TerraThermal®

SuperWell

A Simple Well Bore Flow Simulator in Spreadsheet Format

Mike Timlin

TerraThermal
80 Pelican Lane
Redwood City, CA 94065-1575 USA
MTimlin@TerraThermal.Com

TerraThermal®

ABSTRACT

- Well testing is a key tool for the initial measurement and ongoing monitoring of well properties.
- By coupling it with well bore flow simulation, we can gain valuable information about well and reservoir properties.
- We can use this information to maintain the "health" of our reservoirs and wells.
- We can improve and optimize well and reservoir productivity, providing significant return on our geothermal investments.
- This report outlines the specification, development and testing of a simulator that solves geothermal problems.

TerraThermal®

INTRODUCTION

- Well testing is a very broad topic, comprising a variety of transient and steady state tests, such as injection, warm-up, flow and interference.
- Situations can be classified by well status and fluid flow.
- Well bore flow simulation can provide:
  - Rapid calculation of well output curves
  - Low cost, precise, well sizing studies
  - Down hole pump benefit analysis
  - Well test robustness checking
  - Detection of well damage
  - Decline curve analysis
  - Scaling risk analysis
  - Well histograms

TerraThermal®

SURVEY

- Measured well head values are generally available.
- Casing shoe, slotted liner, and bottom hole values are wanted: not difficult to extremely difficult to calculate.
- Multiple feed zones, a distributed feed zone, or a combination of multiple, distributed feed zones complicate calculations.
- Thermodynamic properties of pure water are very well known.
- Two-phase flow of geothermal water is prevalent, with liquid flashing into vapour and/or vapour condensing into liquid.
- CO_2 and NaCl can proxy for dissolved gas and solid species.
- Many simulators exist; SuperWell implements the ESDU methodology in a spreadsheet approach.

PROCEDURES

- Stepping down

$$P(z+dz) = P(z) + \left[\left(\frac{dP_g}{dz}\right) + \left(\frac{dP_f}{dz}\right) + \left(\frac{dP_a}{dz}\right)\right] \cdot dz$$

- Haaland equation

$$f = \frac{1}{12.96 \cdot \left\{ Log\left[\left(\frac{\varepsilon/D}{3.7}\right)^{1.11} + \left(\frac{6.9}{\mathrm{Re}}\right)\right]\right\}^2}$$

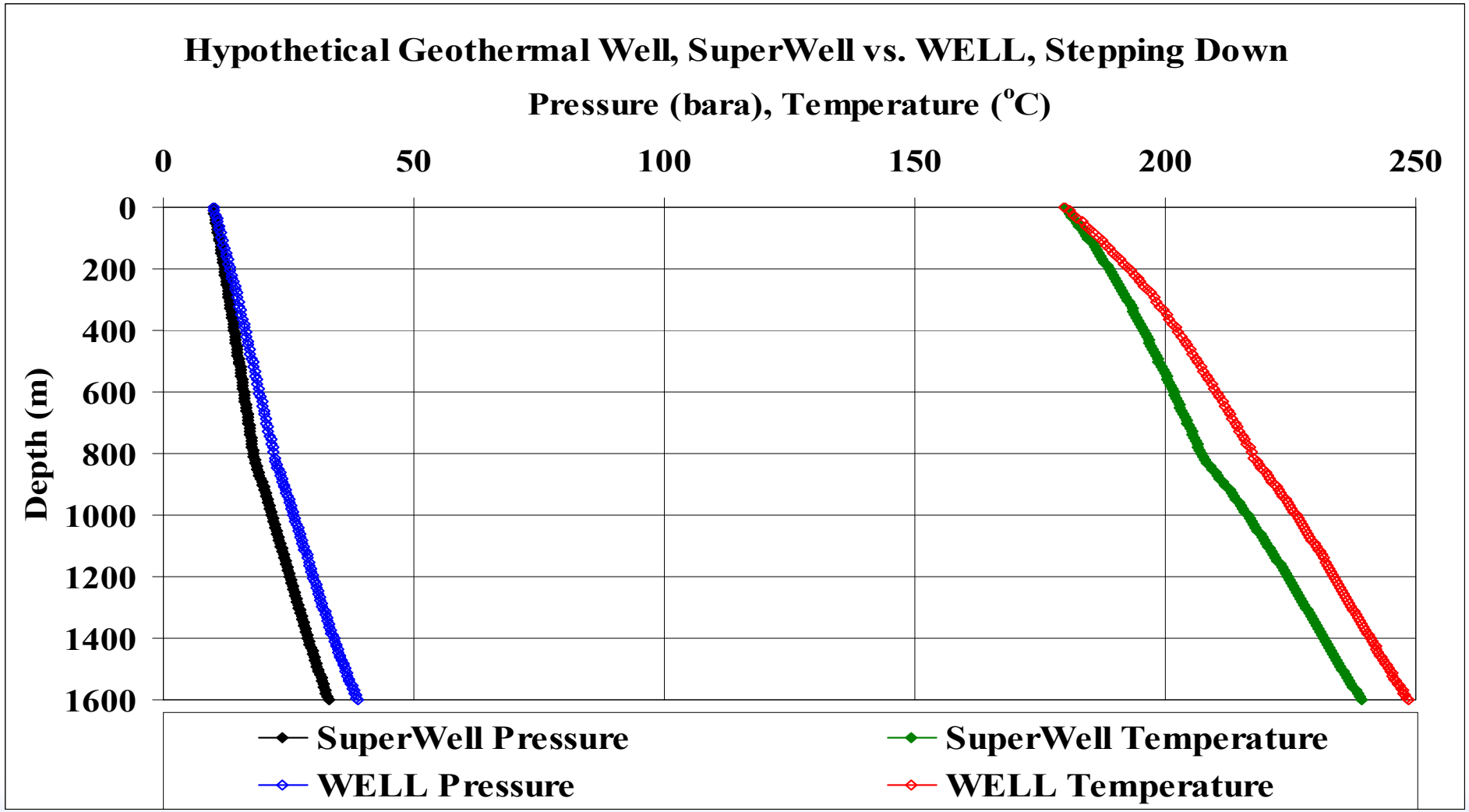
- Stepping up

$$P(z-dz) = P(z) - \left[\left(\frac{dP_g}{dz}\right) + \left(\frac{dP_f}{dz}\right) + \left(\frac{dP_a}{dz}\right)\right] \cdot dz$$

- Output curve

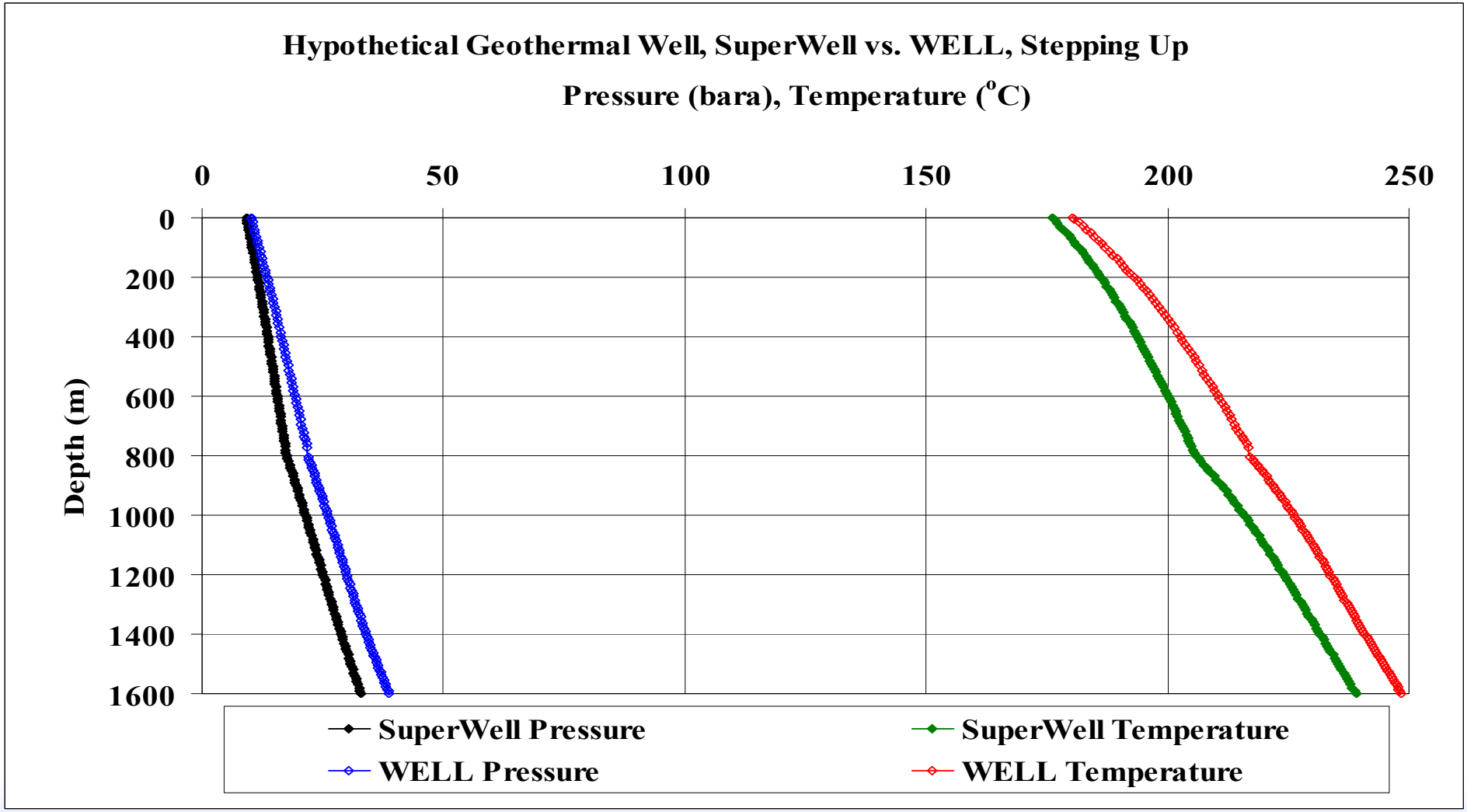
TerraThermal®

STEPPING DOWN



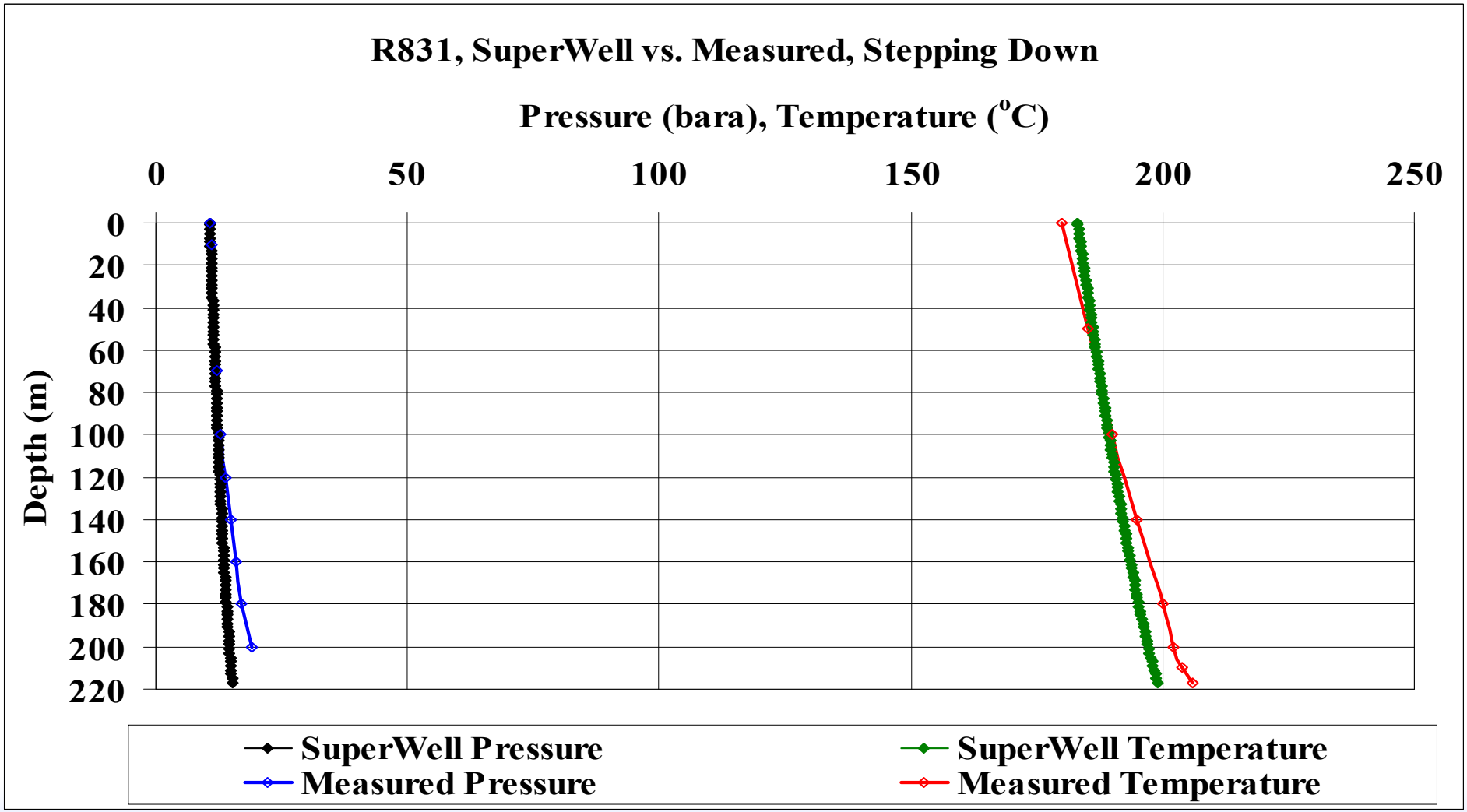
TerraThermal®

STEPPING UP



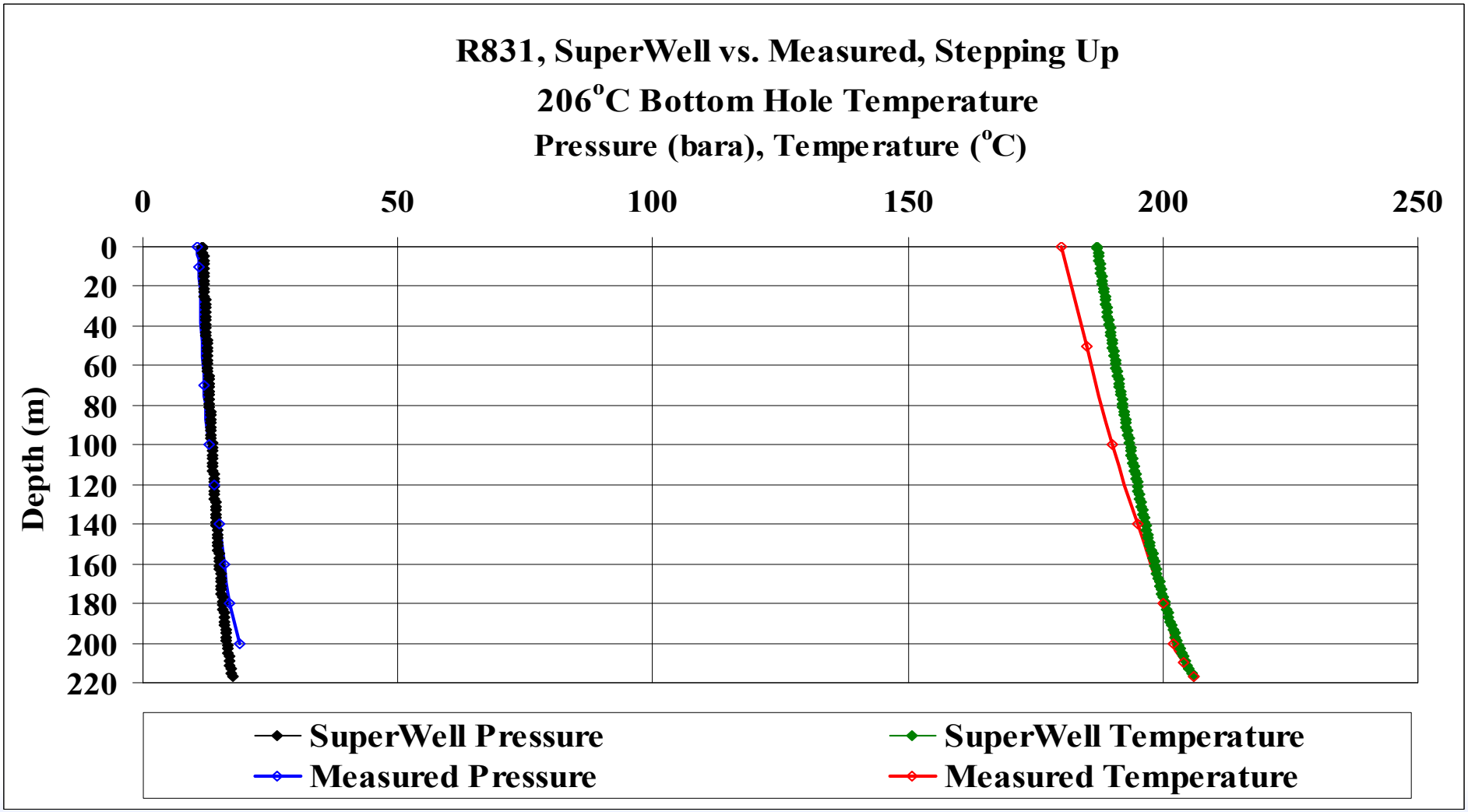
TerraThermal®

R831, STEPPING DOWN



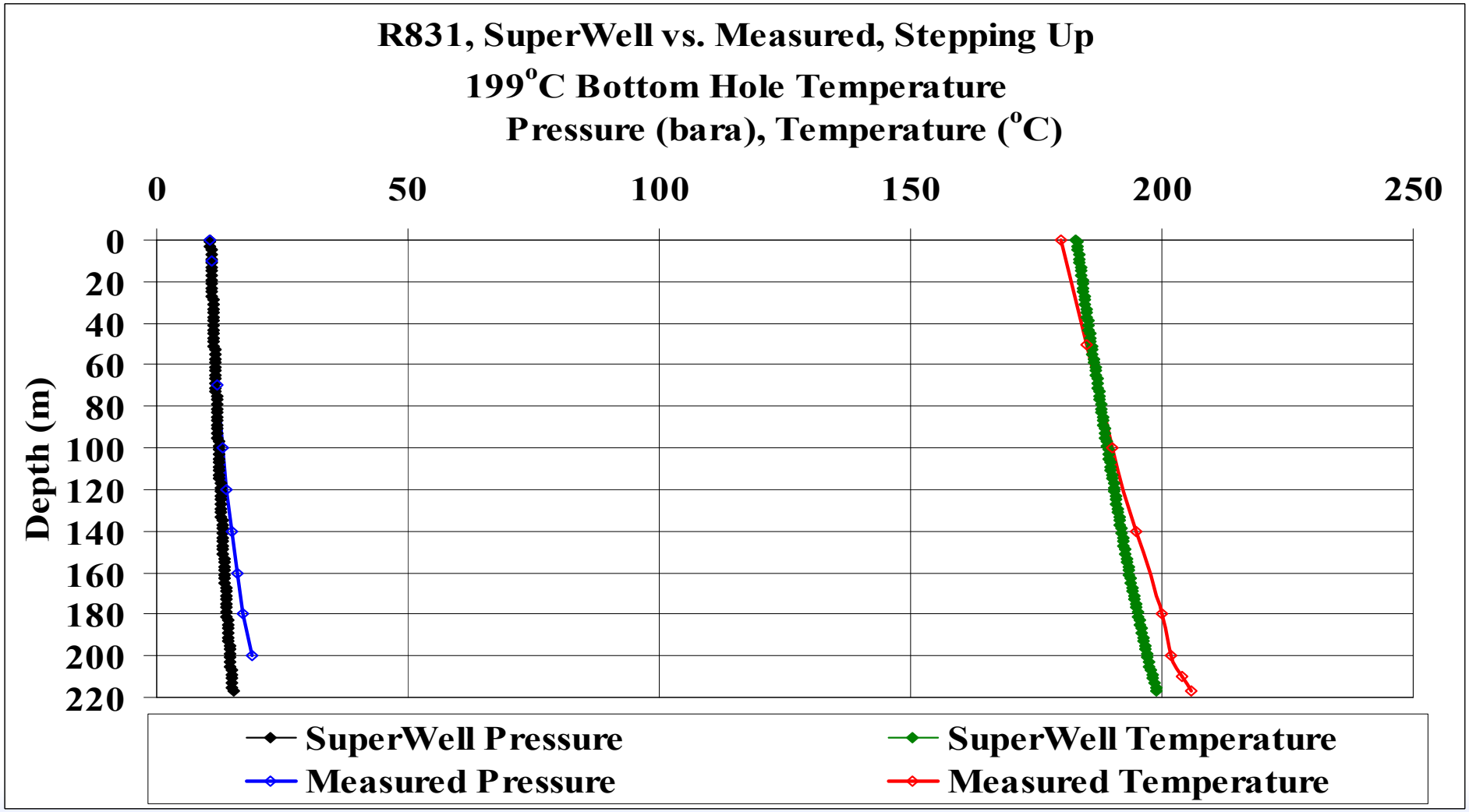
R831, STEPPING UP, 206°C

TerraThermal®



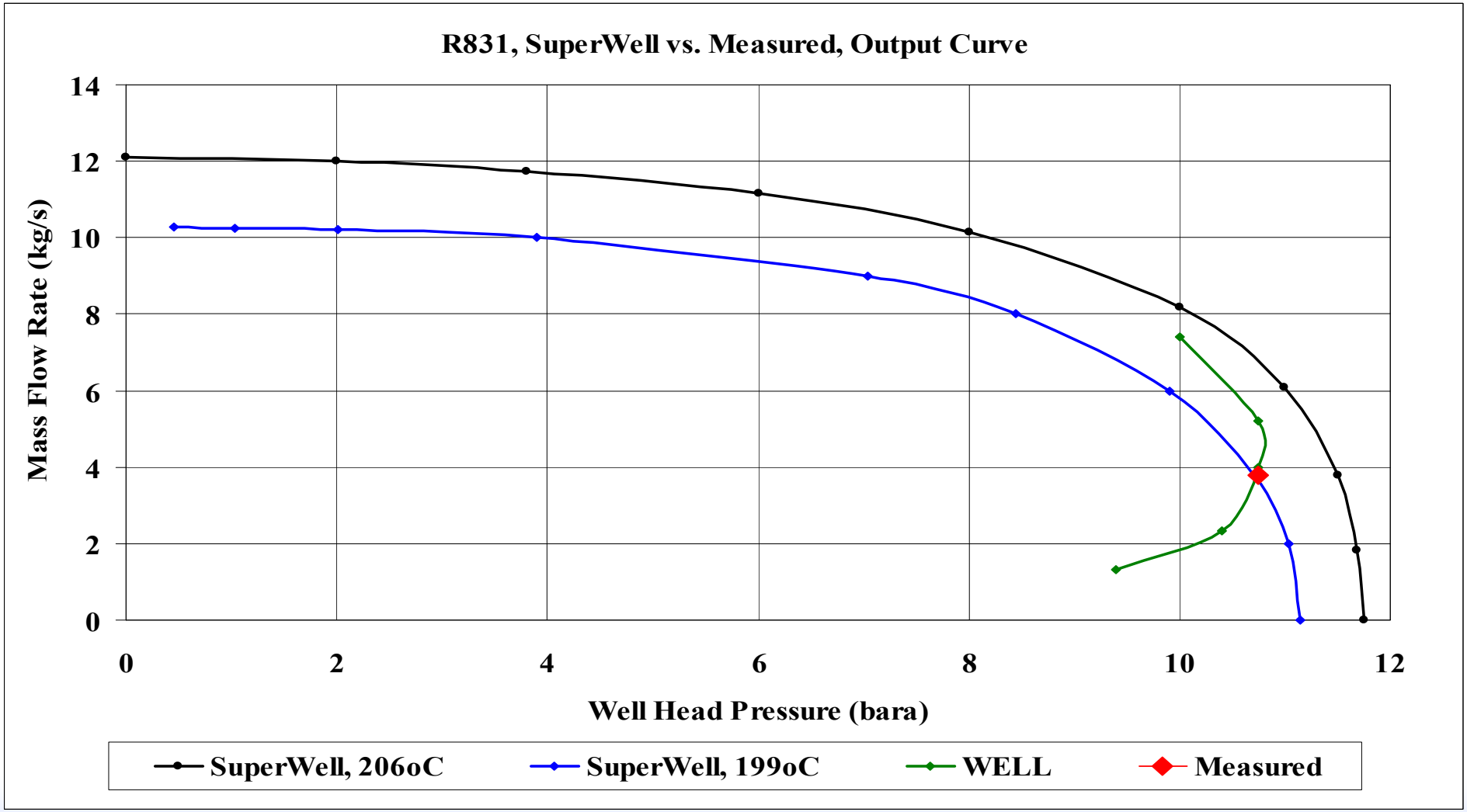
TerraThermal®

R831, STEPPING UP, 199°C



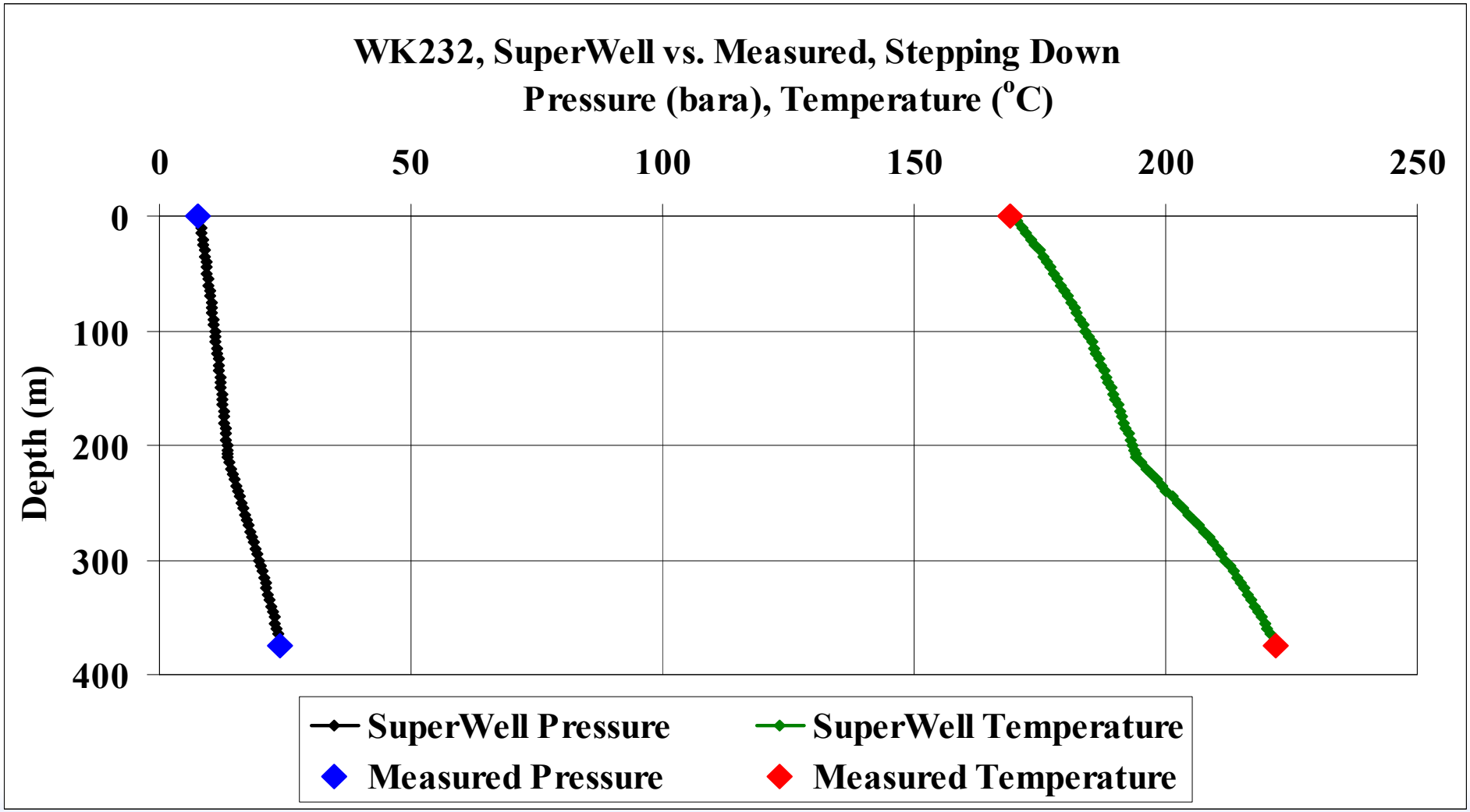
TerraThermal®

R831, OUTPUT CURVE



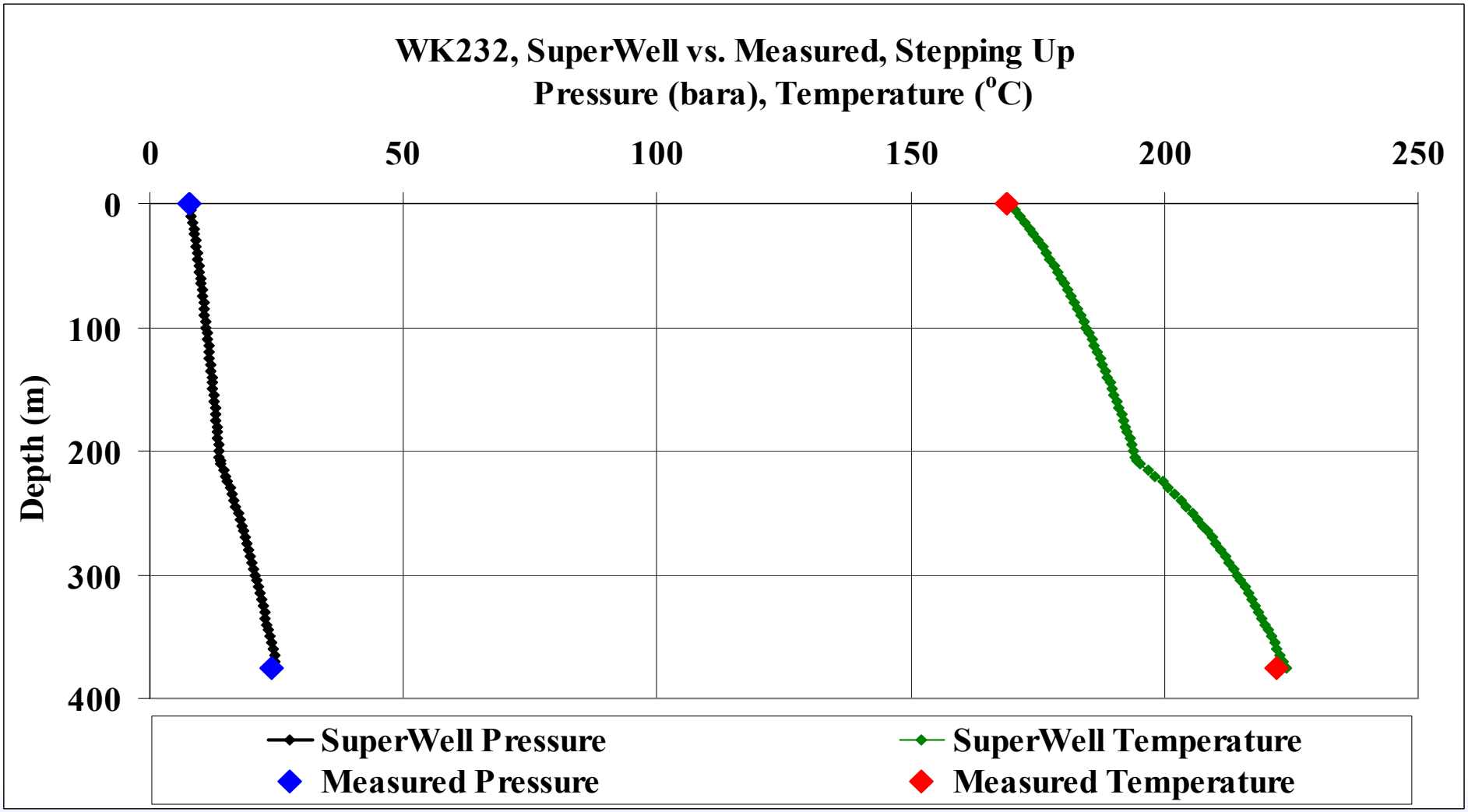
WK232, STEPPING DOWN

TerraThermal®



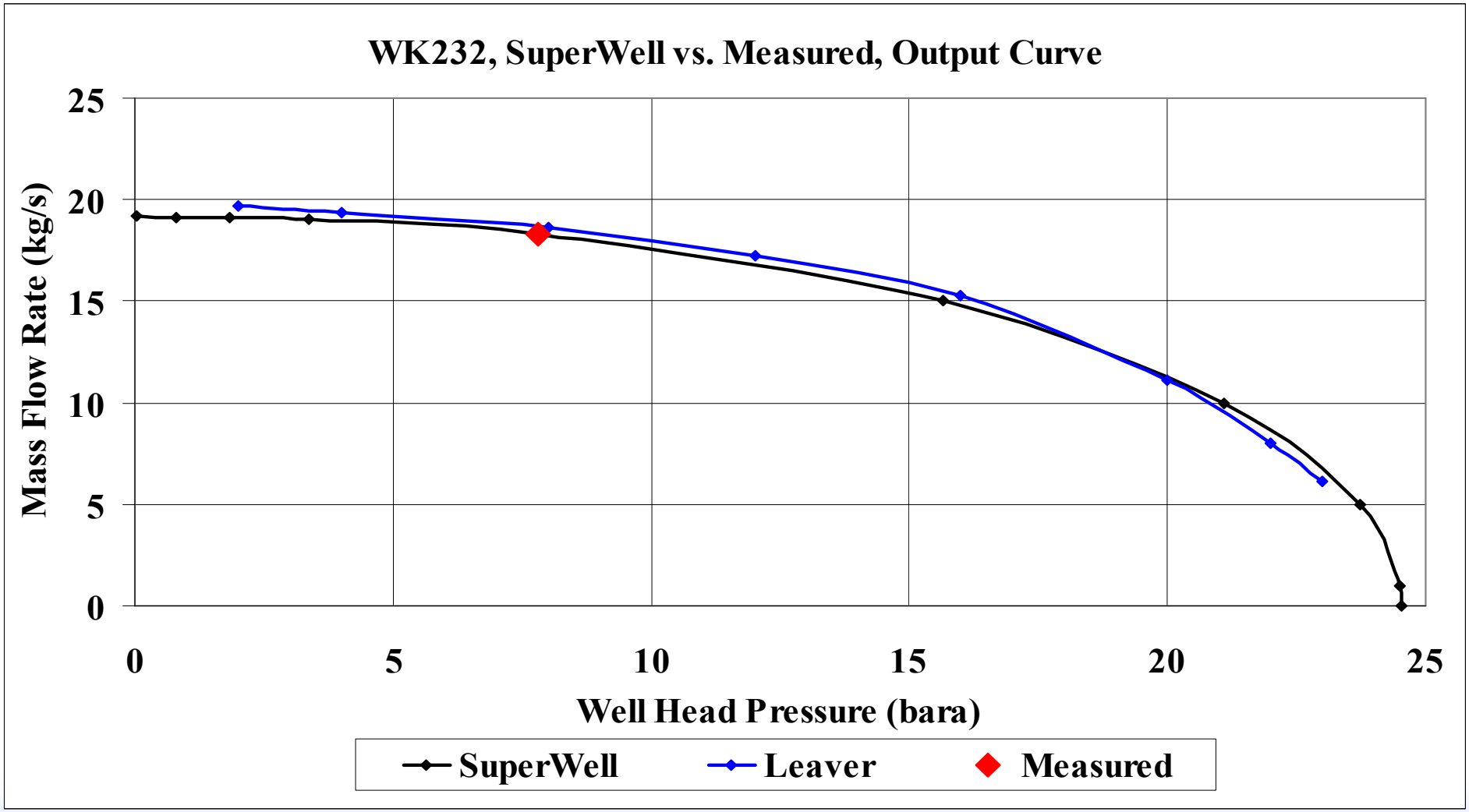
TerraThermal®

WK232, STEPPING UP



TerraThermal®

WK232, OUTPUT CURVE



TerraThermal®

CONCLUSIONS

- High quality results are easily obtained.
- Further testing is needed to validate robustness.
- Multiple and/or distributed feed zones can be handled.
- Spreadsheet format is very popular; it improves productivity.
- There are still a number of improvements that can be made:
  - Down hole pumps need to be addressed.
  - Gases and solids may need to be addressed.
  - Water phase transitions need to be addressed:
    - from subcooled liquid to saturated liquid,
    - to two-phase flow of liquid and vapour,
    - to saturated vapour,
    - to superheated vapour.

TerraThermal®

ACKNOWLEDGEMENTS

- The Geothermal Institute, University of Auckland, NZ
- Dr. Sadiq Zarrouk, my advisor
- Greg Ussher and Peter Barnett of Sinclair Knight Merz
- Technical staff and management at Boart Longyear, Century Resources, Contact Energy, and GNS Sciences
- Electronic steam table functions from Paul Bixley of Bixley Geothermal Consultants and Roland Horne of Stanford University
- The entire staffs of Grafton Hall, the Geothermal Institute, and the University of Auckland

REFERENCES

- BRENNAND, A.W. AND WATSON, A. (1987)
- ENGINEERING SCIENCES DATA UNIT (1971)
- FREESTON, D.H. AND HADGU, T. (1987)
- HAALAND, S.E. (1983)
- HADGU, T. (1989)
- KARAALIOGLU, H. (1998)
- LEAVER, J.D. AND FREESTON, D.H. (1987)
- ROTORUA GEOTHERMAL TASK FORCE (1985)
- SUBARKAH, F. (2001)
- SUGANDHI, A. (1997)
- SUTOYO (2001)