Exploration and Development of the Neal Hot Springs Geothermal Resource, Malheur County, Oregon*

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Abstract

Neal Hot Springs is a Basin-and-Range style geothermal system located 20 km northwest of the Known Geothermal Resource Area at Vale, Oregon. Prior to commercial production and modest pressure drawdown, natural hot springs discharged small volumes of 90°C, neutral pH, chloride water to form opaline sinter near the southward termination of the NNW-striking, W-dipping Neal Fault Zone (NFZ). Brecciated and silicified Miocene volcanic rocks occur along the NFZ surface trace and down dip where they comprise the bulk of the productive reservoir. Production zones occur in fractured andesite to basaltic andesite lavas exhibiting increasing intensity of silica-chlorite-pyrite alteration with proximity to the NFZ. Aside from leakage along the NFZ, the reservoir is generally capped by moderate depth, rhyolite tuff characterized by moderate to intense clay-calcite-pyrite alteration. Miocene volcanic rocks are underlain by Jurassic granodiorite at depths >2100 m below surface and at temperatures >150°C. U.S. Geothermal Inc. acquired and began exploration of the property based on chalcedony geothermometry of surface discharges indicating a resource temperature >145°C and on historic drill intersections indicating high permeability. A simple structural model developed from surface mapping in conjunction with shallow and moderate depth (150-600m) temperature gradient drilling guided the targeting of permeability controlled by the NFZ. Production well NHS-1 was highly successful with flow testing confirming a 141°C reservoir with permeability-thickness >300 darcy-meters. Follow-up drilling resulted in completion of six additional wells into the NFZ. Four production wells intersect the NFZ at depths 700 m to 1100 m below surface and feed 715 kg/s of 141°C brine to an air-cooled, binary power plant that produces up to a maximum of 30 MW (net). Injection is primarily into wells that intersect the NFZ downdip and along strike from production zones at depths 1520 m to 1890 m below surface. Based on long-term flow test and model simulation results, much of the brine is required to be injected

into the NFZ to provide long-term pressure support. Tracer testing showed that moderate depth wells along strike and in the hanging wall returned large percentages of injected tracer mass relatively rapidly to production wells, whereas deep, downdip wells returned only a few percent of tracer mass relatively slowly. Tracer test results were confirmed when rapid cooling at plant startup was quickly remedied with shut-in of the moderate depth injection wells. Currently, the field continues to produce 715 kg/s of 141°C brine with production capped at 30 MW owing to limits of the air-cooled plant equipment and also by the electricity sales contract. Notably, there has been no further temperature decline, something that is typically linear with time in Basin-and-Range-type systems.

Selected References

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Forward Looking Statements

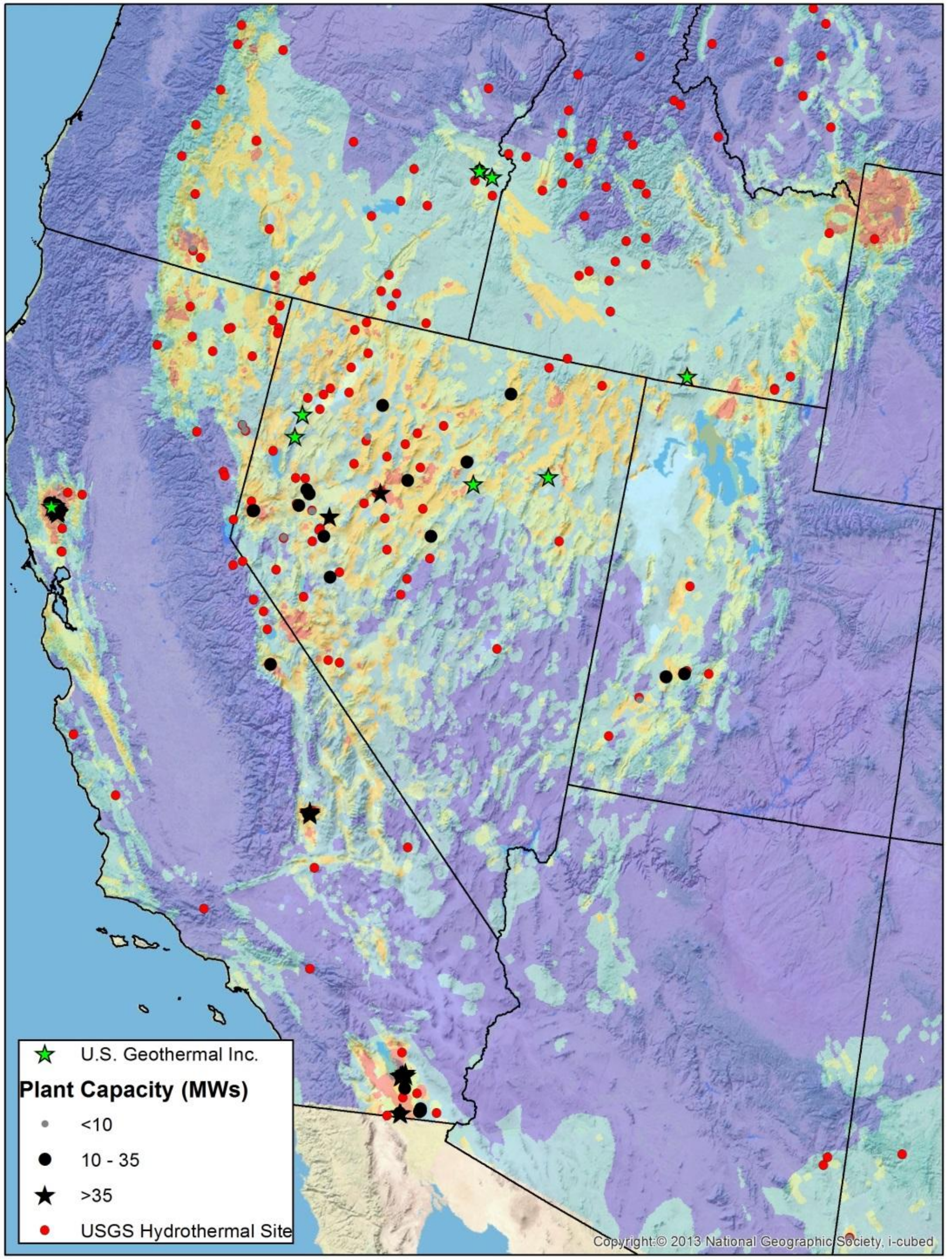
This presentation contains certain “forward-looking statements” within the meaning of the Private Securities Litigation Reform Act of 1995. All statements other than statements of historical fact are forward-looking statements, which reflect the company’s current expectations and beliefs regarding its future results of operations, performance and achievements. These statements are subject to risks and uncertainties and are based upon assumptions and beliefs that may or may not materialize. Forward-looking statements may be identified by words such as “will”, “could”, “prospects”, “potential”, “planned”, “expected”, “estimates”, "schedule", "anticipates" and similar terms.

These forward-looking statements include, but are not limited to, statements concerning the company’s strategy; operating forecasts; capacity, financing and construction of new projects or expansions of existing projects; working capital requirements and availability; illustrative plant economics; and the use of share price value projections. Forward-looking statements are not guarantees of future performance and are subject to various risks and uncertainties that could cause the company’s actual results and outcomes to differ materially from those discussed or anticipated, including the factors set forth in the section entitled “Risk Factors” included in the company’s Annual Report on Form 10-K for the year ended December 31, 2013 and its other filings with the Securities and Exchange Commission.

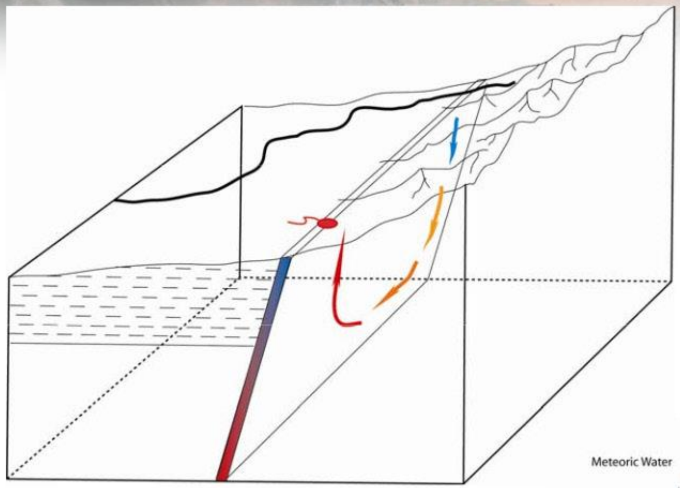
The company does not assume the obligation to update any forward-looking statement.

Western USA Geothermal Resources

- USGS favorability and identified hydrothermal systems-faults, TG, volcanic vents, seismicity…
- Lots of potential but challenging to discover and prove
- Not many large new installations outside of the Geysers and Salton Sea
- Geothermal is a very small piece of the USA power mix and is often left out of countrywide renewables discussions

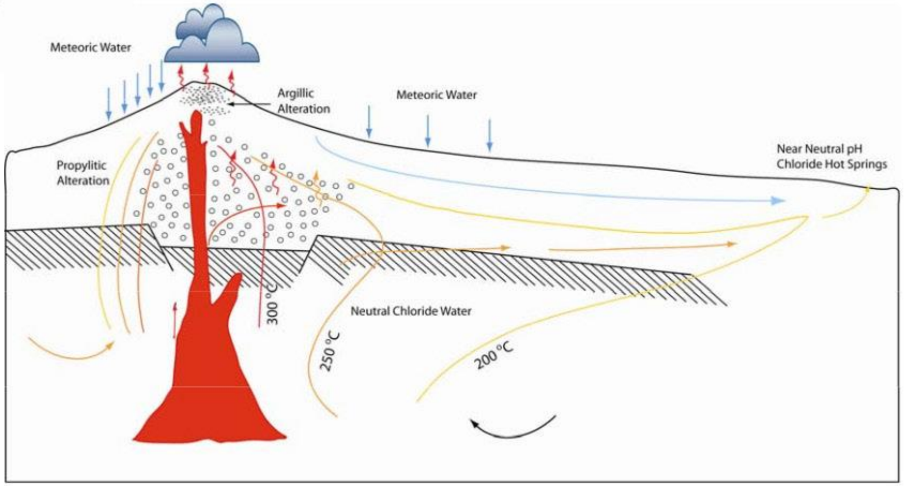


Geothermal Systems and Geologic Setting



From Reed (1983)

Characterizing the geologic setting of a geothermal system can be an important interpretive tool in evaluating geothermal resources, but it is important to remember the diversity of characteristics.



From Henley And Ellis (1983)

USGS

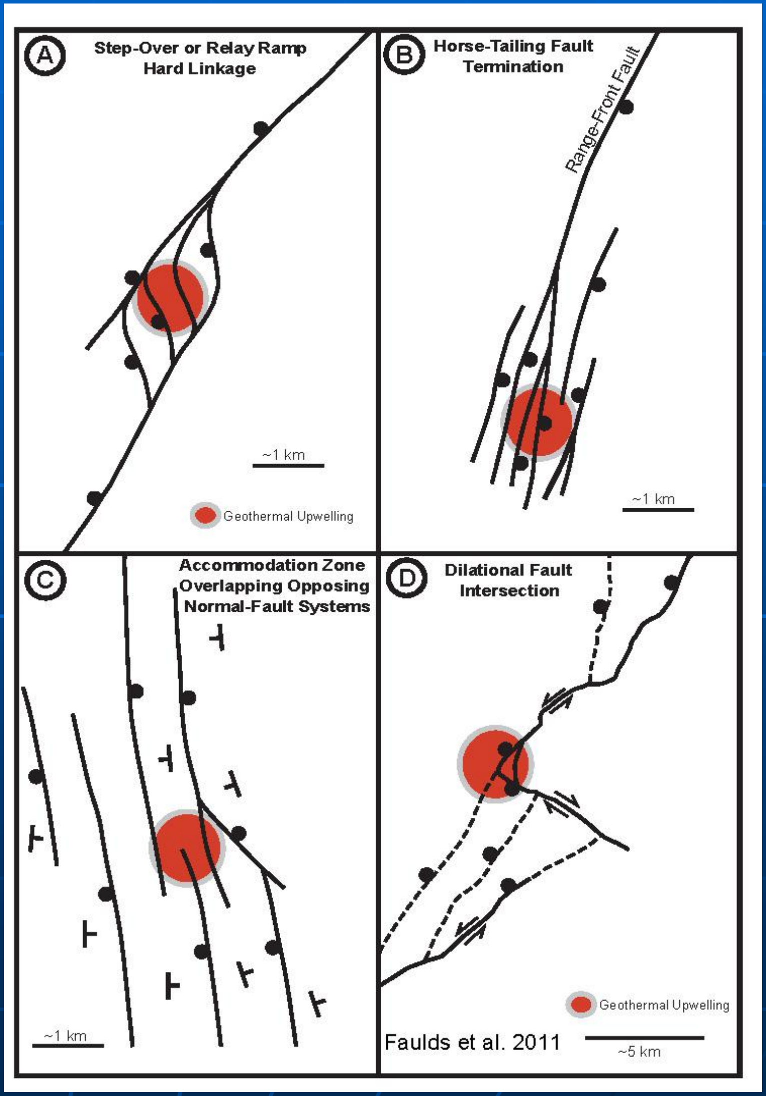
Structural Settings of Geothermal Systems in the Great Basin

- Deeply penetrating normal faults

- Oriented favorably with respect to modern stress field
  - Slip-tendency analysis
  - Dilation-tendency analysis

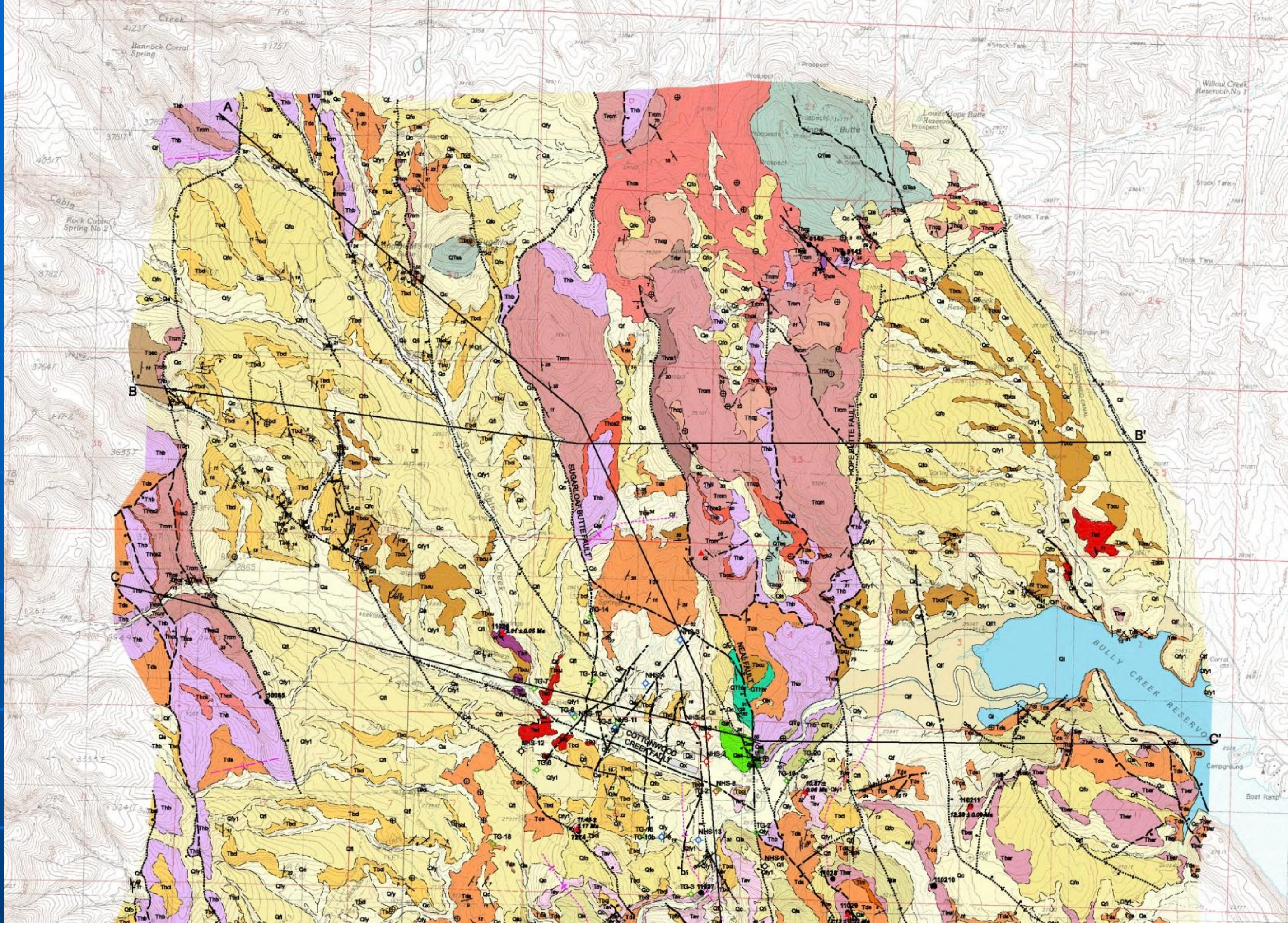
- Interaction of multiple fault strands to enhance dilatancy

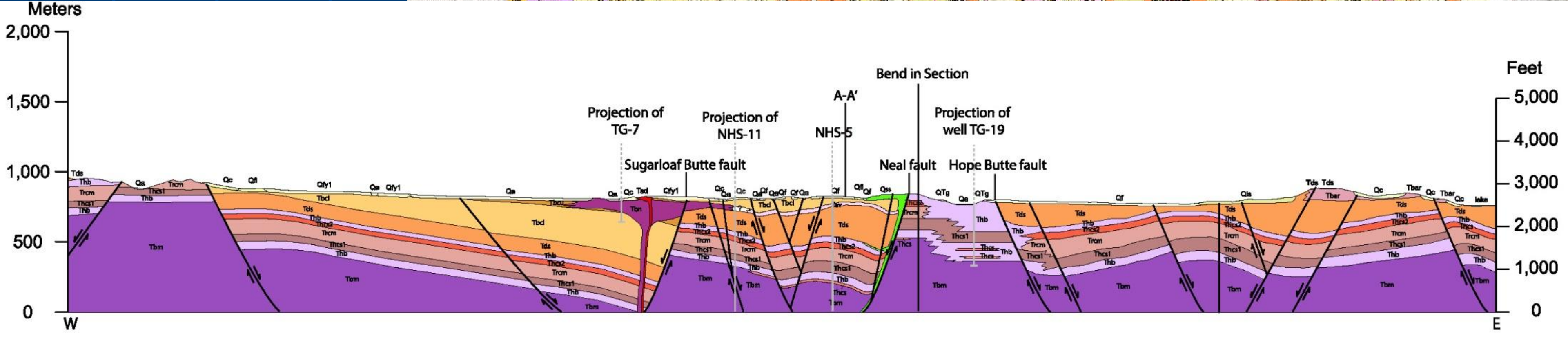
- Hydrothermal alteration
  - Past
  - Present and ongoing



Neal Hot Springs, Malheur Co., OR

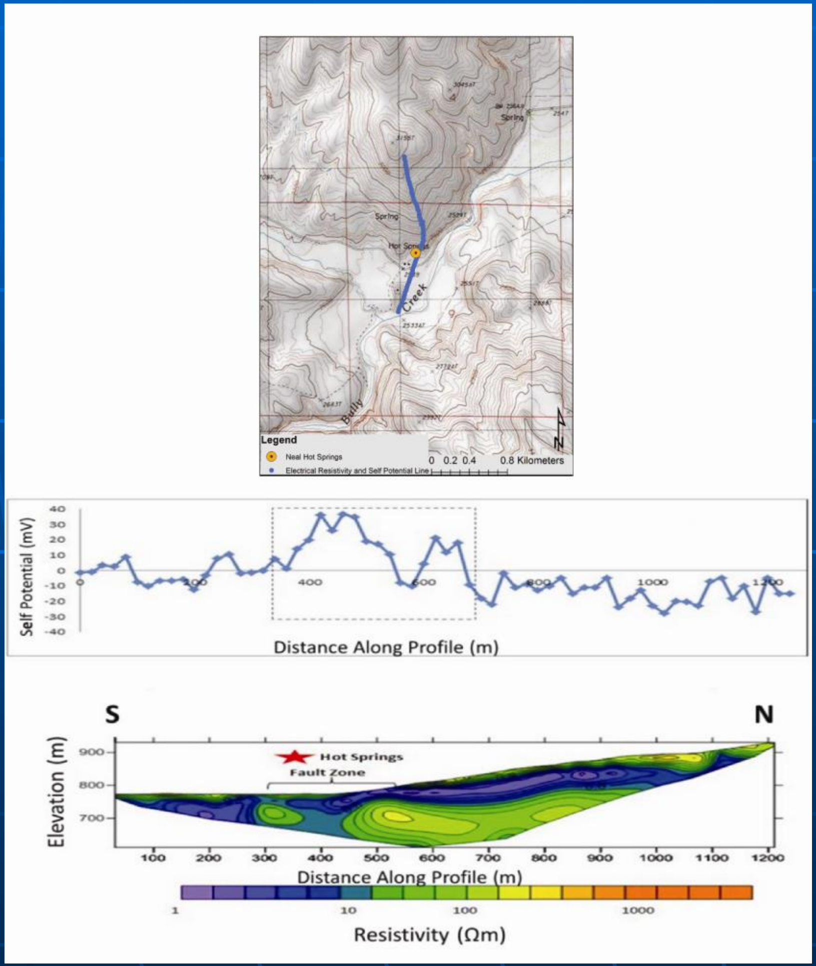
Edwards et al. (2013)

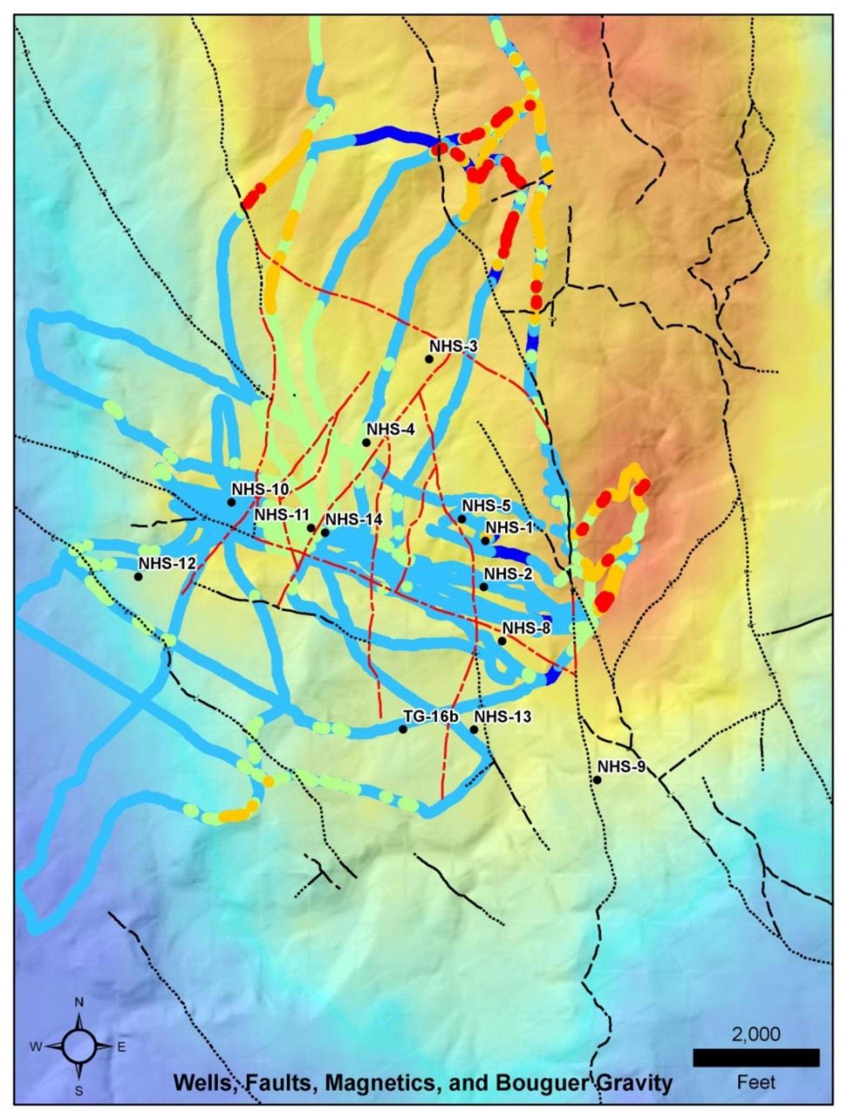




Geophysical Exploration

- Gravity
- Magnetics
- Self potential
- Limited seismic
- CSAMT
- Modeling

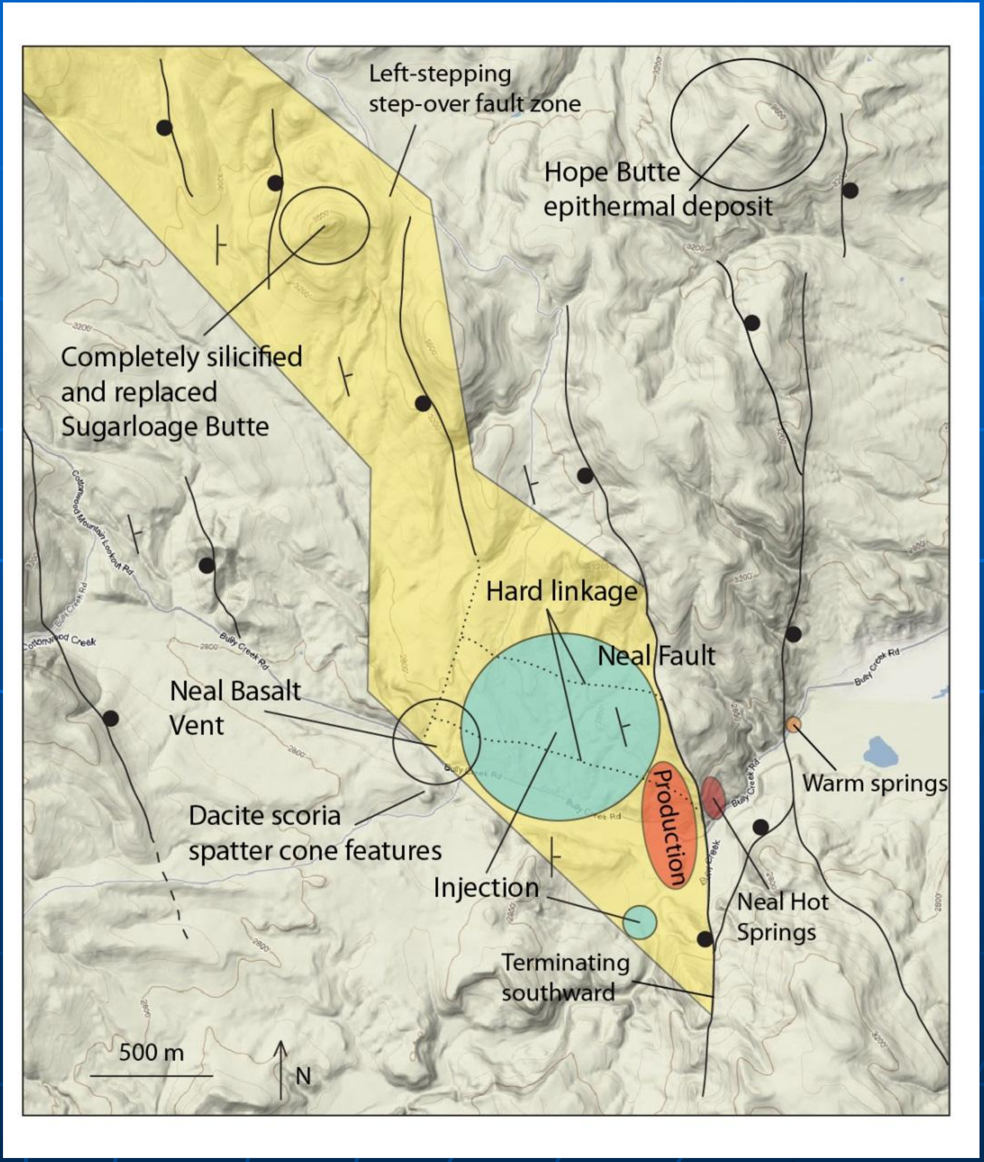




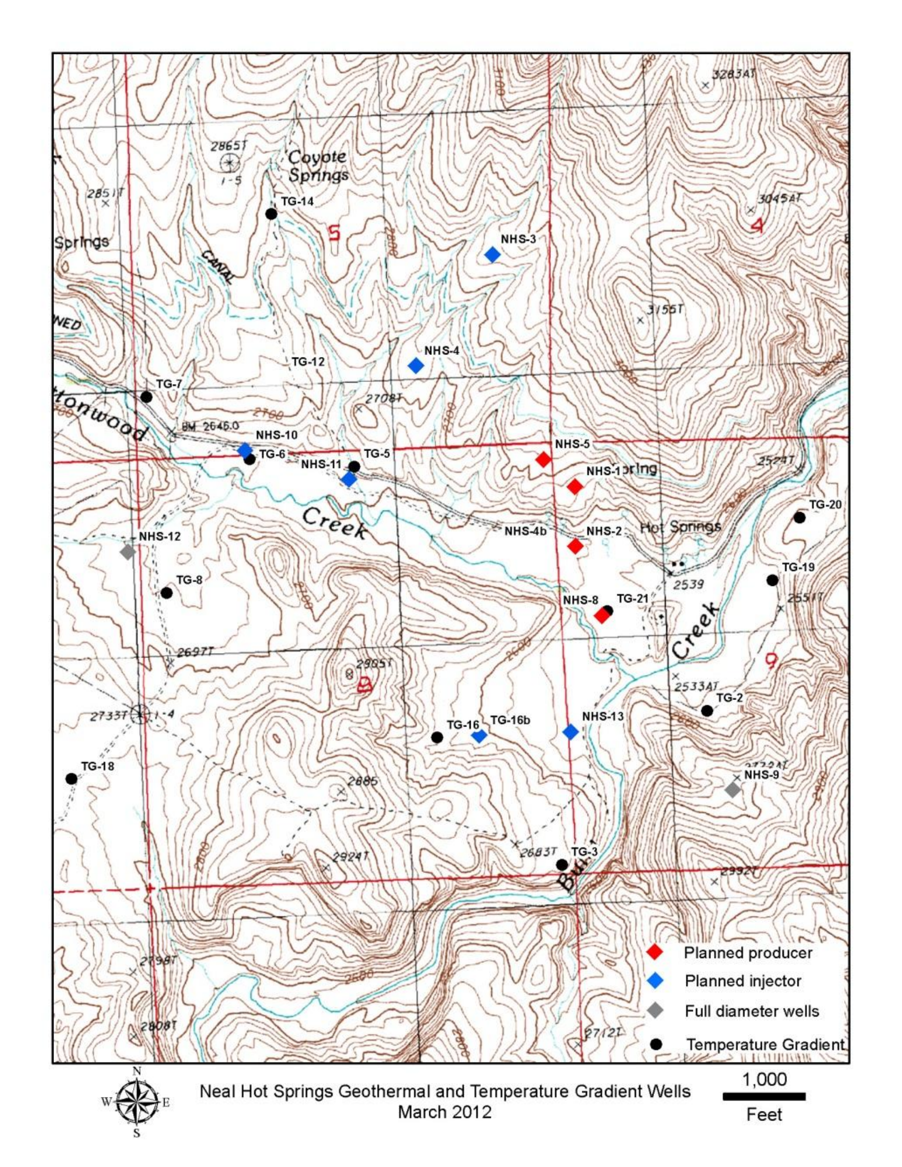
Also: Coulomb stress change modeling; geomechanical modeling

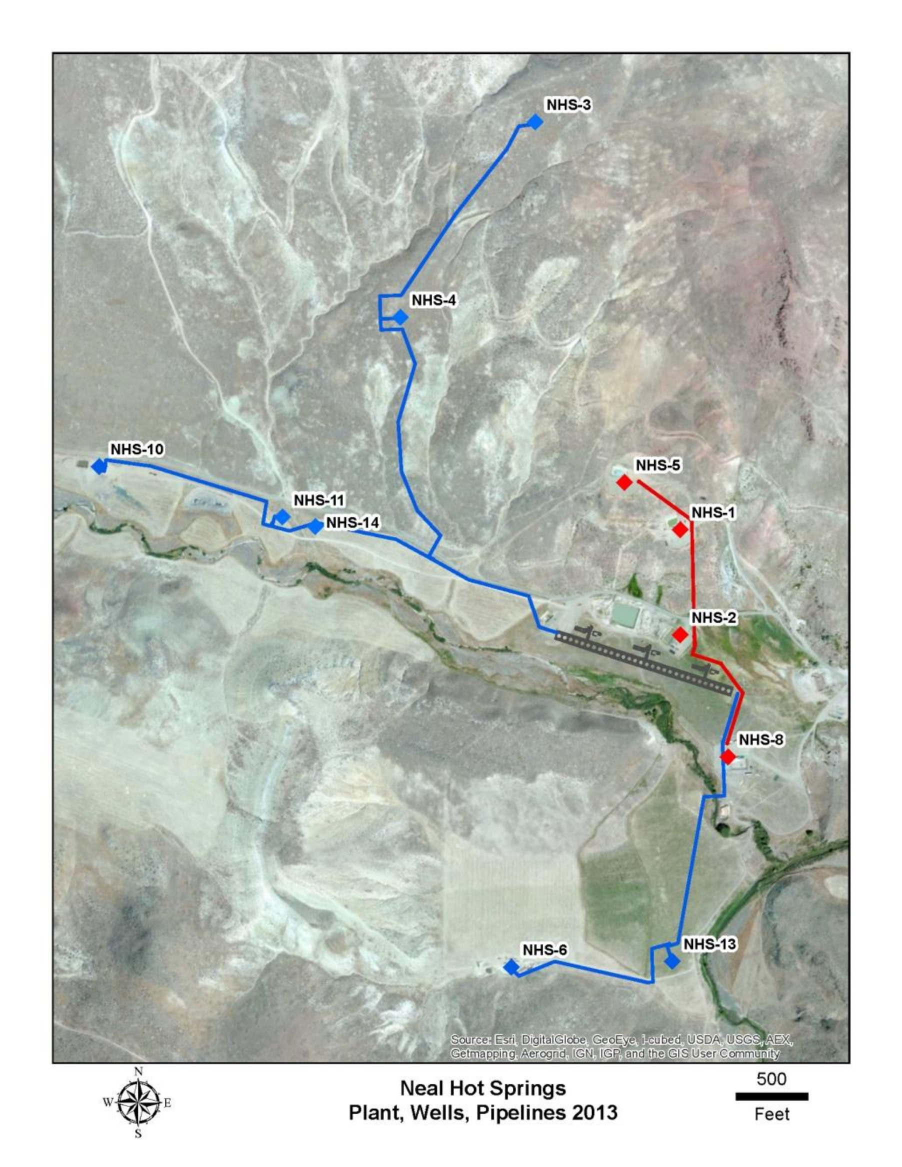
Neal Hot Springs Structural Setting

- Initial field evaluation identified hydrothermally altered fault zone associated with hot springs
- 320F subsurface temperature suggested by silica geothermometry of hot spring discharges
- High permeability fracture zones known from 80s era drilling by Chevron
- Surface mapping, well logging, and whole-rock geochemistry to refine stratigraphy and structure (Edwards, 2013)
- Geophysics inversion guided by evolving geologic understanding (Cowell, 2013; BSU Field Camp)



Neal Hot Springs Exploration and Development

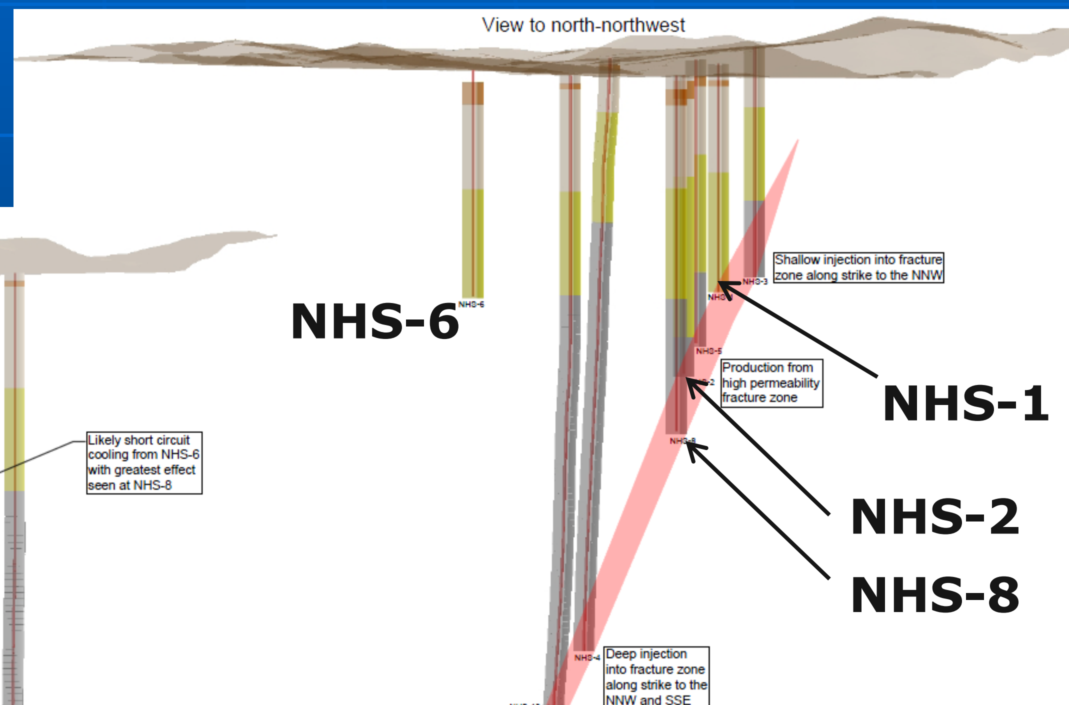


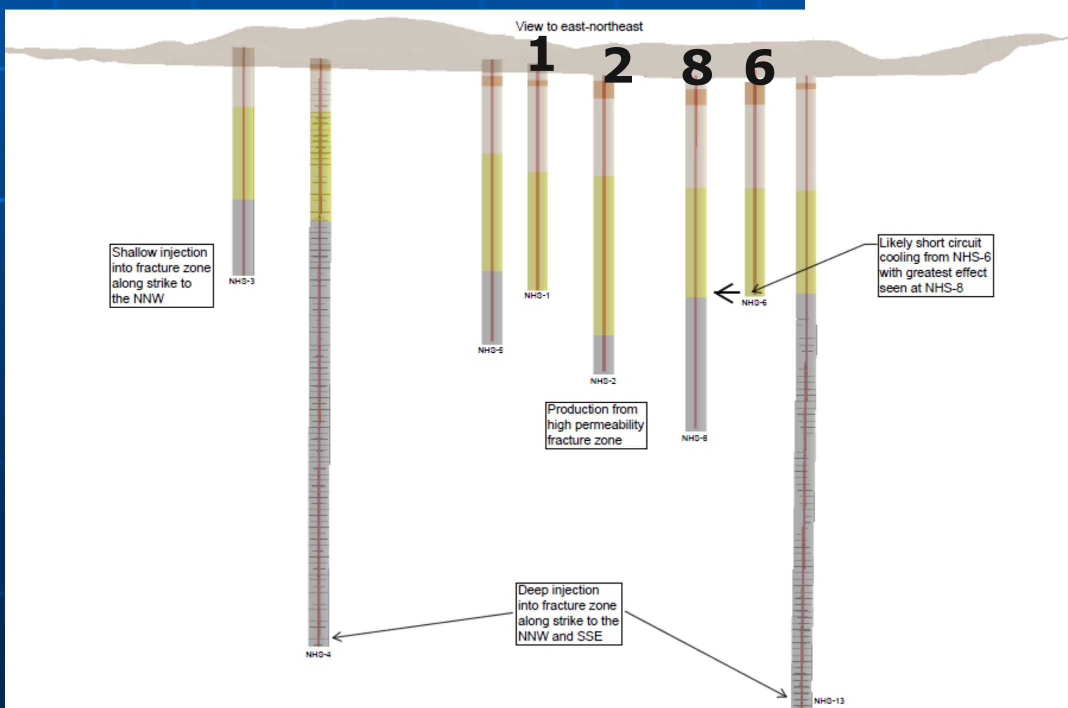


After decades of refining and developing geothermal exploration techniques, TG drilling is still the best tool to explore for temperature and permeability

Neal Long-term Flow test

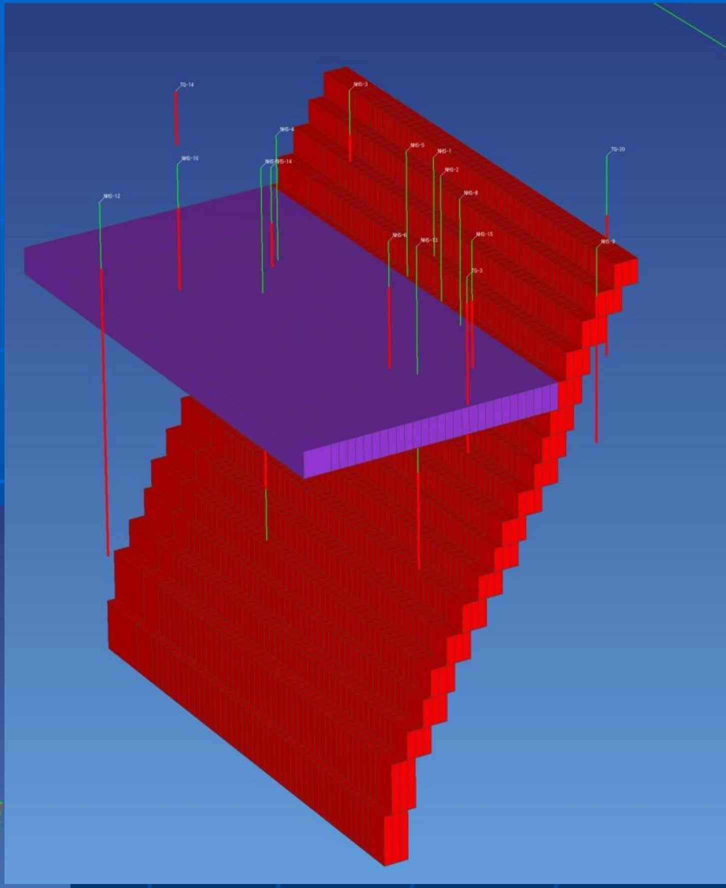
- NHS-1, 2, and 8 flow for 35 days
- Injection into NHS-6 and NHS-10
- Monitor temperature and pressure at multiple wells

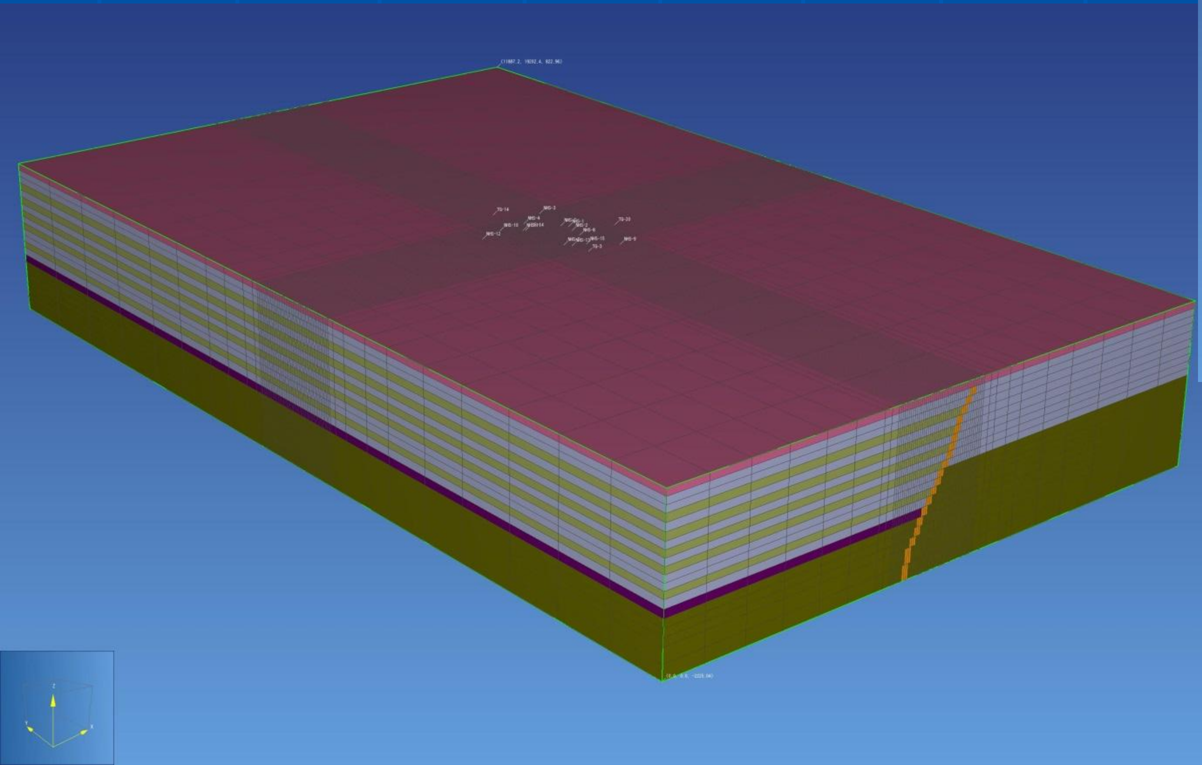




Neal Hot Springs Reservoir Model

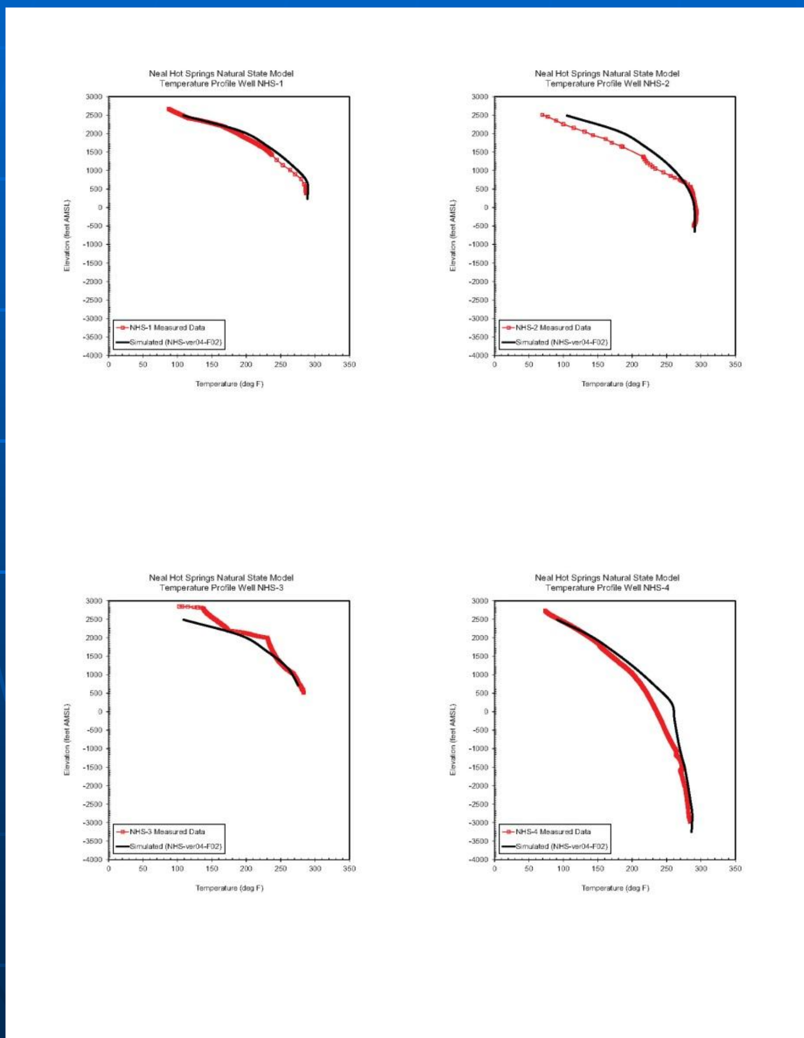
- Numerical model developed with TETRAD and converted to TOUGH2.
- Simple fracture geometry. Limited materials (limited variation in properties, e.g., porosity, permeability)
- Mass input at bottom of fracture. Outflow to the WSW

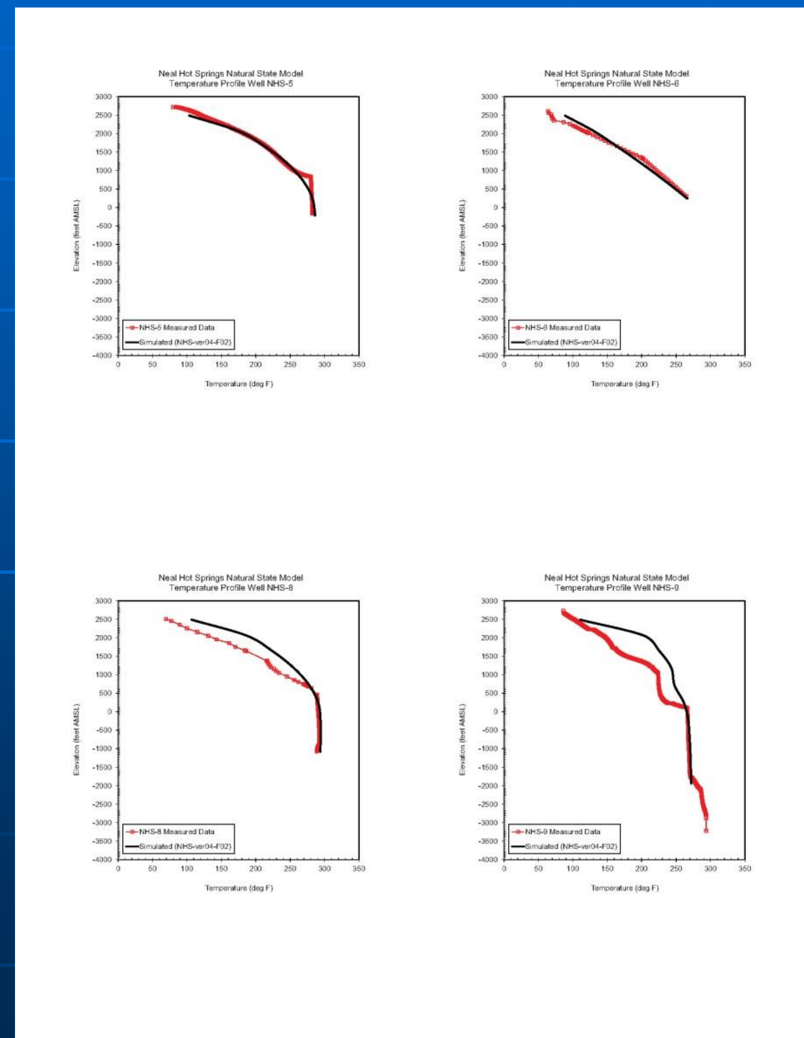




Neal Model History Match

- Parameters adjusted
- Natural state simulated for 100,000s yrs
- Match measured, pre-production temperatures





Simulation of long-term flow test

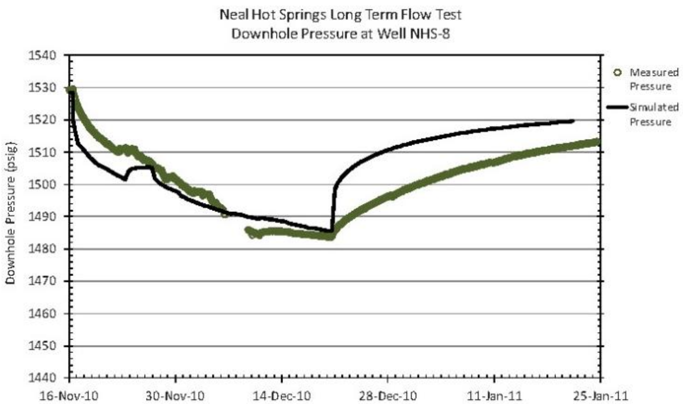


Figure 22: Measured and simulated downhole pressure in well NHS-8.

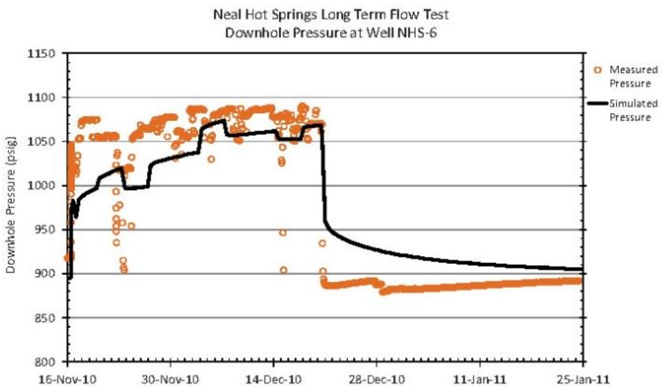


Figure 23: Measured and simulated downhole pressure in well NHS-6.

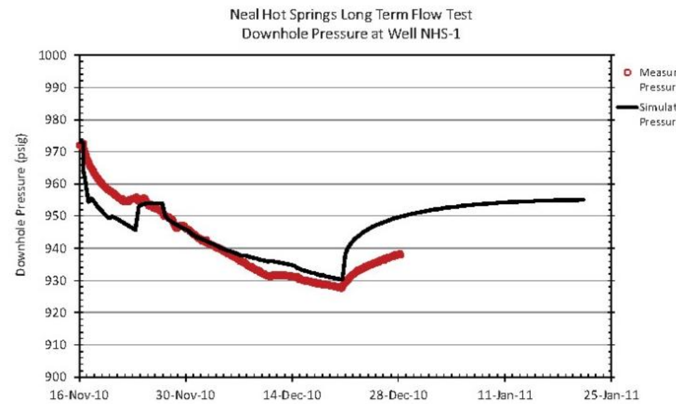


Figure 20: Measured and simulated downhole pressure in well NHS-1.

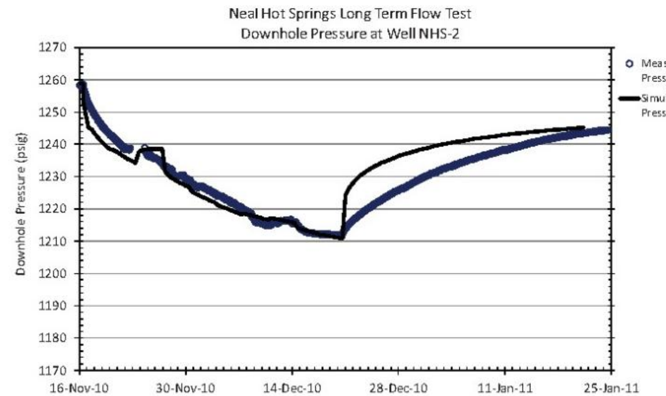
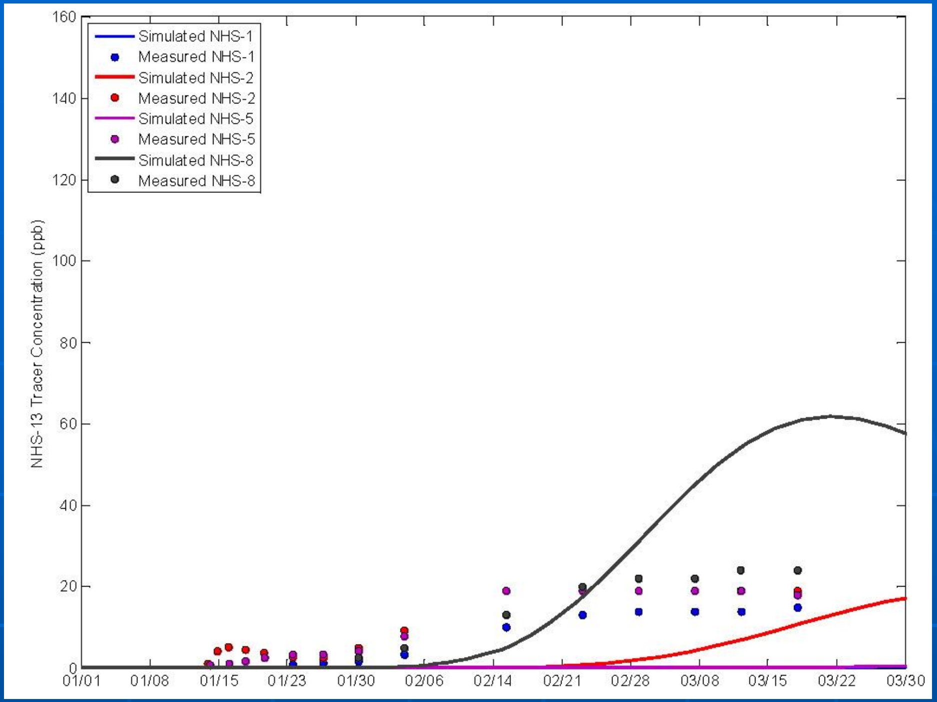


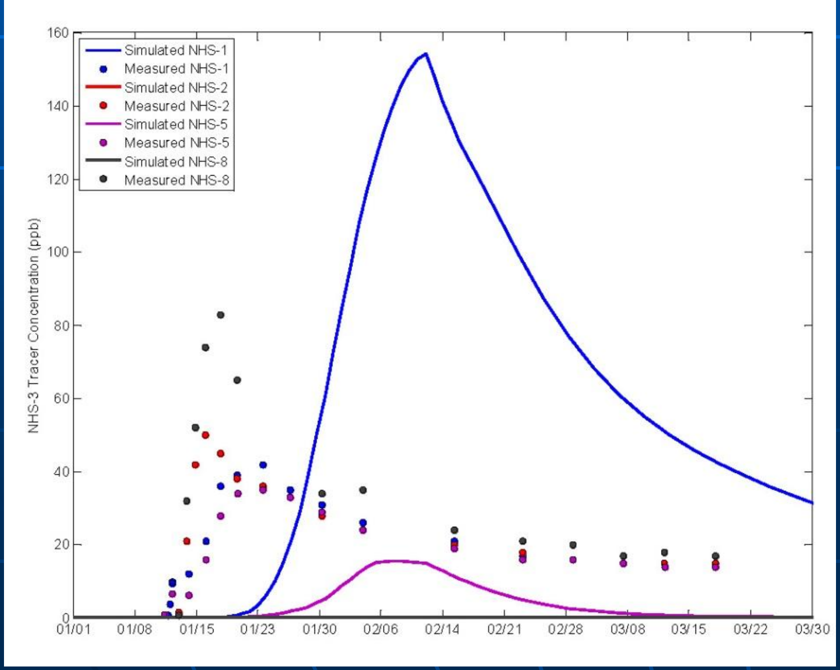
Figure 21: Measured and simulated downhole pressure in well NHS-2.

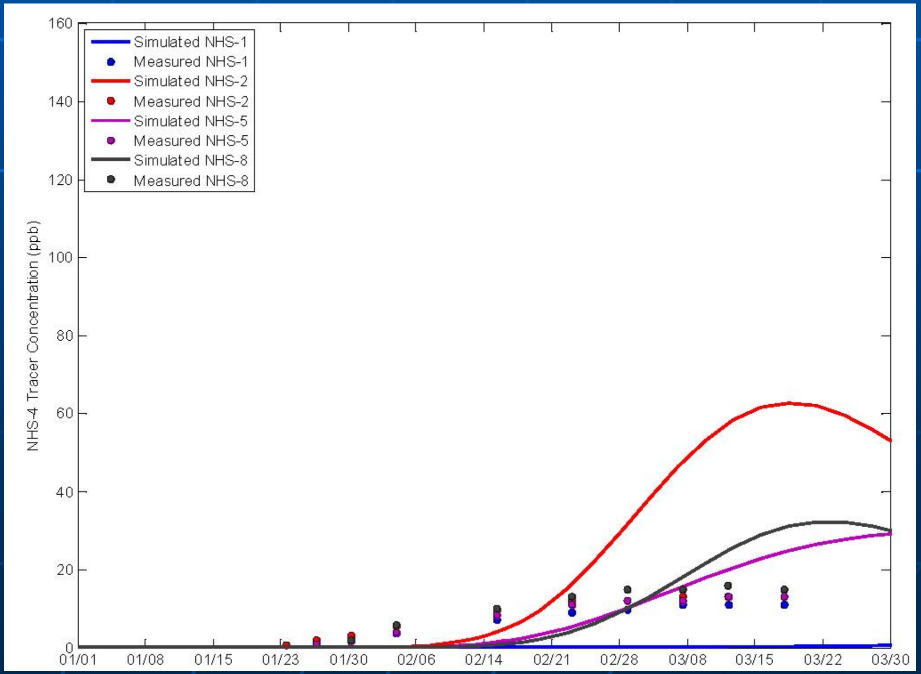
Tracer Testing

Despite a good natural state match and successful simulation of the long-term flow test, the model has to be reassessed based on tracer test results.

<u>NON-UNIQUE SOLUTIONS!</u>

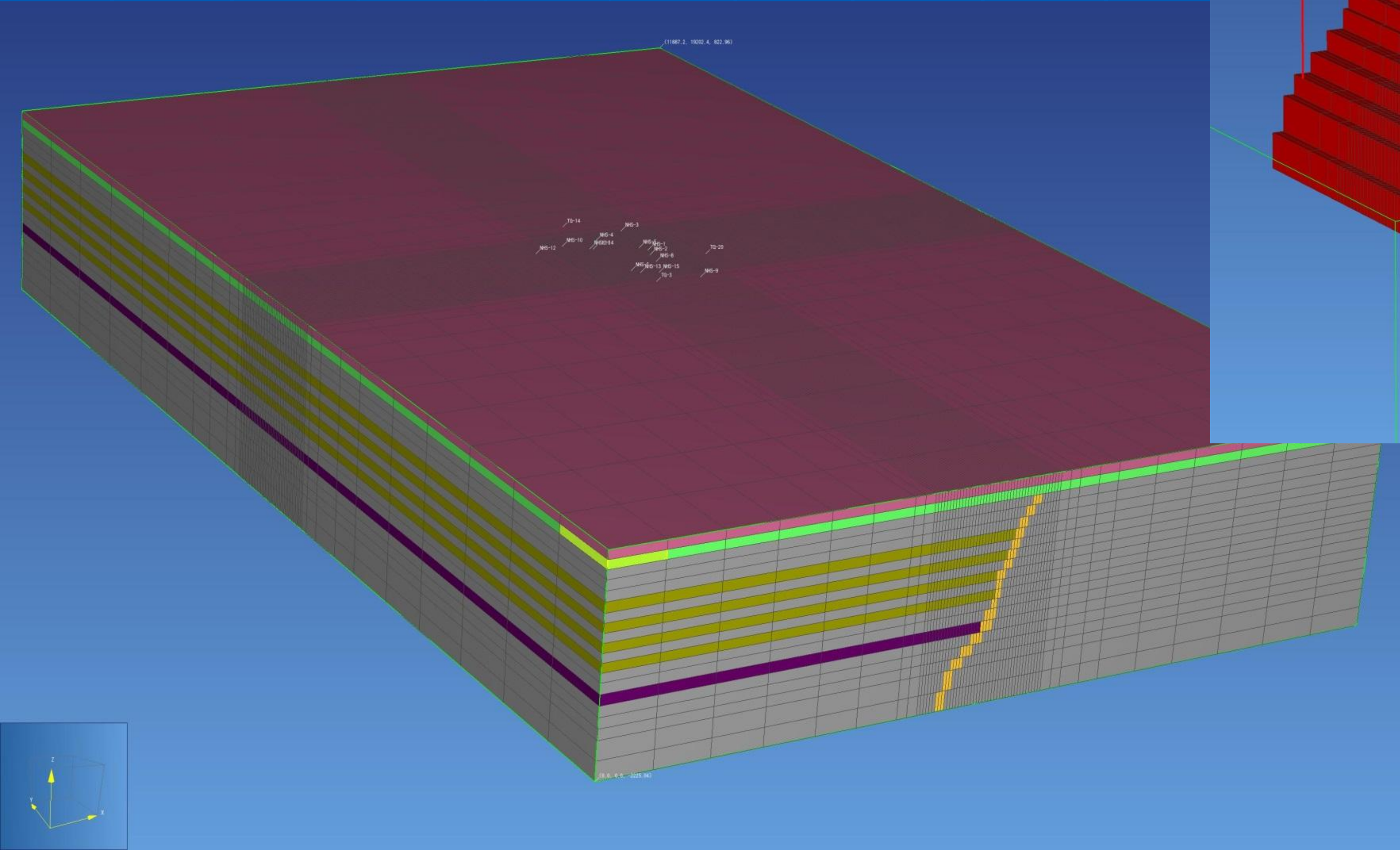


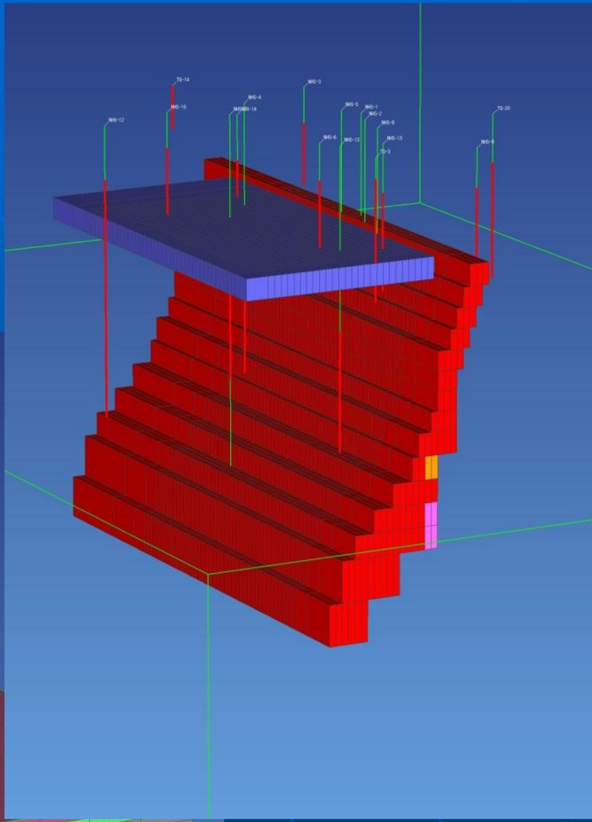




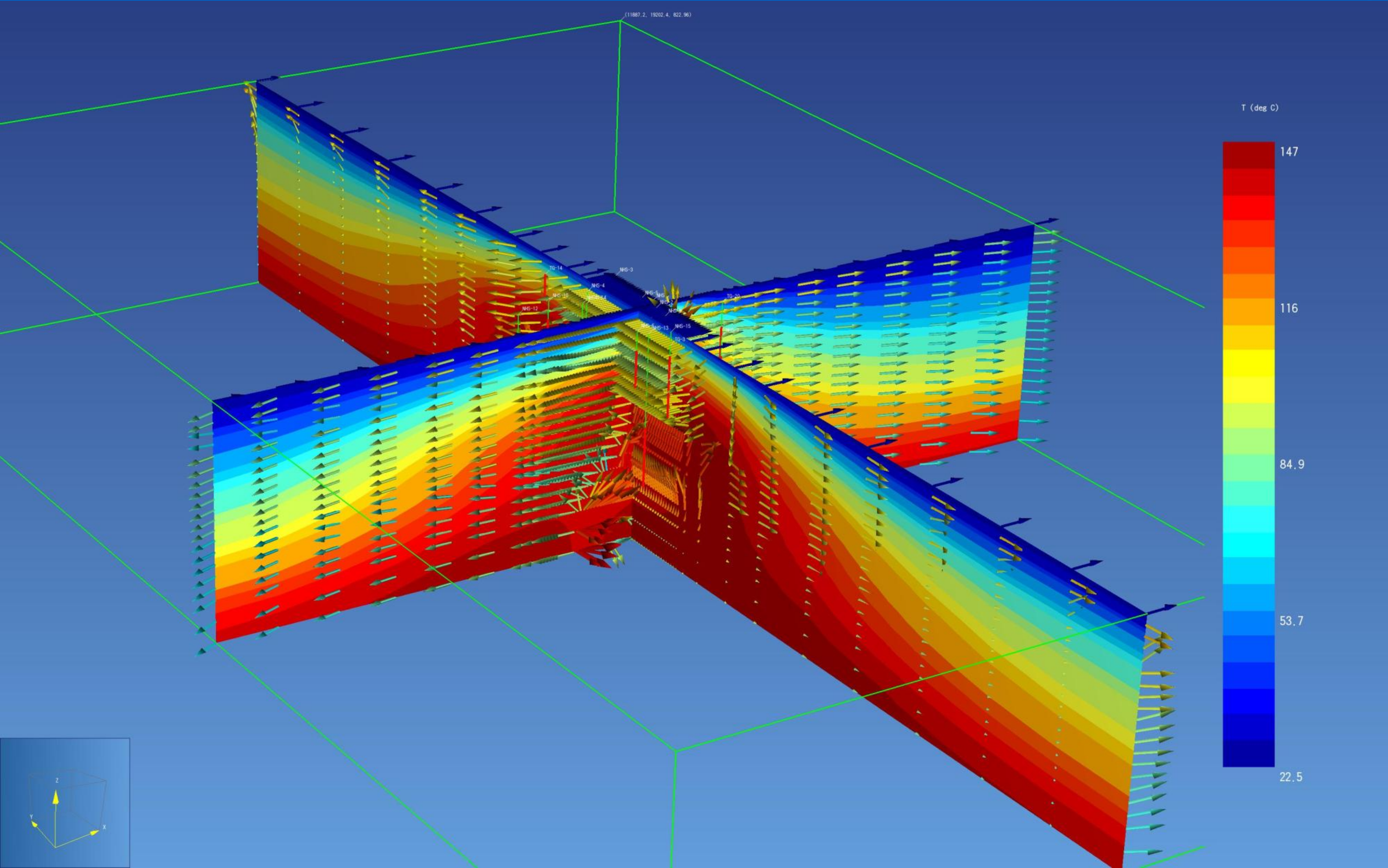
Neal Reservoir Model 2.0

- Permeability modifications
- Fracture geometry modifications
- Outflows north and south along the fracture

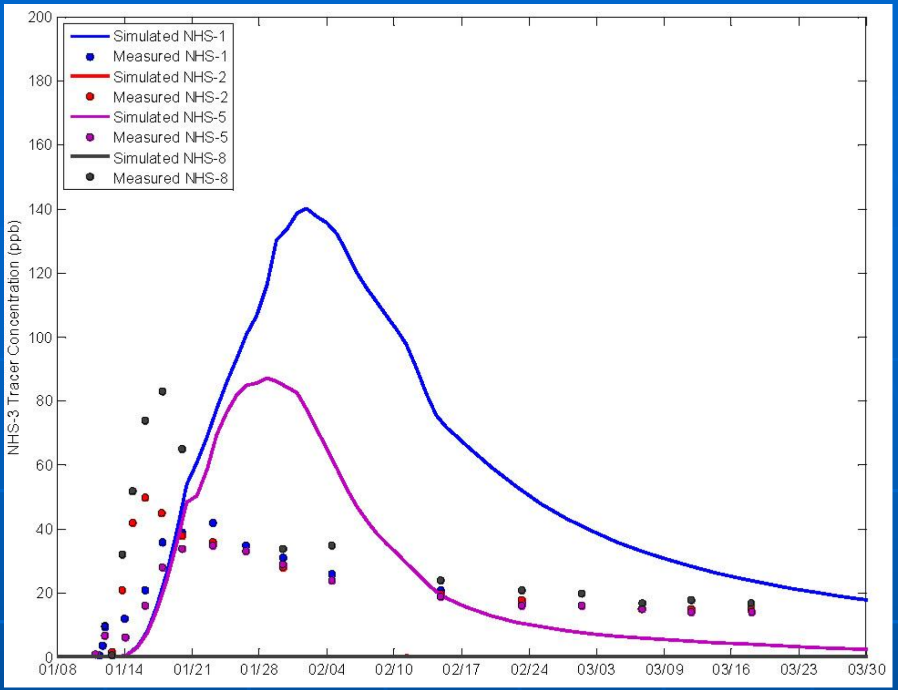


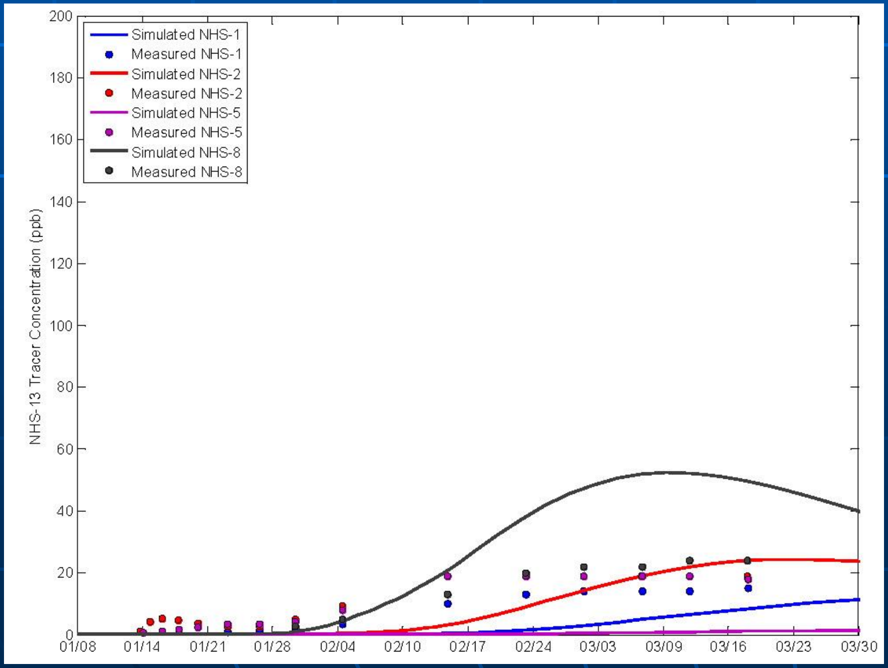


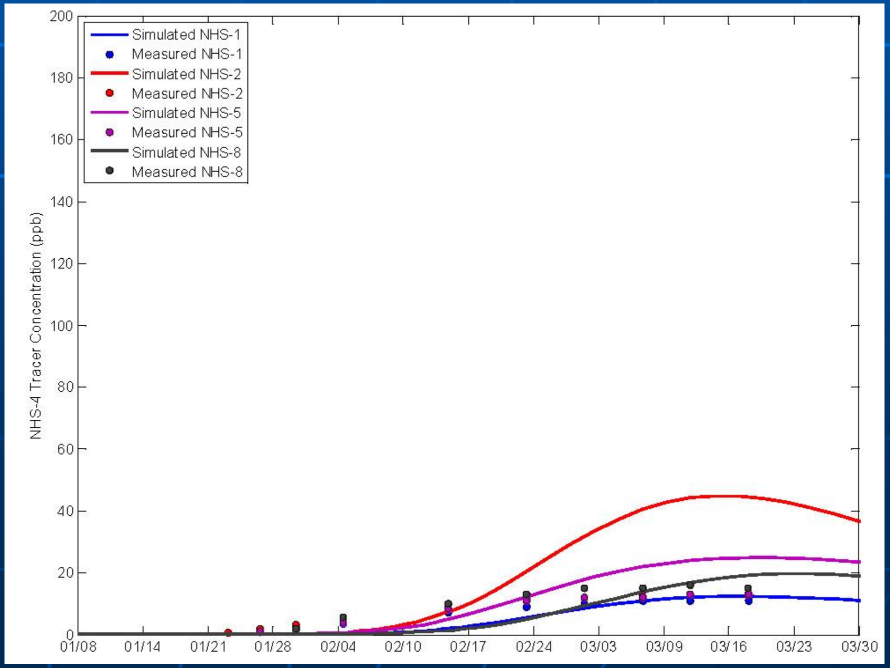
Neal Model 2.0- Good natural state match and long-term flow test simulation



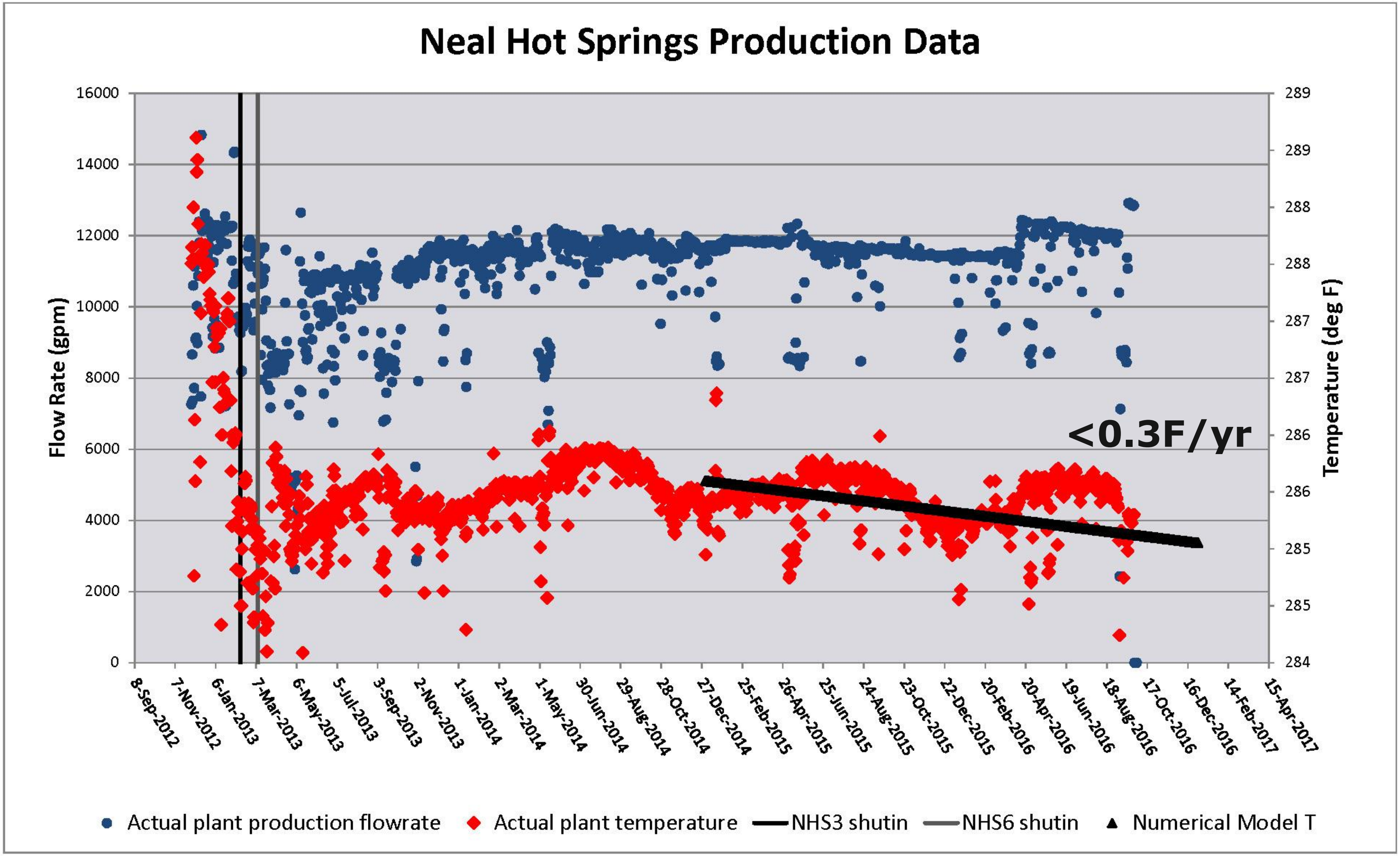
Neal Model 2.0 Tracer Simulation



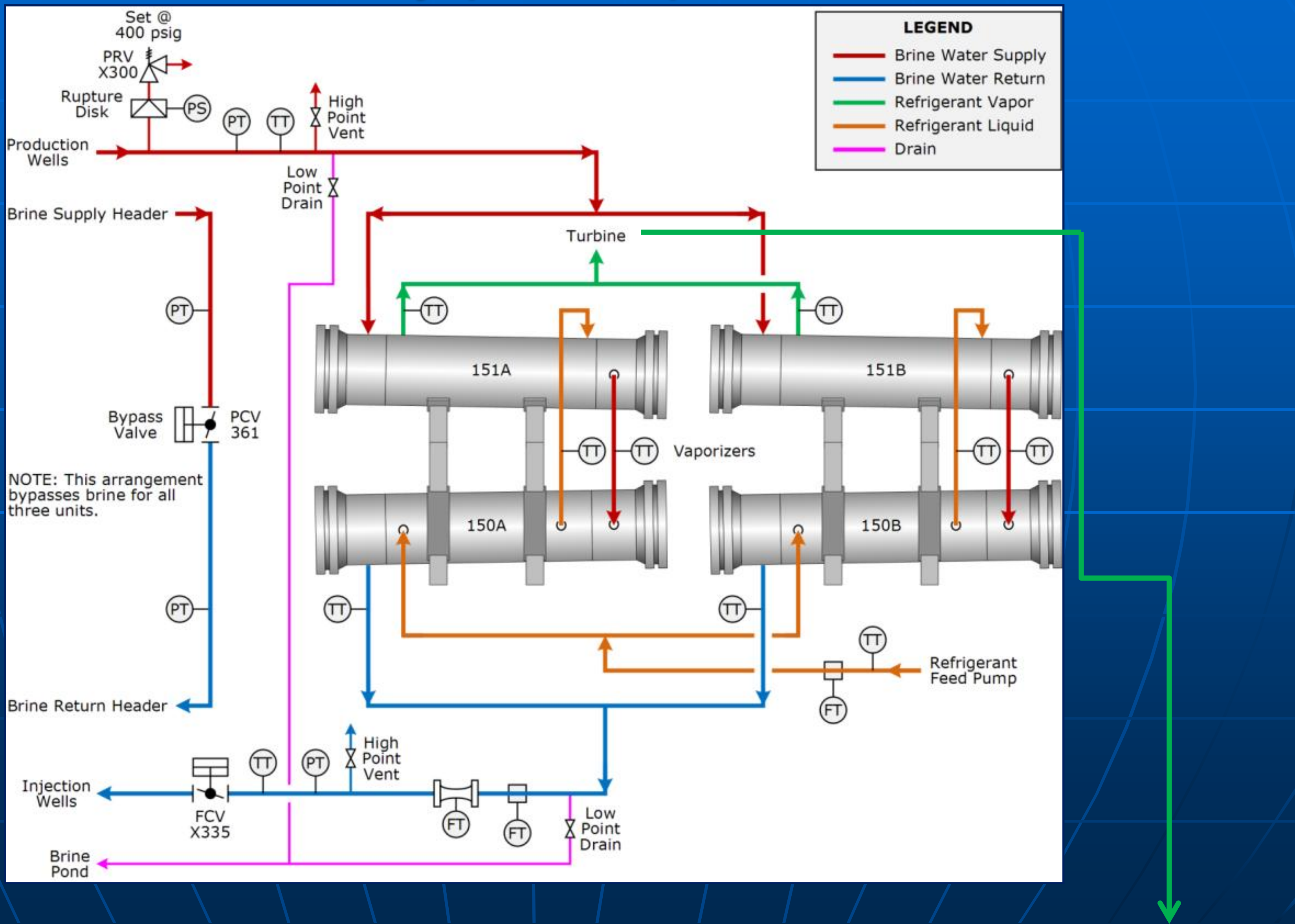




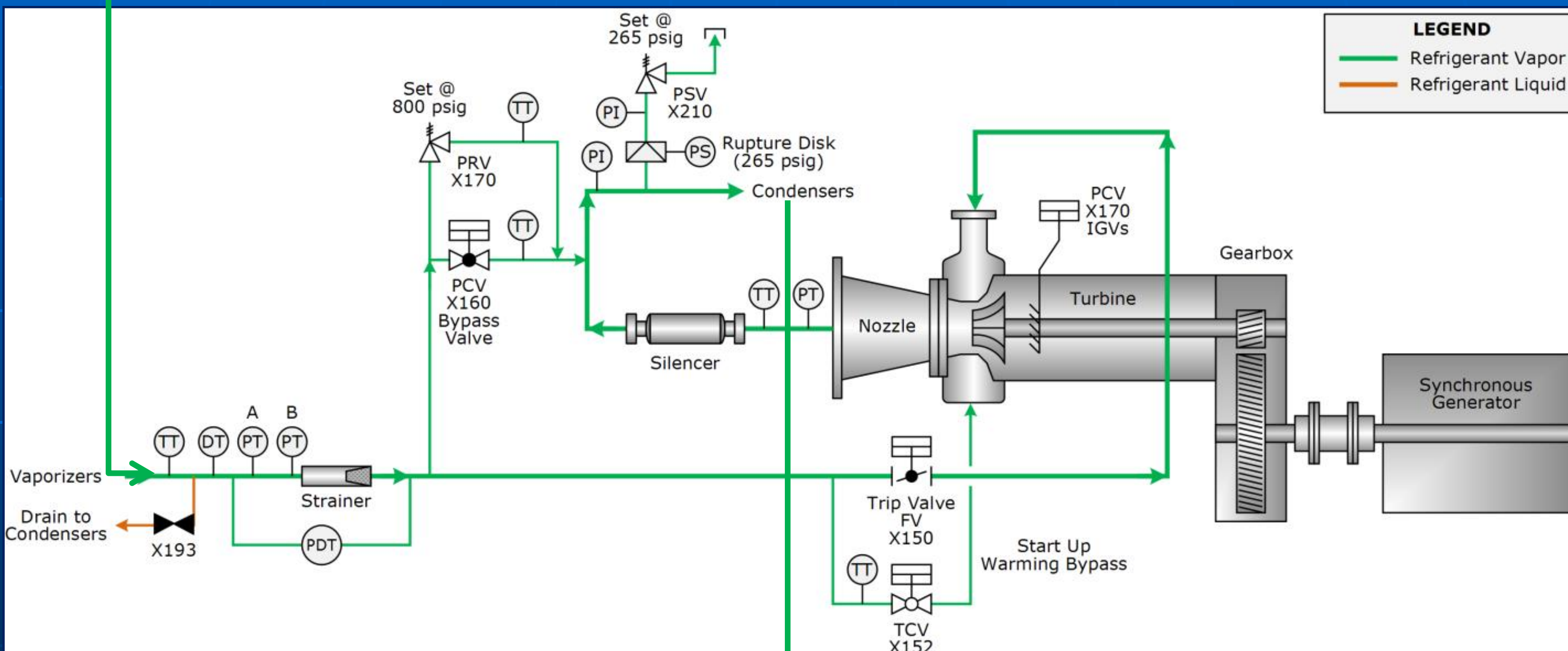
Neal Hot Springs Production



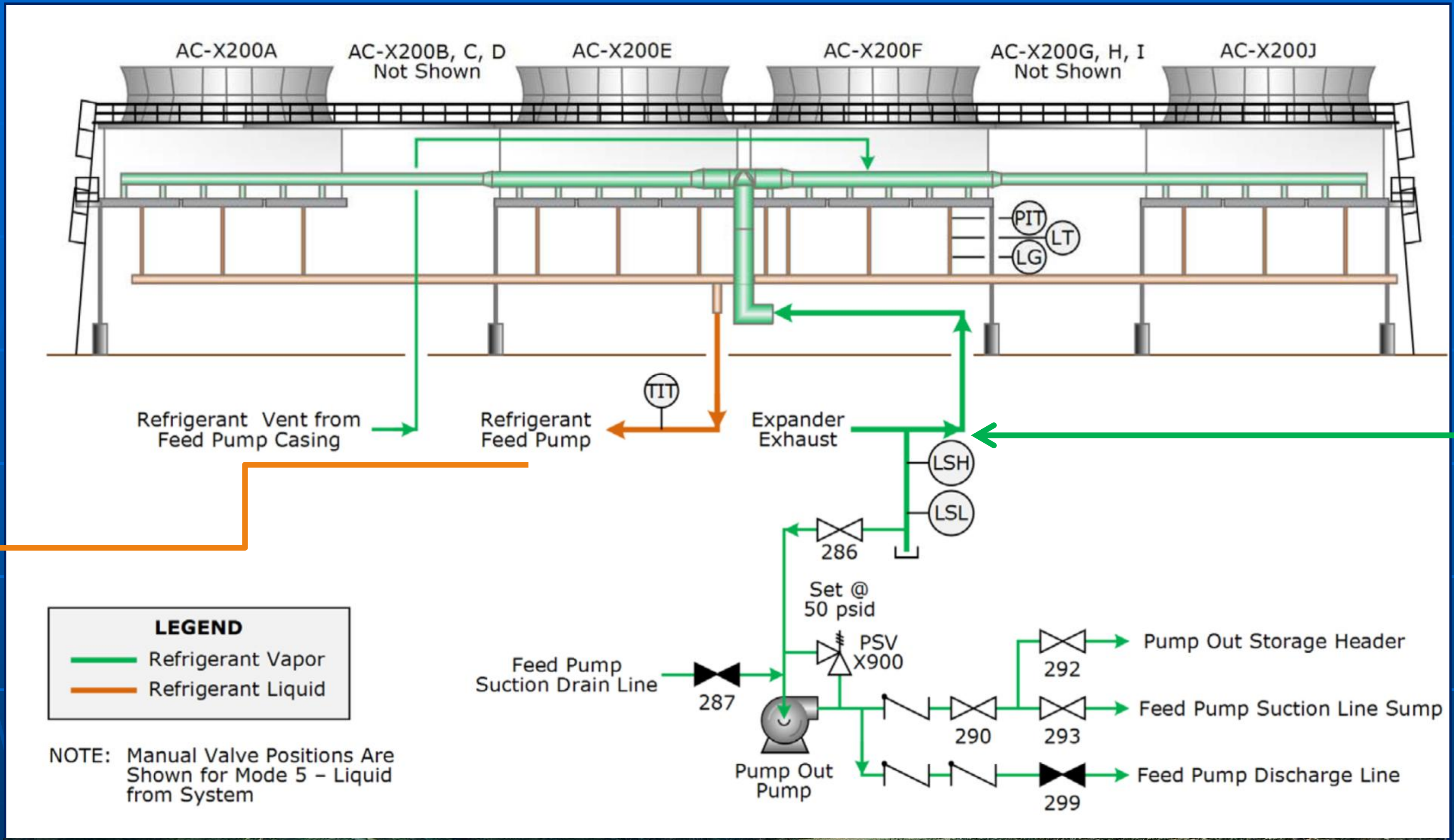
Geothermal brine pathway through the binary power plant



Turbine Detail



Air-Cooled Condenser



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CLEAN GREEN RENEWABLE ENERGY

Thank you!