Advanced Geothermal Technology Solutions: Water Use and EGS

Prevent Water Contamination

Reduce Water Use
Heat Stored in Rock

- 29,300,000 BBL of Oil
- 11,400,000 MWh
- 1.3 Million homes for year

T = 200°C
ΔT = 10°C

1 km x 1 km x 1 km

6.5 km

50°C 100°C 150°C 200°C 250°C 300°C
**Enhanced Geothermal Systems (EGS) Technology**

- **Exploration**
  - Existing data – water or oil wells, mining holes
  - Temperature gradient holes
  - Determine target depth based on economics
  - Evaluate stress field from fracturing/tectonics
- **Drill injector**
- **Create reservoir by stimulation**
  - Evaluate borehole to identify natural fractures, stress field
  - Injection from surface
  - Stimulate natural fractures and map
- **Drill producers into fractured volume**
  - Restimulate if needed to improve connection
  - As many as 4 producers per injector
Geothermal Energy and Water: The Issues

- Water use:
  - Consumptive use of water for wet cooling
  - Use of water for reservoir creation
  - Water loss to reservoir during injection

- Concern about contamination of groundwater
  - Natural geothermal systems can have dissolved minerals that are toxic
    - H2S
    - Mercury
    - Arsenic
  - Naturally occurring radioactive waste
    - Some systems may have
Permeability Enhancement in EGS = Hydroshearing
(not hydrofracking)

- Hydraulic stimulation
- Impermeable rock
- Shear failure
- Existing fractures
- Open hole
- Low pressure
- Days of pumping @~500-700 gpm

Sealed

\[ \tau > (\sigma_n - P) \mu \]

Slipping

Self-propped
Goals of the Newberry EGS Demonstration

- Demonstrate current technology and advances in EGS utilizing AltaRock's proprietary methods and technology*
  - Stimulate and map at least three fracture zones in existing very hot but "dry" well, NWG 55-29 (10,000 ft deep, 600° F BHT)
  - Demonstrate thermo-degradable zonal isolation materials ("TZIM") for multiple zone stimulation
  - Demonstrate single-well test methods to assess productivity after stimulation

- Drill two production wells into EGS reservoir
- Demonstrate economic well productivity
- Establish circulation through three-well system
- Develop conceptual model of complete EGS

* AltaRock has a portfolio of patent filings protecting its proprietary technology and methods.
The Newberry EGS Demonstration Project

- American Reinvestment and Recovery Act
- Department of Energy, Energy Efficiency and Renewable Energy, Geothermal Technologies Program
- AltaRock awarded $21.45m as part of total budget of $43.81m
- Demonstrate EGS at Newberry for future application across the United States

In association with:
- Davenport Newberry
- University of Oregon
- University of Utah Energy and Geoscience Institute
- U.S. Geological Survey
- Temple University
- Texas A&M
- Lawrence Berkeley National Laboratory

Jobs
- Phase I - III – 60 people.
- Power plant construction: 200 people for two years
- Power plant operation: 35 people
- County and State Revenue from taxes and royalties
Project Location

- Deschutes National Forest
- Northwest flank of Newberry Volcano, Deschutes Co, OR
- Federal Geothermal Leases
- Outside western boundary of Monument
- Established by Citizens’ Committee in 1980’s
Milestones

- Award Notification – November 1, 2009
- DOE Limited Release of Funds – May 3, 2010
- Filed Notice of Intent – June 8, 2010
- Initiated EA – September 16, 2010
- Complete Seismic Risk Assessment – November 1, 2010
- Complete EA – October, 2011
- Complete DOE Stage-Gate Review – October, 2011
- Initiate Phase 2 Stimulation Activities – March, 2012
- Acceptance of MSA by DOE – August, 2012
- Complete 55-29 Stimulation – December, 2012
- Phase 2.1 DOE Go/No Go Decision—May, 2013
Newberry EGS Demonstration Site
view from US hwy 97 north of La Pine
Across the highway – the Cascades
Project Objectives

To demonstrate the development and operation of an Enhanced Geothermal System (“EGS”)

- Develop an EGS reservoir in the high temperature, low permeability, very hot resource present in volcanic formations on the northwest flank of Newberry Volcano
- Demonstrate multi-zone stimulation techniques
- Sustain fluid flow and heat extraction from one injection well and up to two production wells
- Conceptual design and project economics of a commercial-scale well field and power plant
Phase I - Pre-Stimulation 2010-2012

- Community Outreach
  - La Pine, Sunriver, Bend
- Geoscience review and lab studies
- Baseline Monitoring
  - MSA design, install, calibrate
  - Water well testing
  - Injection well
    - Integrity test
    - Baseline injectivity
    - Borehole televiewer
- Permitting
  - Induced Seismicity Risk
  - Conduct EA
- Stimulation Plan
- DOE Stage-Gate Review
Phase 2.1 – Stimulation

- Snow removal and road maintenance
- Drill an additional five holes for BH seismometers
- Procure seismic equipment
- Procure Distributed Temperature Sensing equipment
- Install, configure and test MSA
- Field preparation (water delivery and pumps)
- Stimulate at least three zones using TZIM (Aug.-Dec.)
- Single well flow-back test (incl. tracer collection)
Phase 2.3 - Drill and Test Production Wells
Summer 2015

- Drill First Production Well
- Conduct 7-Day Connectivity test
  - Pump groundwater into injector
  - Flow test production well
  - Recycle water to injector
- Stimulate production well, if needed
- Evaluate productivity
- Plan and Drill Second Production Well
- Conduct 7-Day Connectivity test
- Conduct 30-Day Multi-Well Connectivity test
  - Flow test both production wells
Well Design

- Robust casing and cement
  - 4 layers of steel and cement near surface
  - Heavy-wall, corrosion resistant steel
  - Fully cemented
  - 3 layers of steel and cement protect groundwater aquifer
  - 7” perforated liner starting at 6222 ft.
Environmental and Permitting

Risk Mitigation is part of the plan

- Induced Seismicity Hazards Assessment
- Induced Seismicity Mitigation Plan
- Hydrologic Study
  - Background data on water chemistry
  - Develop monitoring plan
  - Pump test water wells
- Stimulation planning
- Hydrologic monitoring plan
- Engineering studies of historic buildings
- Evaluation of Paulina Creek dam
- Wildlife studies
- Microseismic monitoring
- EA prepared by BLM
Hydrologic Impact and Monitoring

- Water impact = major public concern
- Stimulation requires 11 million gallons (33 acre-ft, 41,325 m$^3$)
- Water for stimulation from existing on-site groundwater wells
- 2011 tests: capacity >800 gpm
- Total demonstration will use approximately 60 million gallons (incl. evaporation during flow testing)
- Strong local recharge
- Public water usage plan (Kleinfelder) study found no significant impacts

- Monitoring prior to, during and after stimulation
  - Levels in nearby water wells
  - Composition in water wells and dual-purpose seismic borehole in stimulation area
  - Hot springs at Paulina and East Lakes
  - Domestic Water Wells
Water Usage: All Phases

<table>
<thead>
<tr>
<th>Activity</th>
<th>Estimated Average Water Usage Rate, gpm</th>
<th>Minimum Water Volume, gal</th>
<th>Minimum Water Volume, acre-ft</th>
<th>Duration, days</th>
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</thead>
<tbody>
<tr>
<td>Single well stimulation</td>
<td>200</td>
<td>11,000,000</td>
<td>33.8</td>
<td>41</td>
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<tr>
<td>Drilling producer #1</td>
<td>3,152,150</td>
<td>9.7</td>
<td>90</td>
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<tr>
<td>Drilling producer #2</td>
<td>3,152,150</td>
<td>9.7</td>
<td>90</td>
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<tr>
<td>Connectivity test PW1</td>
<td>198</td>
<td>853,829</td>
<td>2.6</td>
<td>3</td>
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<tr>
<td>Dual well stimulation PW1</td>
<td>1600 (split between 2 wells)</td>
<td>11,520,000</td>
<td>35.4</td>
<td>5</td>
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<tr>
<td>Connectivity test PW2</td>
<td>198</td>
<td>853,829</td>
<td>2.6</td>
<td>3</td>
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<tr>
<td>Dual well stimulation PW2</td>
<td>1600 (split between 2 wells)</td>
<td>11,520,000</td>
<td>35.4</td>
<td>5</td>
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<tr>
<td>Circulation Test</td>
<td>395</td>
<td>17,076,583</td>
<td>52.4</td>
<td>30</td>
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<td><strong>Total</strong></td>
<td></td>
<td><strong>59,128,541</strong></td>
<td><strong>181.6</strong></td>
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</table>

- Water stored in storage basin for buffer during stimulation
- Tanks placed on Pad 29 for water storage, but later removed due to operational difficulties.
Monitoring Plan
<table>
<thead>
<tr>
<th>Monitoring Sites</th>
<th>Analysis</th>
<th>Frequency</th>
<th>Duration</th>
<th>Status</th>
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<tbody>
<tr>
<td>Pad 29 Well</td>
<td>Water level Geochemical suite Tracers Turbidity</td>
<td>C 3x D, 1/M A 3x D, 1/M A 3x D, 2x A</td>
<td>D 1 B, 1 D, 6M A 1 B, 1 D, 6M A 1 B, 1 D, 6M A</td>
<td>Continuous On going On going Pending</td>
</tr>
<tr>
<td>Down gradient well (NN-17)</td>
<td>Water level Geochemical suite Tracers Turbidity</td>
<td>C 1x D, 1/M A 1x D, 1/M A 1x D, 1/M A</td>
<td>D 2 B, 1 D, 6M A 2 B, 1 D, 6M A 2 B, 1 D, 6M A</td>
<td>Continuous On going On going On going</td>
</tr>
<tr>
<td>Up gradient well (NN-18)</td>
<td>Water level Geochemical suite Tracers Turbidity</td>
<td>C 1x D, 1/M A 1x D, 1/M A 1x D, 1/M A</td>
<td>D 2 B, 1 D, 6M A 2 B, 1 D, 6M A 2 B, 1 D, 6M A</td>
<td>Continuous On going On going On going</td>
</tr>
<tr>
<td>Pad 16 Well (up and cross-gradient)</td>
<td>Water level Geochemical suite Tracers Turbidity</td>
<td>C 1x D, 1x A 1x D, 1x A 1x D, 1x A</td>
<td>C 1 B, 1 D, 6M A 1 B, 1 D, 6M A 1 B, 1 D, 6M A</td>
<td>Continuous Pending Pending Pending</td>
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<td>Paulina Hot Springs</td>
<td>Geochemical suite Tracers Turbidity</td>
<td>1x D, 1/M A 1x D, 1/M A 1x D, 1/M A</td>
<td>1 B, D, 6M A 1 B, D, 6M A 1 B, D, 6M A</td>
<td>On going On going On going</td>
</tr>
<tr>
<td>East Lake Hot Springs</td>
<td>Geochemical suite Tracers Turbidity</td>
<td>1x D, 1/M A 1x D, 1/M A 1x D, 1/M A</td>
<td>1 B, D, 6M A 1 B, D, 6M A 1 B, D, 6M A</td>
<td>On going On going On going</td>
</tr>
<tr>
<td>Paulina Lake Campground Well</td>
<td>Geochemical suite Tracers Turbidity</td>
<td>0x D, 1x A 0x D, 1x A 0x D, 1x A</td>
<td>1 B, 6M A 1 B, 6M A 1 B, 6M A</td>
<td>Pending Pending Pending</td>
</tr>
<tr>
<td>Prairie Campground Well (down and cross-gradient)</td>
<td>Geochemical suite Tracers Turbidity</td>
<td>0x D, 1x A 0x D, 1x A 0x D, 1x A</td>
<td>1 B, 6M A 1 B, 6M A 1 B, 6M A</td>
<td>Pending Pending Pending</td>
</tr>
<tr>
<td>La Pine Domestic Water Well #1</td>
<td>Geochemical Suite Tracers Turbidity</td>
<td>0x D, 1/M A 0x D, 1/M A 0x D, 1/M A</td>
<td>1 B, 6M A 1 B, 6M A 1 B, 6M A</td>
<td>On going On going On going</td>
</tr>
<tr>
<td>La Pine Domestic Water Well #2</td>
<td>Geochemical Suite Tracers Turbidity</td>
<td>1x B 1x B 1x B</td>
<td>1x B 1x B 1x B</td>
<td>Completed Completed Completed</td>
</tr>
</tbody>
</table>

- Comprehensive monitoring program designed to provide background and post-stimulation data
- 9 active sampling locations
- On-going monitoring for 6 months after stimulation
- Winterized wells planned for spring data collection
Monitoring Plan

Field Complications

- Springs are artificially ephemeral; influenced by lake levels.
- Turbidity is not useful
- Other measures may vary
- Tracers are best indication of fluid movement
Monitoring Plan

Field Parameters:
Temperature, pH, electrical conductivity, oxidation-reduction potential and turbidity.

For Geochemical Suite:
Samples are filtered with 0.45 micron cellulose acetate in the field, and placed into 750mL, 500mL, and 250mL HDPE bottles with no preservative, HNO₃, and H₂SO₄, respectively, per standard analytical methods used by Sierra Environmental Monitoring.

For Isotopes:
Samples filtered as above and poured into 30mL HDPE bottle

For Tracers:
Samples are collect, unfiltered, in opaque amber 60mL HDPE bottles.
# Water Quality Analysis

<table>
<thead>
<tr>
<th>Source†</th>
<th>East Lake Hot Springs #1</th>
<th>Paulina Hot Springs #1</th>
<th>La Pine Water Well #1</th>
<th>La Pine Water Well #2</th>
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</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>43.71957</td>
<td>43.73195</td>
<td>43.70779</td>
<td>43.71692</td>
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<tr>
<td>Longitude</td>
<td>-121.20452</td>
<td>-121.25179</td>
<td>-121.4456</td>
<td>-121.44296</td>
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<tr>
<td>Type</td>
<td>Spring</td>
<td>Spring</td>
<td>Water Well</td>
<td>Water Well</td>
</tr>
<tr>
<td>Field Temperature (°C)</td>
<td>54.5</td>
<td>49.9</td>
<td>9.1</td>
<td>8.6</td>
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<tr>
<td>Field pH</td>
<td>6.26</td>
<td>6.09</td>
<td>7.38</td>
<td>7.27</td>
</tr>
<tr>
<td>Field Conductivity</td>
<td>1.29-1.19</td>
<td>0.99</td>
<td>0.093</td>
<td>0.064</td>
</tr>
<tr>
<td>Field ORP</td>
<td>-37</td>
<td>81</td>
<td>120</td>
<td>124</td>
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<tr>
<td>Field Turbidity</td>
<td>28.1</td>
<td>Error</td>
<td>Error</td>
<td>0.55-0.56</td>
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<tr>
<td>Alkalinity, Total (mg/L CaCO3)</td>
<td>740</td>
<td>540</td>
<td>57</td>
<td>50</td>
</tr>
<tr>
<td>Alkalinity/Bicarbonate (mg/L CaCO3)</td>
<td>740</td>
<td>540</td>
<td>57</td>
<td>50</td>
</tr>
<tr>
<td>Alkalinity/Carbonate (mg/L CaCO3)</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
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<tr>
<td>Alkalinity/Hydroxide (mg/L CaCO3)</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
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<tr>
<td>Aluminum (mg/L)</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
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<tr>
<td>Ammonia (mg/L)</td>
<td>0.1</td>
<td>0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
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<tr>
<td>Arsenic (mg/L)</td>
<td>0.003</td>
<td>0.015</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
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<tr>
<td>Barium (mg/L)</td>
<td>0.005</td>
<td>0.28</td>
<td>0.002</td>
<td>0.002</td>
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<tr>
<td>Boron (mg/L)</td>
<td>0.61</td>
<td>0.76</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
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<tr>
<td>Calcium (mg/L)</td>
<td>130</td>
<td>48</td>
<td>8.2</td>
<td>5.5</td>
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<tr>
<td>Cesium (mg/L)</td>
<td>&lt;0.002</td>
<td>0.004</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
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<tr>
<td>Chloride (mg/L)</td>
<td>4.5</td>
<td>7</td>
<td>2.4</td>
<td>1.7</td>
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<tr>
<td>Chromium (mg/L)</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
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<tr>
<td>Fluoride (mg/L)</td>
<td>0.5</td>
<td>0.9</td>
<td>0.2</td>
<td>0.2</td>
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<tr>
<td>Iron (mg/L)</td>
<td>0.15</td>
<td>0.13</td>
<td>0.1</td>
<td>&lt;0.05</td>
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<tr>
<td>Lithium (mg/L)</td>
<td>&lt;0.1</td>
<td>0.2</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
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<tr>
<td>Magnesium (mg/L)</td>
<td>54</td>
<td>42</td>
<td>4.7</td>
<td>4.3</td>
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<tr>
<td>Manganese (mg/L)</td>
<td>0.58</td>
<td>2.7</td>
<td>0.002</td>
<td>&lt;0.002</td>
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<tr>
<td>Mercury (mg/L)</td>
<td>&lt;0.0002</td>
<td>&lt;0.0002</td>
<td>&lt;0.0002</td>
<td>&lt;0.0002</td>
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<tr>
<td>Nitrate (mg/L N)</td>
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<td>&lt;0.5</td>
<td>0.9</td>
<td>&lt;0.5</td>
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<tr>
<td>pH</td>
<td>7.9</td>
<td>7.67</td>
<td>7.99</td>
<td>7.93</td>
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<td>pH - temperature (°C)</td>
<td>18.2</td>
<td>18.4</td>
<td>18.8</td>
<td>18.8</td>
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<td>Phosphorus (mg/L)</td>
<td>0.15</td>
<td>0.2</td>
<td>0.22</td>
<td>0.31</td>
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<td>Potassium (mg/L)</td>
<td>13</td>
<td>13</td>
<td>1.4</td>
<td>1.5</td>
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<tr>
<td>Rubidium (mg/L)</td>
<td>0.012</td>
<td>0.032</td>
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<td>0.002</td>
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<td>Silica (mg/L SiO2)</td>
<td>180</td>
<td>160</td>
<td>42</td>
<td>43</td>
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<tr>
<td>Sodium (mg/L)</td>
<td>90</td>
<td>110</td>
<td>10</td>
<td>9.1</td>
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<tr>
<td>Strontium (mg/L)</td>
<td>0.36</td>
<td>0.2</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
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<td>Sulfate (mg/L)</td>
<td>&lt;0.2</td>
<td>3.5</td>
<td>1.7</td>
<td>0.5</td>
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<tr>
<td>TDS (mg/L)</td>
<td>900</td>
<td>720</td>
<td>110</td>
<td>92</td>
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<tr>
<td>d $^2$H</td>
<td>-114</td>
<td>-108</td>
<td>-120</td>
<td>-121</td>
</tr>
<tr>
<td>d $^{18}$O</td>
<td>-15.16</td>
<td>-14.44</td>
<td>-15.72</td>
<td>-16.14</td>
</tr>
</tbody>
</table>

*SEM*
Two-phase sample collection will be conducted according to ASTM Method E1675-04e1, *Standard Practice for Sampling Two-Phase Geothermal Fluid for Purposes of Chemical Analysis*.

Uses Webre sampling separator to separate steam and gas from liquid at the flow line.

Single-phase liquid samples will be collected from the weir box using simple grab methods.

Some analytes will be determined by field analysis, including but not limited to pH, conductivity, redox, alkalinity and hydrogen sulfide (H₂S).

Gas analysis will include but not be limited to the typical geothermal analytes CO₂, H₂S, H₂, N₂, O₂, Ar, CH₄, Hg and He.

Liquid analysis will include but not be limited to the typical geothermal analytes Na, K, Ca, Mg, SiO₂, Sr, Li, As, Hg, Fe, Mn, Cl, F, B, NH₄, H₂S, TDS

Laboratory duplication of the field-measured analytes listed above.
Pre-stim logistics
Status of pumped wells
• NN-17 (to be drilled; transducer and pump to be installed)
• WW#2 (pump to be installed)
• Pad S-16 well (pump, transducer to be powered)
• Pad S-29 well (pump, transducer to be powered)
• Campground well?
• Lake level?

Post-stim logistics
• Winter access (snowmobiles/snowshoes)
• Pumping and power
• Winterization of some wells

Monitoring Plan

<table>
<thead>
<tr>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
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<tbody>
<tr>
<td>...Preparation</td>
<td>STIMULATION</td>
<td>Flow Back?</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Background Sampling</td>
<td>During</td>
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</tbody>
</table>
Phase 2.1 & 2.2 55-29 Stimulation

- Install permanent borehole seismic array with telemetry for real time monitoring of stimulation
- Set up for hydrologic monitoring
- Water supply and pumping
- Install instrumentation and test equipment
- Acceptance of MSA by DOE
- Install flow test equipment
- Conduct step rate injection test
  - Determine rate and pressure at which fractures will extend
  - Measure baseline injectivity conditions
- Initiate constant-rate injection to stimulate fractures
- Grow fracture network to target size while monitoring seismicity
- Shut-in and flow back to relieve system pressure and end stimulation
Newberry Stimulation Site Preparation

Wellhead

MSA

Piping and Pumps
**Multizone Stimulation**

- **Stage 1** – Stimulate deep zones between 2880 m and 2950 m
  - 10/27/2012-11/2/2012
  - Total HP pumping time – 104 hours
  - Maximum WHP 13.8 MPa (2040 psi)

- **Stage 2** – Pump TZIM 1
  - 11/25/2012-12/3/2012
  - Seal permeable zones between 2880-2950 m
  - At end of stage zones around 2080 m open up.
  - Total HP pumping time – 130 hours
  - Maximum WHP 15.2 MPa (2200 psi)

- **Stage 3** – Pump TZIM 2
  - 12/3/2012-12/07/2012
  - Seal permeable zones ~ 2080 m
  - Total HP pumping time – 101 hours
  - Maximum WHP 16.7 MPa (2420 psi)

- **All Stages**
  - Total injected volume 41,325 m³ (11,000,000 gal)
  - Maximum WHP 16.7 Mpa (2420 psi)
  - 179 seismic events located by 12/31/12
  - Estimated total improved injectivity – 6.03 l/s/MPa
  - Injection at dP of 10 MPa ~62 l/s/MPa
DTS results: Newberry EGS

How do we know where the water is going?
Distributed temperature sensing using fiber optic technology.
Stage 1

- Two or more permeable zones between 2880 m and 2950 m are taking majority of the injected fluid.
- The deep zones from 2880 to 2950 m are stimulated at pressures above 10 MPa.
- Darker red color after higher pressures indicates improvement – zones take more fluid and therefore cool more.
- Other small permeable zones exist around 2550 m, 2670 m and 2850 m.
Stages 2 & 3

- Permeable zone developed below 2,080m during Stage 2 stimulation, and was mostly plugged with TZIM.
- Zones at 2,040m, 2,060m show smaller changes in temperature gradient indicating they are taking less fluid than zone at 2,080m.
Mapping EGS with Microseismic Array

Phase II array
- 15-stations
- 8 borehole sensors: 700-900’
- 7 surface sensors
- Real-time telemetry

Strong motion sensor (SMS) near Paulina Lake Visitor Center (NNVM)
Borehole Geophones and Surface Equipment

2 Hz, 3-component geophone

Digitizer, Modem, & Power

Hole Lock

Solar Panels and Antennas
Seismic Data Processing

EGS: Interactive Map of Earthquakes at the Newberry Caldera
Hydroshearing initiated at WHP 12.5 MPa (1,800 psi)
Seismicity continued for 2 weeks after stimulation
Events for Three Stages of Stimulation

Stage 1
10/29-11/25/2012

Stage 2 – TZIM 1
11/25-12/3/2012

Stage 3 – TZIM
12/3-12/11/2012

Legend
- Surface Seismic Stations
- Borehole Seismic Stations
- 1000 Meters From Wellhead

55-29 Path
55-29 Wellhead
Depth BG5 (m)
-2707
-140

Magnitude (Mw)
- 0.14 - 0.54
- 0.54 - 0.75
- 0.75 - 0.95
- 0.95 - 1.42
- 1.42 - 2.39
Flow back sampling of NWG 55-29

• Two phase and single phase flow
• Operations to measure properties as often 15 minutes, geochemical sampling up to 2/day
• Field and lab analysis
• Tracer and additional sampling rates to be determined by specific researchers
EGS Reservoir Sampling and Analysis

Additional sampling frequency, analytes, or methods will depend on groups needing data:

- University of Utah
- Lawrence Berkeley National Laboratory
- Penn State
- Idaho National Lab
- BLM
- State Department of Water Resources
- State Department of Environmental Quality
Use of Water in Large Scale EGS Development

Potential water sources:

- Surface water – salt water can be used, but wells will need special metallurgy and treatment
- Groundwater – May be saline, or otherwise non-potable. Again, may need corrosion/scale mitigation
- Spent conventional geothermal fluids.
- Treated waste water
- O&G produced water
EGS Project - Shallow Low Temperature

Water use during EGS Reservoir Creation

<table>
<thead>
<tr>
<th>Year</th>
<th>New Wells</th>
<th>Annual Water Loss from Operations (Mgal)</th>
<th>Annual Water Loss from Stimulation (Mgal)</th>
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- 6800-9200 ft wells in sedimentary basin
- 302°F resource temperature
- Average 3.28 MW per producer using TZIM stimulation

Year 1 Wellfield layout
EGS project – Deep High Temperature

- 11,150-16,000 ft wells in basement
- 482°F resource temperature
- Average 6.64 MW per producer using TZIM stimulation

### Water use during EGS Reservoir Creation

<table>
<thead>
<tr>
<th>Year</th>
<th>New Wells</th>
<th>Annual Water Loss from Operations (Mgal)</th>
<th>Annual Water Loss from Stimulation (Mgal)</th>
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- 11,150-16,000 ft wells in basement
- 482°F resource temperature
- Average 6.64 MW per producer using TZIM stimulation
For More Information

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- On [facebook](http://www.facebook.com/NewberryEGS)

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