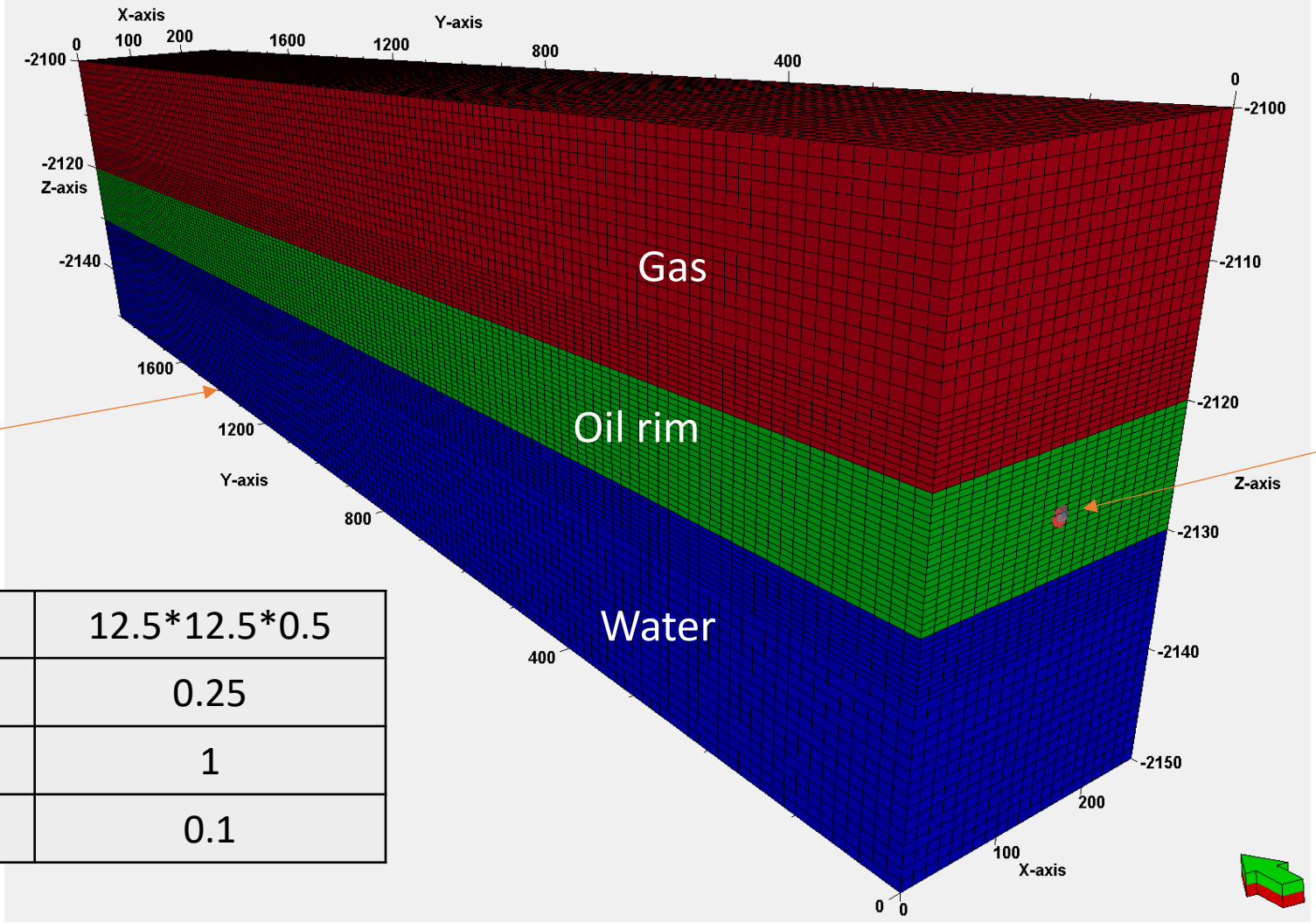






Example - Reservoir modelling using the Insight work process

Bottom water drive MULTPV=1e6

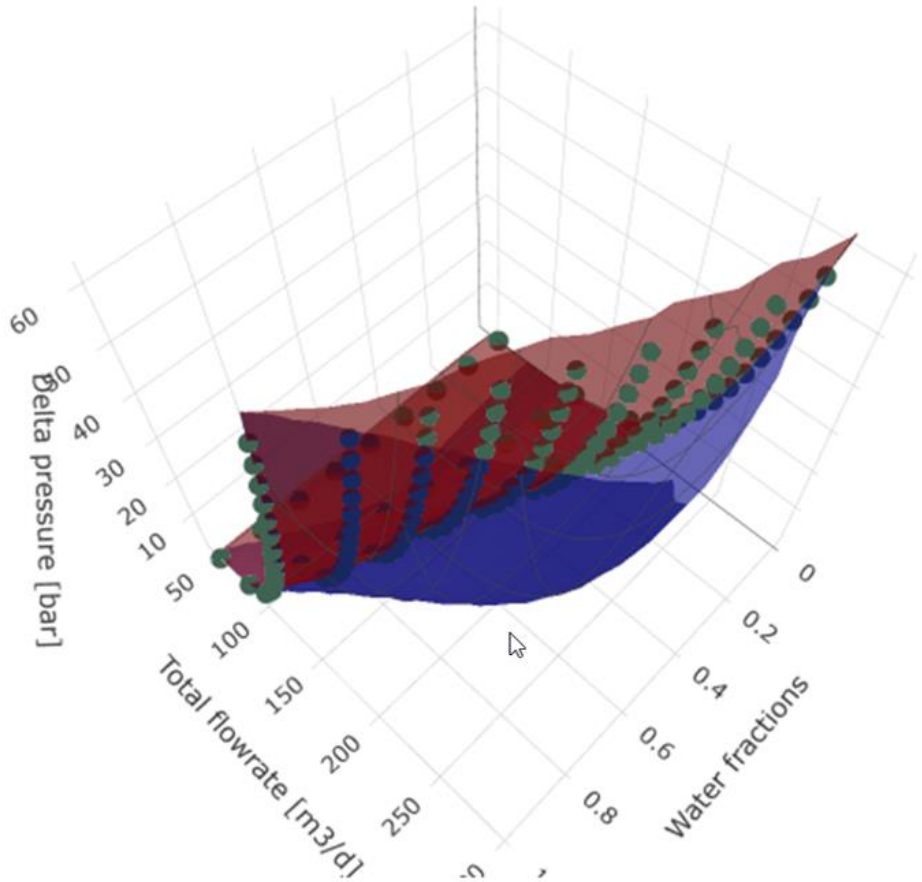


2000m horizontal well

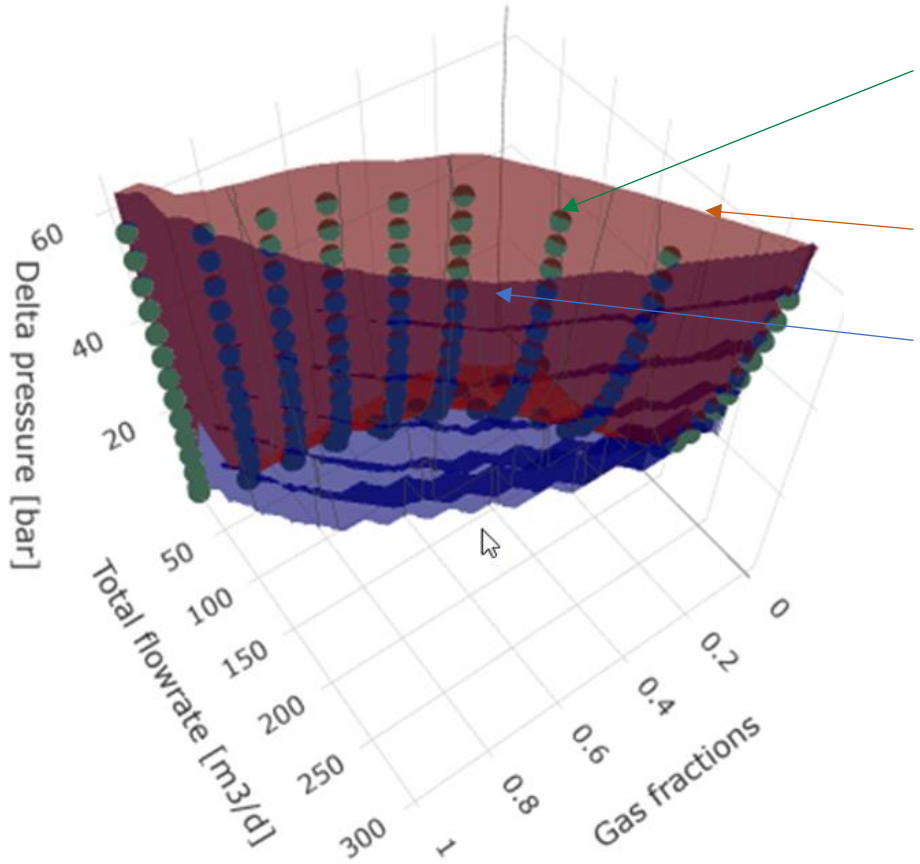
Grid (m)	12.5*12.5*0.5
Porosity (frac.)	0.25
Permeability hor. (D)	1
Permeability vert. (D)	0.1

Upscaled AICV Zone Inflow performance from Insight

Oil-water mixtures



Oil-gas mixtures



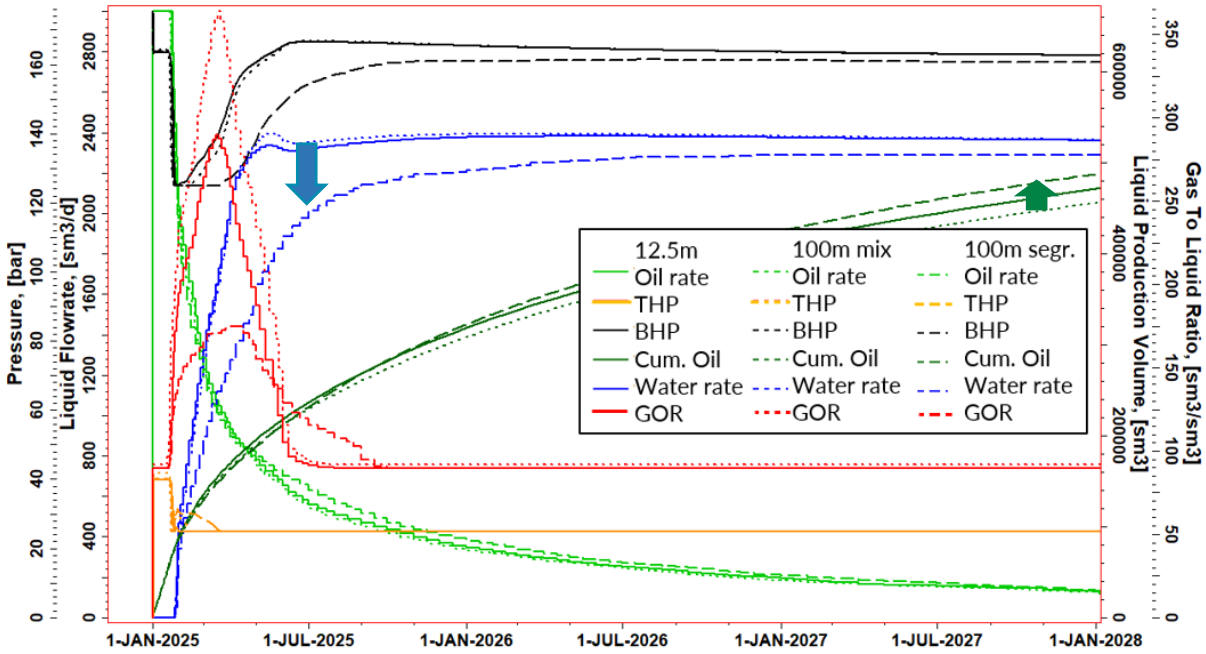
Simulated steady state results with phase segregation

Fitted surface (VFP)

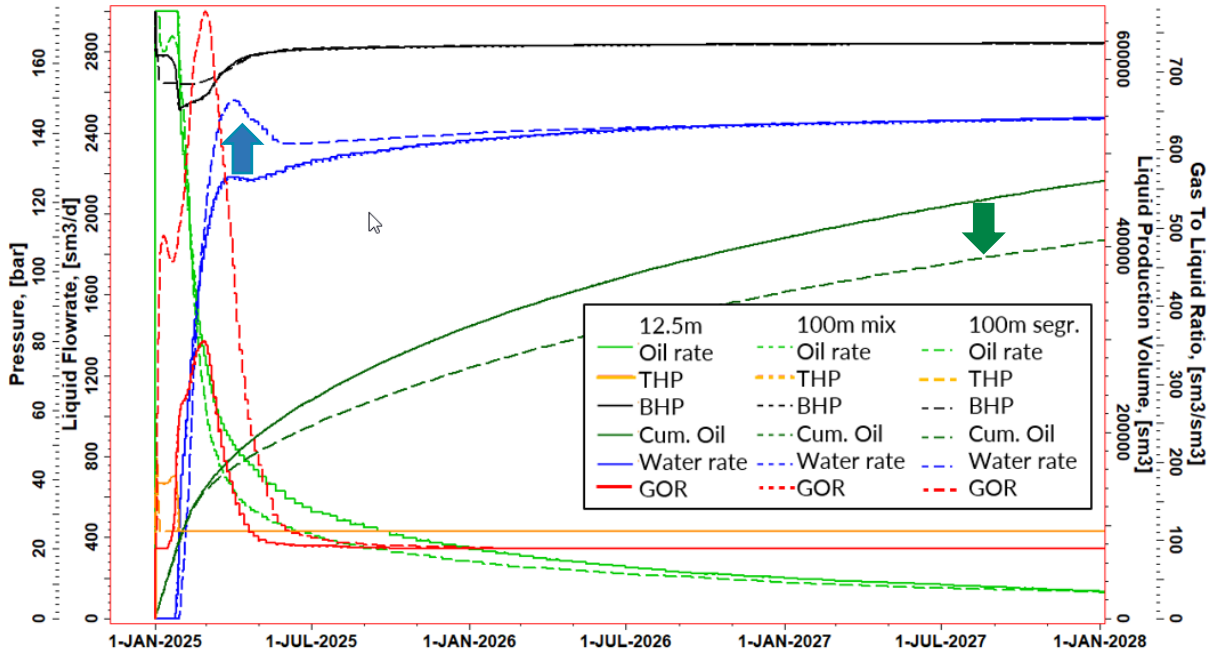
Results without phase segregation

Effect from new workflow on AICV and ICD modeling

- AICV - Performance underestimated with old workflow

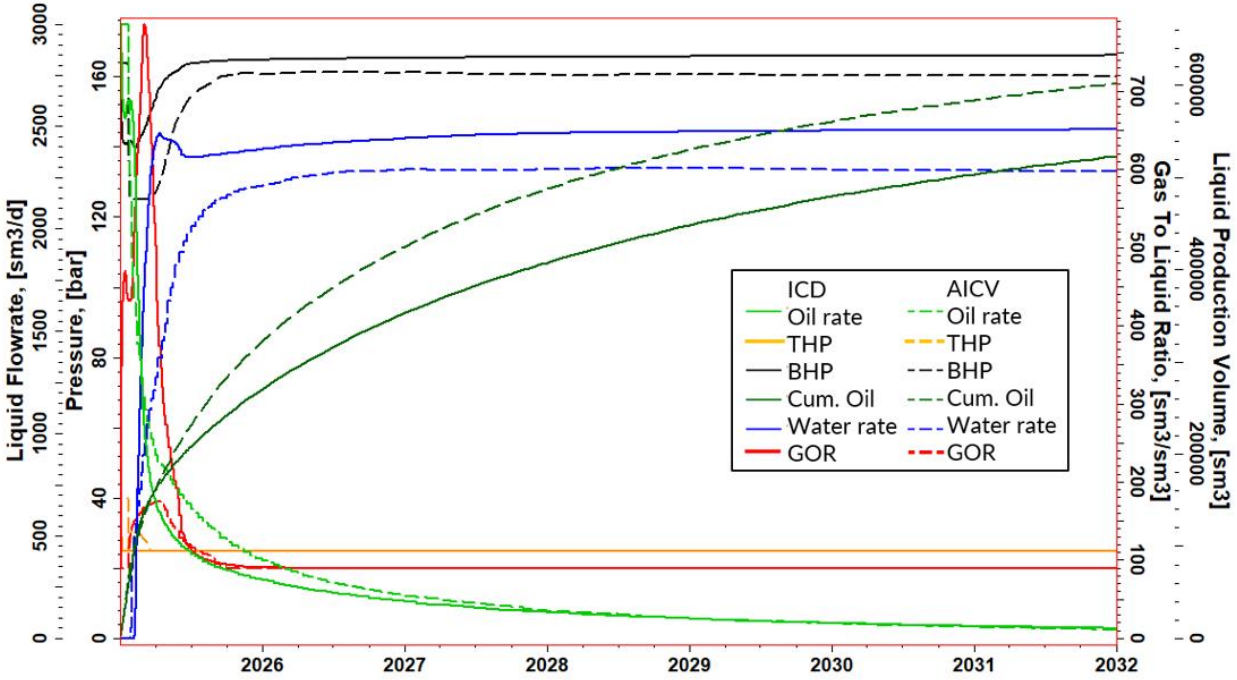


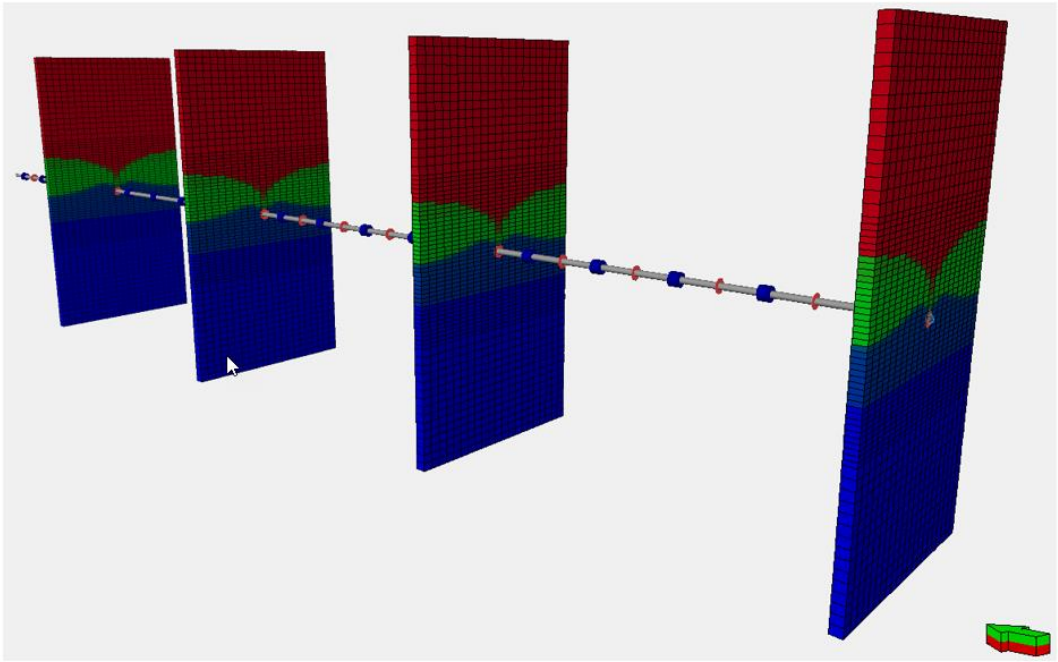
- ICD - Performance overestimated with old workflow



Homogeneous reservoir model – with new workflow

- AICV case recovers 11.5% more oil and 8.7% less water

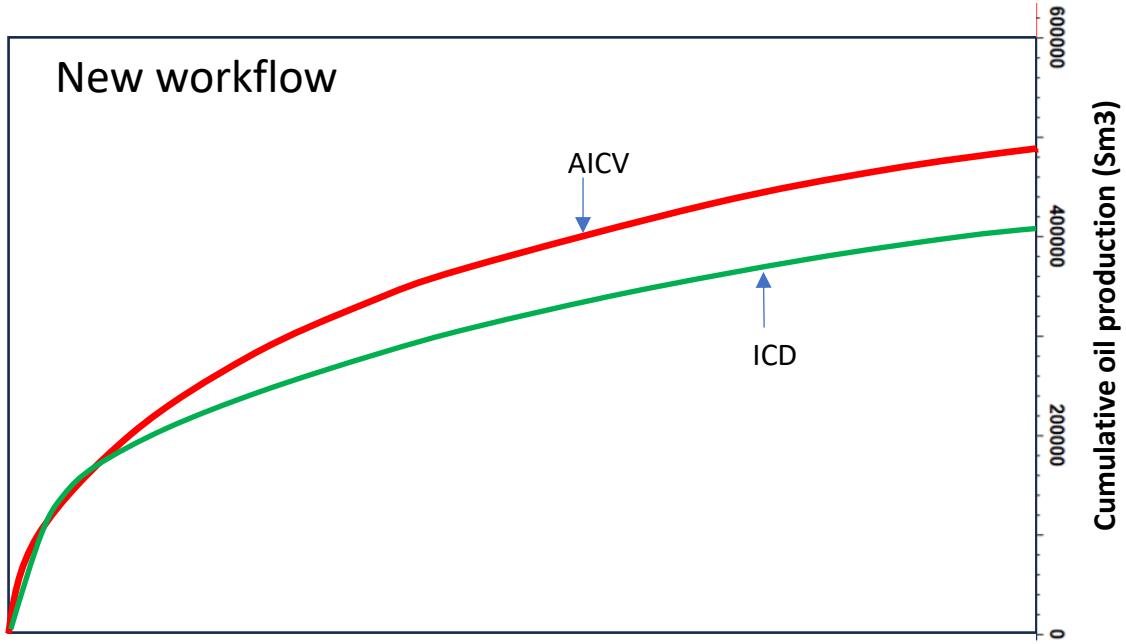




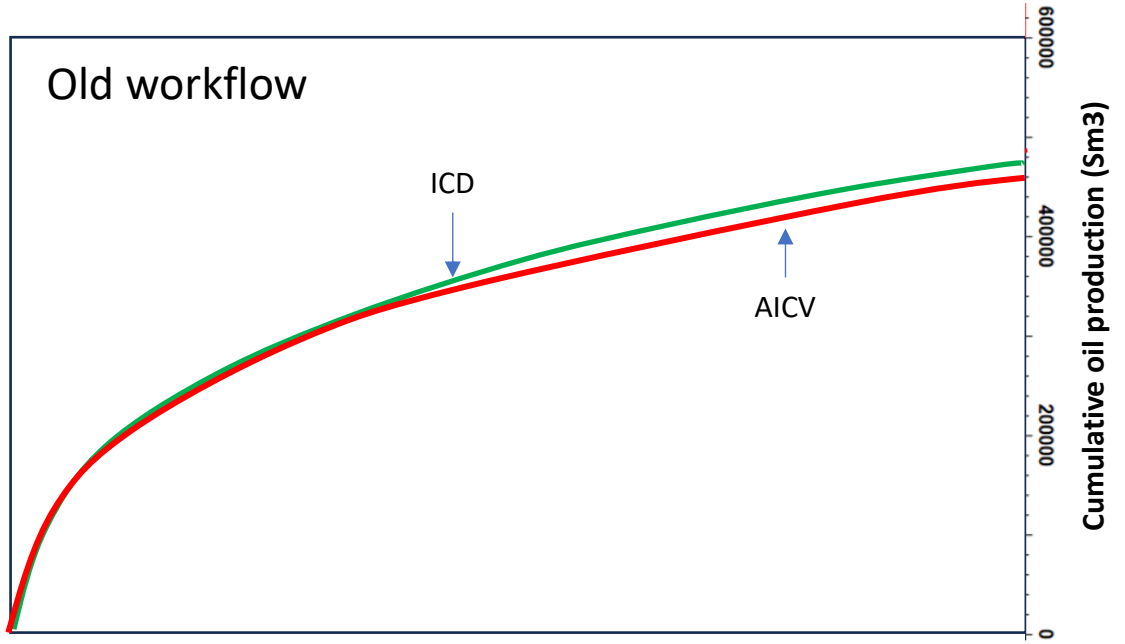
AICV and ICD performance comparison - Segregated vs. Mixed Flow in Annulus

With new workflow, AICV is the ICT of choice.
With old workflow, ICD would be the ICT of choice.

AICV outperforms ICD with segregated flow in annulus



ICD outperforms AICV with mixed flow in annulus



Conclusion

Use of new (Insight) vs. old workflow will influence

- The type of ICT equipment to be used
- The design of ICT solution (number and size)

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