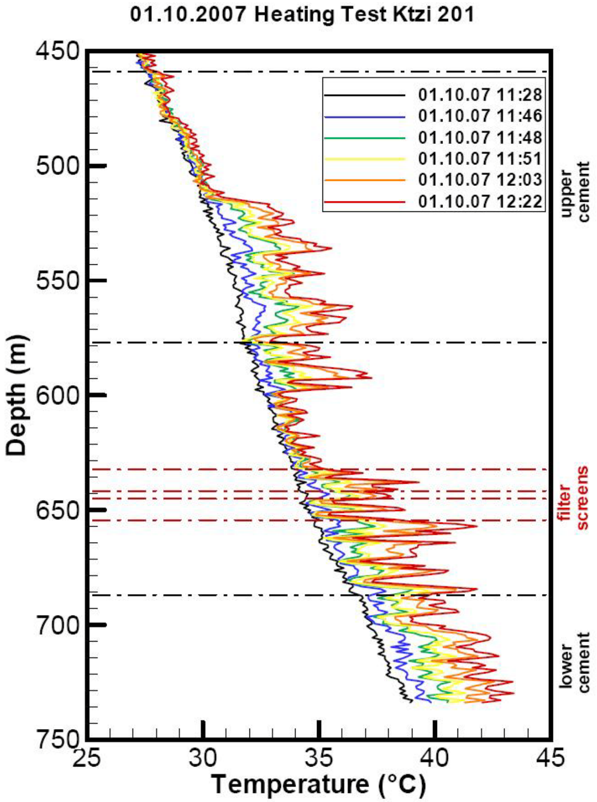
DTPS Images Courtesy GeoForschungsZentrum, Potsdam



Imaging Fluid Flow in Geothermal Wells Using Distributed Thermal Perturbation Sensing

May 18, 2010

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High Temperature Tools and Drilling

Project Overview

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Timeline
  - Project start – April 2010
  - Project end – September 2011
- Budget
  - Total project funding $400K, DOE share $400K,
  - Funding for FY10 $196K, DOE share $196K
- Barriers
  - “High temperature instrumentation for borehole imaging and other purposes is a key technology deficiency” (From multi-year RD&D Plan)
- Partners
  - High temperature hybrid cable manufacturer (contracting is in process)

Relevance/Impact of Research

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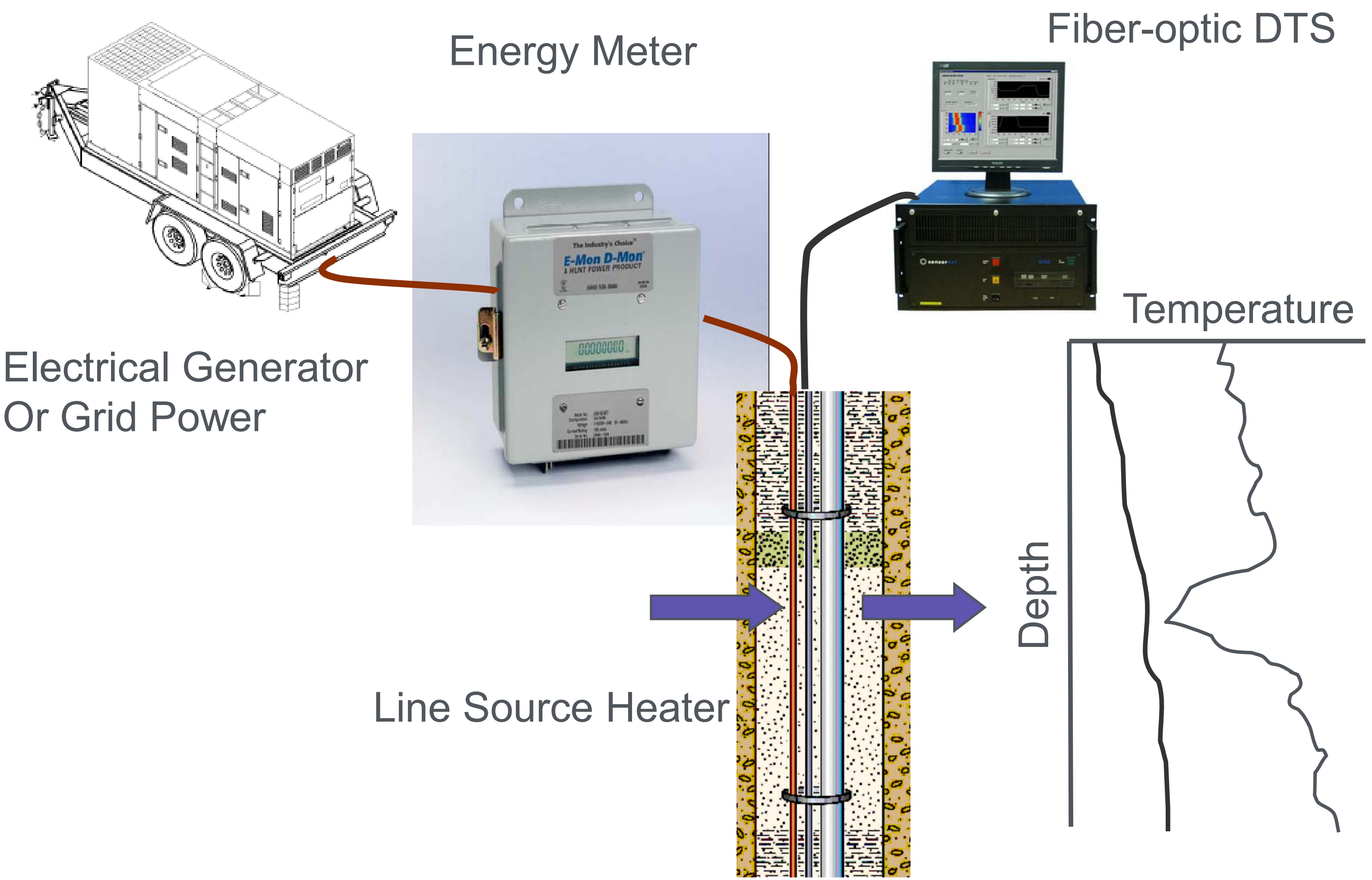
Project Objective – A New Geothermal Well Imaging Tool

1. To develop a robust and easily deployable DTPS for monitoring in geothermal wells, and
2. Develop the associated analysis methodology for flow imaging, and—when possible by wellbore conditions—to determine *in situ* thermal conductivity and basal heat flux.

- DTPS will permit the quantitation of flow distribution within a well and provide
- Cost effective methodology for thermal and hydrological property evaluation

Scientific/Technical Approach

- What is a Distributed Thermal Perturbation Sensor (DTPS)?



Scientific/Technical Approach

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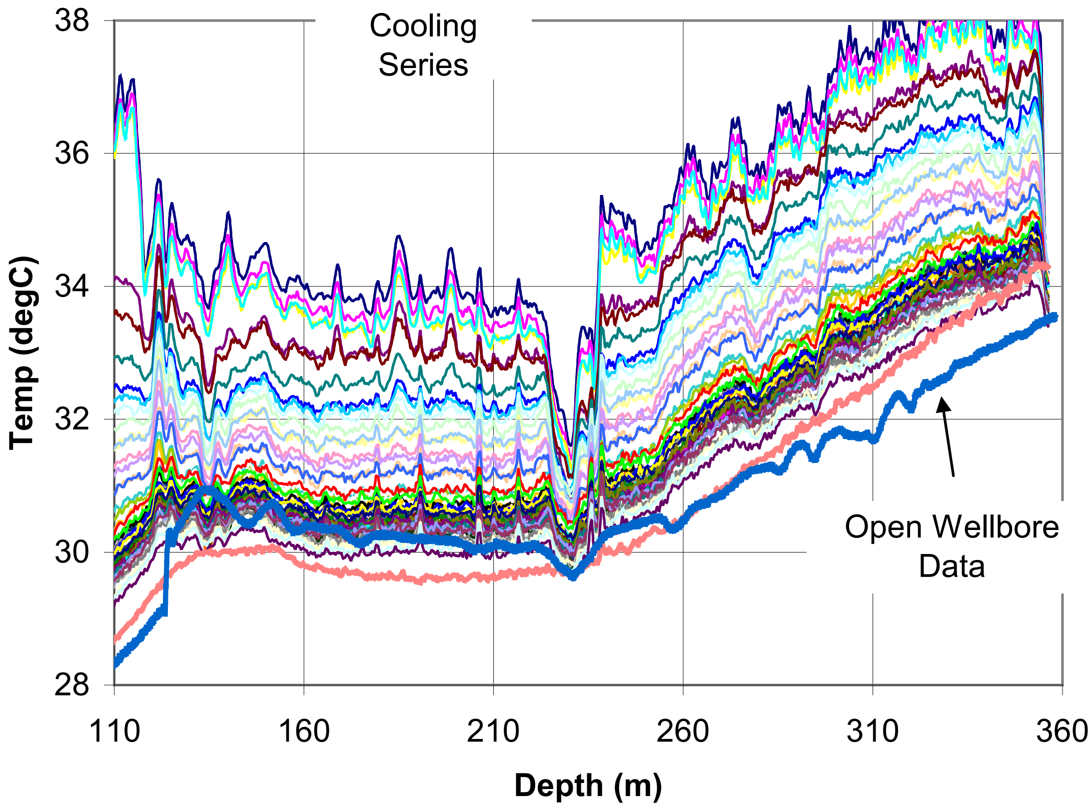
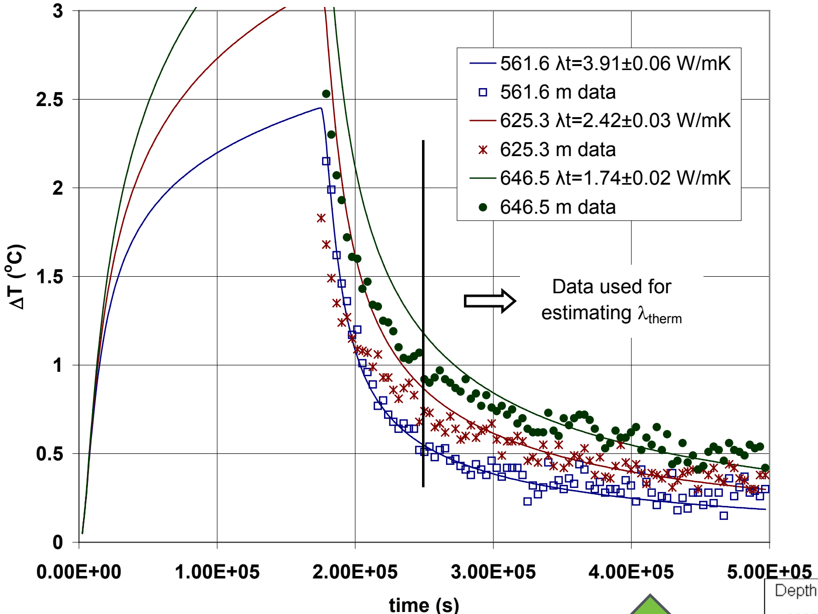
- DTPS Low Temperature Examples – Yucca Mountain, Nevada

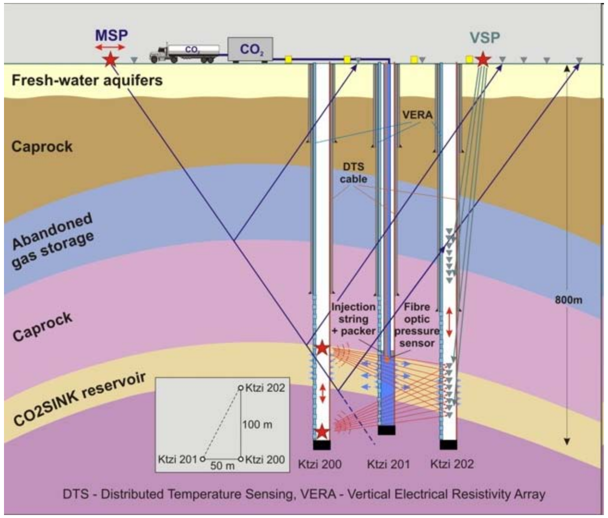


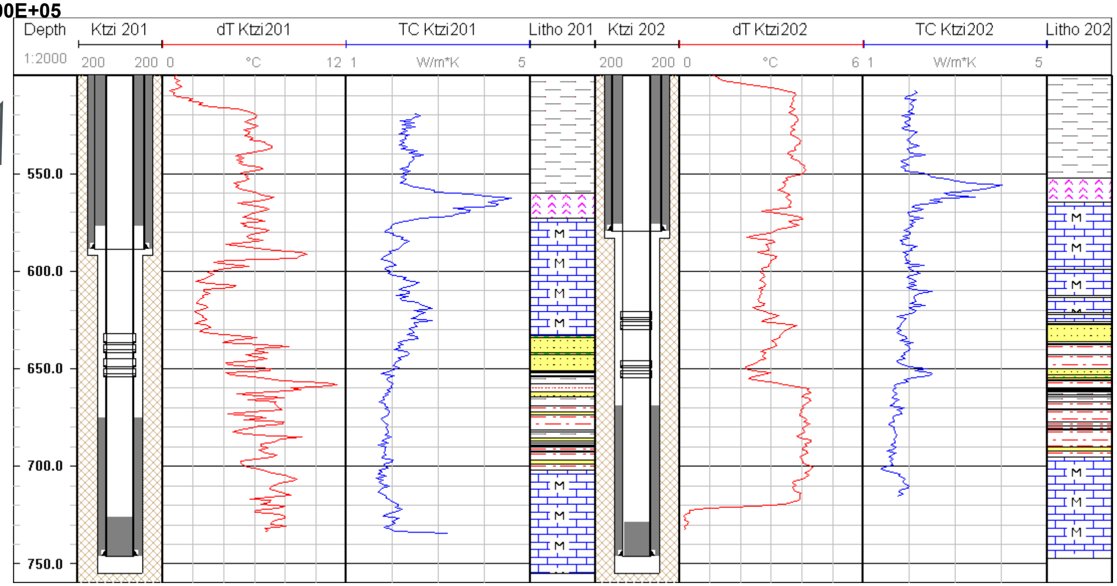
Other examples at CO2SINK, Ketzin Germany
High Lake Site, Nunuvut Territory, Canada

DTPS Data Reduction Example – CO2SINK

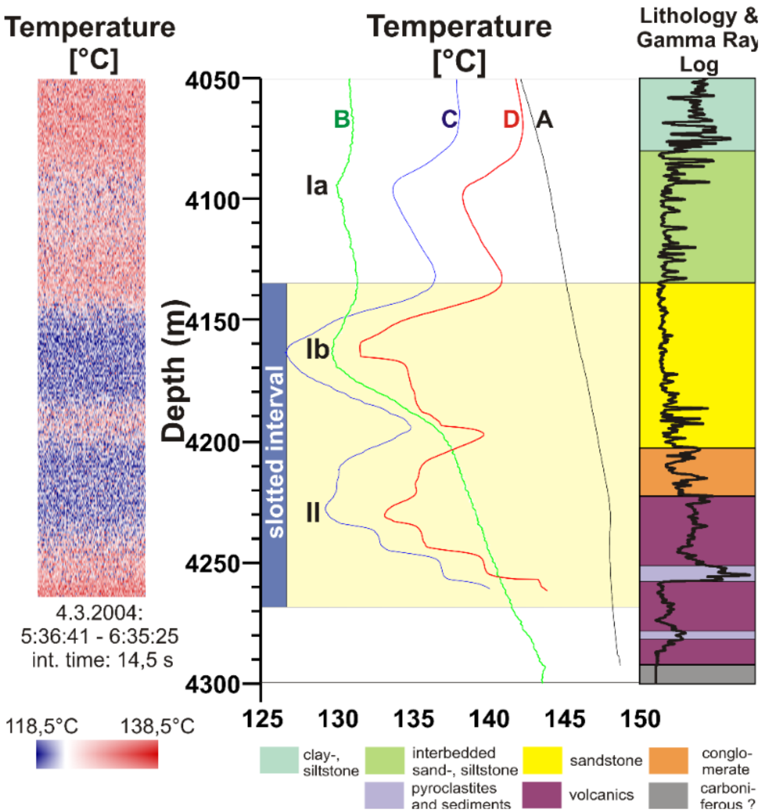


Well logs for Ktzi201 and Ktzi202 showing temperature changes (dT) during DTPS heating and calculated thermal conductivities (TC) along with well layouts and lithologies [after Förster et al., GHGT-9, 2008].





- Thermal Logging at Groß Schönebeck, Germany 100 m^3 cold water injection post-stimulation. (courtesy J. Henninges & E. Huenges)



Left: Colormap plot of DTS temperatures (left) and temperature logs (Henninges et al., 2005).

- **A = baseline after opening of well (Oct. 2001)**
- **B = before massive stimulation (Nov. 4, 2003)**
- **C = after cold water injection (Mar. 5, 2004)**
- **D = Apr. 28, 2004**

Hydraulic active zones are denoted as Ia, Ib, and II.

Example of DTS Imaging from Ikeda

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“fiber-optic distributed temperature log, when it is properly deployed, literally can visualize the fluid movement occurring in wellbore, which consequently makes it easier to diagnose what is behind causing such phenomena”…Ikeda, 28th Stanford Workshop on Geothermal Res. Eng.

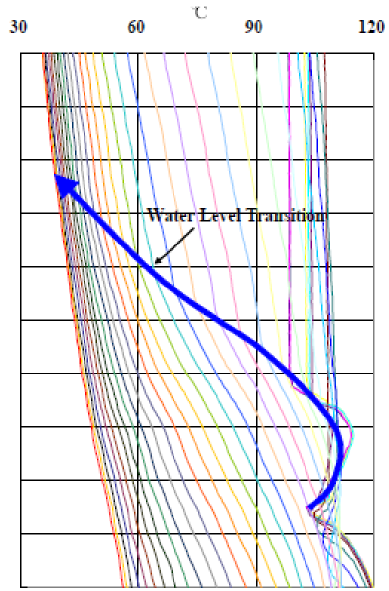


Figure 8. Temperature profiles and water level transition during injecting water.

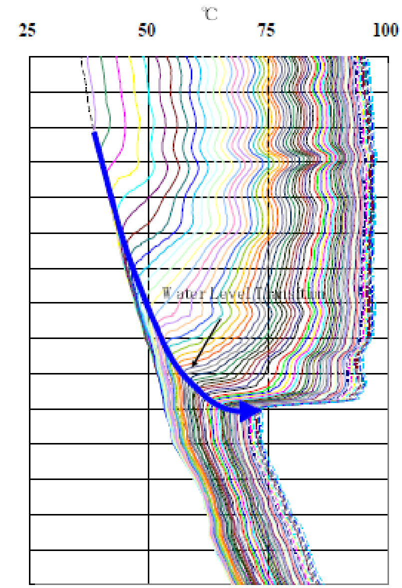
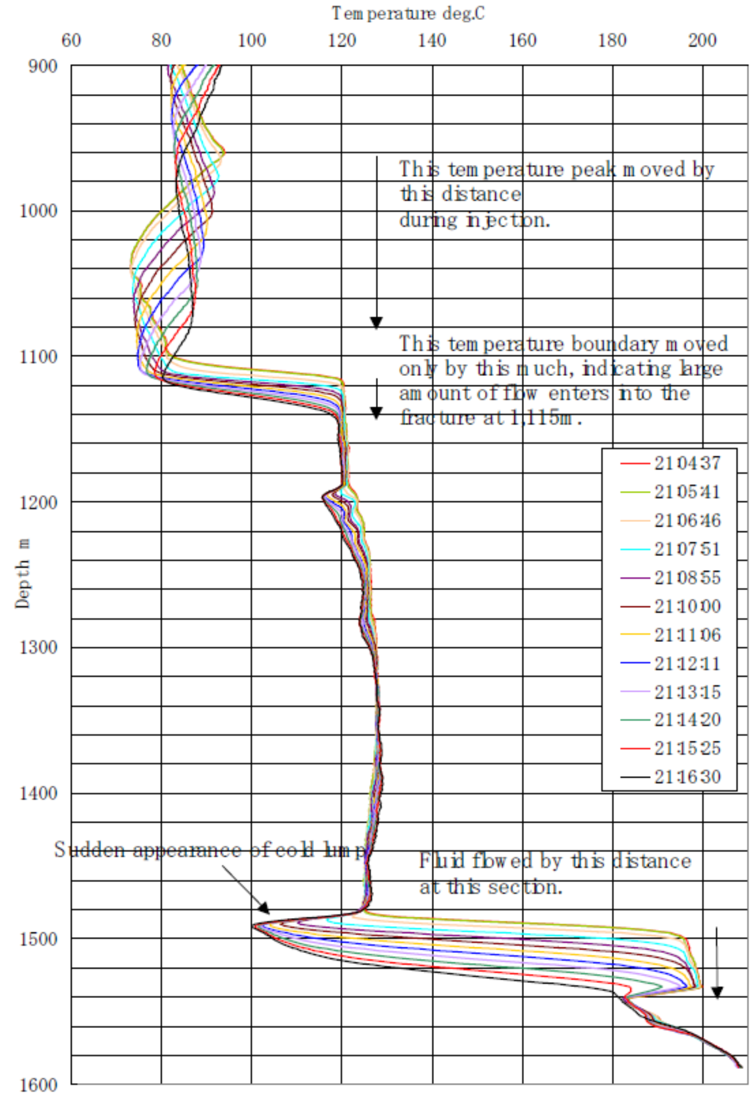


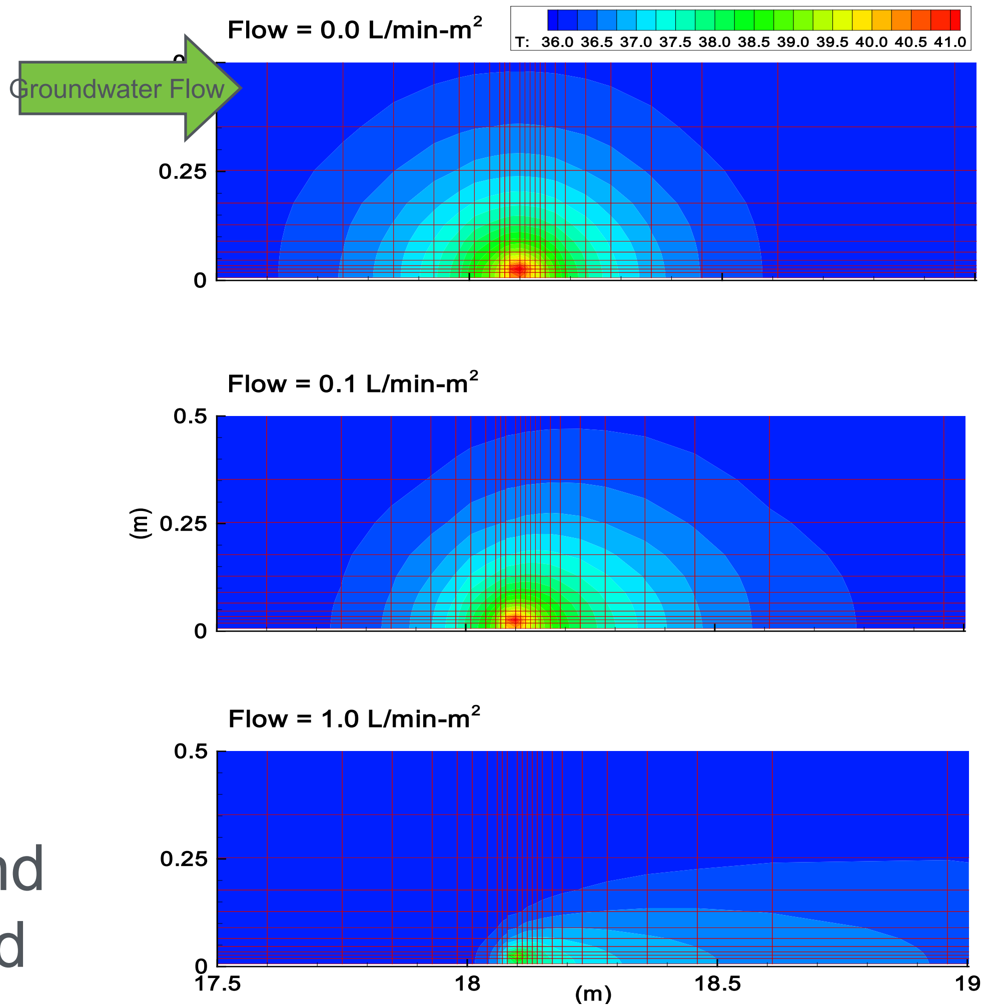
Figure 9. Temperature profiles and water level transition after stopping water injection.



Accomplishments, Expected Outcomes and Progress

- We have started the design process and scoping studies for prototype fabrication of a mid-temperature geothermal DTPS cable

- Future work - numerical sensitivity studies using existing data sets to determine applications and limitations of the proposed method



TOUGH2 Heat & Mass flow simulations of DTPS system

Project Management/Coordination

- Project management – effort split between co-PIs (2 yr effort)
  - Task 1 Development of DTPS cables suitable for application in mid- to high-temperature geothermal wells \$250k – Barry Freifeld
  - Task 2 Development of a numerical method for analysis of DTPS data for flow profile imaging and *in situ* determination of thermal conductivity profiles and heat flux \$100k – Stefan Finsterle
  - Task 3 – Reporting \$50k
- Schedule
  - FY10 Development of DTPS technology < 250° C (fabrication, bench top testing, numerical data reduction techniques)
  - FY11 Development of DTPS technology ≤ 350° C
- Leveraged Funds
  - DTPS is being used in some Carbon Sequestration demonstration projects (CO2SINK & CO2CRC Otway Project) → leveraging of engineering and modeling effort through cross fertilization is planned

Future Directions

- Identification and deployment at geothermal field sites.
  - Preliminary contacts have been made for potential field deployments at various sites
  - Depending on success of cable development will determine when we can go from technology development to technology demonstration
  - Decision point (go/no go) based upon success of bench top testing of a DTPS at elevated temperatures

DTPS Summary Slide

- The DTPS has successfully been used for non-geothermal applications
- Our program will develop the technology and methodology for application of DTPS for geothermal applications
- A successful outcome will be
  - Development of robust, deployable hardware
  - Software tools for interpretation of acquired data
  - Formulation of plans for technology demonstration at a field site