



## Desert Peak EGS Project

DOE Award: DE-FC6-02ID14406

Project Officer: Bill Vandermeer

Total Project Funding: \$7.6M

April 22nd, 2013

Ethan Chabora

**GeothermEx, a Schlumberger  
Company**

Ezra Zemach

**Ormat Nevada Inc.**

- Timeline
  - Project start date: September 2002
  - Project end date: Q3 2013
  - Percentage complete: 90%
- Budget
  - Total project funding: \$7,563,499
  - DOE share: \$5,453,982
  - Awardee share: \$2,109,516
  - As of April-2013, spent \$7,563,499

For EGS activities and development in Ormat's 2 Desert Peak wells:

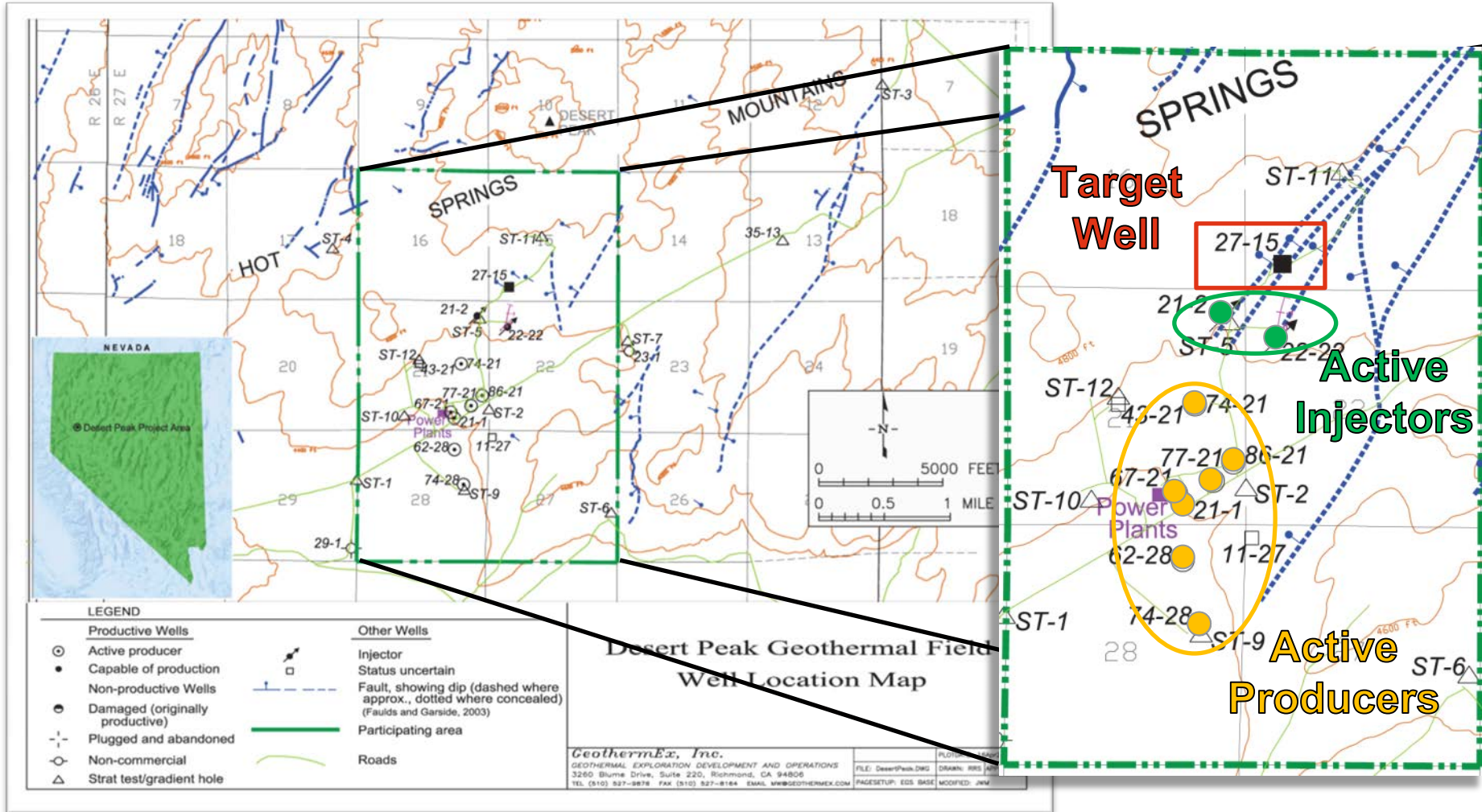
Well 23-1 (2003-2006)

East of producing field

Well 27-15 (2007-2013)

In-field well

# Ormat's Desert Peak Geothermal Field



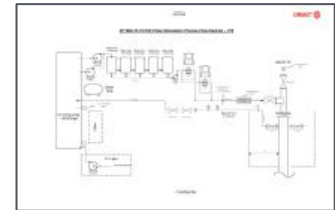
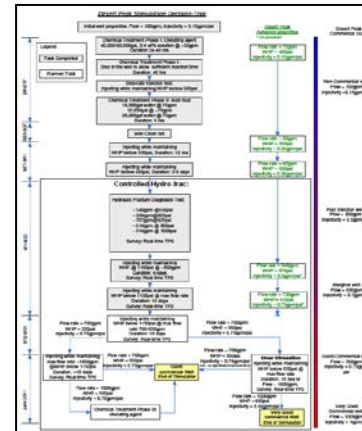
*Faults from Faulds et al. (2003)*

## Commercializing unproductive wells in Ormat's existing geothermal fields

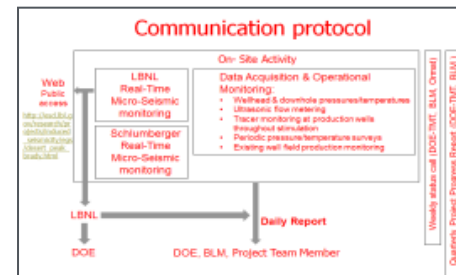
- **Project Goals (2007-2013):**
  - Increase the permeability/injectivity of well 27-15 to commercial levels
  - Improve the hydraulic connection to the producing geothermal field
  - Demonstrate enhanced power generation through successful stimulation
  - Deploy cost-effective techniques that are transferrable to other EGS projects
- **Project Challenges:**
  - Creating a sustainable man-made reservoir by applying commercially available stimulation technologies
  - Achieving “self-propping” shear stimulation
- **Successful Demonstration of Technology:**
  - Enhances economic value of Ormat's geothermal resource
  - Potential to LCOE Yields by increasing production rate and power generation
  - Commercial viability of transferable and repeatable EGS technologies
  - Enables exploitation of sub-commercial wells in existing geothermal fields

## Ormat's Method:

- Coordination with Ormat's existing and operating Desert Peak power plant
- Managing a multi-disciplinary, multi-partner investigation
- Executing stimulation plan, gathering data & scheduling
- “Decision-tree” workflows developed for rapid operational decision process
- Information flow & exchange:
  - Conducting technical workshops and quarterly meetings
  - Disseminating daily stimulation reports to stakeholders
- Predecessor for Bradys EGS Project



Sandia, USGS and Temple University Televiewer survey



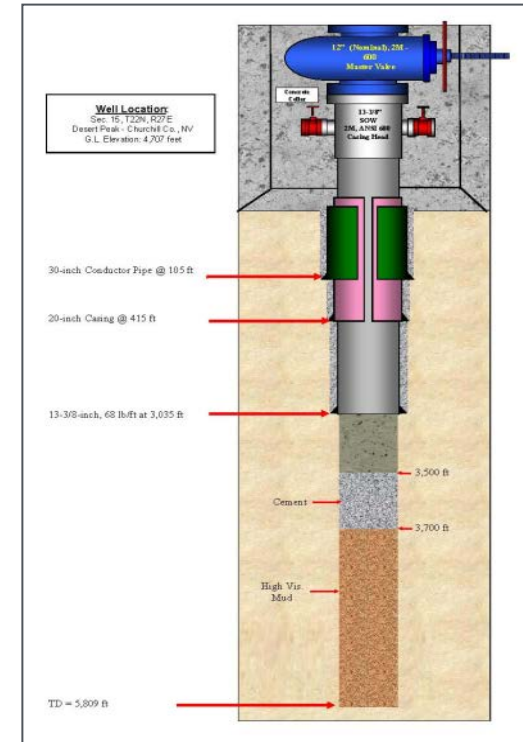
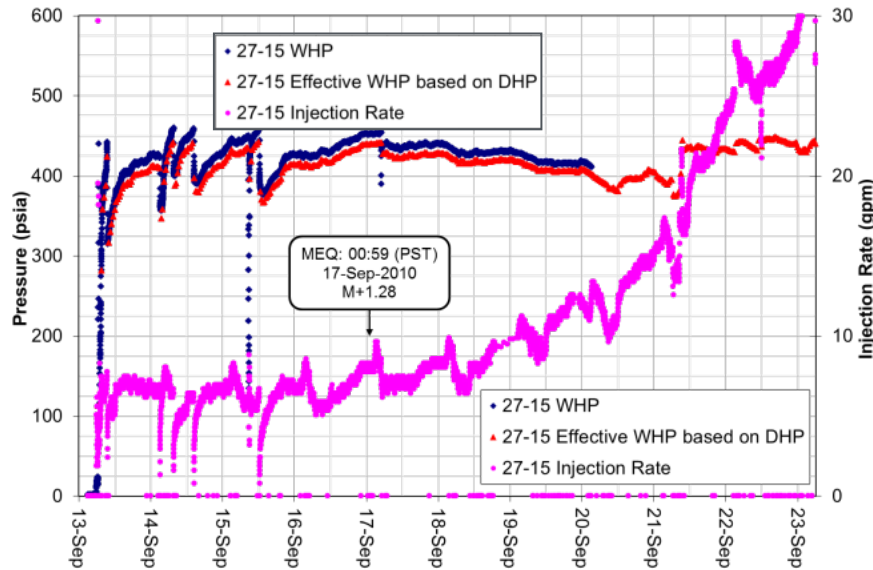
ThermaSource Pump Trucks



- Project Leader: Ormat Nevada, Inc.
  - Co-Management: GeothermEx, Inc.
  - Universities: Temple University, University of Utah
  - Federal Agencies /National Laboratories: USGS, LBNL, SANDIA, LANL
  - International Collaborations: Mil-Tech (UK), Bestec (Germany)
  - Sub contactors: Rain for Rent, ThermaSource, Schlumberger, TerraTek

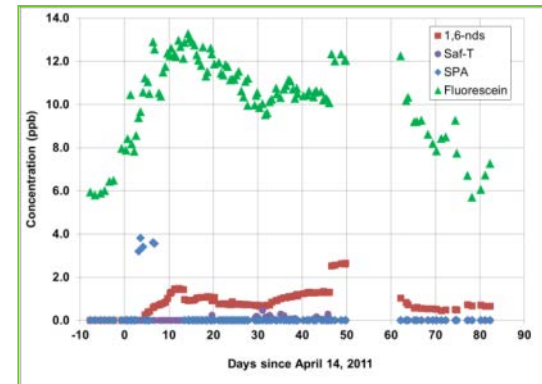
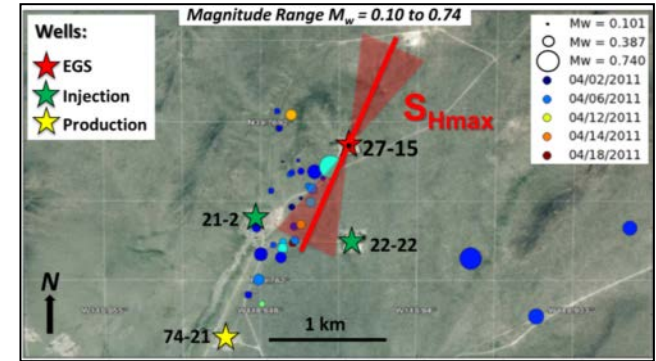
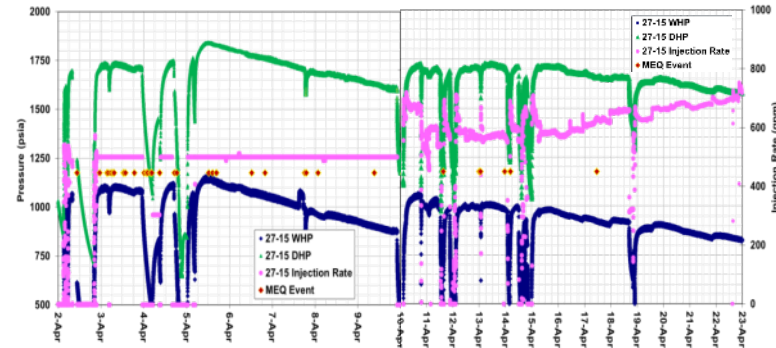


- **Shear Stimulation Phase, Aug-Nov 2010, (113 days):**
  - Injection rate increased from few gpm to tens of gpm
  - Increased injectivity by an order of magnitude
  - Initial reservoir cooling period (preconditioning) prior to shear stimulation



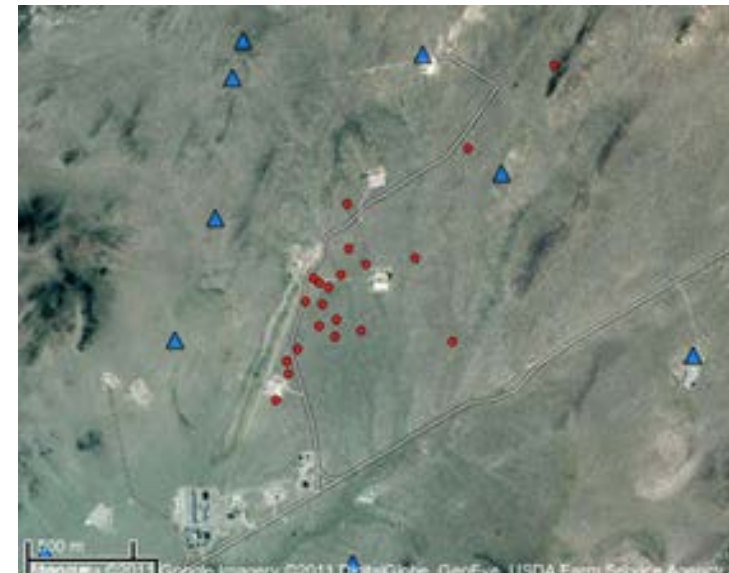
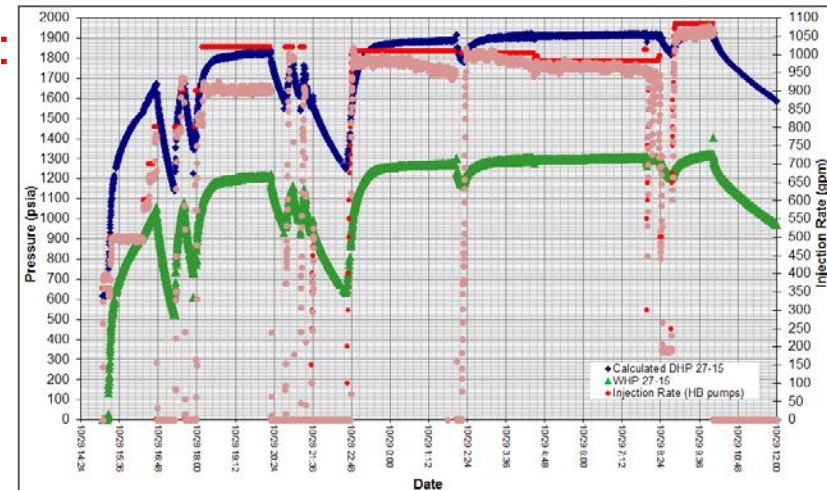
- **Chemical Stimulation Phase (10 days):**
  - Temporarily increased injectivity but created wellbore instability
  - Well work-over required to clean out well

- **Controlled Hydro-Frac Phase, April 2011, (60 days):**
  - Increased injection rate to hundreds of gpm
  - Increased injectivity by 6 fold (0.63 gpm/psi)
  - Seismic Analysis:
    - 68 MEQ events located in “Target Area”
    - Event locations consistent with stress-field model
    - $M_w = 0.1 - 0.74$
  - Tracer Analysis:
    - Initial modest connection between D.P. producer 74-21 and EGS well
    - Substantial improvement in connectivity: break-through in ~4 days





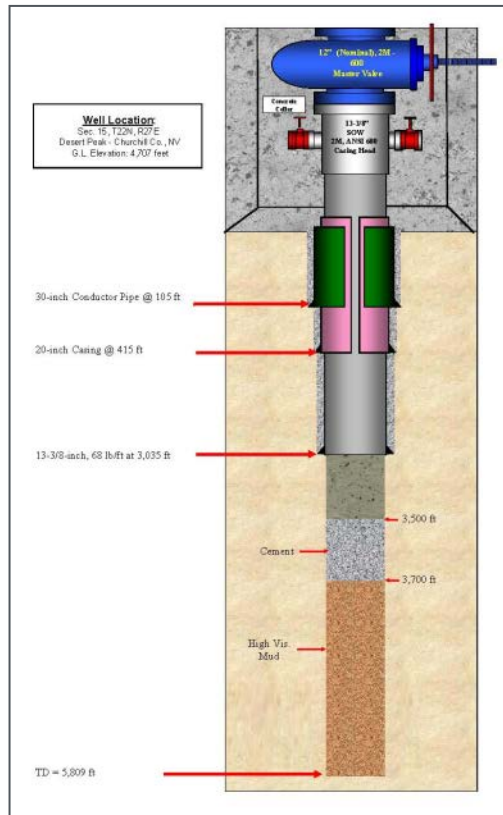
- **Pulse Stimulation, October 2011, (3 days):**
  - Recorded injectivity of nearly 0.8 gpm/psi
  - Injection rates in excess of 1200 gpm
  - Seismic Analysis:
    - Installed (5) additional borehole geophones (300') within Study Area
    - 23 MEQ events detected in “Target Area”
    - Event locations consistent with stress-field model
    - $M_w = -0.08 - 0.605$



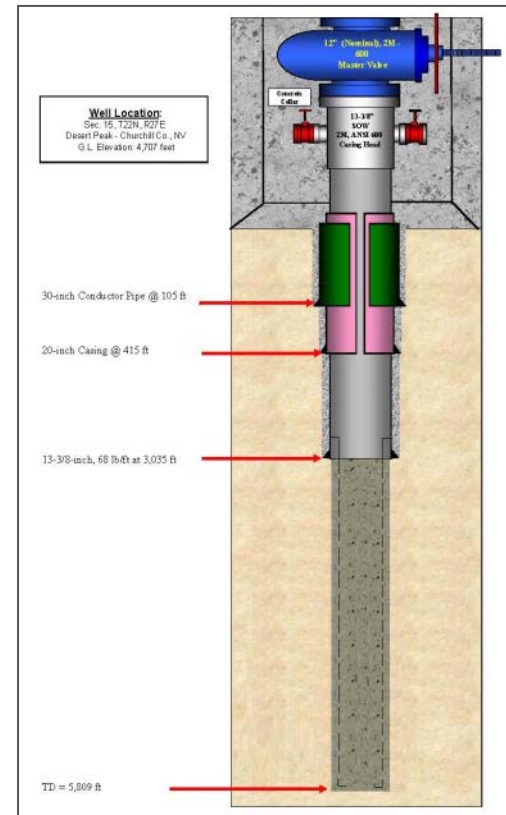
## **Stimulation Conclusion:**

**The zone between 3,035'-3,500' was successfully stimulated. Injectivity is just shy of the commercial level of ~1 gpm/psi.**

- **Workover and Re-completion, November 2012:**
  - Drill cement plug from 3,500'-3,700'
  - Circulate out viscous mud from 3,700' to 5,800' (TD)
  - Installed 9 5/8" 0.25" by 2.4" Slotted liner

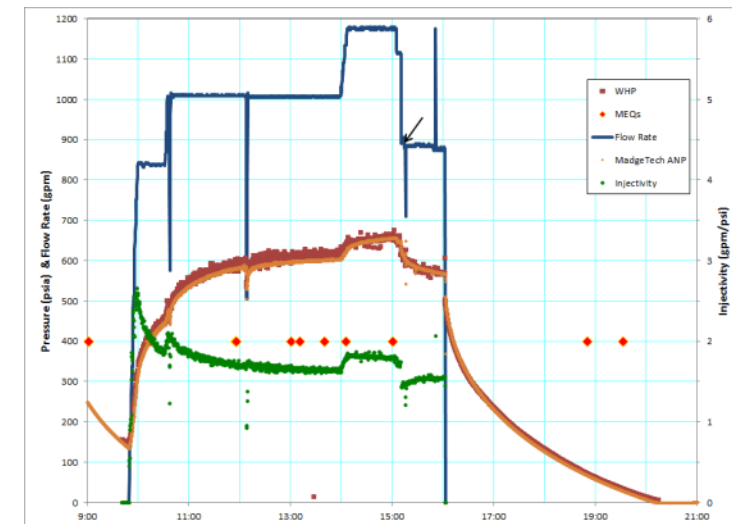
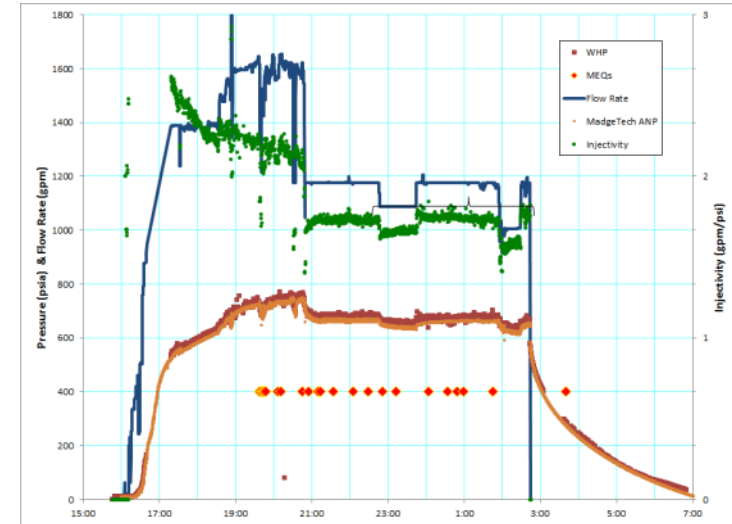
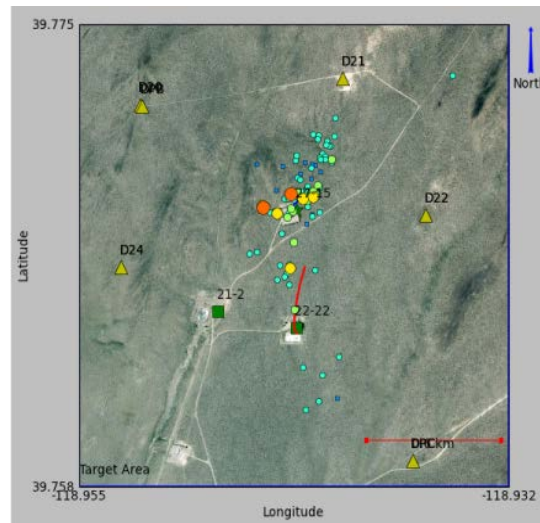


2009-2011 well completion

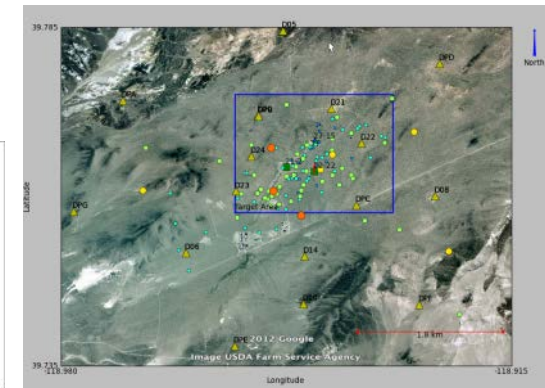
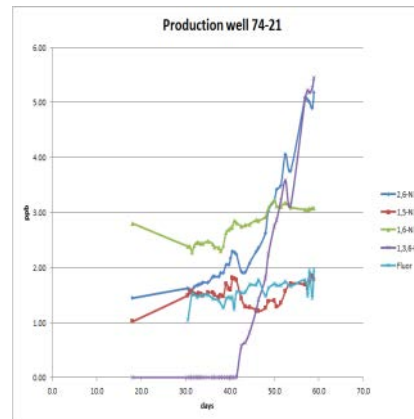
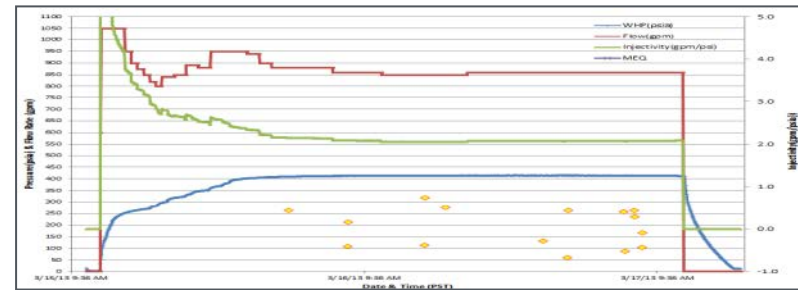
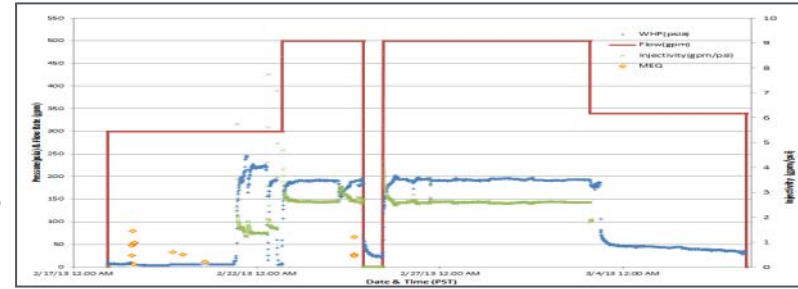


2012-2013 well completion

- **High Flow Rate stimulation 3,035'-TD, January 2013:**
  - Increased injection rate to 1,600 gpm
  - Recorded injectivity: 2.15 gpm/psi
  - Seismic Analysis:
    - 94 MEQ events located in “Target Area”
    - Event locations consistent with stress-field model
    - $M_w = -0.026 - 1.6$
  - Tracer Analysis:
    - Inject 100kg of 2,6-NDS



- **Long Term Stimulation below Fracture Propagation Pressure, Feb-Mar 2013:**
  - Injecting at 340, 500 and 860gpm for 30days
  - Confirmed injectivity of 2.1 gpm/psi
  - Injected ~180degF brine
  - Seismic Analysis:
    - 118 MEQ events located in “Target Area”
    - Event locations consistent with stress-field model
    - $M_w = -0.026 - 1.7$
  - Tracer Analysis:
    - Inject 100kg of 1,3,6-NDS
    - Returns detected after 40 days
  - Power Production gain
    - 1.7MW



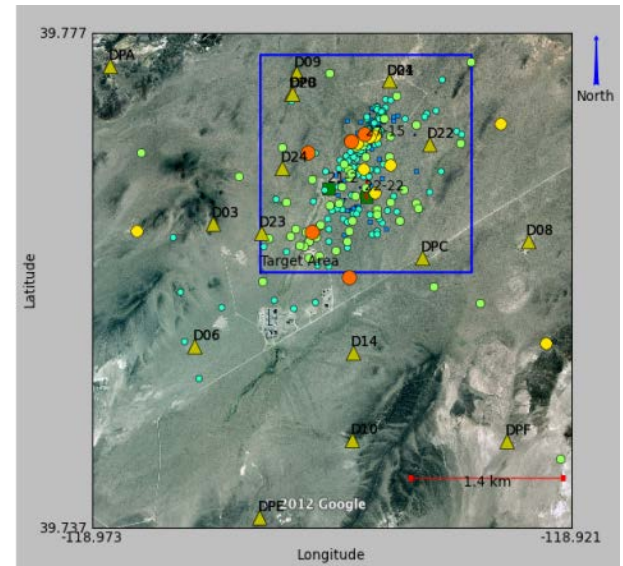


Desert Peak Stimulation Activity Summary	Duration	Injection rate (GPM)	WHP (PSI)	Injectivity (GPM/PSI)	Targeted Injectivity (GPM/PSI)
Starting Point	8/1/10	<4	>450	<b>0.012</b>	--
Shear stimulation	8/1/10-2/10/11	~100	550	0.15	0.5
Chemical stimulation	2/10/11-2/17/11	~75	550	0.05-0.15	0.5
Controlled hydro Shear – Medium flow rate	4/1/11-4/10/11	550	1,000	0.52	0.7
Controlled hydro Shear – High flow rate	4/10/11-4/23/11	735	835	0.73	0.7
Pulse Stimulation	10/26/11-10/29/11	1,000	1,200	0.8	1.0
High Flow Rate Stimulation	1/16/13-1/20/13	1,600	700	2.1	1.0
Post-high-flow rate hydro-shear conditions	2/16/13-3/18/13	300-860	415	<b>2.1</b>	1.0

**175-fold**

**303 MEQ events were recorded throughout the stimulation stages**

**Over the course of all stimulation stages a max flow rate of 1,600 gpm was achieved and the overall injectivity was increased by 175-fold, exceeding the project goal**





## Project Phase III (Pending):

- Comprehensive analysis and stimulation report
- Update DP structural and reservoir model
- Reservoir sustainability study
- MEQ analysis
- Pressure interference study
- Tracers test
- Collect multiple TPS logs – evaluate “permeability” distribution throughout well & monitor evolution over time

	FY2011	FY2011	FY2012	FY2013
Target/ Milestone	Complete Planned Stimulation	Commercial Scale Injection Well (>1 gpm/psi)	Schedule Workover	High Flow Rate Stimulation
Results	Completed Q1 FY2012	~ 0.8 gpm/psi Q1 FY2012	Q42012	~ 2.1 gpm/psi Q1 FY2013

**The Desert Peak project seeks to advance the commercial viability of EGS in Ormat's existing geothermal fields and has demonstrated:**

- 175-fold increase in injectivity in the target formation
- Cost-effective techniques and technologies that are transferrable
- Effectiveness of multi-phase stimulation approach
- Adaptive, real-time approach to operations management