



A GENERATION AHEAD,
today

**Northwest Geysers
Enhanced Geothermal System
Demonstration Project**

2011.08.17 Update

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Geophysicist
Calpine Corporation



Northwest Geysers Enhanced Geothermal System Demonstration Geothermal Energy Benefits



- Renewable (sustainable) energy source
- Clean energy; $\sim 1/6^{\text{th}}$ the CO_2 emissions of an efficient natural gas power plant
- Reliable; available 24 hours /day; 365 days/year
- Reduced dependence on foreign oil resources
- Local employment and tax revenues
- Recharge with secondary/tertiary treated water
The Geysers – numerous environmental awards

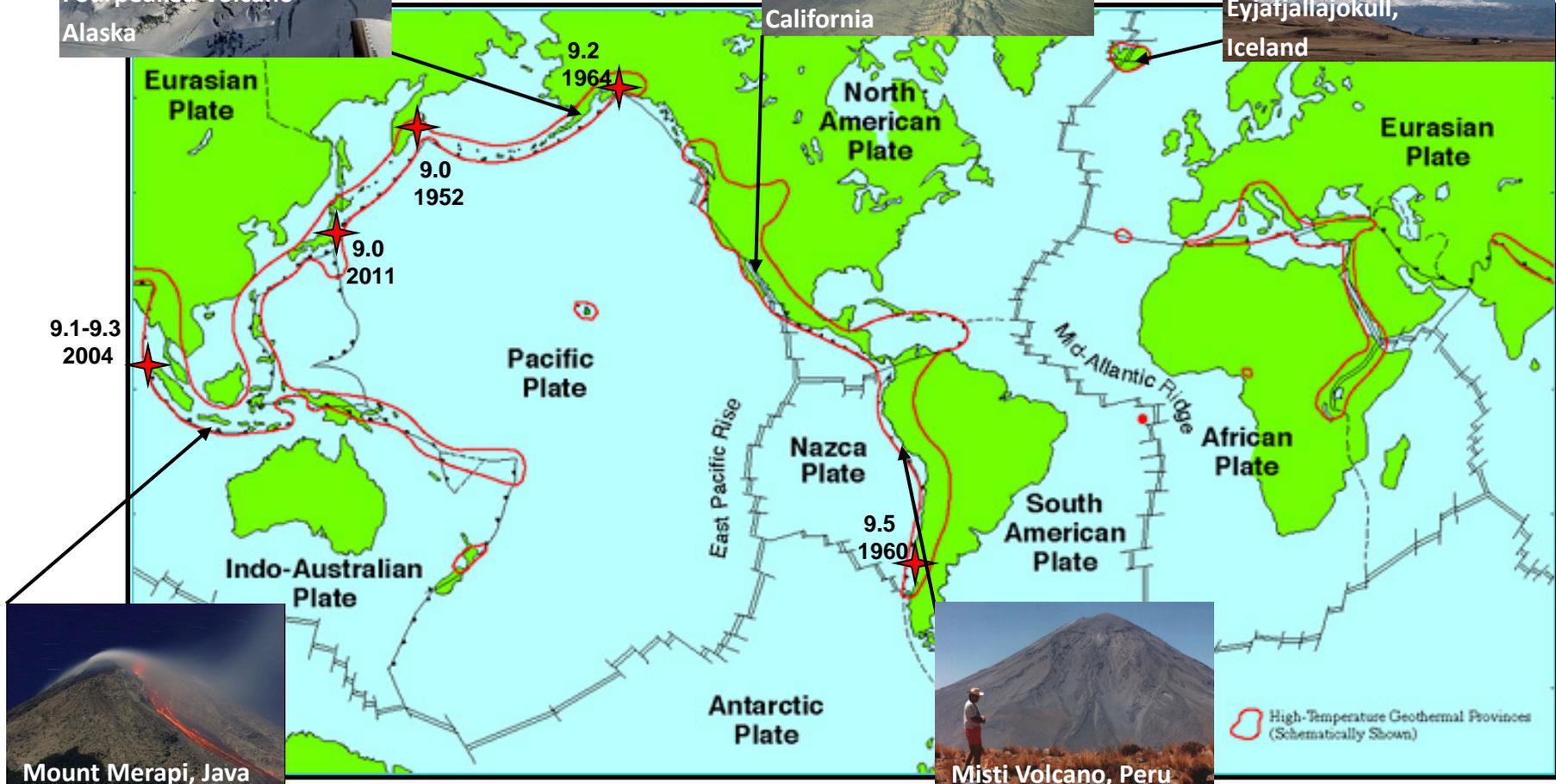


Northwest Geysers Enhanced Geothermal System Demonstration Worldwide Resource Distribution



Plate boundaries (associated with volcanic activity; seismicity)

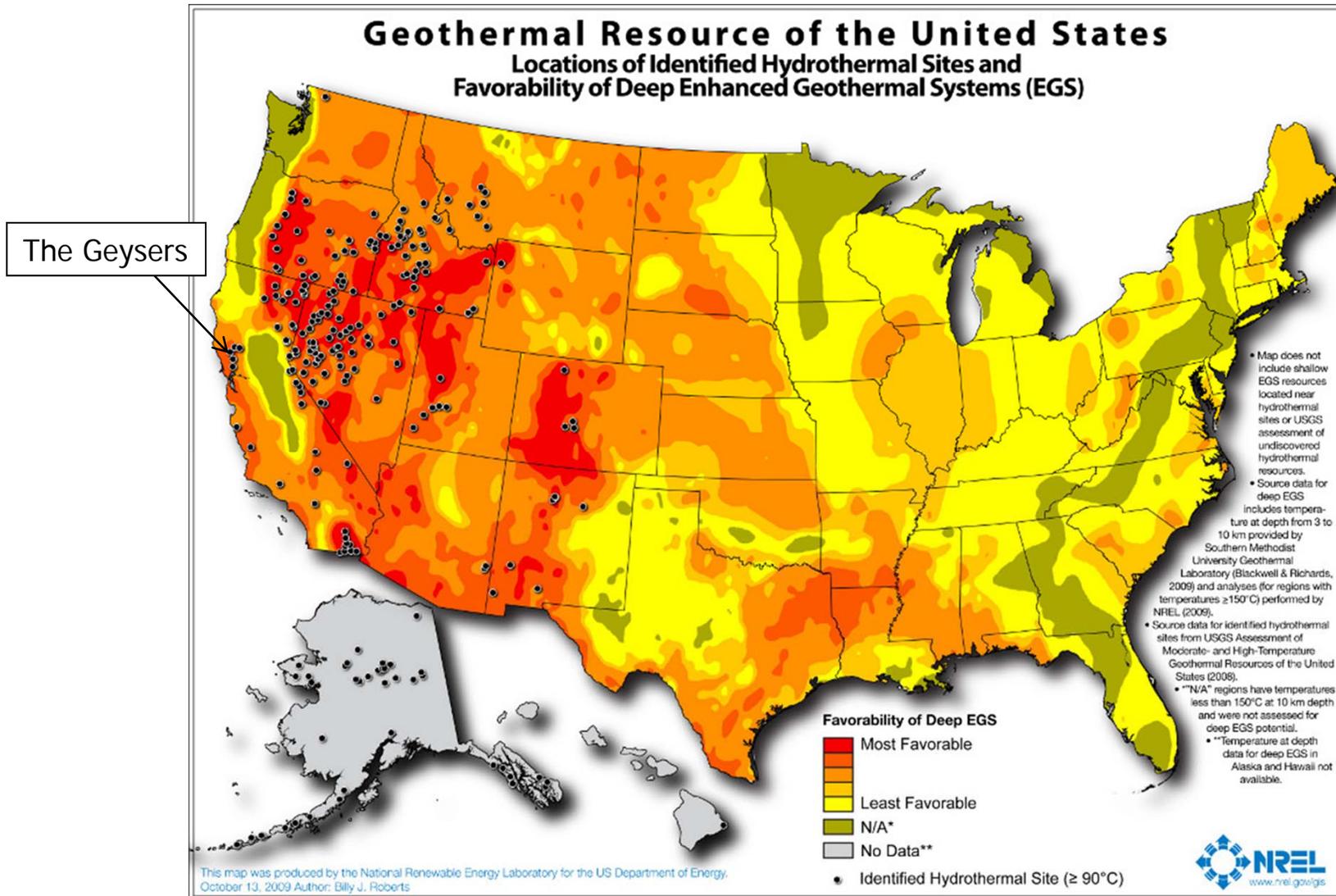
Pacific "Ring of Fire": 75% of volcanoes (452); 90% of earthquakes



Northwest Geysers Enhanced Geothermal System Demonstration USA Resource Distribution (National Renewable Energy Laboratory)



Present geothermal power generation is from hydrothermal reservoirs ...



Northwest Geysers Enhanced Geothermal System Demonstration Hydrothermal Resource Requirements



High Temperature Heat Source

Magma or Recently Crystallized Rock

Primary internal heat sources:

natural radioactive decay

heat of planetary accretion (formation)

Permeable Reservoir Rock

Breccia, Fractures, Faults

Ability to Transmit Fluid

Reservoir Fluid

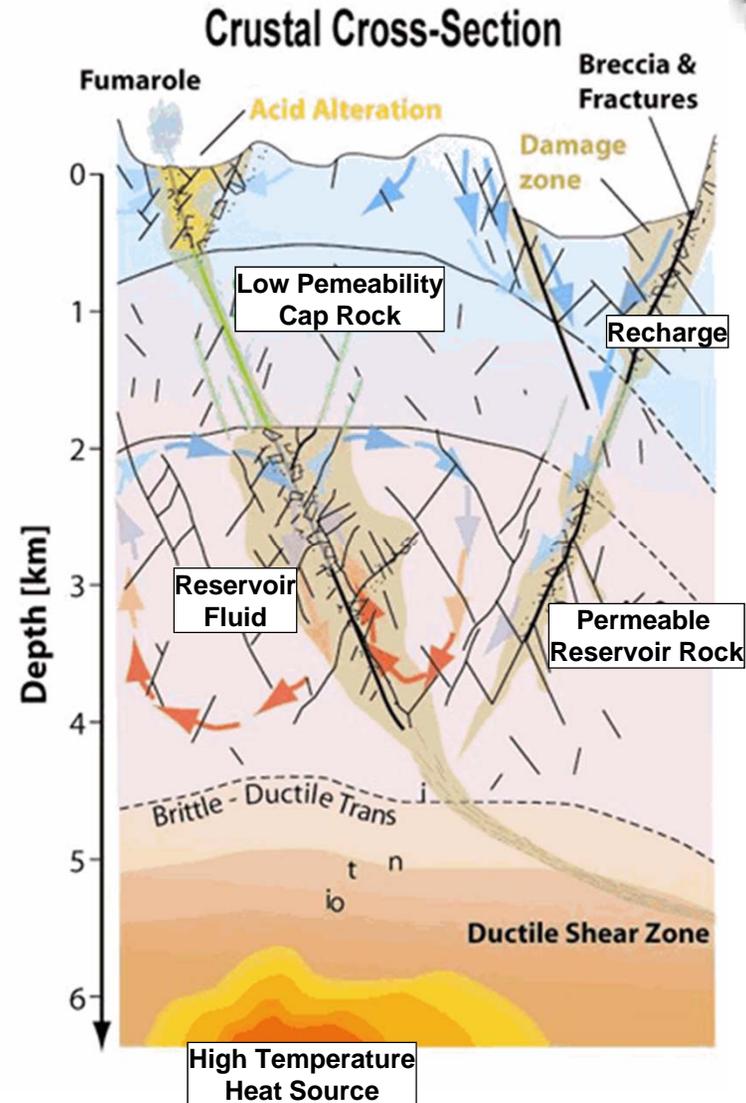
Steam and/or Water

Low Permeability Cap Rock

Fluid/Heat Containment

Natural or Engineered Fluid Recharge

Resource Sustainability



Northwest Geysers Enhanced Geothermal System Demonstration

What is EGS?



High temperature deep subsurface rocks do not always have sufficient fluid content or fracture development for power generation (fluid flow / heat transfer limitations)

Research is being conducted worldwide on Enhanced Geothermal Systems

Concept:

Water injection into zones of deep, hot, dry rock

Develop a subsurface micro-fracture system and improved fluid flow

Continued injection provides fluid which is heated within the resource

Heated fluid then produced to surface for power generation

Benefits:

Potential for dramatically expanding USA and worldwide geothermal energy utilization

More than 100,000 MW of potentially viable geothermal capacity in the continental USA

40x present hydrothermal production; potential to provide 10% of today's USA energy requirements

Calpine's The Geysers:

Operations produce about 725 MW (~ 725,000 homes; = San Francisco)

Largest complex of geothermal power plants in the world

~ 40% of USA geothermal electrical generation

~ 25% of California's renewable energy

Northwest Geysers Enhanced Geothermal System Demonstration Key Accomplishments



DOE Participation

February 2009	Notice of Financial Assistance Awarded
November 2009	Induced Seismicity Protocol Reviewed and Approved
June 2010	Environmental Assessment / Finding of No Significant Impact
July 2010	Go-ahead to drill

LBNL Modeling

February 2010	3D geologic model completed
April 2010	Geo-mechanical model completed

Calpine Well Preparation

August 2010	Prati State 31 deepened to 10,034'
September 2010	Prati 32 deepened to 11,143' ; 750 degree F encountered
June 2011	Prati 32 completed; Injection interval 8400' to 11143'
August 2011	Prati State 31 completed; Production interval 6900' to 10000'

Pipeline Preparation

December 2010	4800' injection pipeline completed
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Water Injection

September 2011	Water injection step test start scheduled for early September
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Northwest Geysers Enhanced Geothermal System Demonstration Technical Objectives



Develop an EGS Research Field Laboratory

Development and evaluation of surface and borehole monitoring technologies for EGS

Collaborative effort of scientists and engineers from Calpine and Lawrence Berkeley National Laboratory

Primary Calpine Investigator: Senior Geologist Mark Walters

Project co-funded by U.S. Department of Energy

Develop and demonstrate techniques to stimulate the productivity of deep, very hot fractured rocks

“Cold” treated wastewater injected directly into the high temperature zone (500°F to 750°F)

Mechanical processes: shrinkage due to cooling; fracture shear reactivation

Chemical processes: rock dissolution

Monitor the spatial and temporal response of carefully designed injection “step-tests”

Microseismicity, Pressure (water level), Temperature

Satellite-based surface deformation analysis

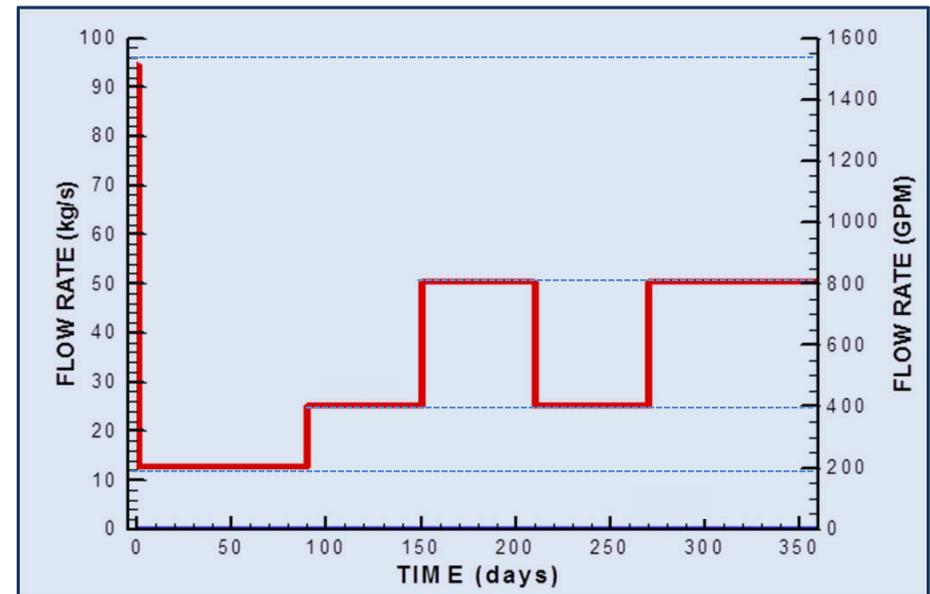
InSAR, GPS; cm scale

Geochemical analysis of injection/production fluids

Coupled fluid flow and geo-mechanical modeling

Linking injection and production to rock physics

Flow data recorded at 15 second interval

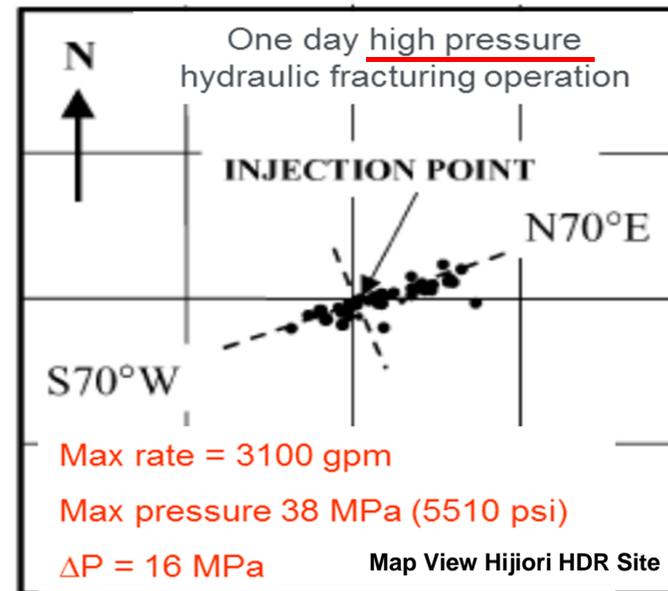
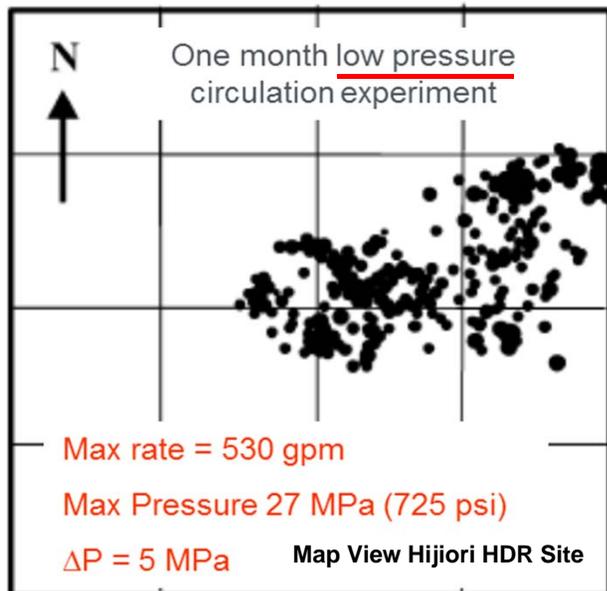


Northwest Geysers Enhanced Geothermal System Demonstration Technical Objectives



Low pressure injection tests

- Pressure well below fracture pressure
- Designed to avoid potentially damaging hydraulic fracturing
- Promotes gradual shear reactivation of existing fractures



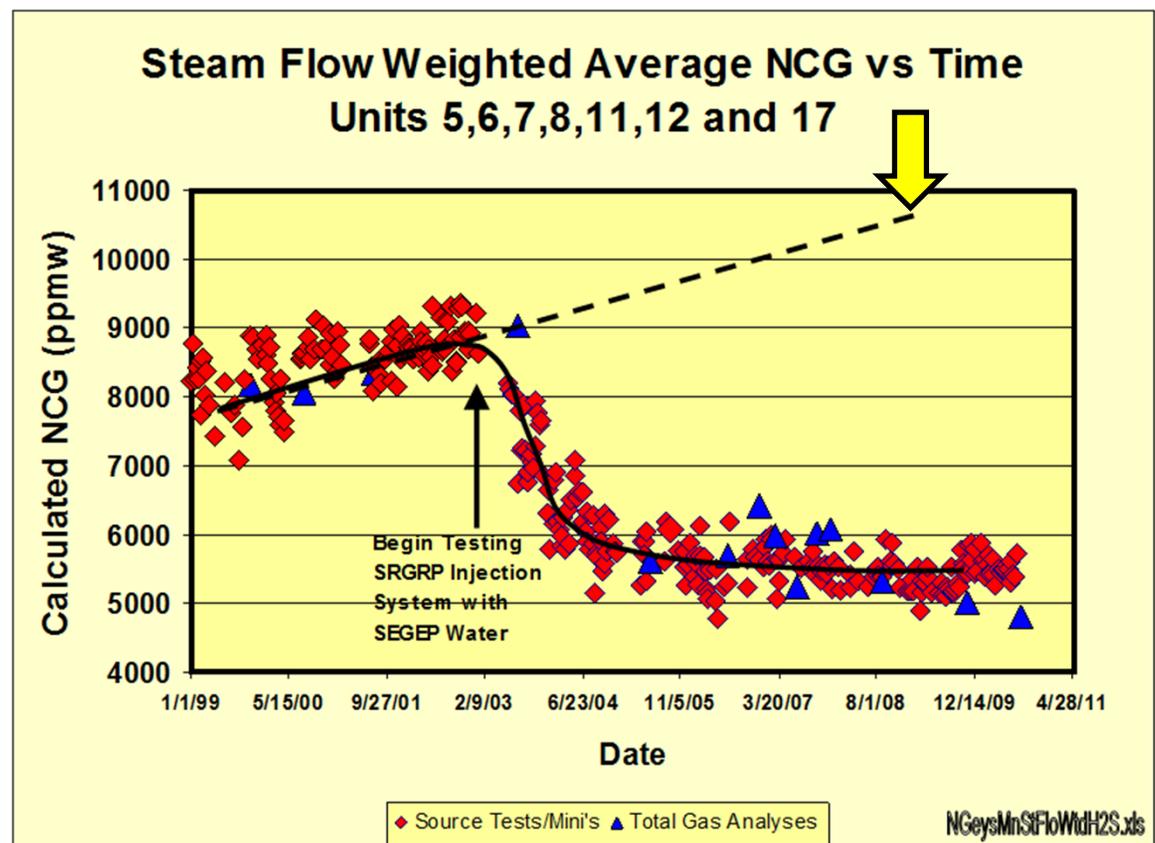
Northwest Geysers Enhanced Geothermal System Demonstration Field Objectives



Increase steam production in under-produced NW Geysers
Solutions developed for previous technical obstacles

Minimize non-condensable gas (NCG) concentrations in the high temperature reservoir
Field wide strategy to lower NCG concentrations
Improves plant efficiency
Mitigation for corrosion

Approach 100% fluid replacement
For sustainable electrical production



Northwest Geysers Enhanced Geothermal System Demonstration Public Relations Objectives



Increased Public Outreach

Highlight U.S. Department of Energy Programs

Energy Efficiency and Renewable Energy (EERE)

Geothermal Technologies Program

Enhanced Geothermal System exhibits at Geothermal Visitors Center

Expand EGS online information <http://www.geysers.com/>

Address public concerns on injection-induced seismicity

Significant seismic monitoring program w/ LBNL

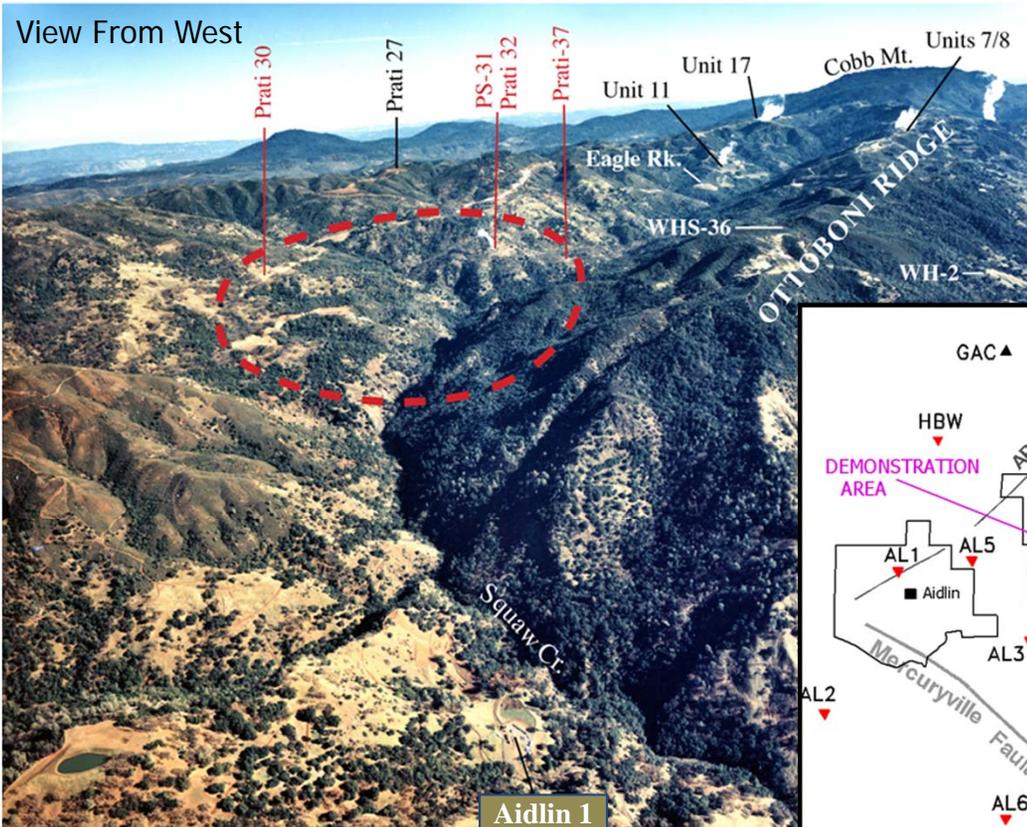
Associated research



Northwest Geysers Enhanced Geothermal System Demonstration Location



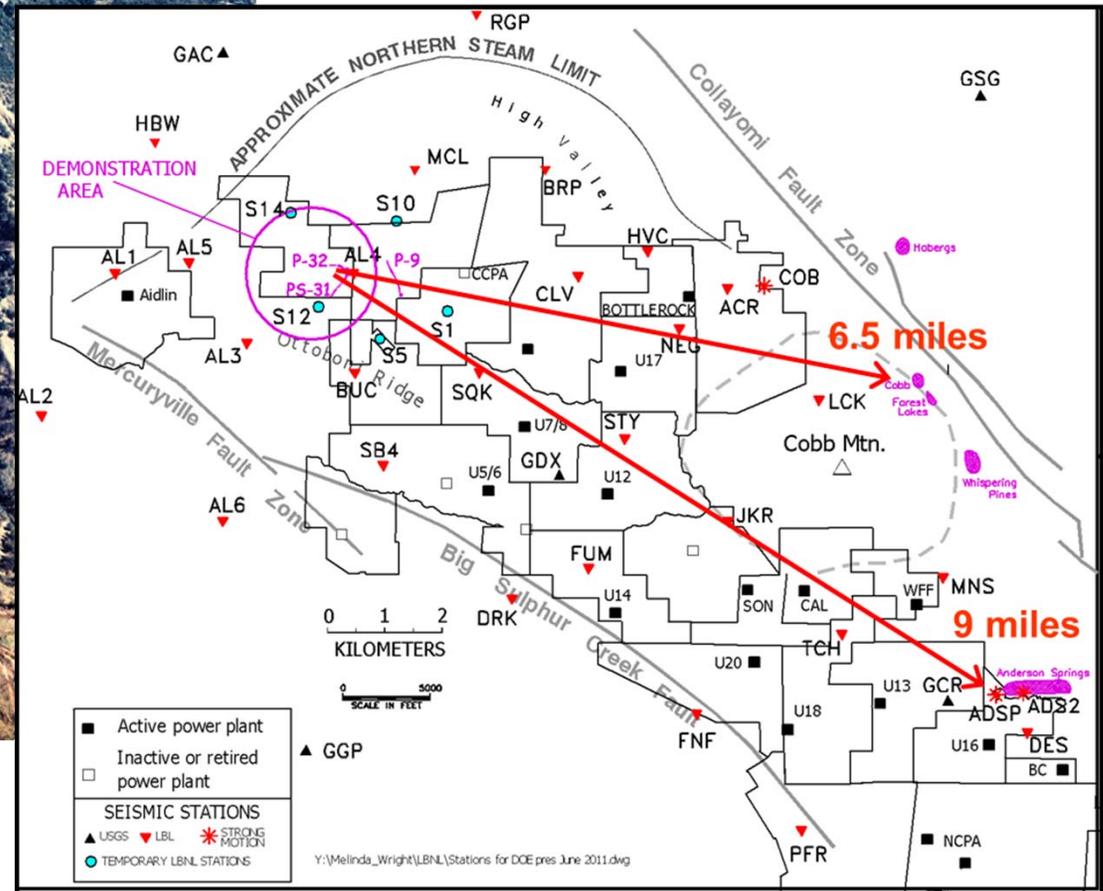
View From West



NW Geysers explored in 1980's
High concentrations non-condensable gas
Corrosive chloride gas
 Technology and process improvements ...

Selected Wells:

Prati State 31		
656 °F	1983	
Prati 32		
600 °F	1985	
750 °F	2010 - Deepened	



Northwest Geysers Enhanced Geothermal System Demonstration Location and Technique

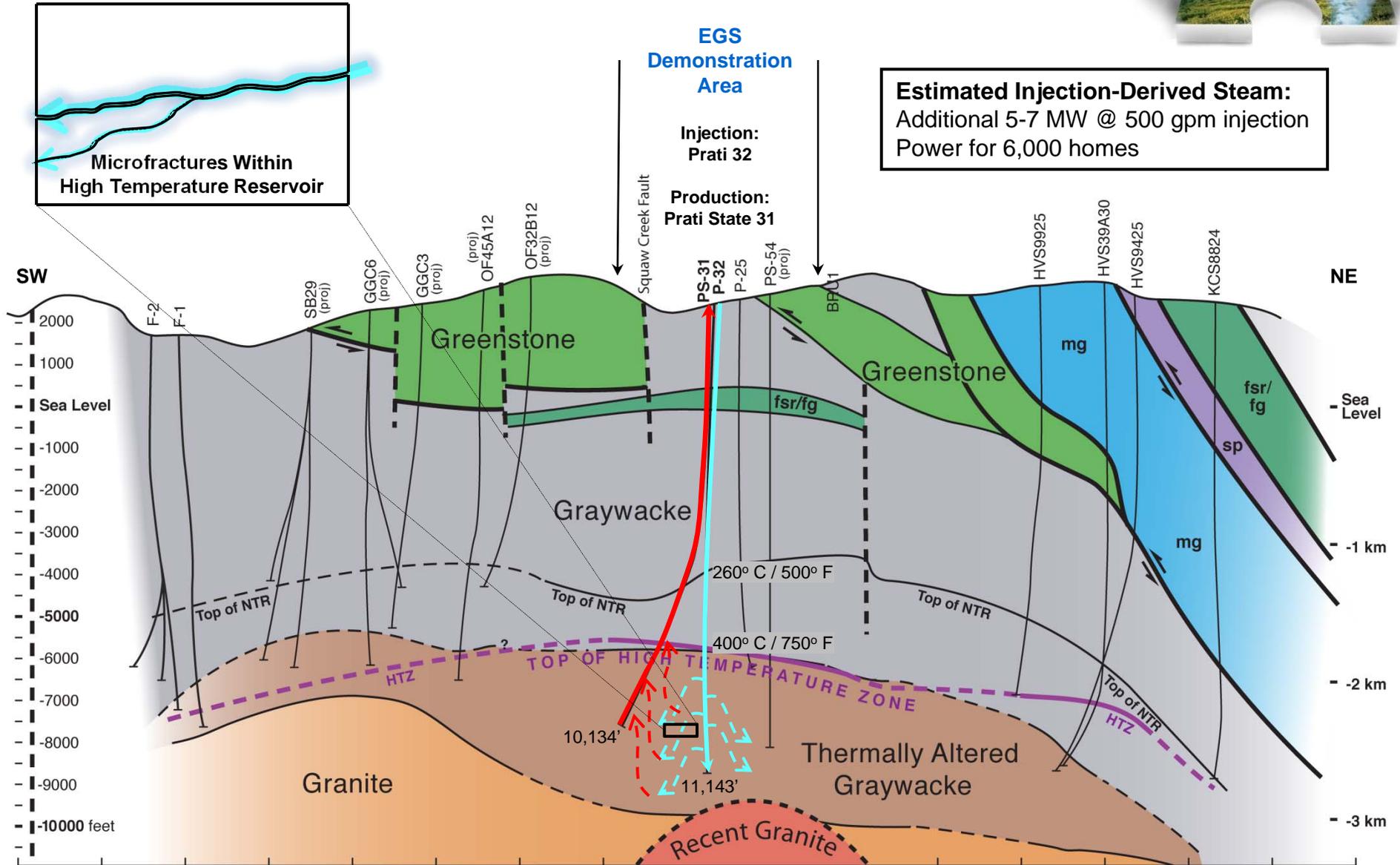
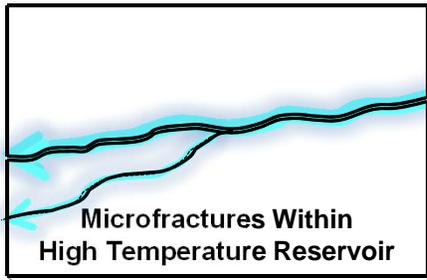


Estimated Injection-Derived Steam:
Additional 5-7 MW @ 500 gpm injection
Power for 6,000 homes

**EGS
Demonstration
Area**

**Injection:
Prati 32**

**Production:
Prati State 31**

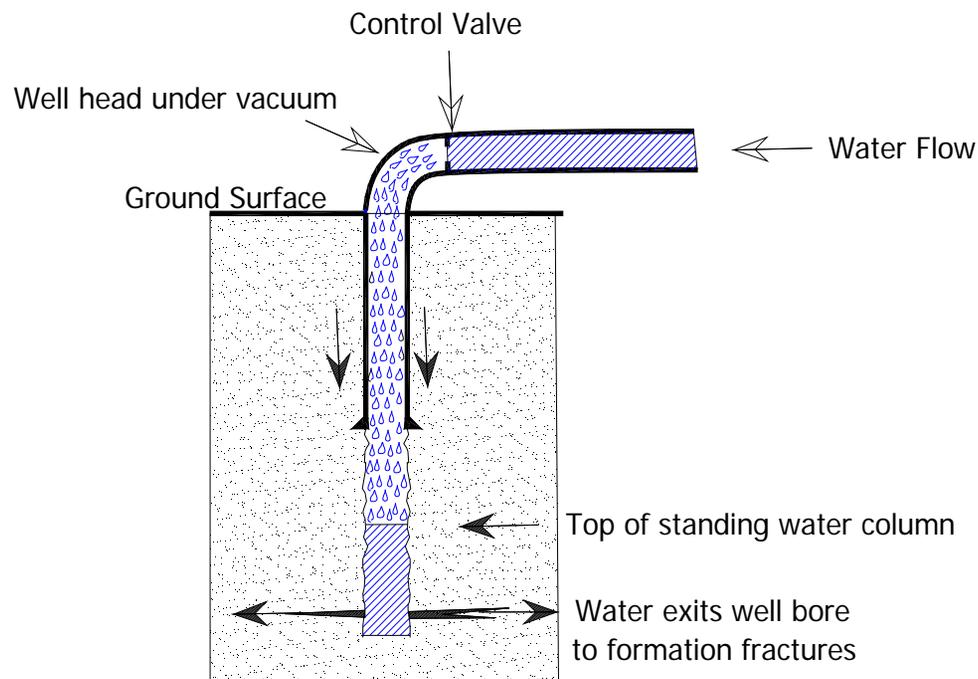


Northwest Geysers Enhanced Geothermal System Demonstration Water "Injection" Under Vacuum



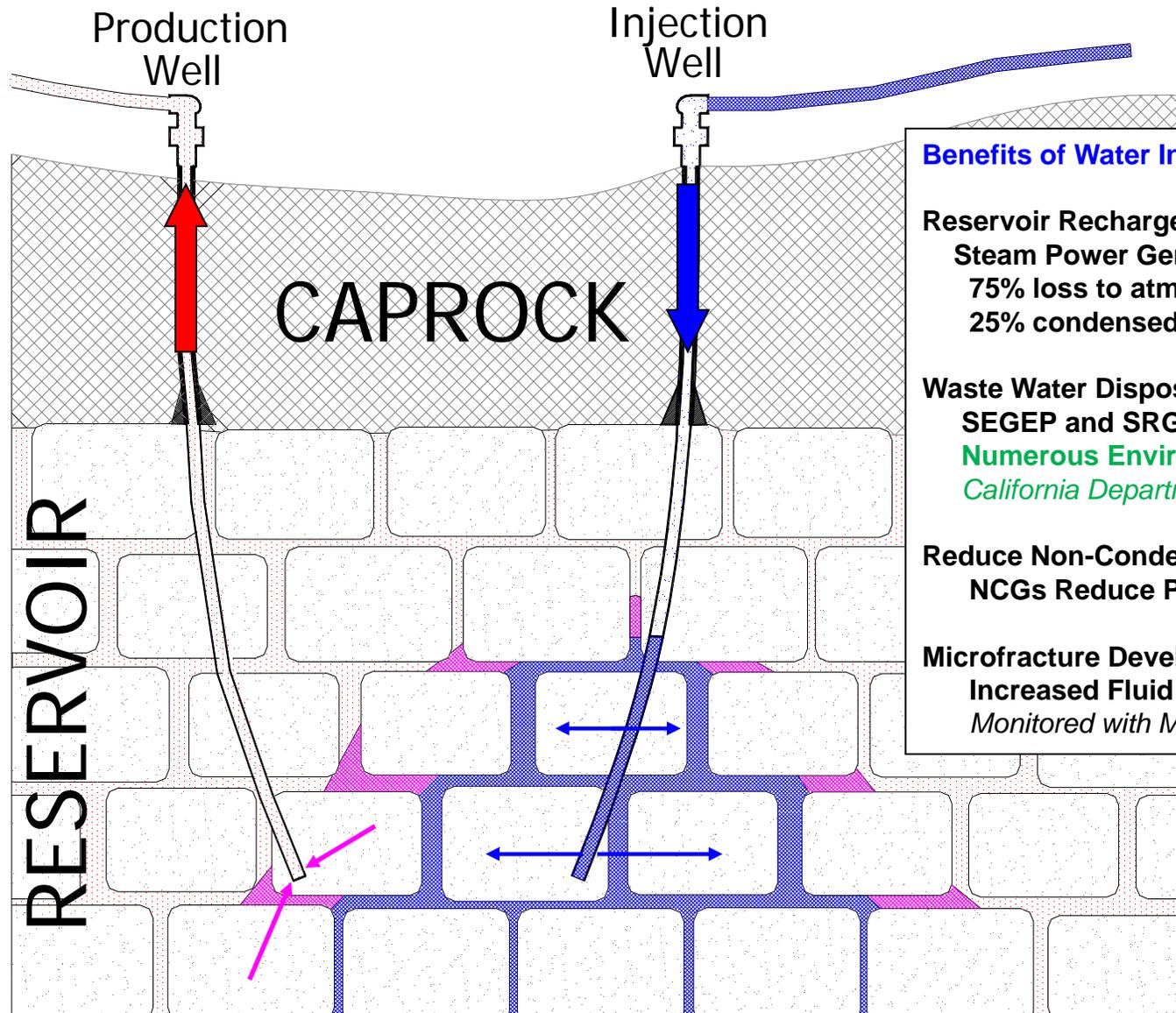
The NW Geysers EGS Demonstration Project will "inject" water under vacuum conditions (as with all water injection at The Geysers)

Micro-fracture development will rely on thermal effects, not pressure



Hydrofracturing (gas shale), waste injection, CO2 sequestration and oil/gas waterflooding all utilize high pressure fluid

Northwest Geysers Enhanced Geothermal System Demonstration Injection / Production Diagram



Benefits of Water Injection:

Reservoir Recharge – Mitigate Water Loss

Steam Power Generation:

75% loss to atmosphere

25% condensed and re-injected

Waste Water Disposal Solution

SEGEP and SRGRP

Numerous Environmental Awards

California Department of Conservation

Reduce Non-Condensable Gas Concentrations

NCGs Reduce Plant Efficiency, Increase Costs

Microfracture Development (Thermal)

Increased Fluid Flow in Low Permeability Zones

Monitored with Microseismicity

Northwest Geysers Enhanced Geothermal System Demonstration Seismic Monitoring Networks



Permanent Monitoring / Real-Time Processing

Lawrence Berkeley National Laboratory

- ▼ Installed in 2003; continued upgrades
31 stations; M 1.0 threshold
Primary Contact: Dr. Ernie Major (LBNL)

US Geological Survey

- ▲ Installed in 1970's; some upgrades
5 stations; M 1.5 threshold
Primary Contact: David Oppenheimer (USGS)

Strong motion instruments: 3

- * Installed in 2003; perceived shaking
3 stations; ~0.1% g threshold
Primary Contact: Jim Cullen (USGS contracted)

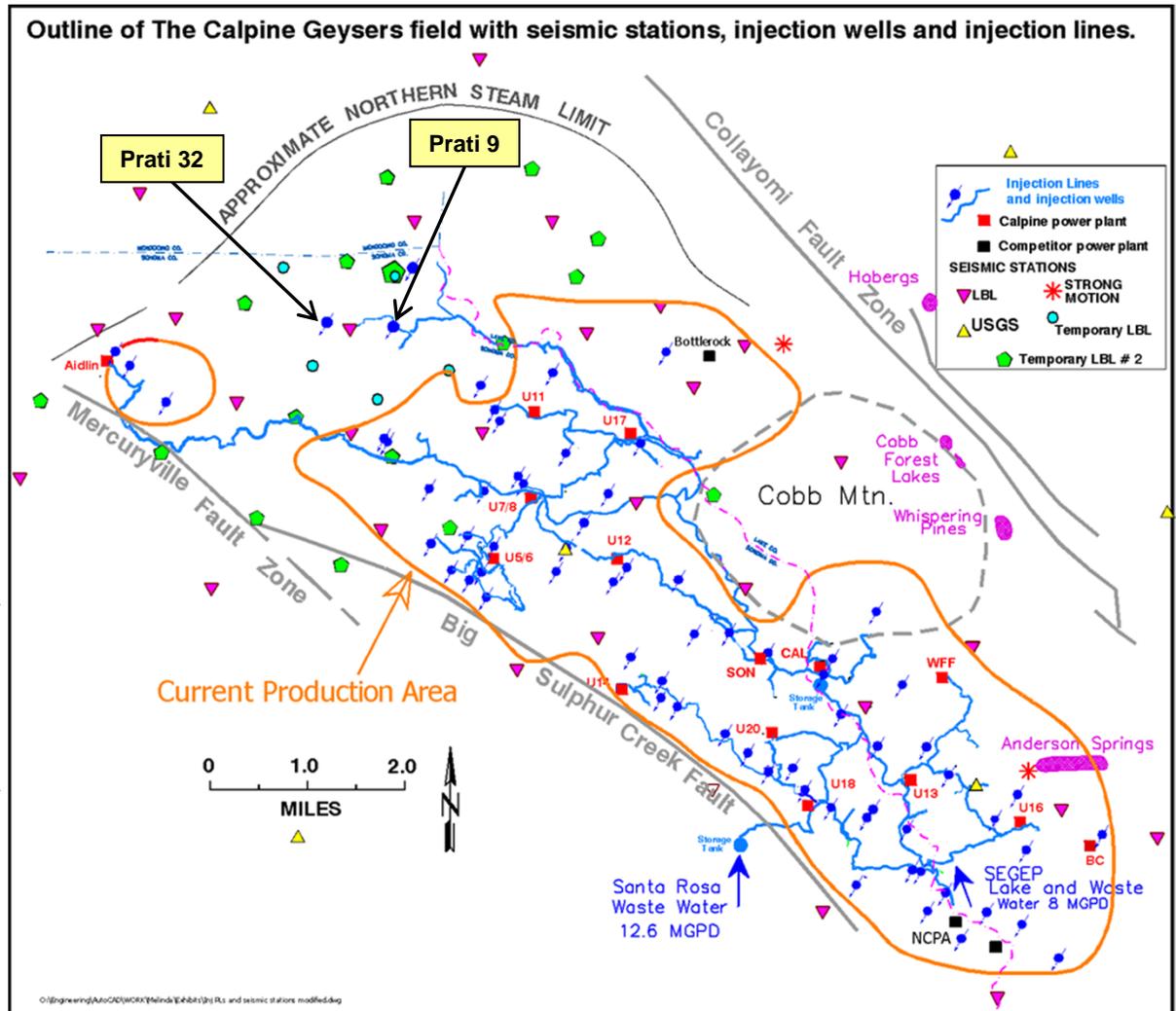
Project Dedicated Temporary Monitoring

Lawrence Berkeley National Laboratory

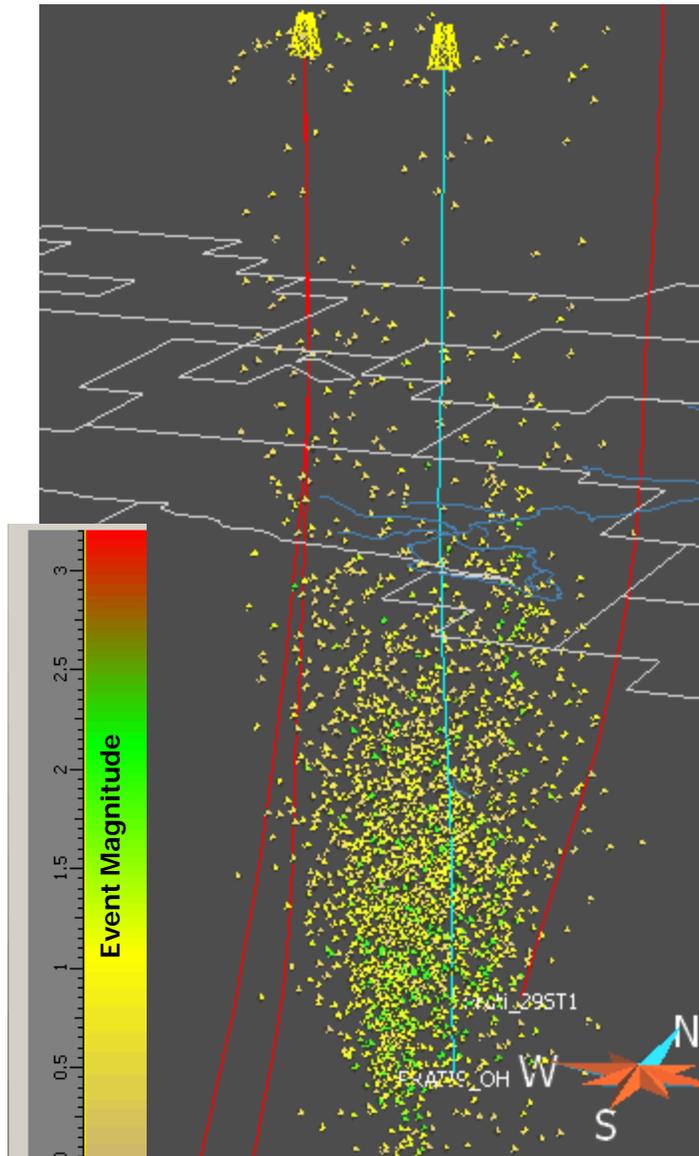
- Installed in 2010, ~ M1.0 threshold
5 stations; 4-6 months storage
Primary Contact: Dr. Ernie Major (LBNL)

Lawrence Berkeley National Laboratory

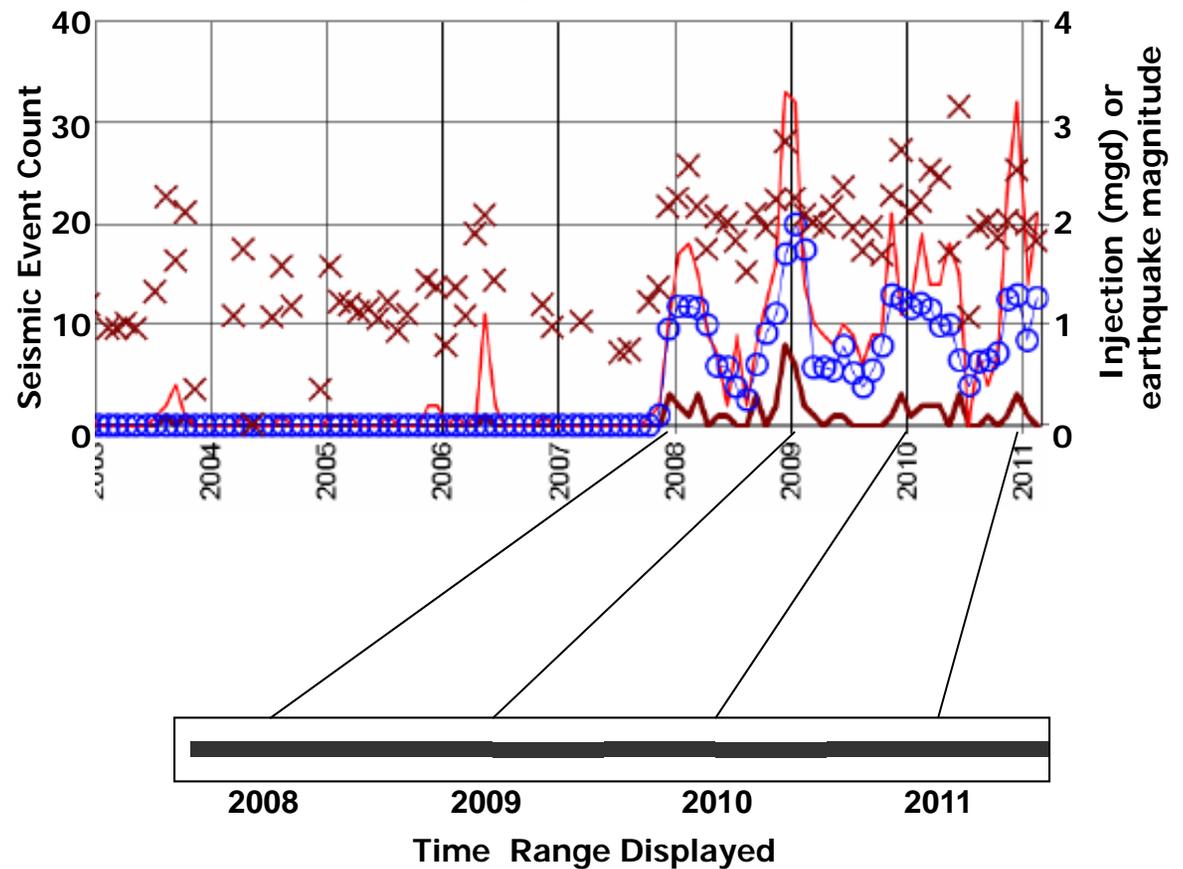
- ◆ Installed in 2011, ~ M1.0 threshold
14 stations; 3-4 weeks storage
Primary Contact: Dr. Lawrence Hutchings (LBNL)



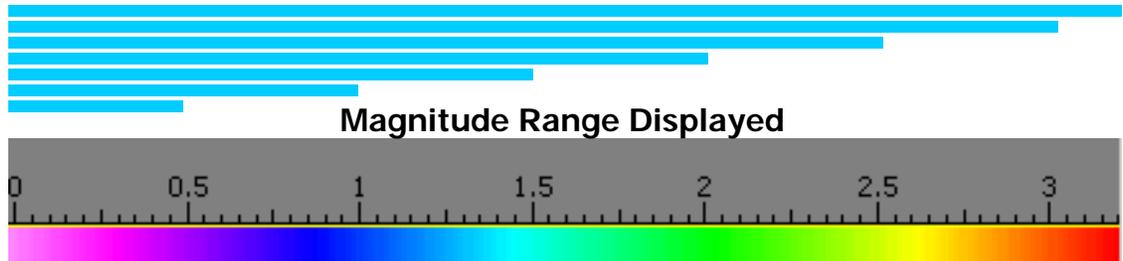
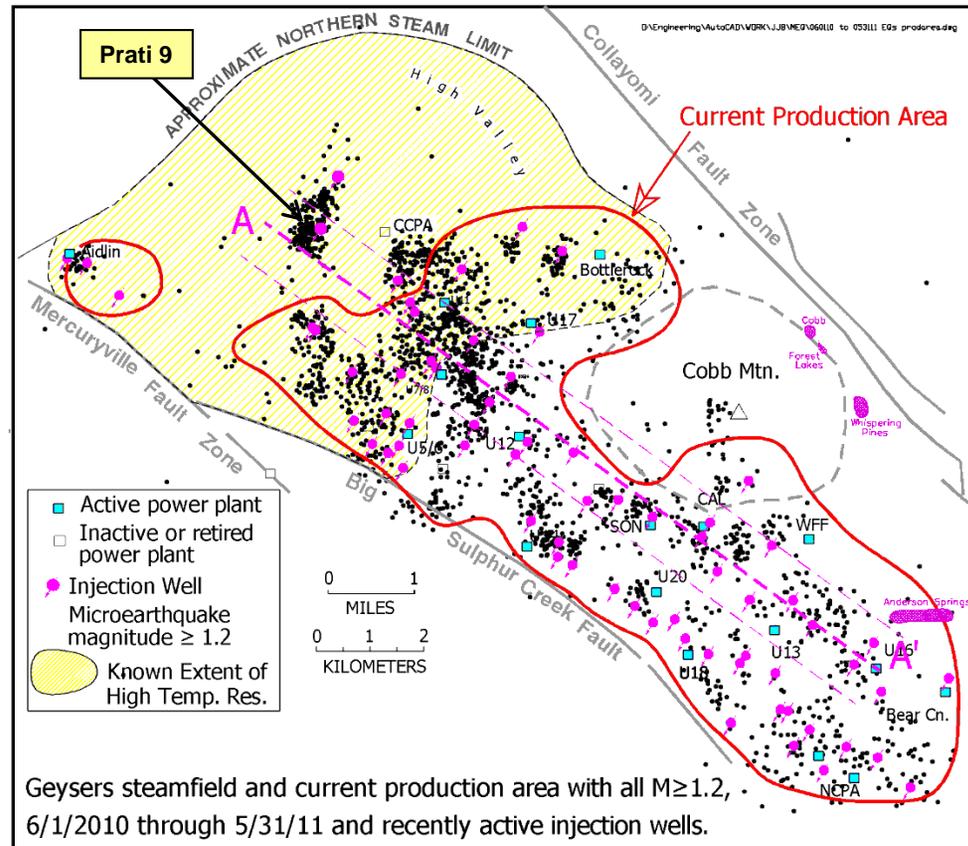
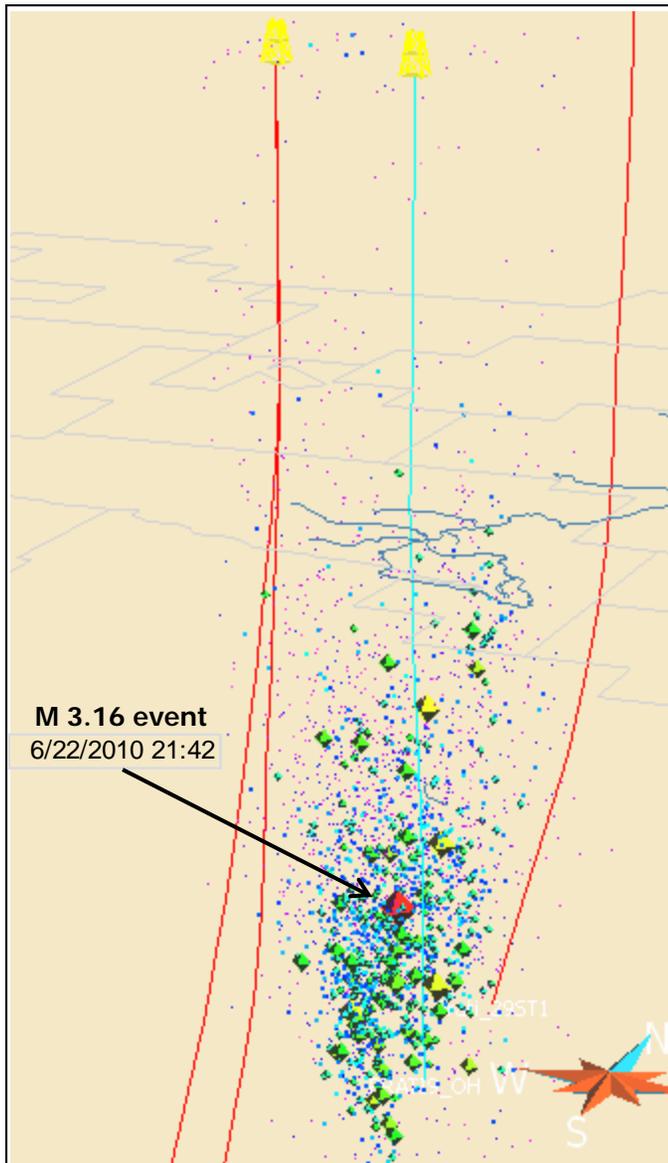
Northwest Geysers Enhanced Geothermal System Demonstration Prati 9 Injection Response



- Blue circles: monthly water injection
- Red line: monthly count of earthquakes of $M \geq 1.2$
- Brown line: monthly count of earthquakes of $M \geq 2.0$
- Brown X's: maximum magnitude each month



Northwest Geysers Enhanced Geothermal System Demonstration Prati 9 Injection Response



Northwest Geysers Enhanced Geothermal System Demonstration Prati 9 Injection Response



Prati 9 M 3.16 event

Cobb Strong Motion Station

Peak Ground Acceleration
26 cm/sec² (2.6% g) MMI IV

Peak Ground Velocity
0.51 cm/sec MMI II-III

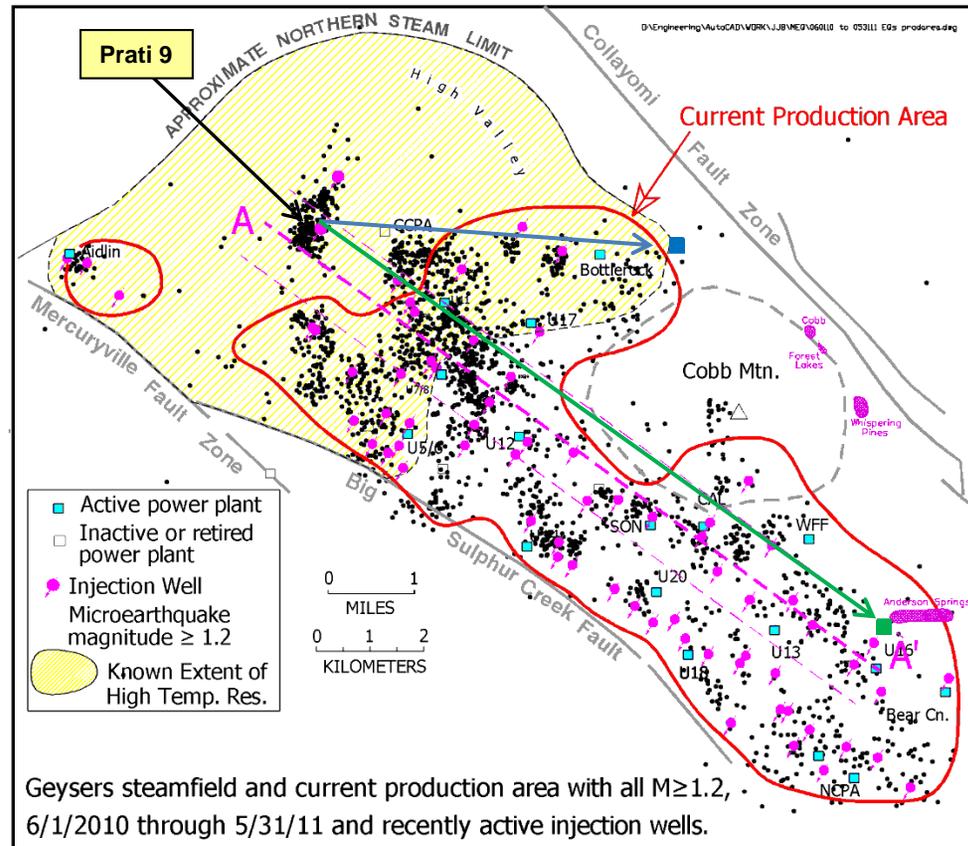
One felt report

Anderson Springs Strong Motion Station

Peak Ground Acceleration
6.7 cm/sec² (0.7% g) MMI II

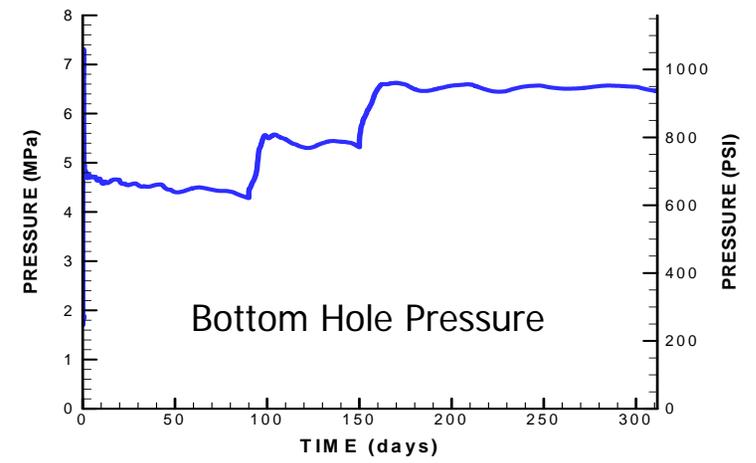
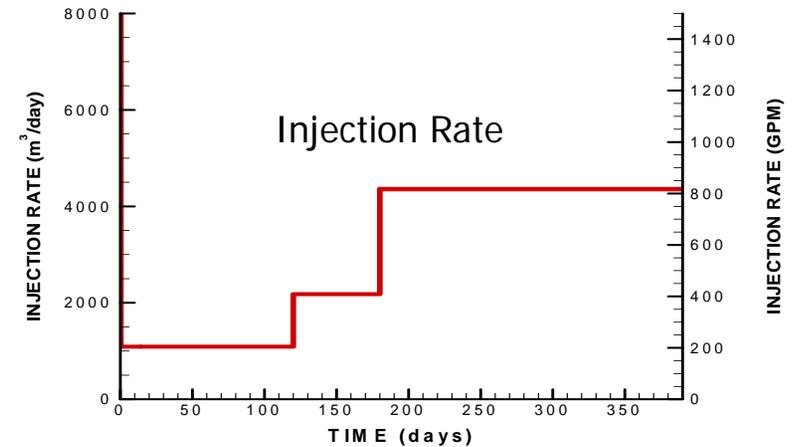
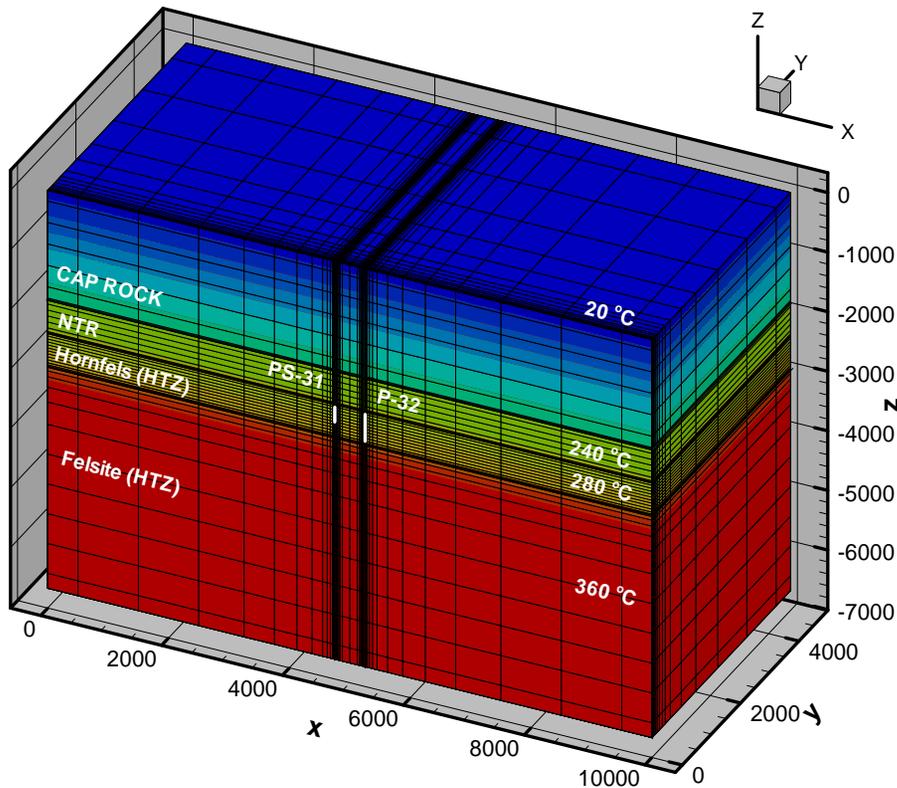
Peak Ground Velocity
0.12 cm/sec MMI II

No report



Perceived Shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Damage	None	None	None	Very Light	Light	Moderate	Mod/Heavy	Heavy	Very Heavy
Peak Acceleration (% of g)	< 0.17	0.17 - 1.4	1.4 - 3.9	3.9 - 9.2	9.2 - 18.0	18.0 - 34.0	34.0 - 65.0	65.0 - 124.0	> 124.0
Peak Velocity (cm/sec)	< 0.10	0.1 - 1.1	1.1 - 3.4	3.4 - 8.1	8.1 - 16.0	16.0 - 31.0	31.0 - 60.0	60.0 - 116.0	> 116.0
Modified Mercalli Intensity	I	II-III	IV	V	VI	VII	VIII	IX	X

Northwest Geysers Enhanced Geothermal System Demonstration Reservoir Modeling



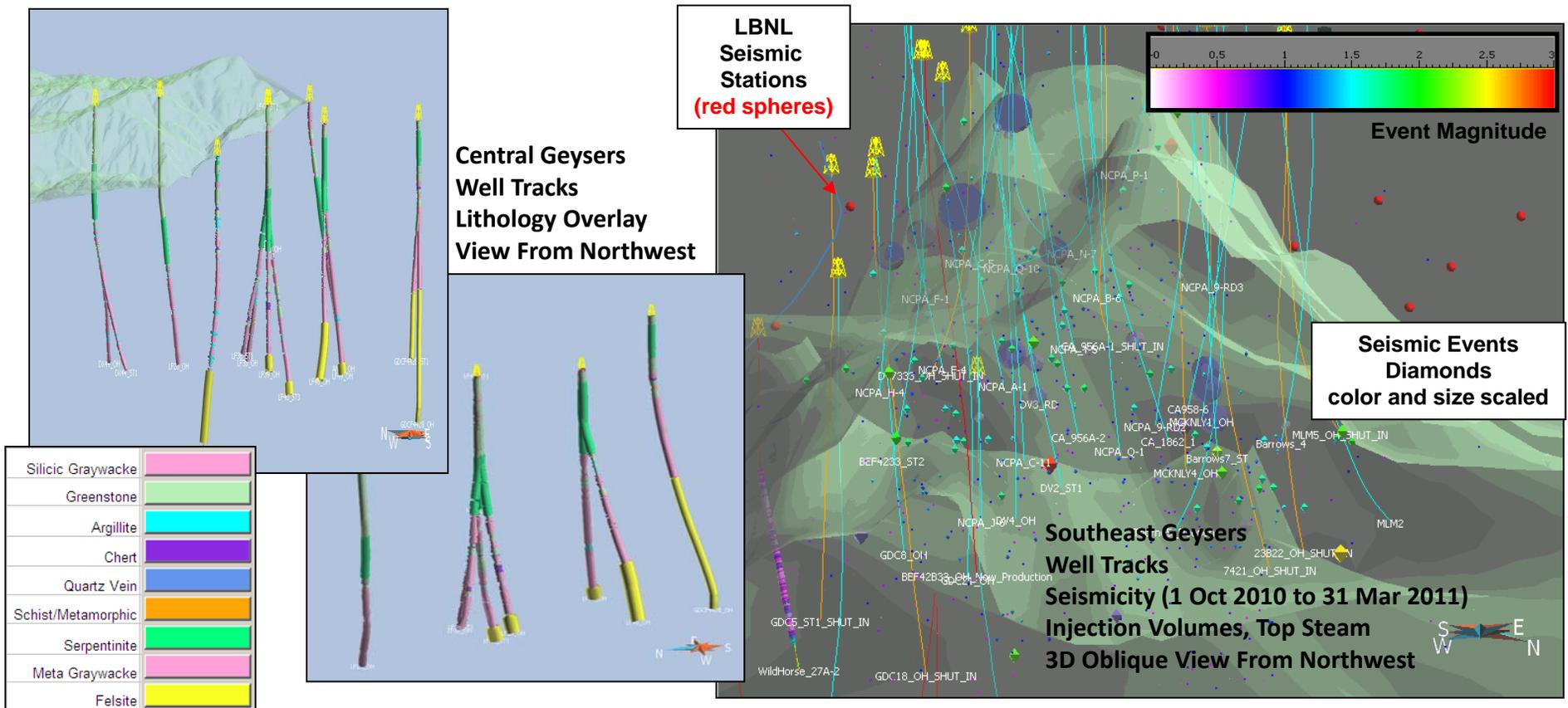
Staged injection rates over 12 months
 “Gentle” progressive stimulation of the High Temperature Zone

Northwest Geysers Enhanced Geothermal System Demonstration Modeling Refinement



3D Model Building and Visualization is beginning to assist with refinements to:

- 3D geological/geophysical and reservoir models
- Understanding of relationships between production, injection and seismicity
- Velocity model development for refined seismicity hypocenter determination
- Direct detection of fault/fracture surfaces and networks



Northwest Geysers Enhanced Geothermal System Demonstration Calpine - Operational Modifications



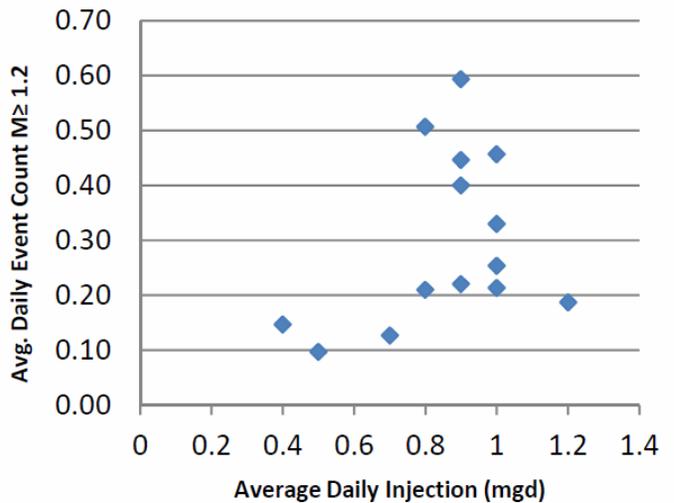
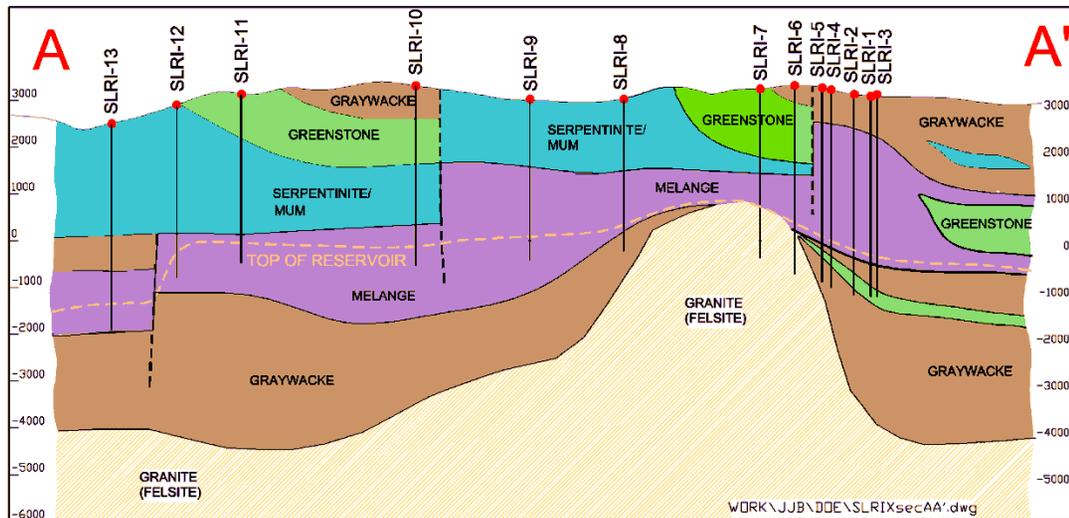
Better distribution; more uniform injection rates

Lower injection rates per well being evaluated
(e.g. 500 gallons per minute; 0.72 million gallons/day)

Minimization of injection rate variability (individual well and field-wide)

Distributed injection, particularly near surrounding communities
Shallow low rate injector (SLRI) wells

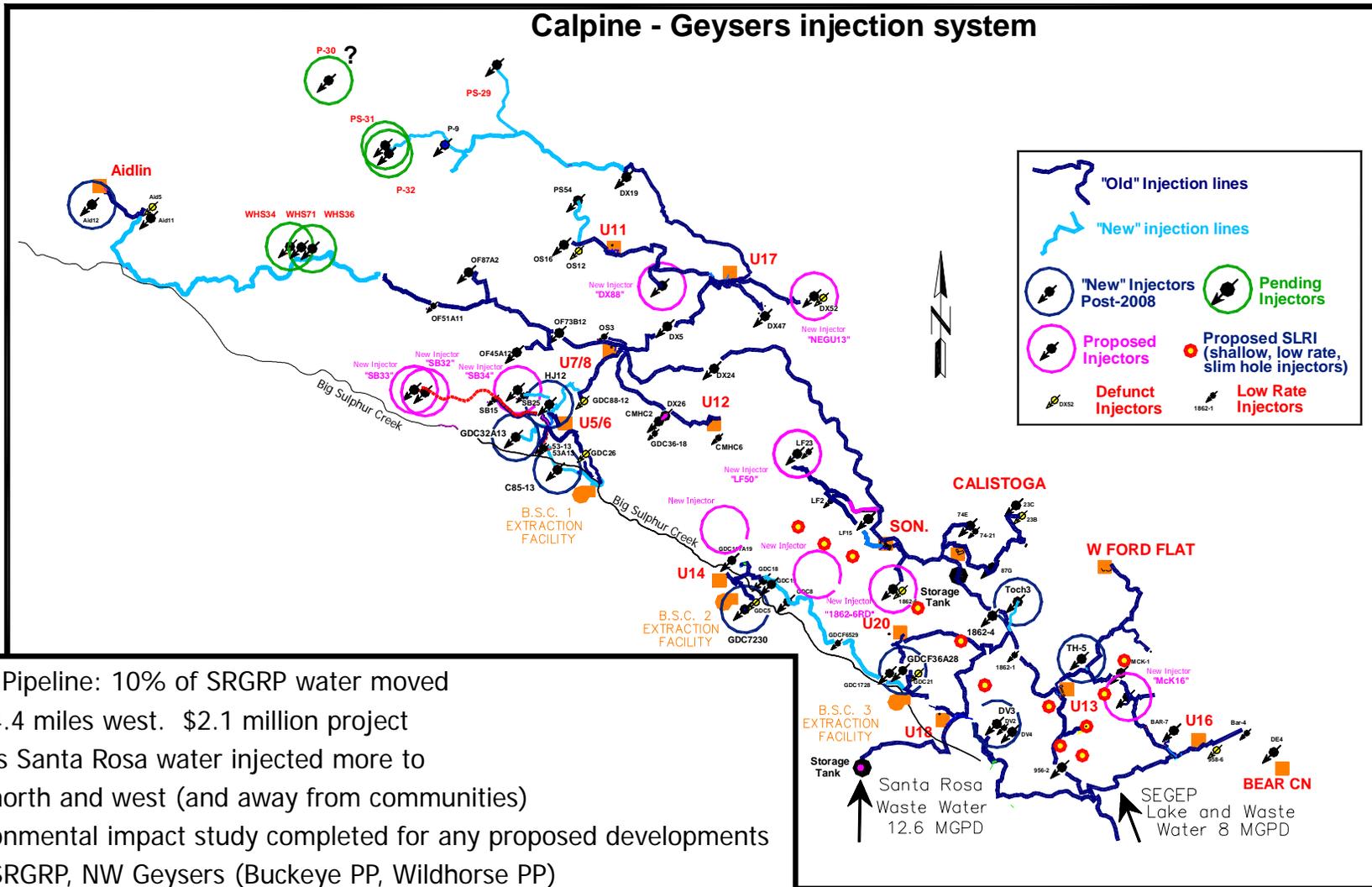
Seismicity and Injection Rates Around SRGRP Injection Wells



Planned shallow, slim hole, low rate injection wells ("SLRI's). Small diameter completions to be drilled only into the upper part of the reservoir. Injection rates to be limited to ≤ 200 gpm.

Shifting injection towards NW and away from communities

Northwest Geysers Enhanced Geothermal System Demonstration Calpine - Operational Modifications



Aidlin Pipeline: 10% of SRGRP water moved
 4.4 miles west. \$2.1 million project
 Excess Santa Rosa water injected more to north and west (and away from communities)
 Environmental impact study completed for any proposed developments
 SRGRP, NW Geysers (Buckeye PP, Wildhorse PP)

**Northwest Geysers
Enhanced Geothermal System Demonstration
Calpine Communication and Public Relations**



On December 7th, 2004, the Lake County Board of Supervisors passed Resolution 2004-199 establishing a Geothermal Impact Mitigation Fund:

“To assist in the mitigation of current adverse impacts to the communities of Anderson Springs and Cobb Valley from the development and production of geothermal resources in the Geysers Area of Lake County.”

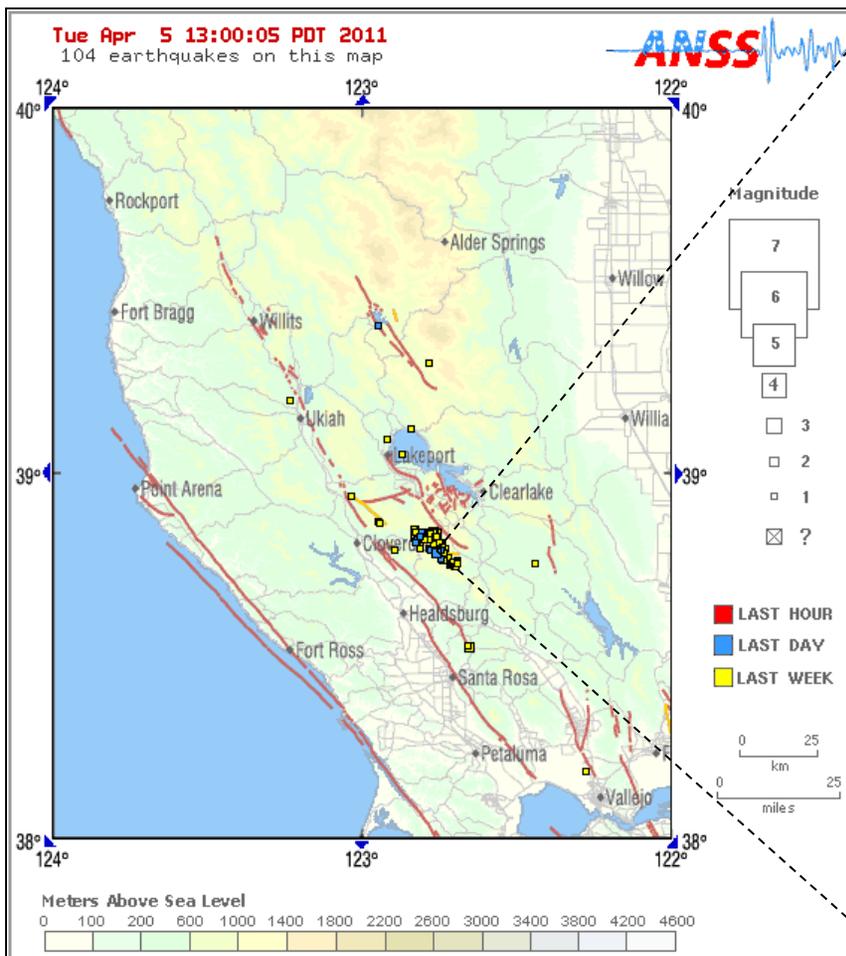
Total Funding Provided: \$502,348 (Anderson Springs: \$344,387; Cobb Valley: \$157,961)

Northwest Geysers Enhanced Geothermal System Demonstration Calpine Communication and Public Relations



LBNL / USGS Seismic Monitoring Network

The Geysers seismicity data is available to the public through a well-developed website



Earthquake Details

This event has been reviewed by a seismologist.

Magnitude	2.1
Date-Time	Tuesday, April 05, 2011 at 16:04:30 UTC Tuesday, April 05, 2011 at 09:04:30 AM at epicenter Time of Earthquake in other Time Zones
Location	38.779°N, 122.757°W
Depth	1.7 km (1.1 miles)
Region	NORTHERN CALIFORNIA
Distances	5 km (3 miles) ESE (117°) from The Geysers, CA 6 km (4 miles) W (275°) from Anderson Springs, CA 7 km (4 miles) SSW (206°) from Cobb, CA 23 km (14 miles) E (96°) from Cloverdale, CA 37 km (23 miles) N (353°) from Santa Rosa, CA 115 km (71 miles) WNW (283°) from Sacramento, CA
Location Uncertainty	horizontal +/- 0.1 km (0.1 miles); depth +/- 0.2 km (0.1 miles)
Parameters	Nph= 63, Dmin=1 km, Rmss=0.07 sec, Gp= 36°, M-type=duration magnitude (Md), Version=3
Source	California Integrated Seismic Net: USGS Caltech CGS UCB UCSD UNR
Event ID	nc71547965

**Northwest Geysers
Enhanced Geothermal System Demonstration
Calpine Communication and Public Relations**



Voicemail Hotline (877) 4-GEYSER

Calls transcribed and reviewed weekly since 12/16/2003

Compared with strong-motion measurements for Cobb and Anderson Springs stations

Detailed Reporting of Events of $M \geq 4.0$ (or $M \geq 3.5$; $MMI \geq 5$; $PGA \geq 3.9\%$)

Provided to Calpine employees, community leaders, industry and academic representatives

Biannual Reporting to the City of Santa Rosa

SRGRP injection and seismicity relationships

URS Corporation geophysicists perform independent data analysis and report generation

Biannual Meeting with Seismic Monitoring and Advisory Committee

Field activity and seismicity update to community leaders, industry and academic representatives

Geothermal Visitors Center

Wednesday – Saturday

Expansion to include Enhanced Geothermal System exhibits

Geysers Field Tours

Approximately monthly tour groups (Spring to Fall)

Community Newsletter

2-3 publications yearly by mail

Northwest Geysers EGS Demonstration Community Updates



Conclusion

Northwest Geysers Enhanced Geothermal Systems Demonstration