GEOTHERMAL UTILIZATION

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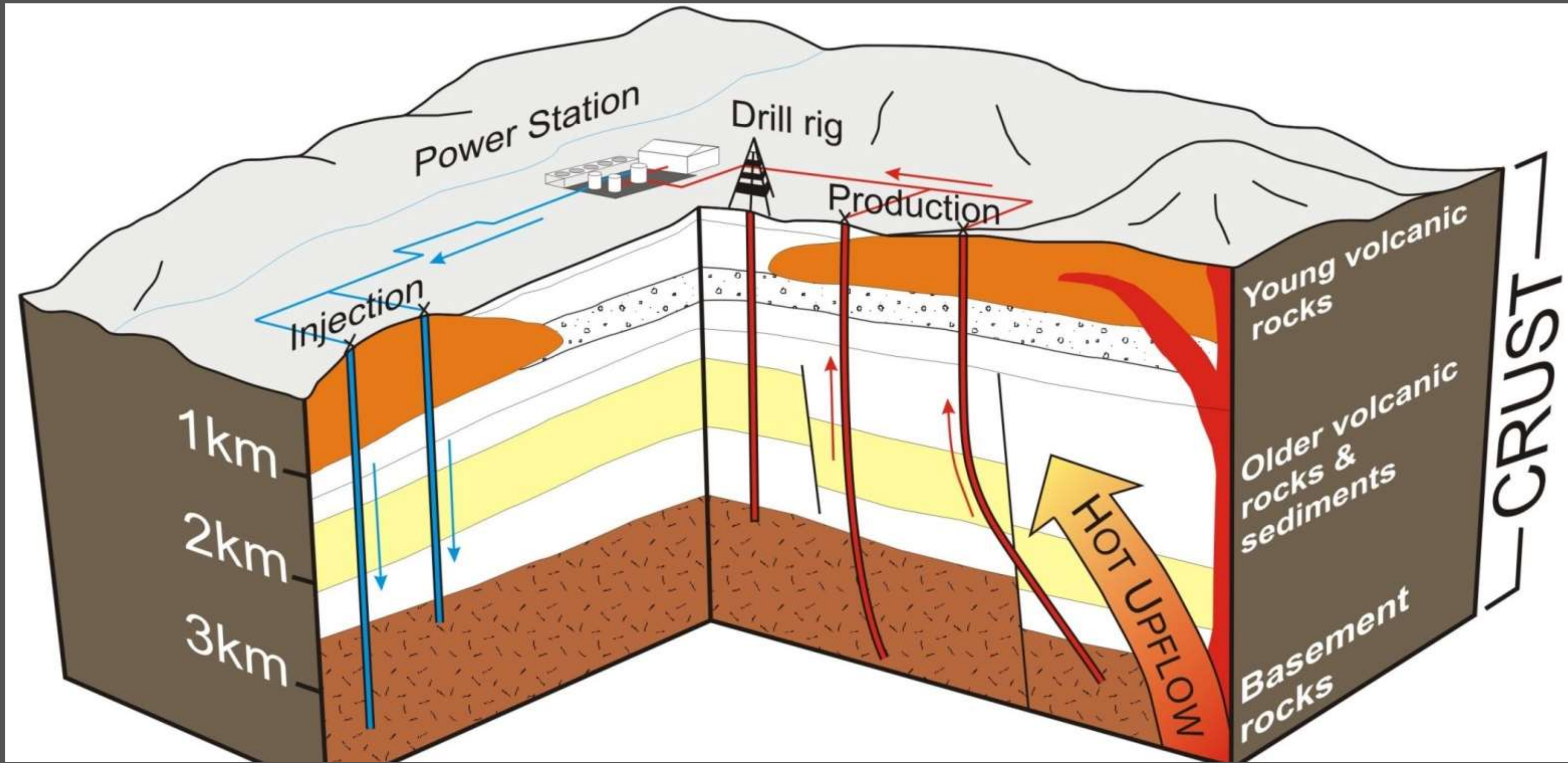
HE KAI
KEI AKU
RINGA

'There is food at the end of my hands'

A person (or people) should use their abilities and the resources around them to create success for them and future generations

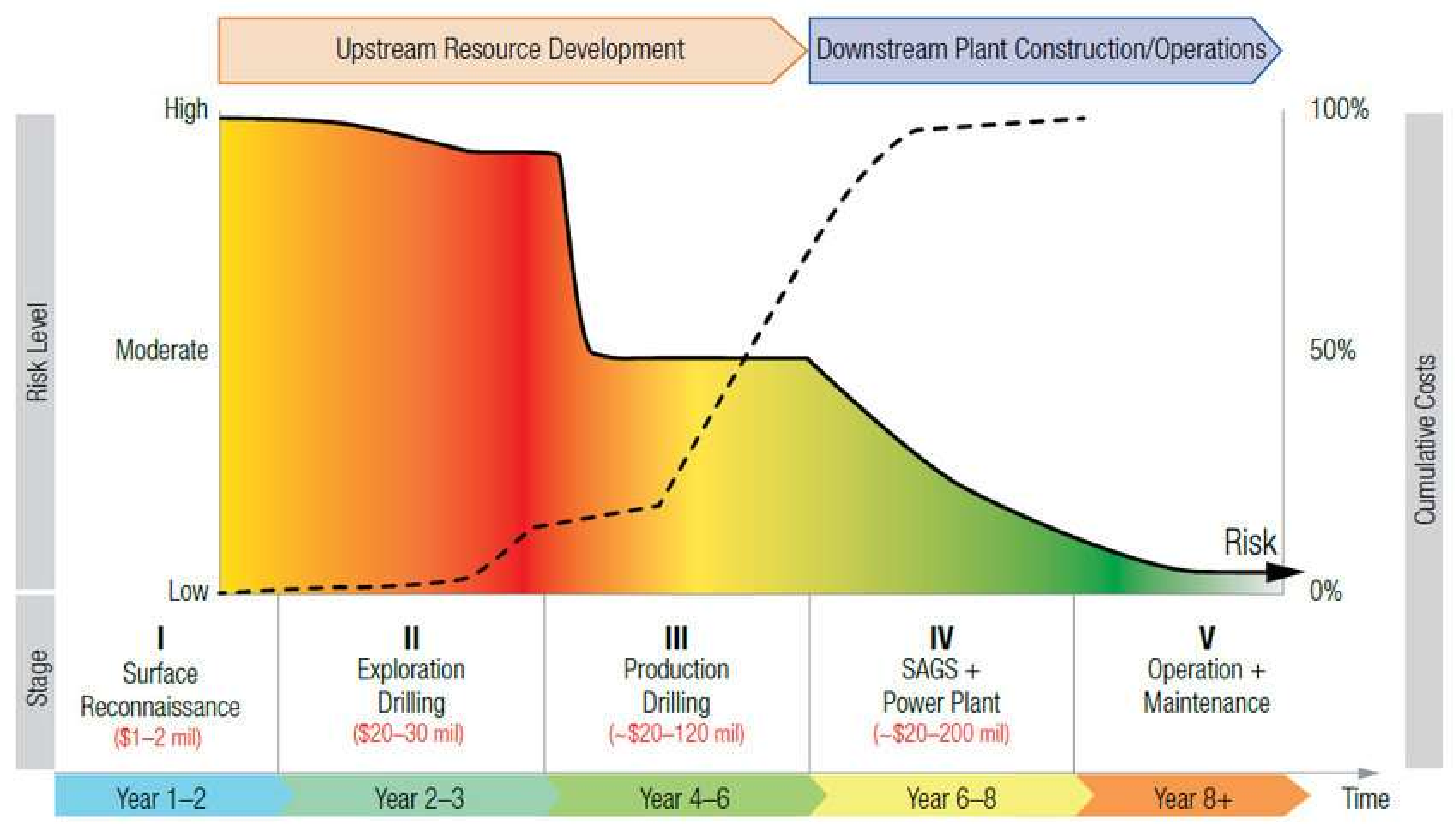
Upflow

Geothermal Electricity Developments



Credit: Karl Spinks, Western Energy Services

Geothermal Project Model



Exploration of viable geothermal energy business models for gas & oil (G&O) companies in the Netherlands - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/A-conceptual-representation-of-the-lifecycle-of-a-geothermal-projects-with-the_fig4_326734294 [accessed 24 Mar, 2019]

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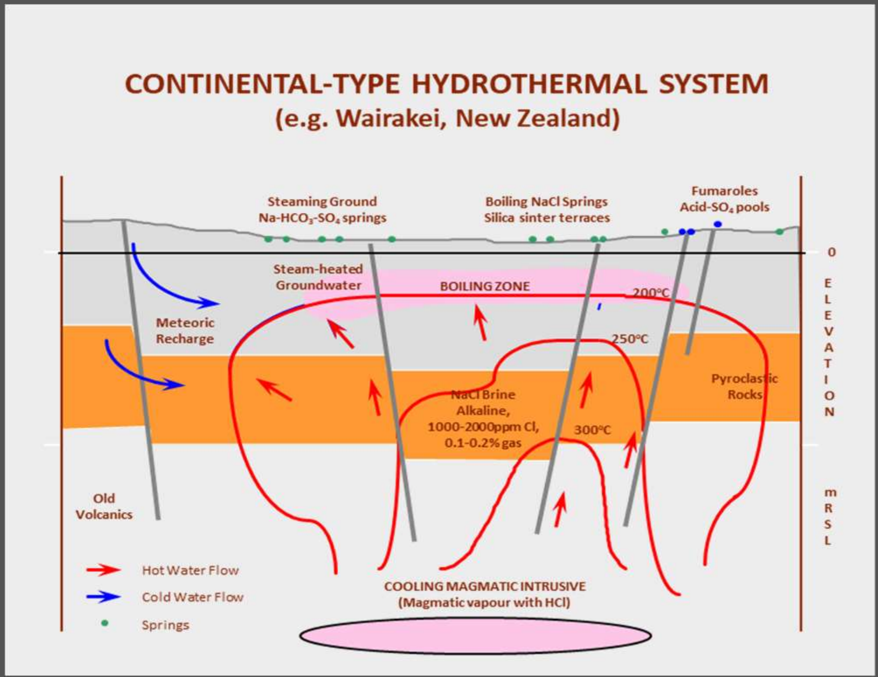
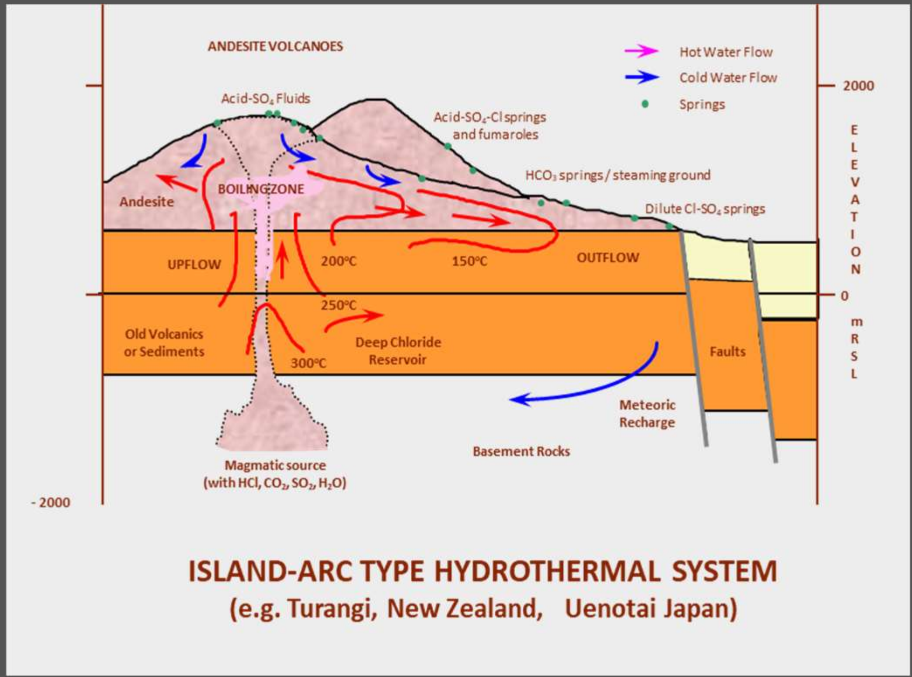
Types of Geothermal Systems

No two geothermal systems are the same



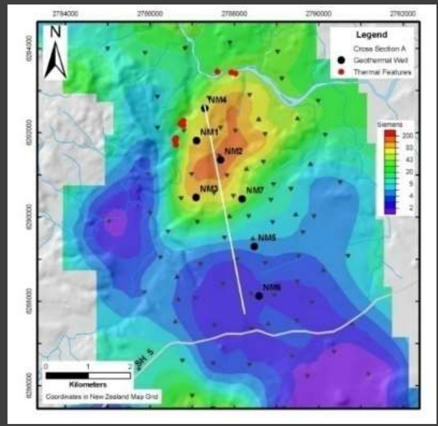


Credit: Greg Bignall, GNS Science

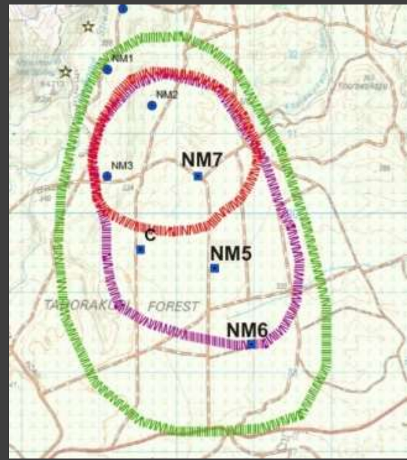
Exploration Process

Fieldwork

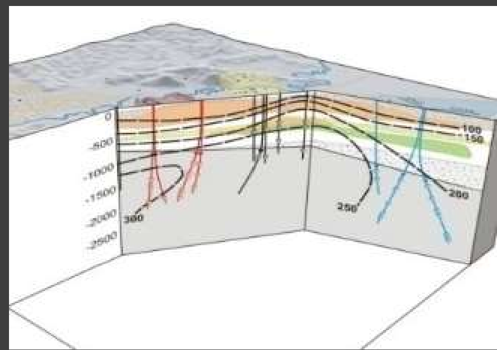
Geophysics



Exploration Plan



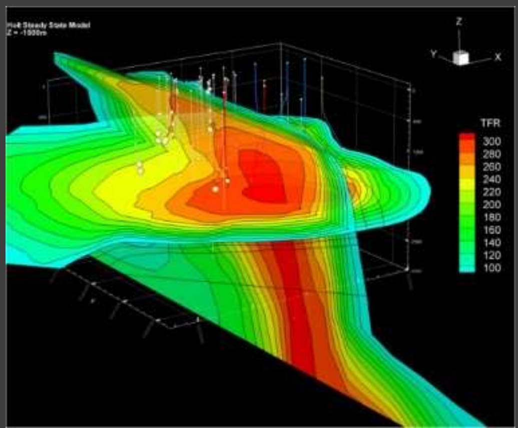
Conceptual Model



Credit: Karl Spinks, Mighty River Power

Drilling

Numerical Modelling



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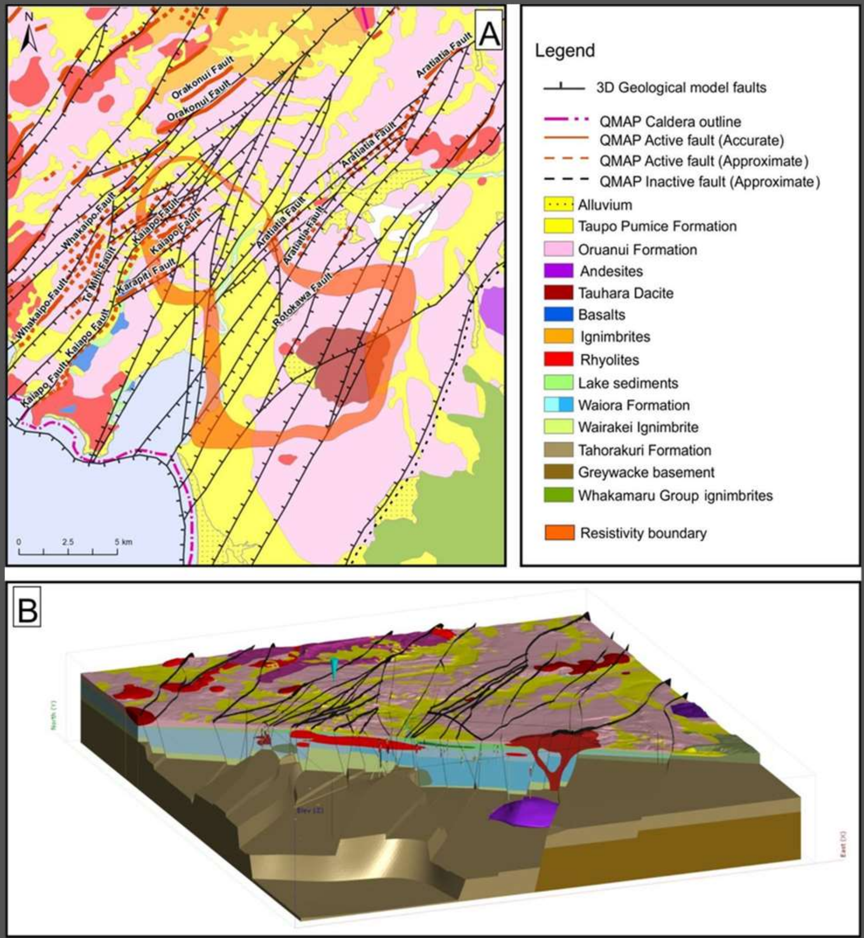
Geology

Geological mapping



Exploring Structure and Stress from Depth to Surface in the Wairakei Geothermal Field, New Zealand - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/A-Geological-map-of-the-Wairakei-Tauhara-area-Leonard-et-al-2010-with-superimposed_fig3_295720172 [accessed 24 Mar, 2019]

Credit: Juliet Newson, Reykjavik University

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Geochemistry

Fluids and gases at the surface tell us a lot about what is happening deep in the potential reservoir

By Sampling these we can learn about:

- Source of Fluid
- Type of Fluid
- Temperature in the reservoir
- Possible issues with reservoir fluids
- Changes in reservoir conditions

Credit: Jean Power, GNS Science

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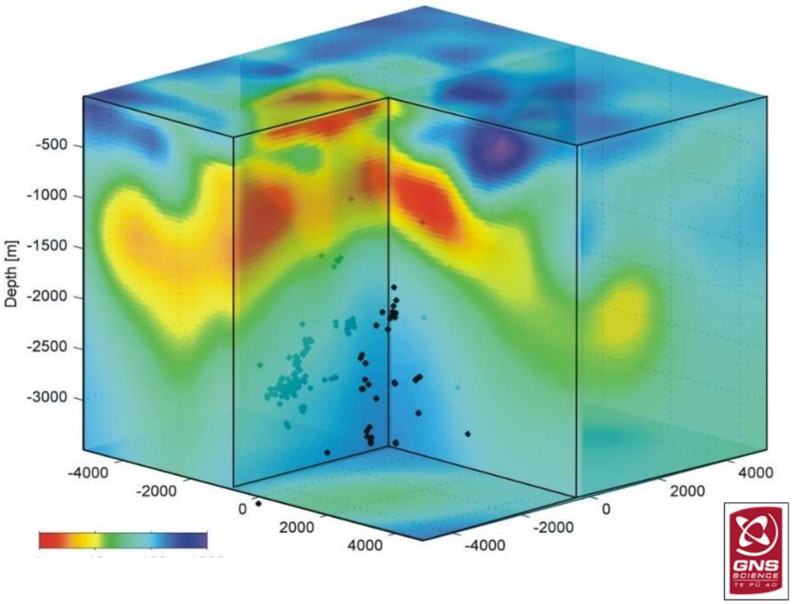
Geophysics

To assess the dimension of reservoir.
Provide information on:
- reservoir structure
- likely location of productive zones
- natural heat balance

Geophysical surveys:
- Heat flow surveys
- Remote sensing
- Gravity
- Magnetics
- Resistivity
- Magneto-tellurics
- Seismic surveys
- Borehole geophysics

The success of any geophysical investigation depends on applying the best combination of techniques in the correct sequence to explore a prospect



Heise et al., 2008 Three-dimensional modelling of magnetotelluric data from the Rotokawa geothermal field, Taupo Volcanic Zone, New Zealand. *Geophysical Journal International, 173(2):* 740-750

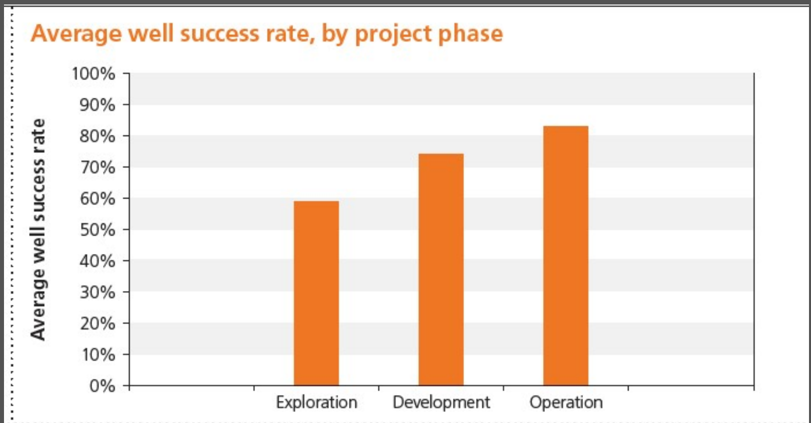
- Red colours are low resistivity, blue colours are high resistivity.
- Black dots are earthquake locations.

Drilling

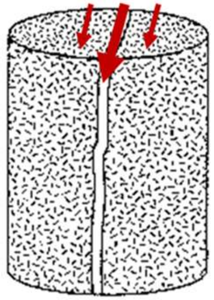
Identify controls on fluid flow, and tap deep-sourced fluid and heat.

The best way to understand reservoir potential but also the most expensive and highest risk

Credit: Kate Young , NREL

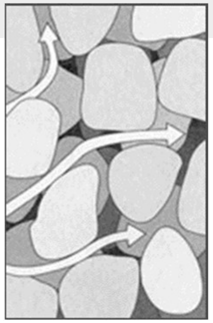


Permeability: "The state / quality of a material that causes it to allow liquids or gases to pass through it"



Permeabili

Fracture permeability (welded ignimbrite, andesite)



Bulk permeability (e.g. tuff, ignimbrite)

Resource Modelling

Models are not reality – they evolve over time with more knowledge

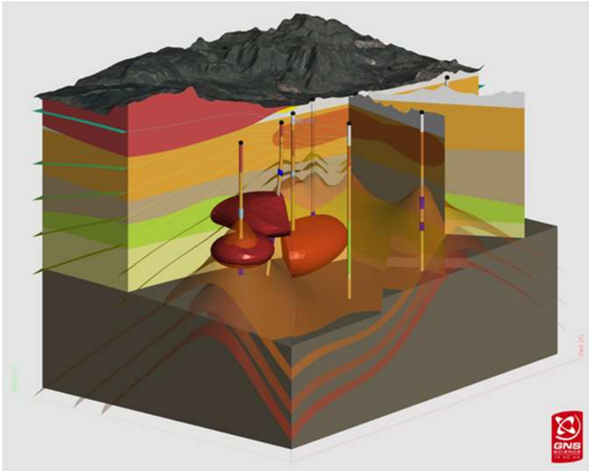
Conceptual (incl. geological framework)

Numerical Modelling

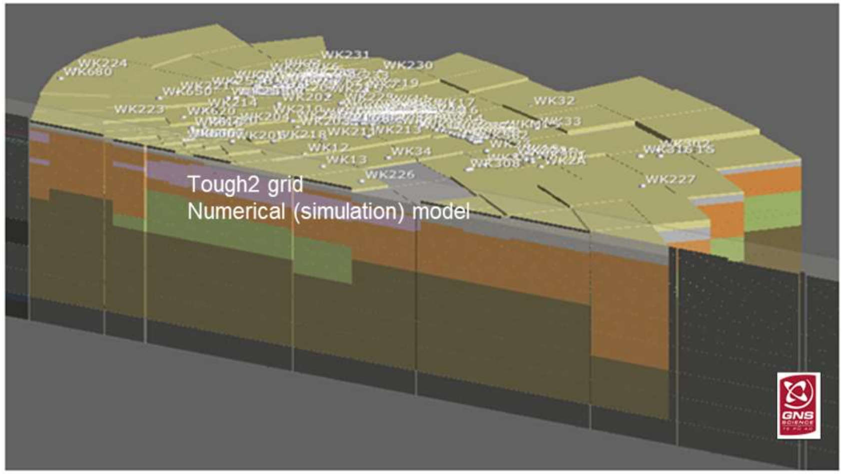
- Pre-development Steady State
- Long term Reservoir Performance
- Development Scenario Modelling (incl. effect of use on existing activities / features preliminary plant sizing etc).

Validation by geoscience investigation

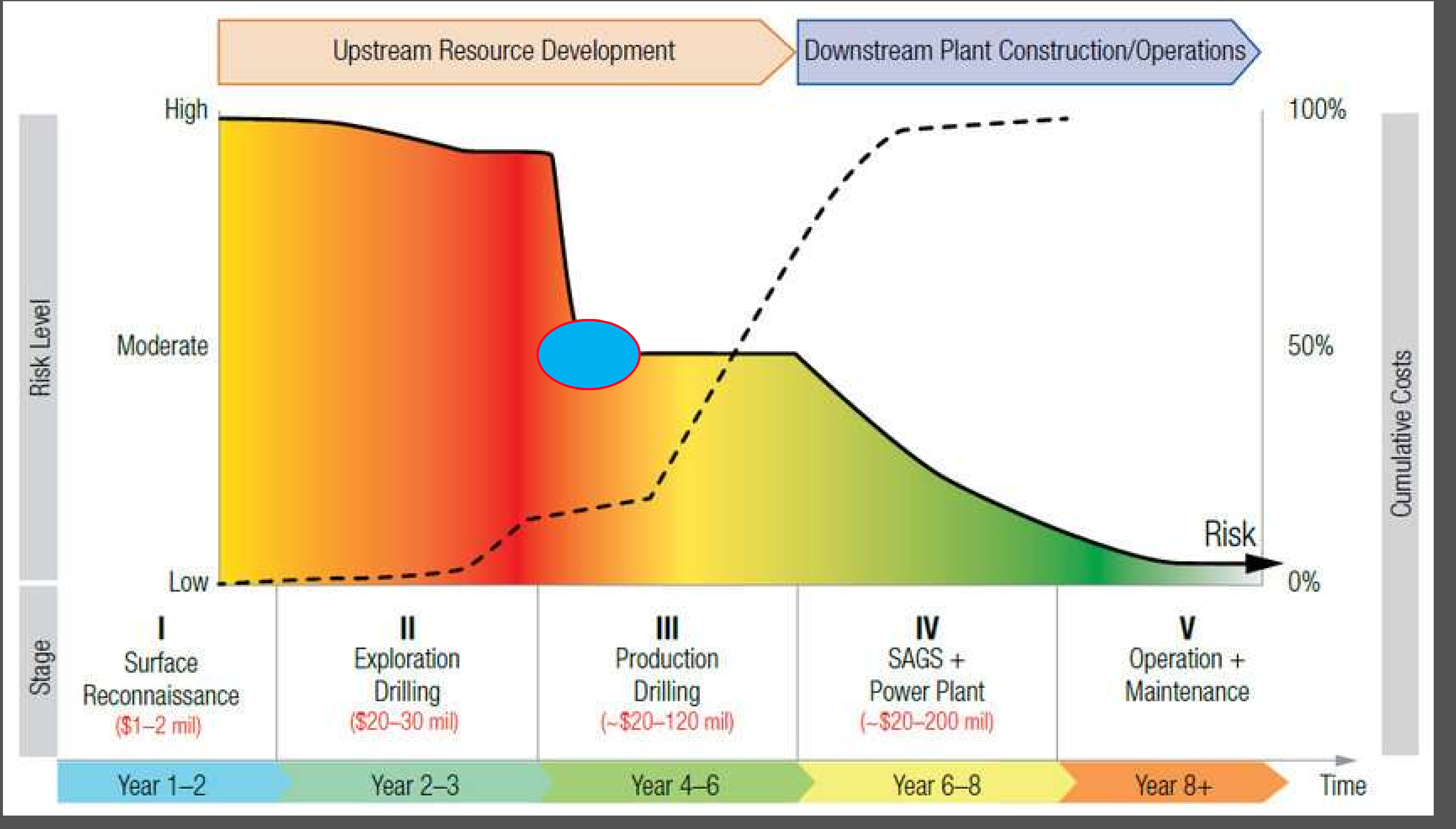
Conceptual Model



Numerical Model



Geothermal Project Model



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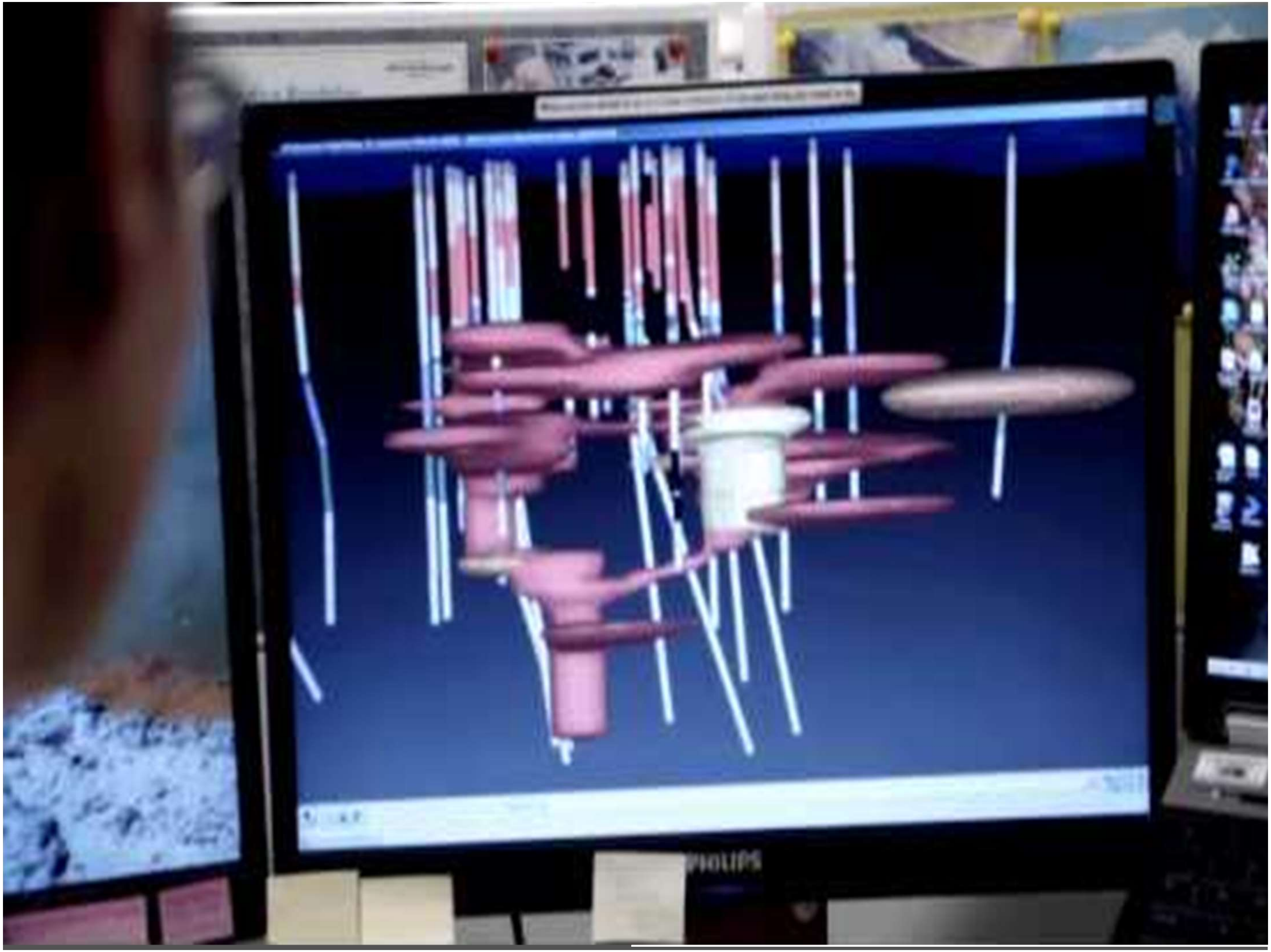
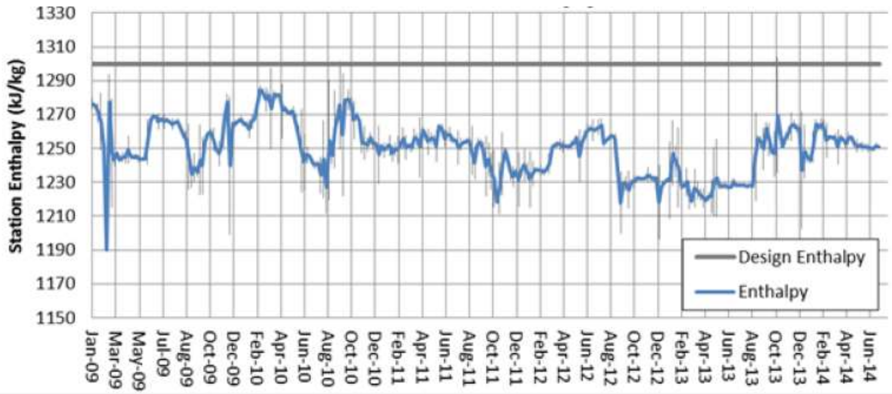

PHILIPS

Operation and Maintenance

- Cost reduction vs maximising asset performance and output
- Changes in pressure, enthalpy and output over time
- Managing:
  - Steam purity
  - Scaling and corrosion
  - Matching changes in steamfield to power plant equipment
  - Plant maintenance
  - Effluent discharges

Silica scale of injection pipe, Dieng, Indonesia (Tohoku Electric Power Co, 2006)



(Lee, M., Operational Challenges in Geothermal Power Generation 2014)

Monitoring

The Primary Objective: to achieve sustainable resource use, while adaptively managing environmental issues, through strategies to avoid, remedy, or mitigate effects.

Monitoring is used to map the response of the geothermal reservoir to production:

- Maximise use (longevity of use)
- Identify (as early as possible) & minimise adverse environmental effects

Sampling of steam and water to identify:

- Changes in the aquifer
- Evidence of recharge
- Changes in natural features and shallow monitor bores

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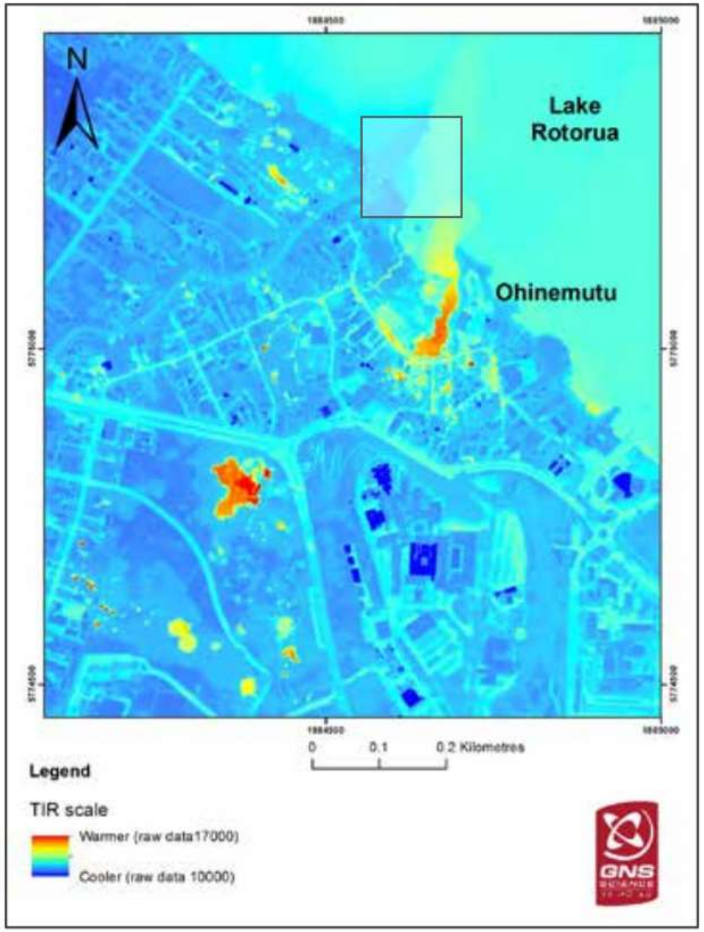
Monitoring

Geophysical surveys:

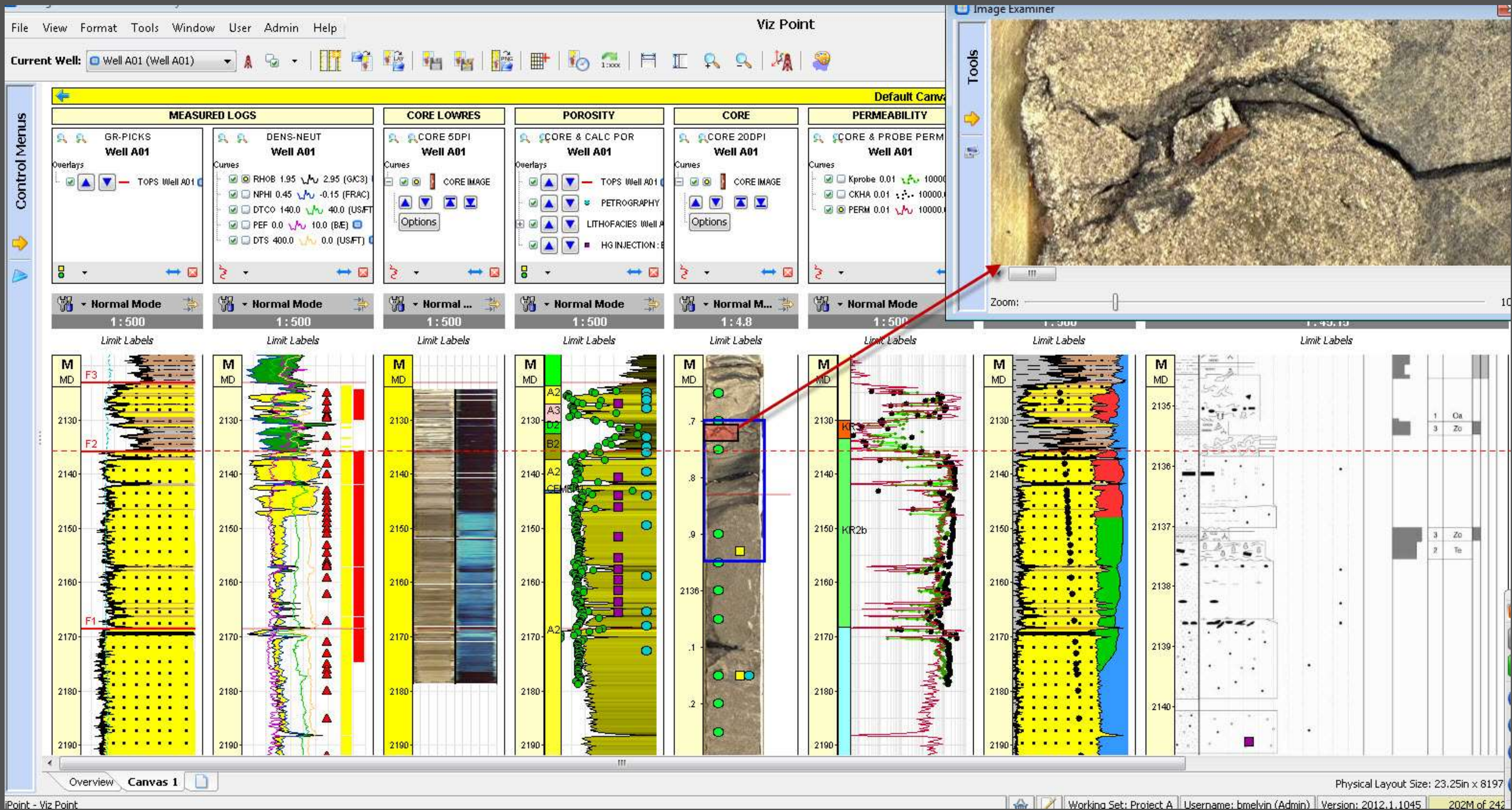
- Micro-gravity (subsurface mass changes)
- Micro-earthquake array
- Levelling surveys
- Airborne infra-red surveys & satellite imagery
- Surface heat-flux



From Reeves et al (2014)

Data

An effective resource data system, and utilising the data appropriately, is integral to effective resource management.



www. blog.leapfrog3d.com iPoint Software, Seequent, NZ

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Environmental Considerations

Multifaceted approach to management of the environment.

Expertise required:

- Modelling
- Civil, Mechanical and Electrical Engineering
- Geoscience (Geology, Geophysics, Geochemistry)
- Air and noise pollution
- Ecology
- Traffic
- Landscape
- Cultural
- Archaeology
- Land Discharges
- Carbon Footprint and Climate Change
- Geotechnical (Building & Infrastructure Effects)
- Economic analysis

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Potential Issues

- Subsurface fluid phase changes & recharge (micro-gravity changes)
- Induced earthquakes
- Subsidence or inflation
- Gas emissions (CO_2, H_2S, Hg)
- Thermal feature decline
- Triggered hydrothermal eruptions & landslides
- Thermal ecosystem decline (plants, animals, insects or extremophiles)
- Toxic chemicals in water

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Solutions

- Optimized field management through adaptive strategy
- Practical mitigation schemes e.g. targeted reinjection
- Gas extraction and sequestration technologies
- Protocols for hazard identification and avoidance
- Protection of selected representative thermal habitats
- Treatment of waste water – chemical, biological

Credit: Contact Energy Green Borrowing Programme Framework 2018

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Enhancing Surface Features

Shallow reinjection raised pressures and increased discharge of a natural acid-chloride pool (2000-2004)

When shallow injection rates reduced, spring discharge ceased (2006)

Images: Colin Harvey

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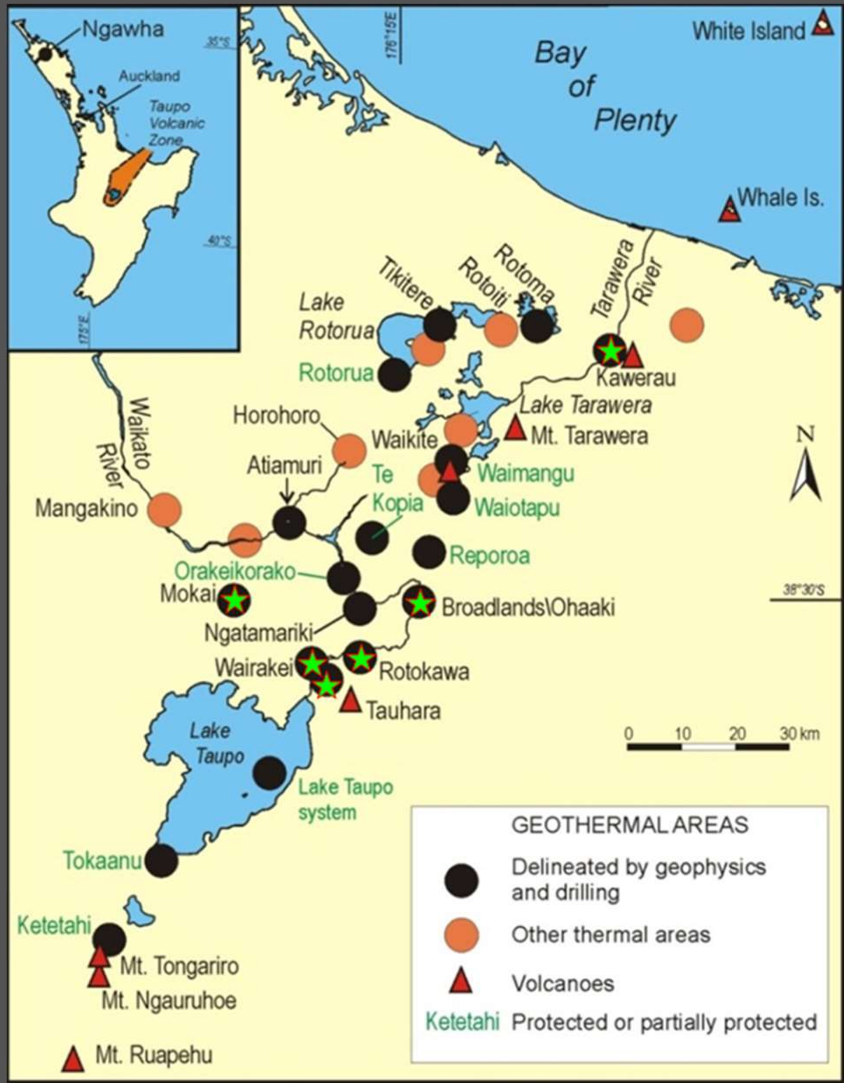
Geothermal Use

Geothermal Classification System

- Development
- Limited
- Protected

Balances the differing ways in which communities value geothermal resources



GNS Science

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Carbon

dissolved gases in solution

- In ground thermal storage

Tenon

- 400,000 tonnes a year of logs
- 9 batch kilns
- Drying 150,000 m3 timber per annum
- 2006 moved to Geothermal Kiln drying
- Replaced a natural gas fired system
- Uses two phase geothermal fluid to provide heat to the kiln
- Kiln loops run at 180°C and 150°C
- 265 Employees

Transiting from gas to geothermal

- Reduced CO_2 emitted by 28,000 tonnes/year
- Reduced operating costs by NZ$1.2 Million/year
- Increased timber drying capacity by 5%

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Image: Eric Lindberg