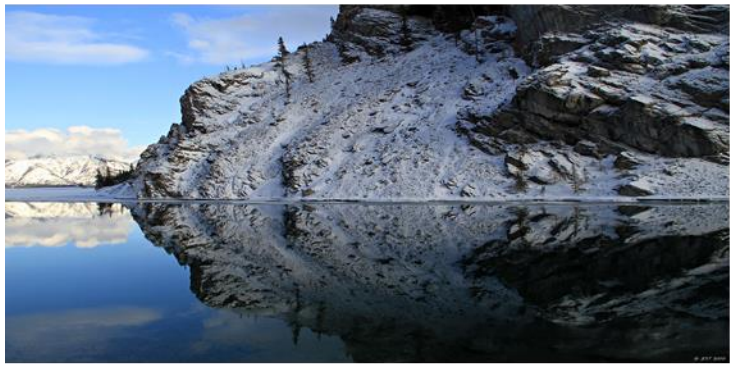
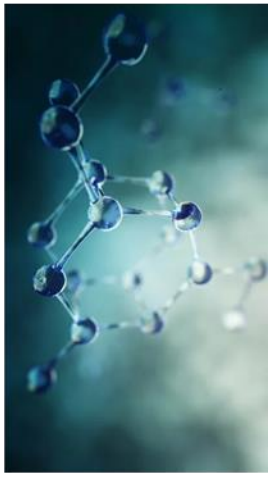
Well clean-up optimisation using advanced modelling processes





Mike Byrne

Dr Lesmana Djayapertapa

Dr Miguel Reyes

Martyn Burns

Ken Watson

Presentation Outline

- **Why?**
- **What?**
- **So what?**

Why?

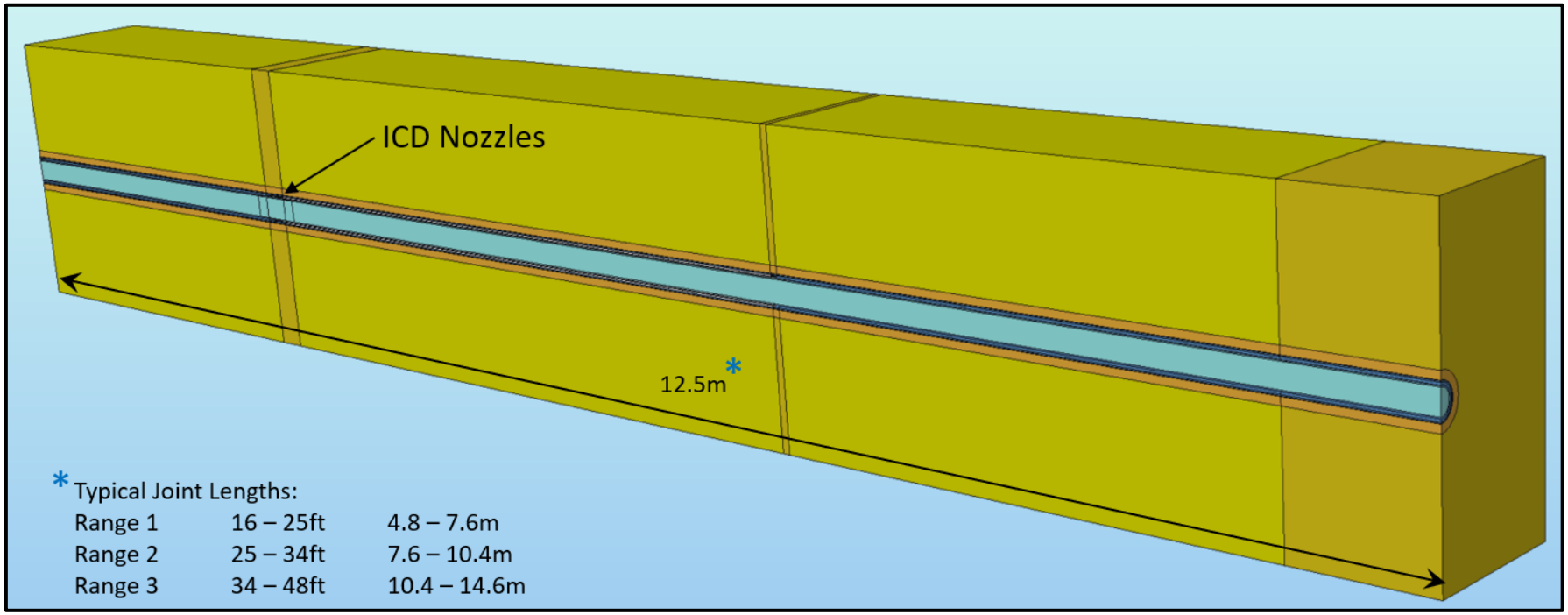
- When a well is drilled and completed, the next step (for production wells or back-flowed injection wells) is to “clean-up” the well by flowing (or allowing flow) from the reservoir to the wellbore and producing fluids to surface
- This process depends on a myriad of transient parameters and normally multiphase flow through the reservoir, in to the well and back to surface
- But how do we know:
  - For how long should we clean-up?
  - At what rates?
  - Do we need to gas lift?
  - To a temporary rig or platform or facility?
  - How will the near wellbore and any lower completion flow control impact the clean-up?

How will the near wellbore and any lower completion flow control impact the clean-up?

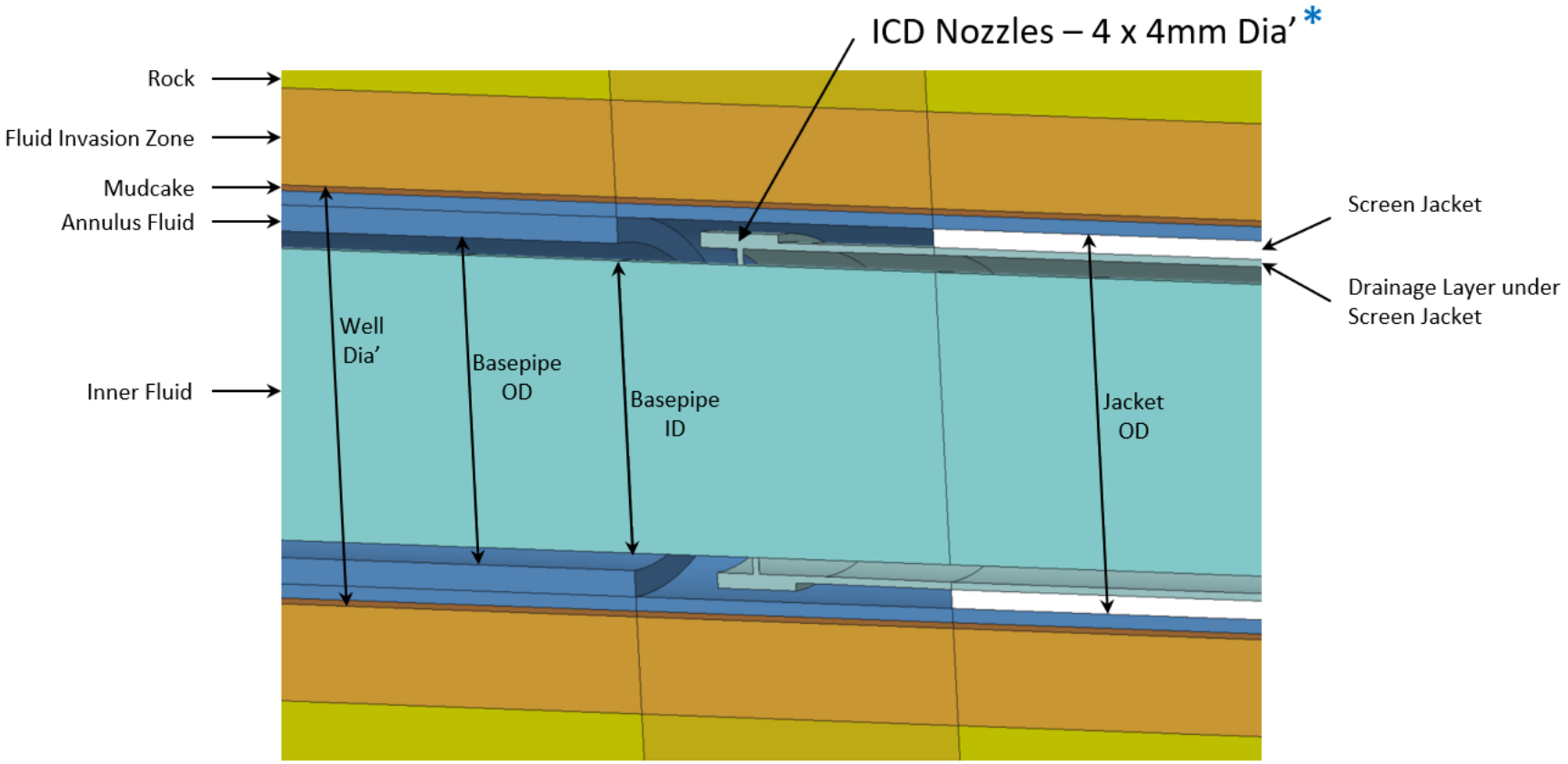
- It is possible to use simple nodal or 1D models however:
  - Continuity of fluid from deep reservoir to well and through completion is missed
  - Phenomena such as heel to toe and in and out flow through the completion are missed or underestimated
  - Formation damage and completion damage are not fully captured

- Fully connected (no nodes or pressure drops employed) 3D finite volume CFD is available to capture all reservoir and well fluid dynamics
  - Reservoir quality (permeability) fully captured
  - Reservoir to well connection fully (two way) coupled
  - Completion geometry fully captured – ICDs, ICVs, sand screens, etc.
  - Near wellbore impairment (formation damage and completion damage) can be included (steady state or transient)

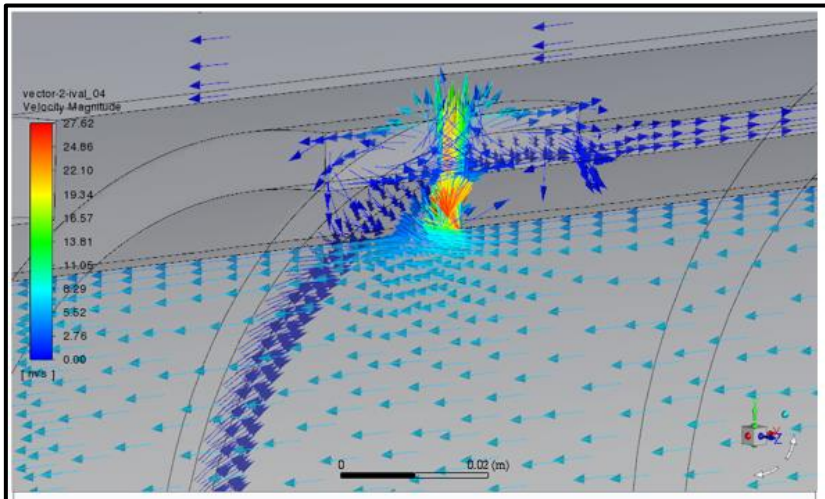
Geometry of a single screen joint



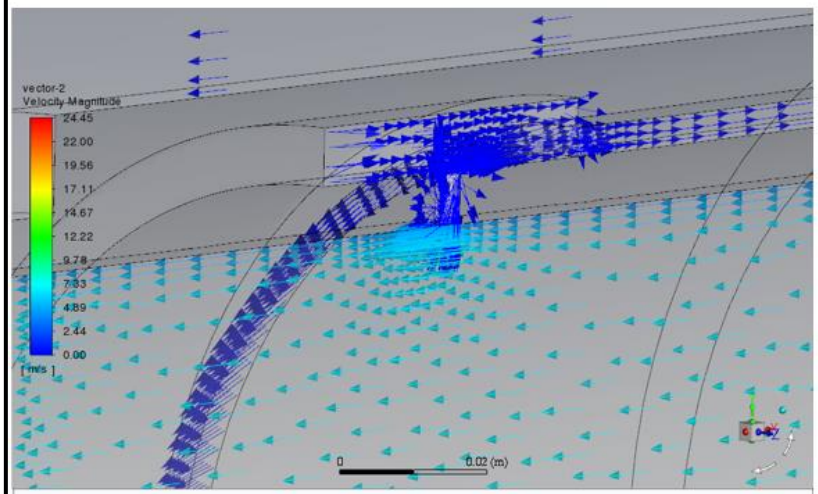
Detailed “typical” nozzle ICD geometry



Full flow through completion captured

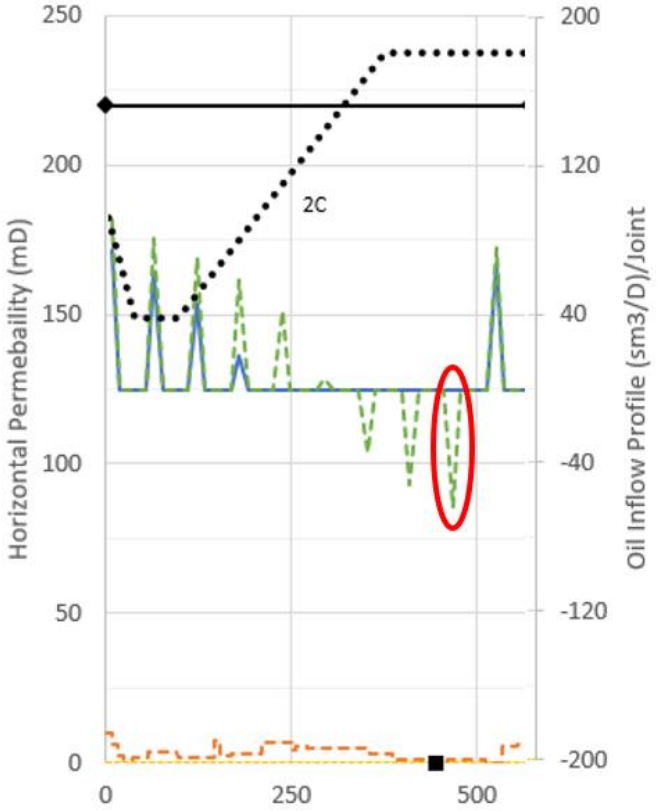


Zoom In on ICD Without Check Valve (Reverse Flow)



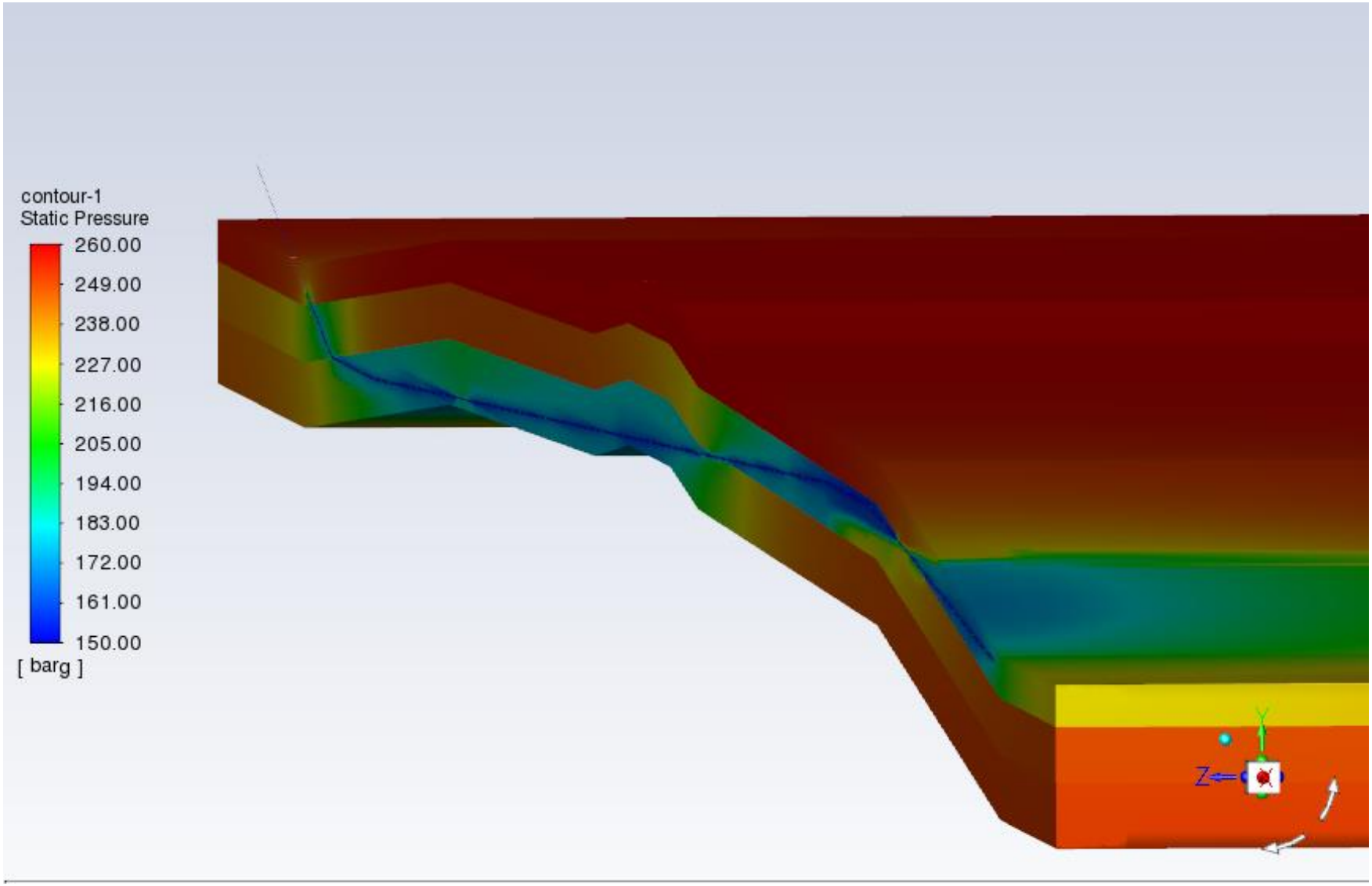
Zoom In on ICD With Check Valve (No Flow Through ICD Nozzle)

Without Check Valve (Reverse Flow - Dashed Green Line)
Nozzle High Side



With Check Valve (No Flow Through ICD Nozzle)
Nozzle High Side

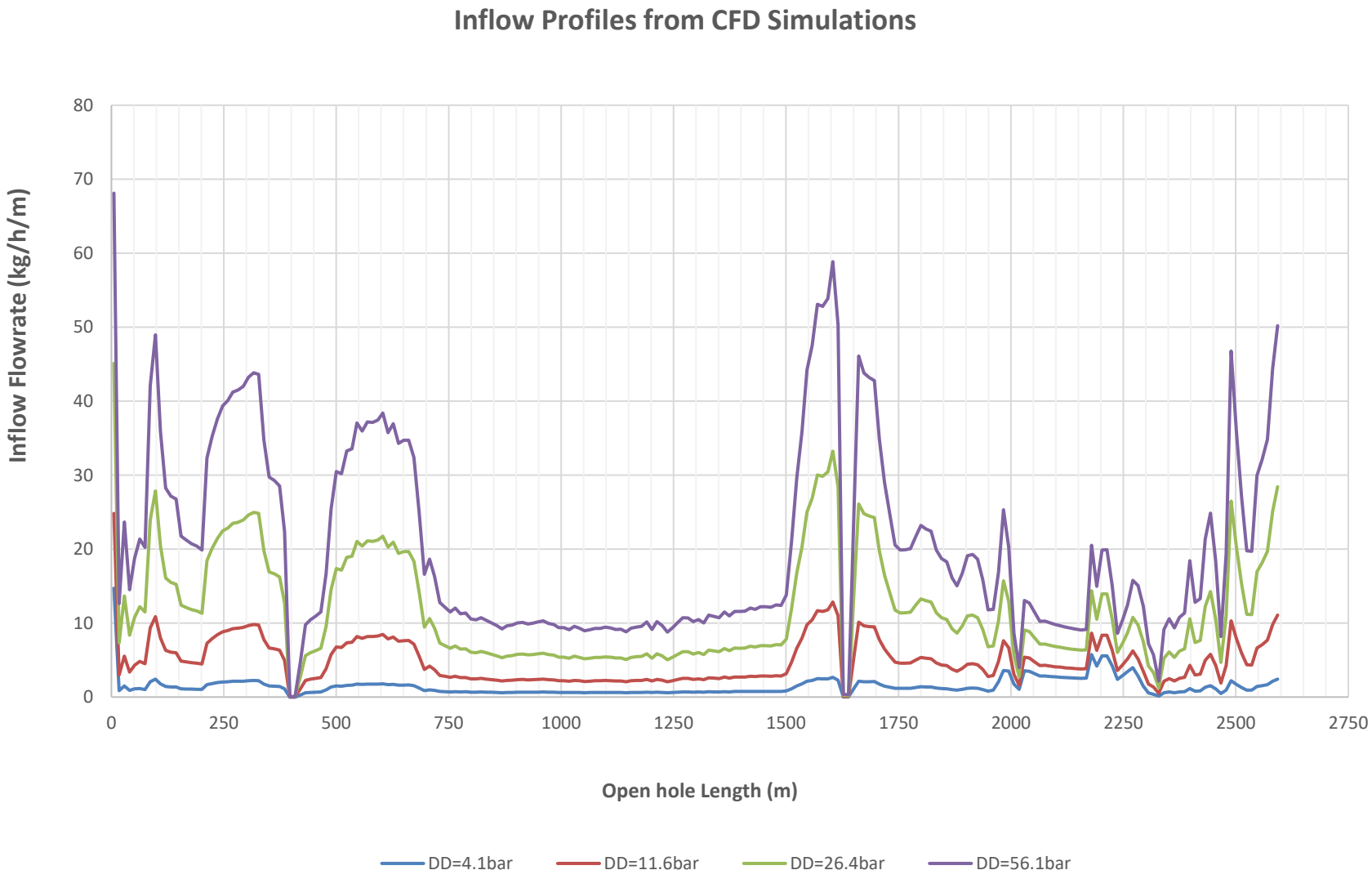
Overview of pressure profile in 8,000 ft long well



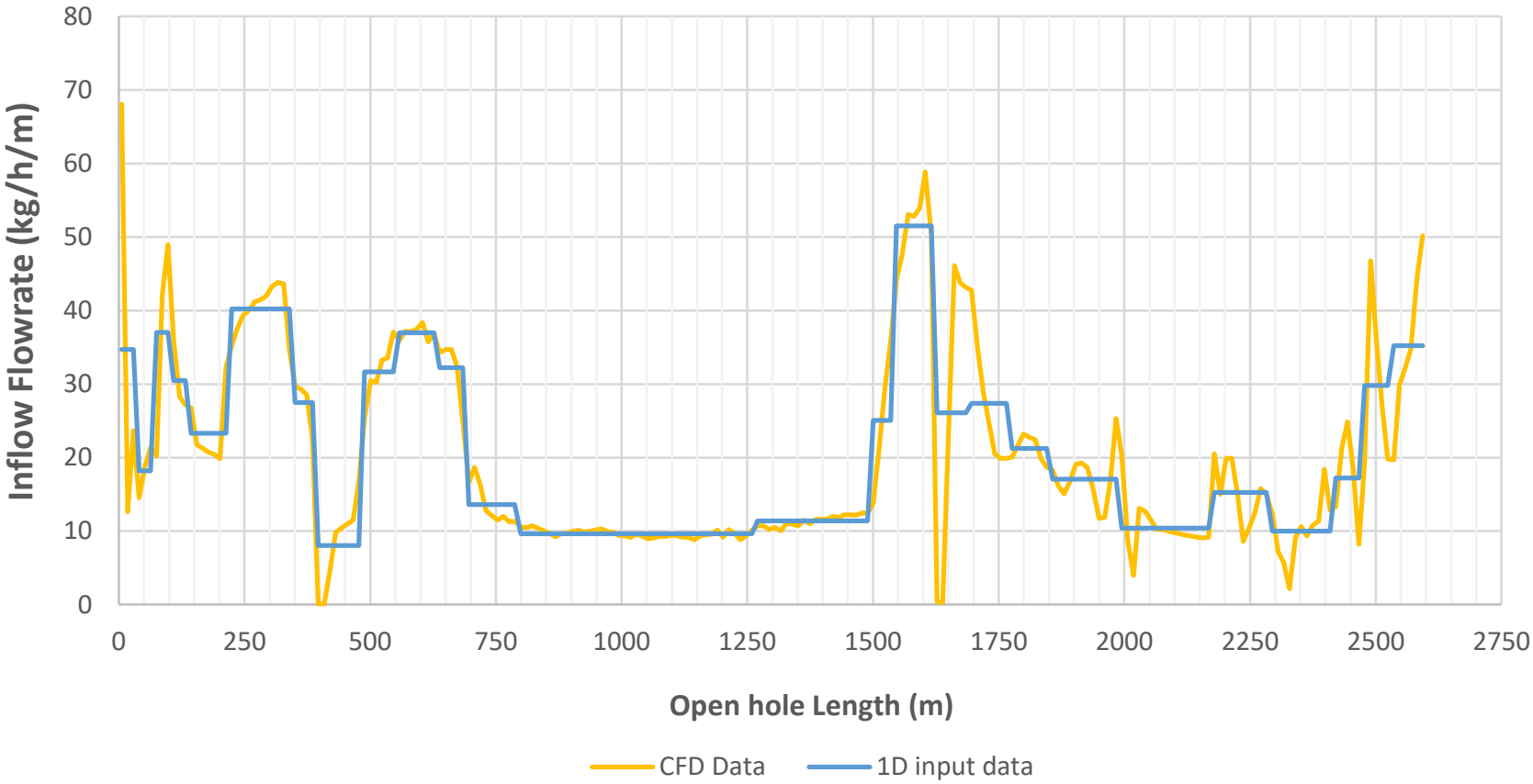
From CFD to well clean-up model

- Well inflow is simulated in CFD at multiple drawdowns
- Inflow profiles (per meter/per foot/per joint as required) generated for each drawdown pressure
- Pressure versus rate plots generated
- Segmented well inflow profile generated for clean-up model
- Look-up table included and used as input during transient well clean-up simulations

Full well inflow profiles at multiple drawdowns



Converted to segment model

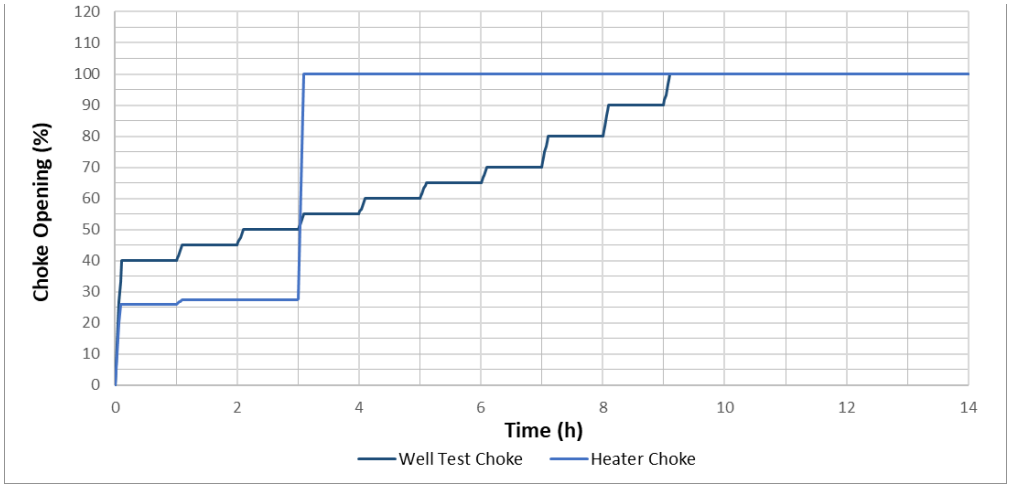


“Handshake” - table as input for 1D transient model

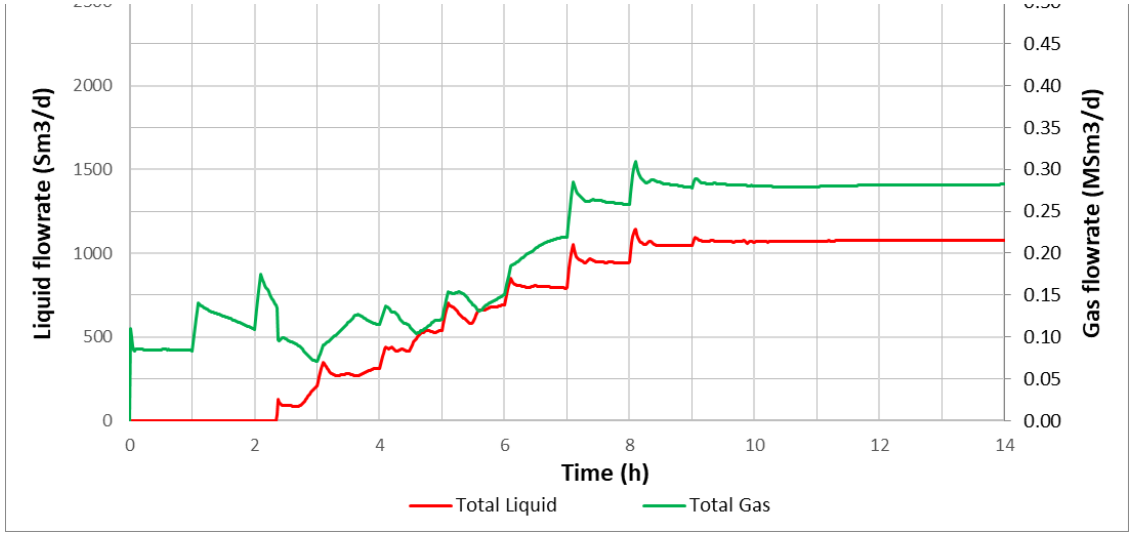
	Drawdown (bar)				Mass flow rate (kg/m/h)			
Segment	DD1	DD2	DD3	DD4	Flow 1	Flow 2	Flow 3	Flow 4
1	2.46	9.91	24.79	54.53	5.69	11.12	22.02	34.79
2	2.10	9.57	24.49	54.33	1.05	4.17	10.44	18.20
3	2.01	9.45	24.31	54.01	1.83	8.24	21.10	37.08
4	1.94	9.39	24.27	54.01	1.53	6.80	17.35	30.45
5	1.89	9.35	24.25	54.02	1.21	5.23	13.29	23.30
6	2.06	9.49	24.31	53.94	2.07	9.01	22.92	40.21
7	2.25	9.70	24.57	54.27	1.37	6.12	15.64	27.48
8	2.41	9.89	24.82	54.66	0.48	1.85	4.60	8.02
9	2.49	9.92	24.75	54.37	1.55	7.03	18.00	31.66
10	2.50	9.92	24.73	54.31	1.74	8.14	20.96	36.96
11	2.52	9.95	24.77	54.38	1.52	7.10	18.26	32.20
12	2.54	10.01	24.89	54.64	0.79	3.13	7.80	13.62
13	2.60	10.07	24.96	54.71	0.64	2.28	5.56	9.65
14	2.68	10.14	25.01	54.71	0.73	2.66	6.49	11.37
15	2.70	10.14	24.95	54.54	1.31	5.61	14.21	25.07
16	2.71	10.09	24.80	54.17	2.39	11.31	29.12	51.51
17	2.85	10.28	25.07	54.62	1.23	5.75	14.79	26.11
18	3.05	10.48	25.27	54.81	1.46	6.17	15.58	27.38
19	3.26	10.70	25.52	55.11	1.29	4.92	12.17	21.23
20	3.56	11.00	25.83	55.46	1.34	4.22	9.96	17.06
21	15.90	23.36	38.21	67.90	2.71	4.19	7.15	10.39
22	15.59	23.04	37.89	67.55	4.09	6.26	10.59	15.28
23	2.91	10.37	25.23	54.91	0.71	2.40	5.78	9.99
24	2.36	9.81	24.64	54.28	1.07	4.01	9.88	17.23
25	2.02	9.45	24.23	53.78	1.42	6.57	16.86	29.80
26	1.64	9.06	23.83	53.33	1.69	7.78	19.92	35.20

Example results from 1D transient models

Choke opening sequence

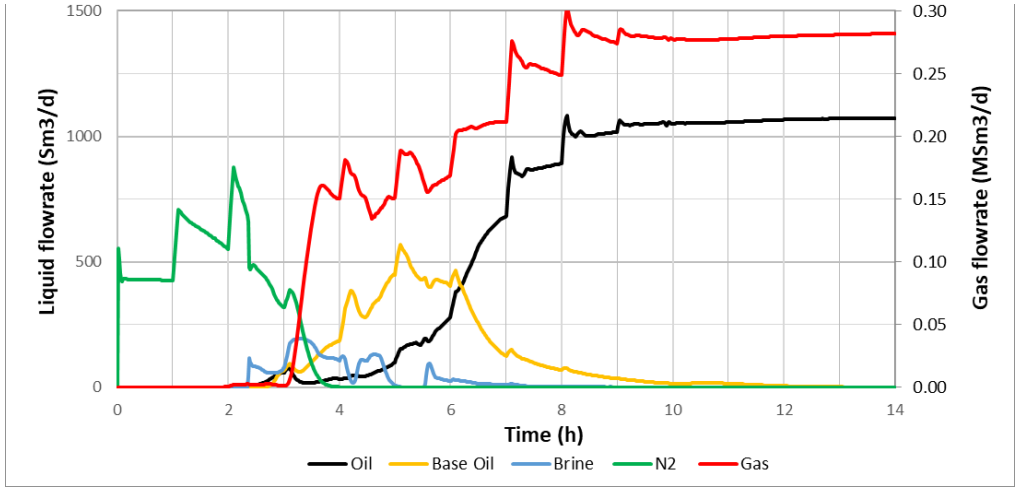


Topside gas and liquid rates during clean-up

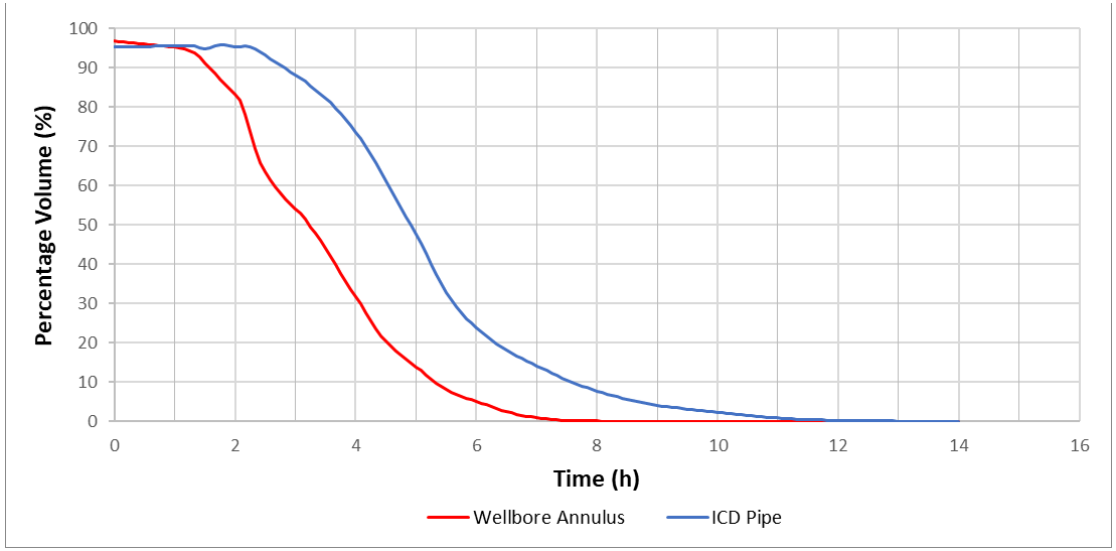


Example results

Fluid rates during clean-up



Percentage of base oil in well during clean-up



Key results

- Time required for full well clean-up (circa 10 hours)
- Gas lift requirement
- Comparison between rig and platform clean-up
- Choke opening sequence and risk of low temperature (due to gas lift)
- Optimum fluid sequence prior to clean-up
- Fluid arrival times, temperatures, etc. throughout clean-up

So what?

- Improved prediction of well clean-up – verified in real well performance which accurately predicted fluid arrivals to within minutes
- Design of well clean-up operations
- Optimum well inflow modelling with optimum well clean-up modelling
  - Near wellbore and in well impairment properly captured
  - Well completion impact fully captured

- Moving towards fully coupled (two way) transient models

Thank you

Mike Byrne

Rock Properties Manager

T: +44 1224 829200

mbyrne@axis-wt.com