GFLOW: A Supercritical Wellbore Simulator

Simulation of Ultra hot IDDP Wells in Iceland

Julius Rivera and John Burnell

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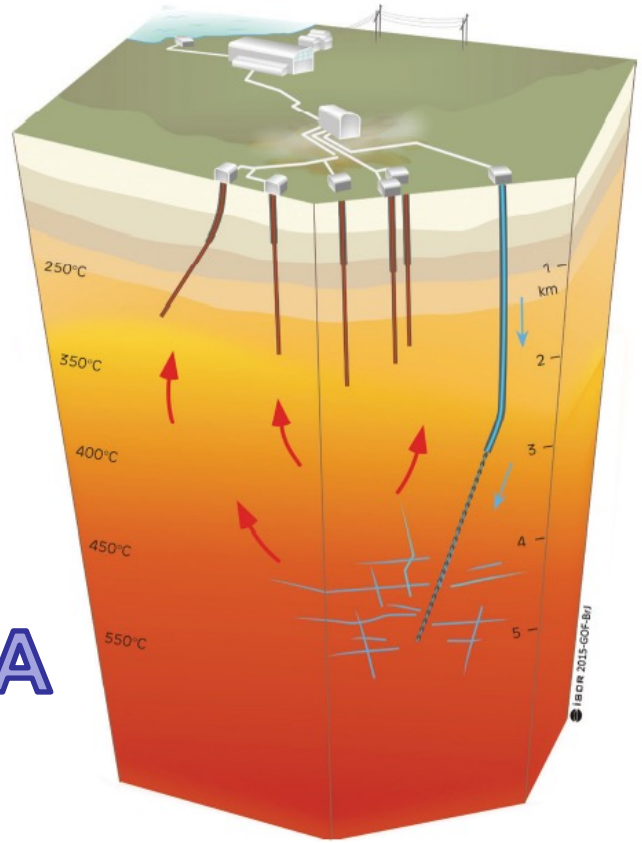
Background: Well IDDP-1 on Test

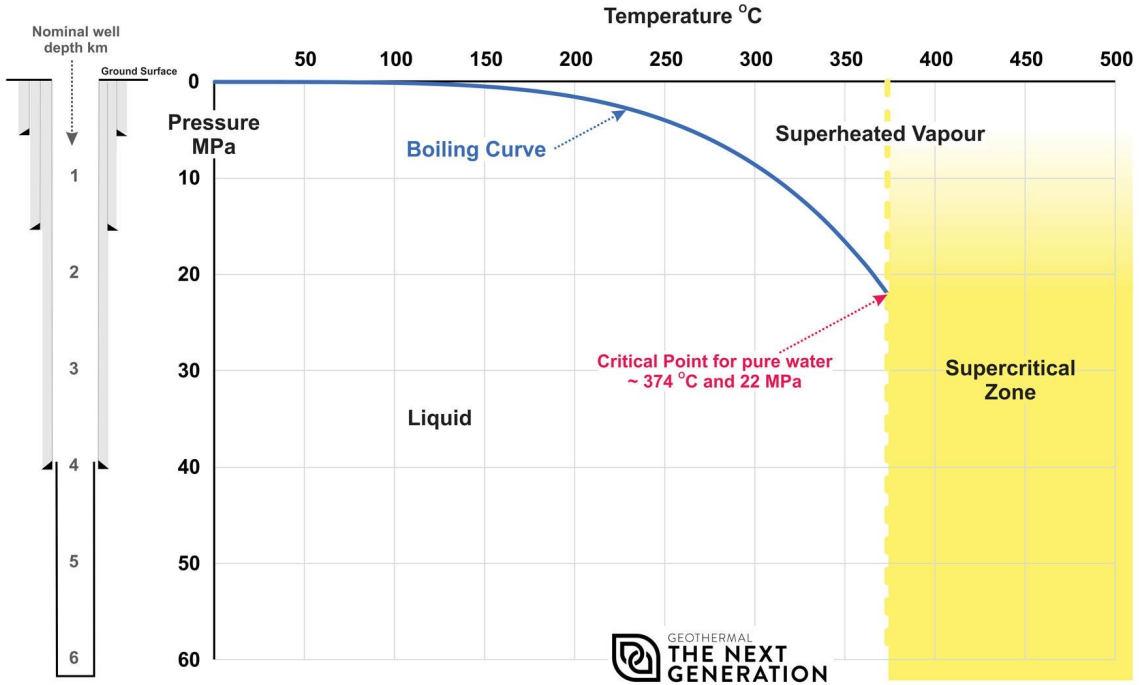
GNS SCIENCE TE PŪ AO

THE CONCEPT OF SUPERCRITICAL WELLBORE MODELLING



USA

Japan



Supercritical Reservoir Conceptual Model (from Fridleifsson and Elders, 2017)

Let's give **GFLOW** a GO!

WHO WE ARE: THE AUTHORS

Julius Rivera – Geothermal Reservoir Engineer (GNS Science)

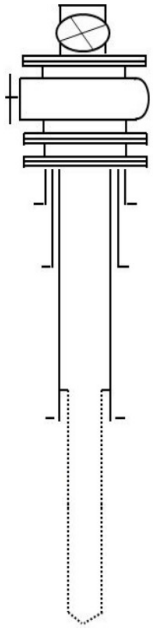
- Experienced Reservoir Engineer
- More than 10 years of work in the geothermal industry (Philippines)
- Wellbore modelling and evaluation
- Resource management and sustainability
- Well Integrity Management Lead and Subsurface Risk Officer

John Burnell - Senior Reservoir Modeller (GNS Science)

- Experienced reservoir modeller
- Have worked on reservoir models around the world for > 35 years
  - New Zealand, Philippines, Japan, Papua New Guinea, South America
- Developed reservoir simulation and wellbore modelling software

What's with the GFLOW Wellbore Simulator

Developed by GERD (Japan) and GNS Science (NZ)

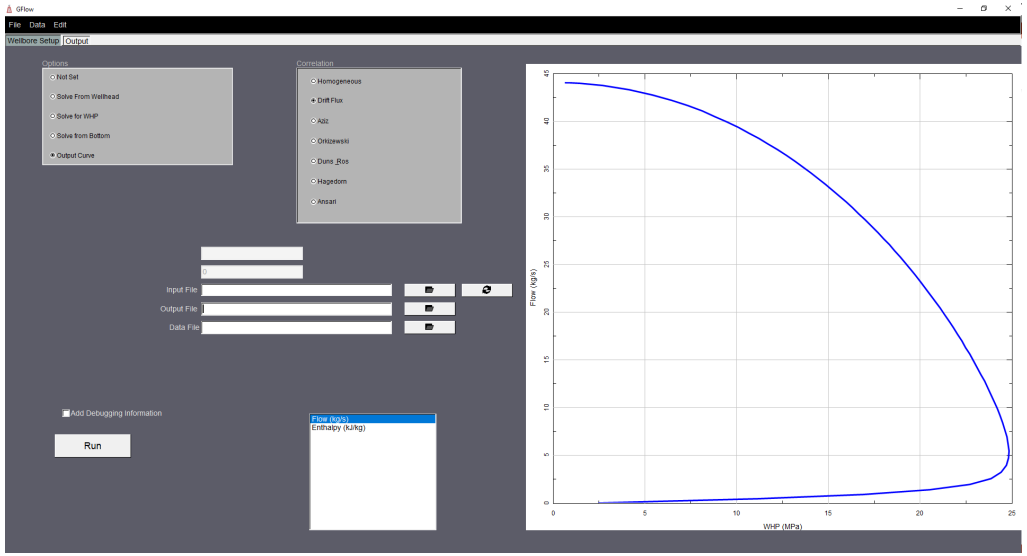


Conservation of energy and momentum

$$\frac{dP}{dL} = g\rho_m \cos\alpha - \frac{f_m v_m^2 \rho_m}{2d} - \rho_m v_m \frac{dv_m}{dL}$$

$$\frac{dH}{dL} = g\cos\alpha - v_m \frac{dv_m}{dL} - Q/w$$

$$w = PI\left(\frac{k_{rl}\rho_l}{\mu_l} + \frac{k_{rv}\rho_v}{\mu_v}\right)(P - P_{reservoir})$$



- Correlations for friction factor and pressure drop (Orkiszewski, Duns and Ros, Hagedorn, etc.)
- Several fluid flow calculation options (Top down, bottom up, output curve)

What's so special about the GFLOW?

Water + NaCl + CO_2

- Pure water: IAPWS-IF97 (2007)
- NaCl Solutions: Driesner et al. (2007)
- CO_2 Mixtures: Mao et al. (2010)

Drift Flux Correlation (Kato et al., 2015)

- Pressure drop calculation for highly deviated wells

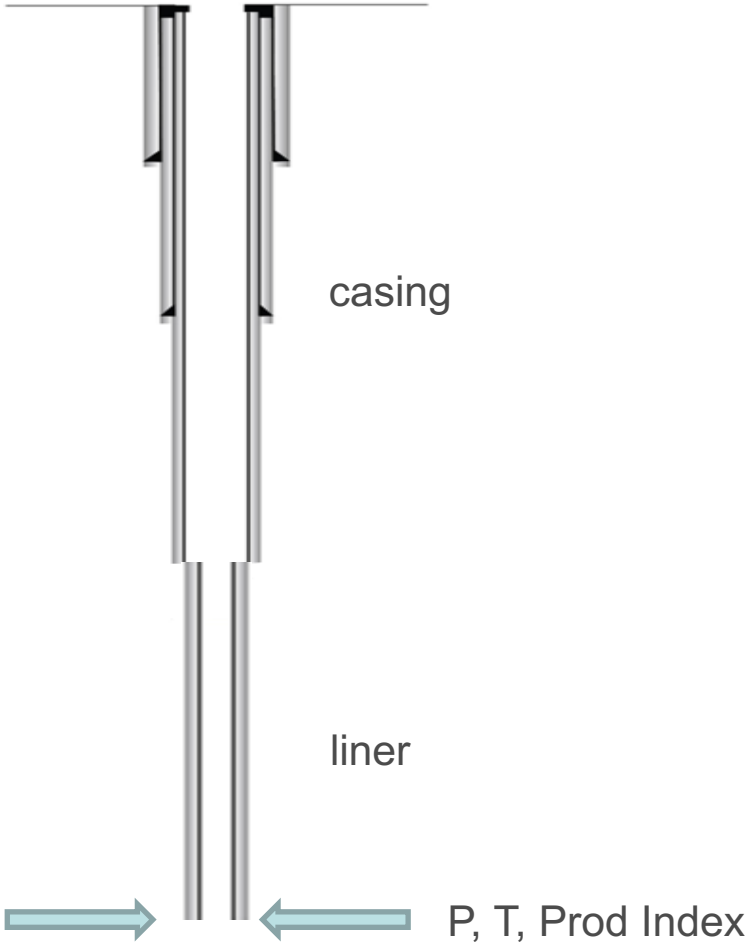
Supercritical Capability

- Temperature up to 800^{o}C and pressure up to 1000 bar
- Temperature up to 1000^{o}C and pressure up to 500 bar

But is it really working?

- Calibration of IDDP-1 Discharge Test Data
- Calibration of Well IDDP-2 Injection Temperature Data
- Well Output Forecast of Well IDDP-2

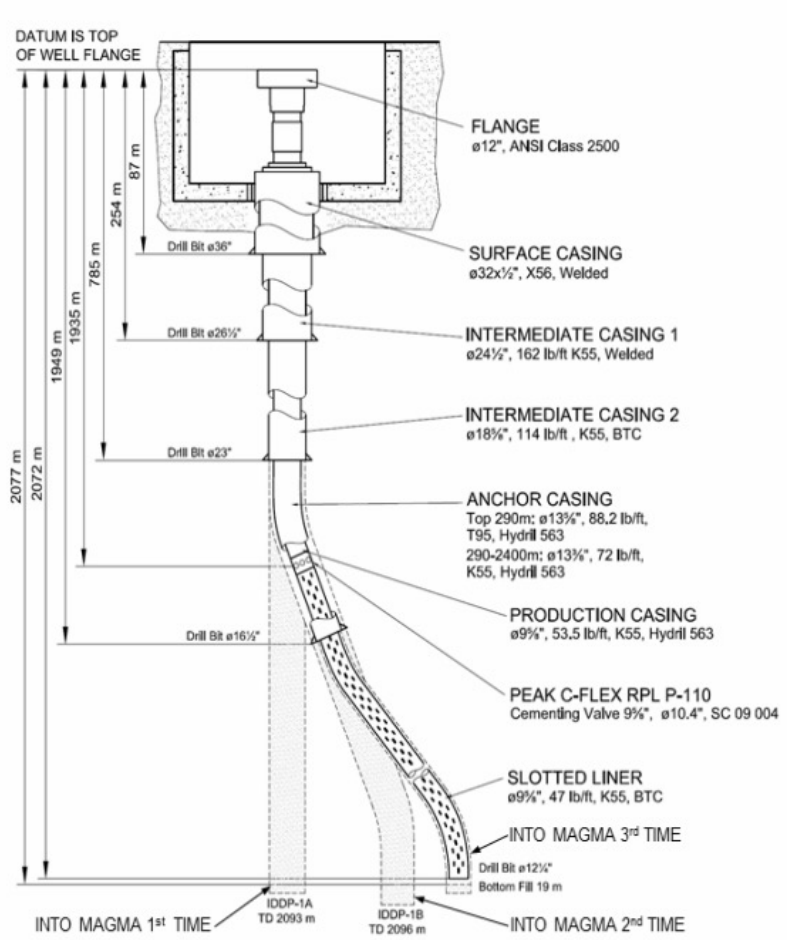
Supercritical Wellbore Model and Simulation



- **Wellbore Modelling Details**
  - Fluid assumed as pure water
  - Heat transfer to formation at t = $1x10^7$ s (~115 days)
  - Casing roughness value = 0.5 mm

Formation Properties	Values
Density (kg/m^3)	2700
Thermal conductivity (W/m-K)	2.56
Specific heat (J/kg-K)	800

Case 1: Calibration of Well IDDP-1 Discharge Test Data



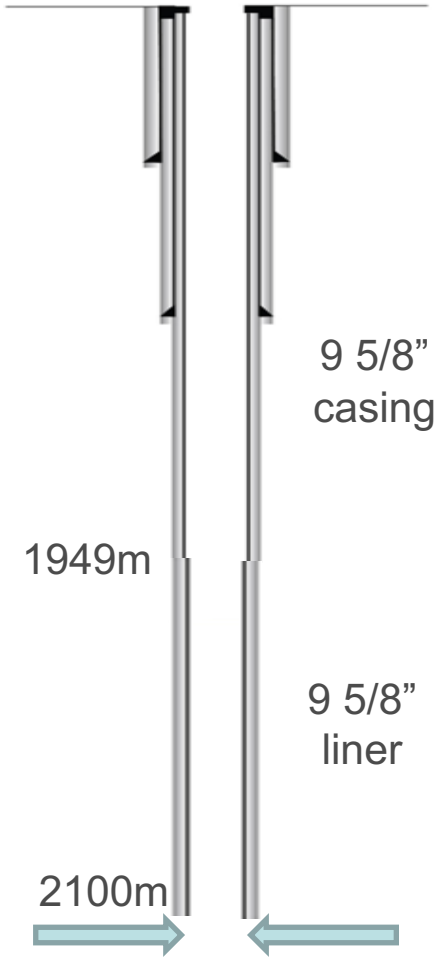
IDDP-1 well casing profile drawing (as built) (Friðleifsson et al. 2015).

- First IDDP well drilled in Iceland (2009)
- Target 4500m; TD at 2096m
- Did not reach supercritical reservoir.
- Heat-up for seven months

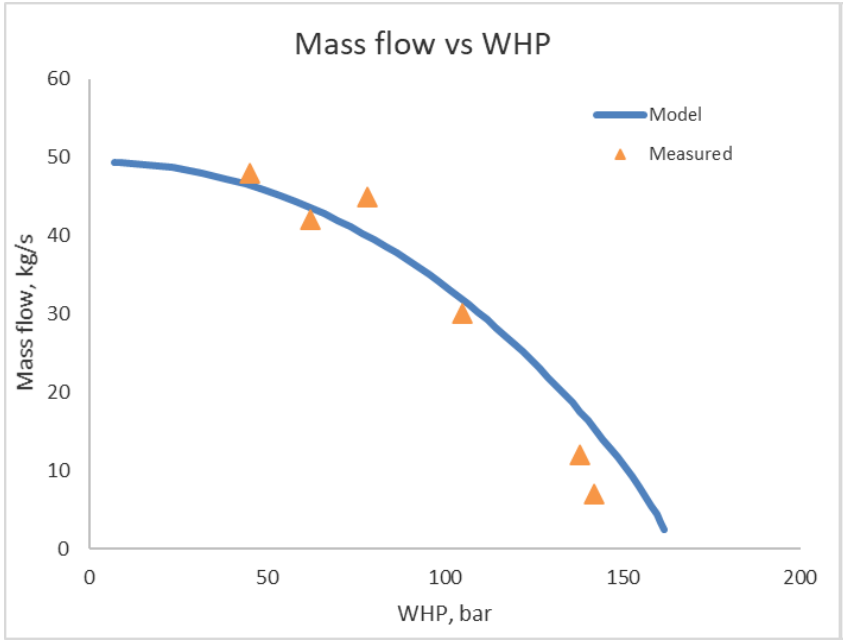
Five stages of discharge testing were done, which created a bore output curve.

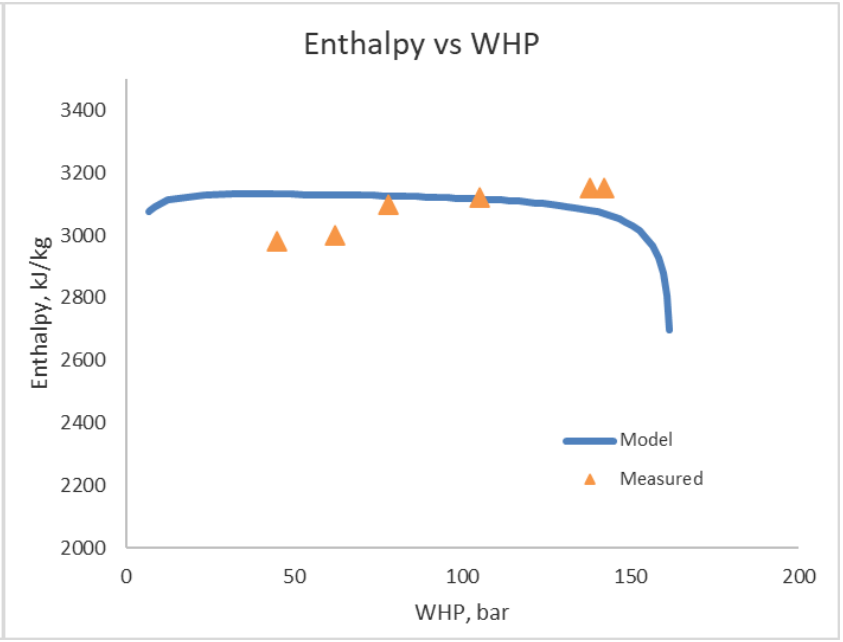
Max MF = 50 kg/s; H = 3000 kJ/kg

Case 1: Calibration of Well IDDP-1 Discharge Test Data



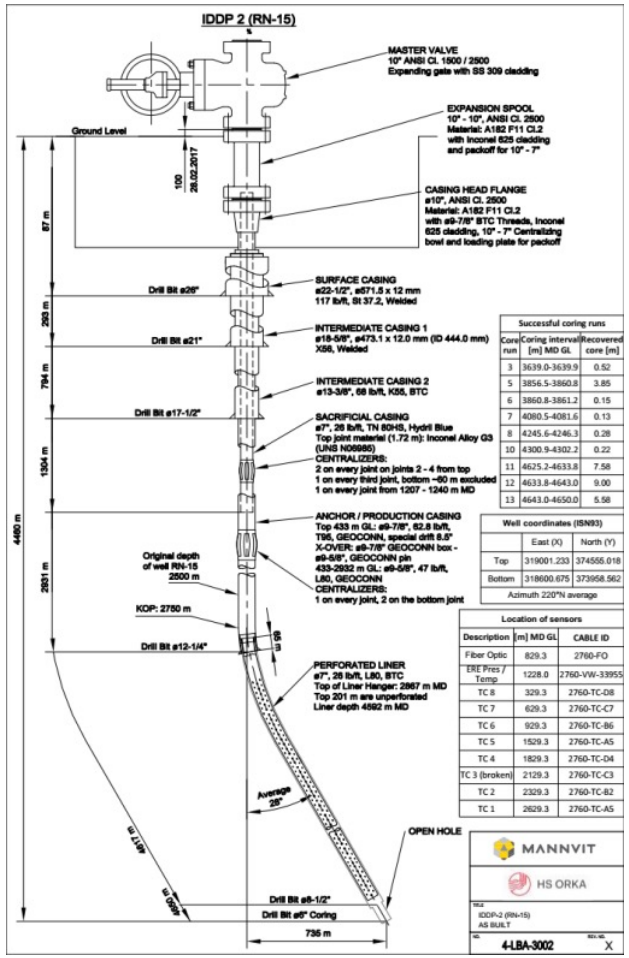
P =180 bar
T = 470°C





Productivity Index = 2.9×10^{-12} m^3

Case 2: Calibration of Well IDDP-2 Injection Temperature Data

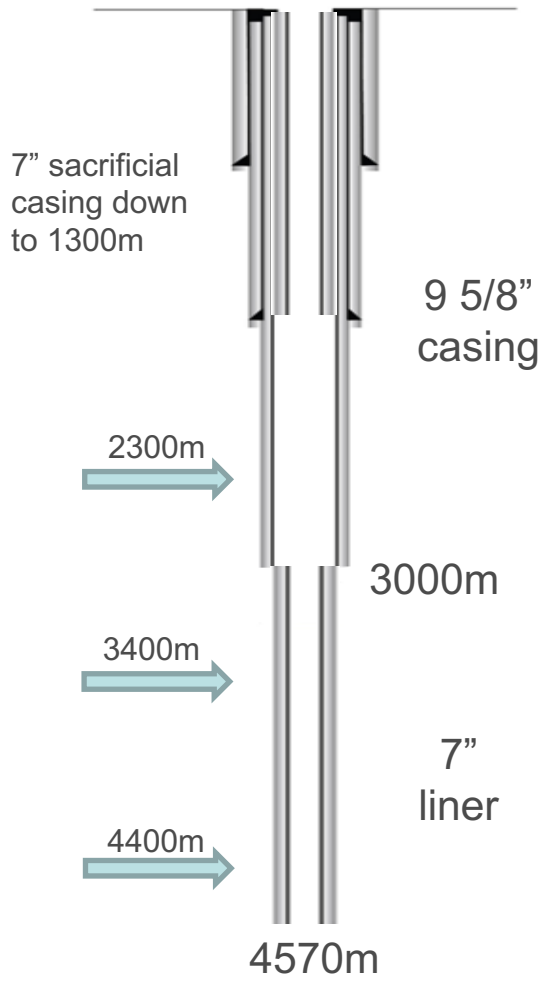


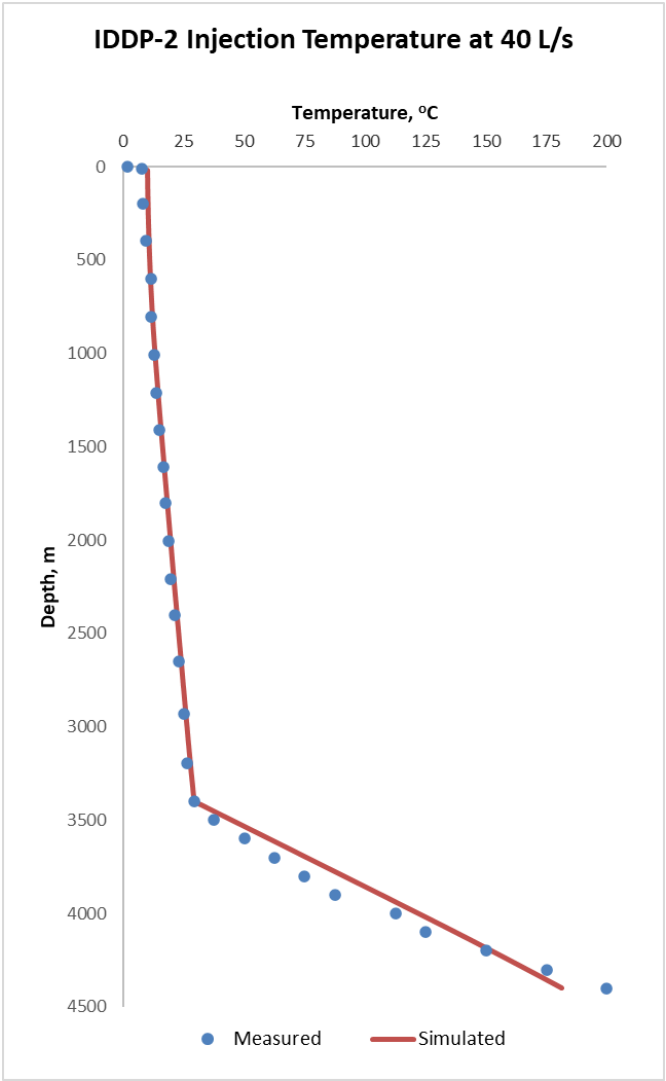
IDDP-2 well casing profile drawing (as built) (Stefansson et al., 2017).

- Deepest well in Iceland (2017)
- Deepened RN-15 (2500m) to 4569mMD.
- Reached the supercritical reservoir
- Good permeability found from the well.

Injection temperature log on Jan 2017 used for calibration.

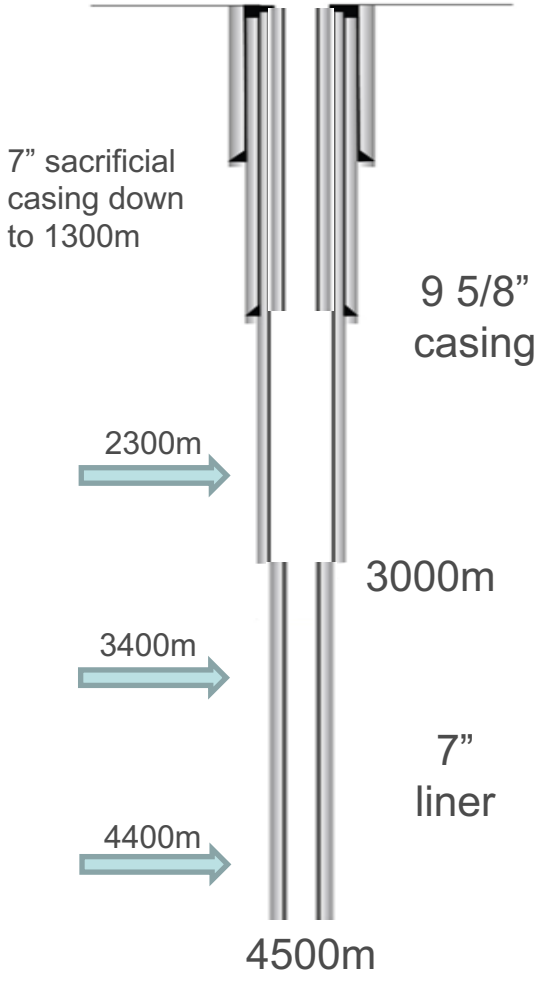
Case 2: Calibration of Well IDDP-2 Injection Temperature Data





Feedzone depth *m*	Injectivity Index *L/s/bar*	Productivity Index m^3
2300	0.013	1.36×10^{-13}
3400	0.356	3.27×10^{-12}
4400	0.017	2.85×10^{-14}

Case 3: Well Output Forecast of Well IDDP-2

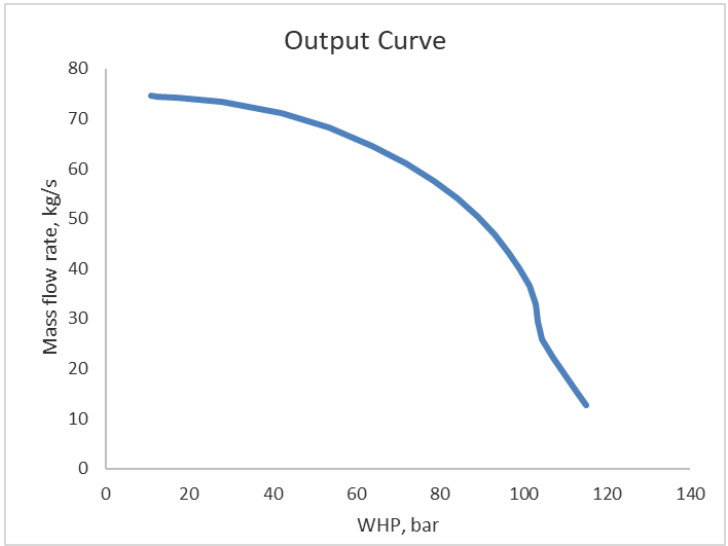


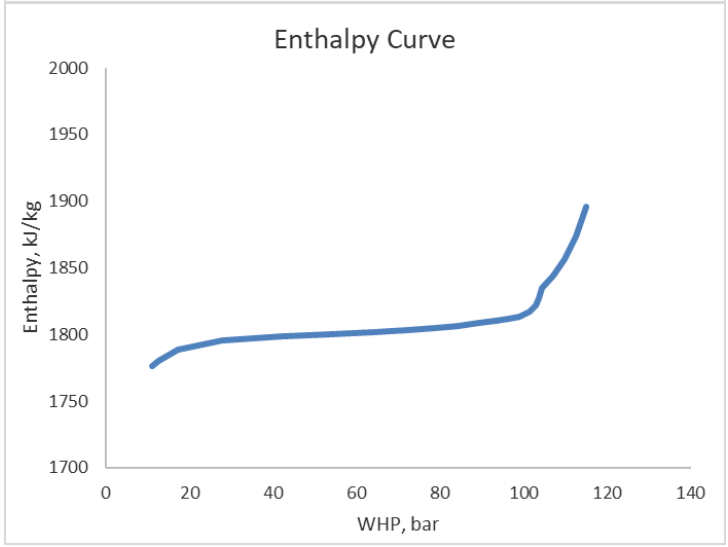
Feedzone Parameters

FZ Depth *m*	Temperature *^oC*	Pressure *bar*	PI *m^3*
2300	282	145	1.36×10^{-13}
3400	370	227	3.27×10^{-12}
4400	508	305	2.85×10^{-14}

Temperature profile from Hokstad and Tanavsuu-Milkevicienne (2017).
Hydrostatic pressure from water level of 540 m (Saether, 2020)
Productivity Index from Calibration

Case 3: Well Output Forecast of Well IDDP-2



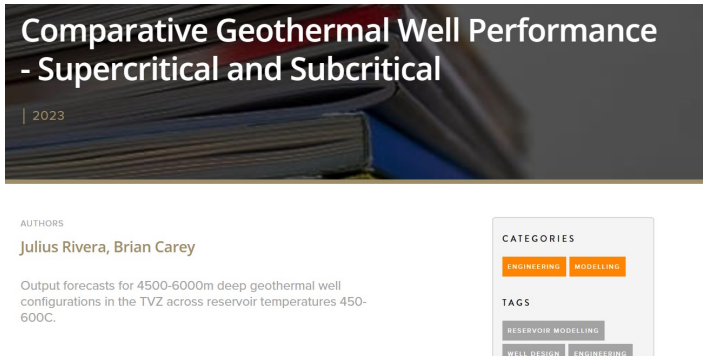


- **Output Estimate Result**
  - WHP of 50 bar
    - MF = ~60 kg/s
    - H = ~1800 kJ/kg
  - WHP of 10 bar (assumed FO)
    - MF = 75 kg/s
    - H = 1780 kJ/kg

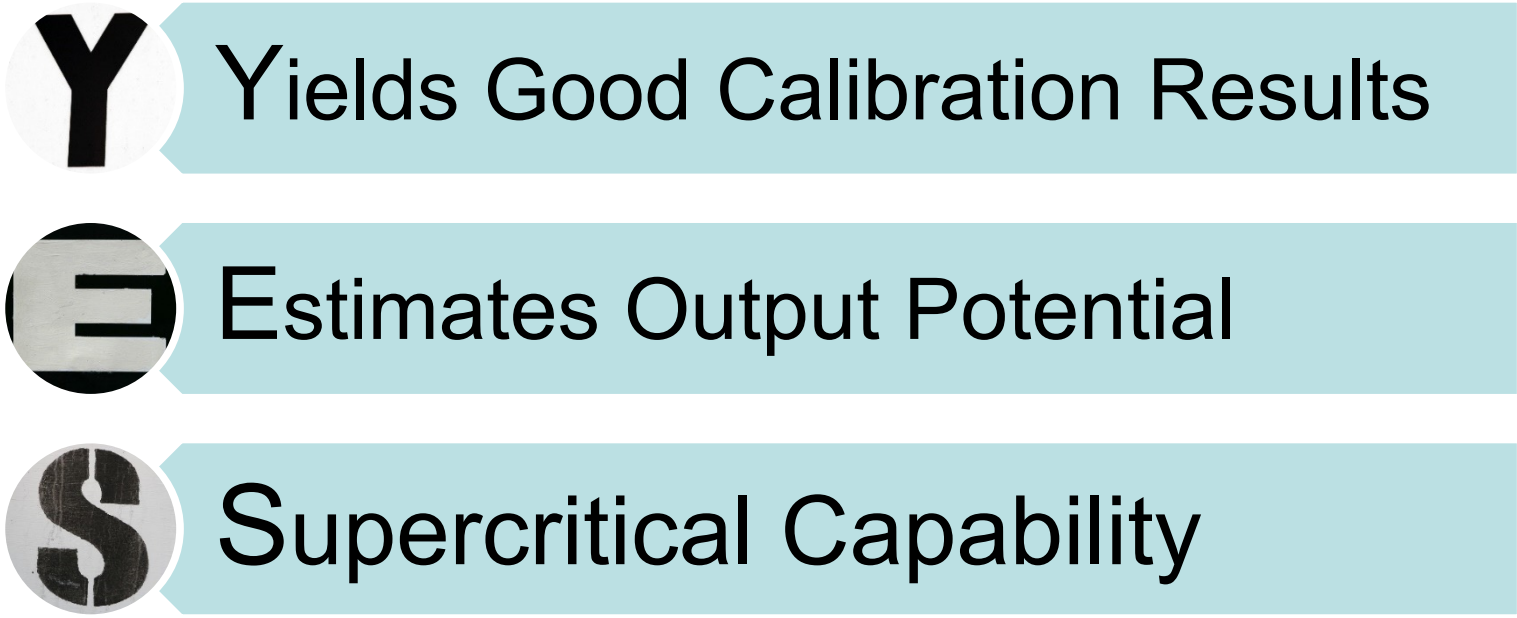
Where else did we use GFLOW?

- **TVZ Supercritical Wellbore Modelling and Simulation**
  - by Rivera, Carey, and Chambefort (2023)
  - Presented in 2023 Geothermal Rising Conference (GRC) 1-4 Oct

- **Comparative Geothermal Well Performance Report**
  - GNS Science Report 2023/01 (Rivera and Carey)
  - https://www.geothermalnextgeneration.com



Are we going with GFLOW?



We GO with **GFLOW**

Thank you very much
Ngā mihi nui

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