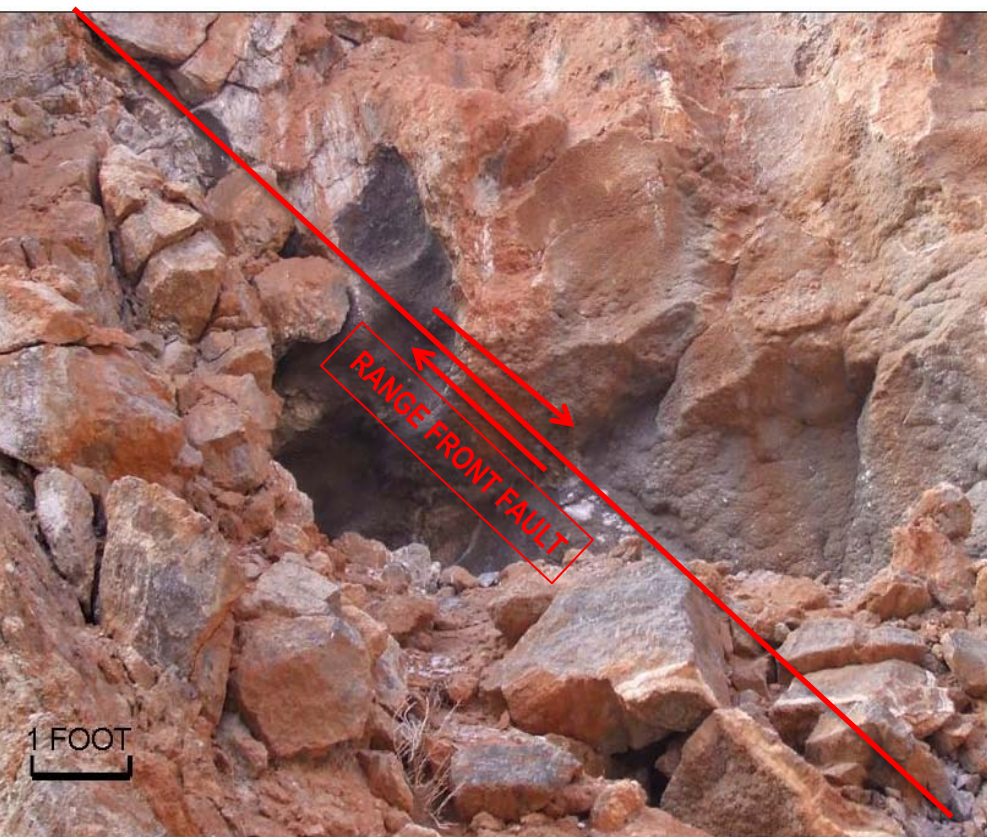




FINDING LARGE APERTURE FRACTURES IN GEOTHERMAL RESOURCE AREAS USING A THREE-COMPONENT LONG-OFFSET SURFACE SEISMIC SURVEY, PSInSAR, AND KINEMATIC ANALYSIS

Project Officer: Ava Coy / Erik Swanton
Total Project Funding: \$3.77 Million
April 2013

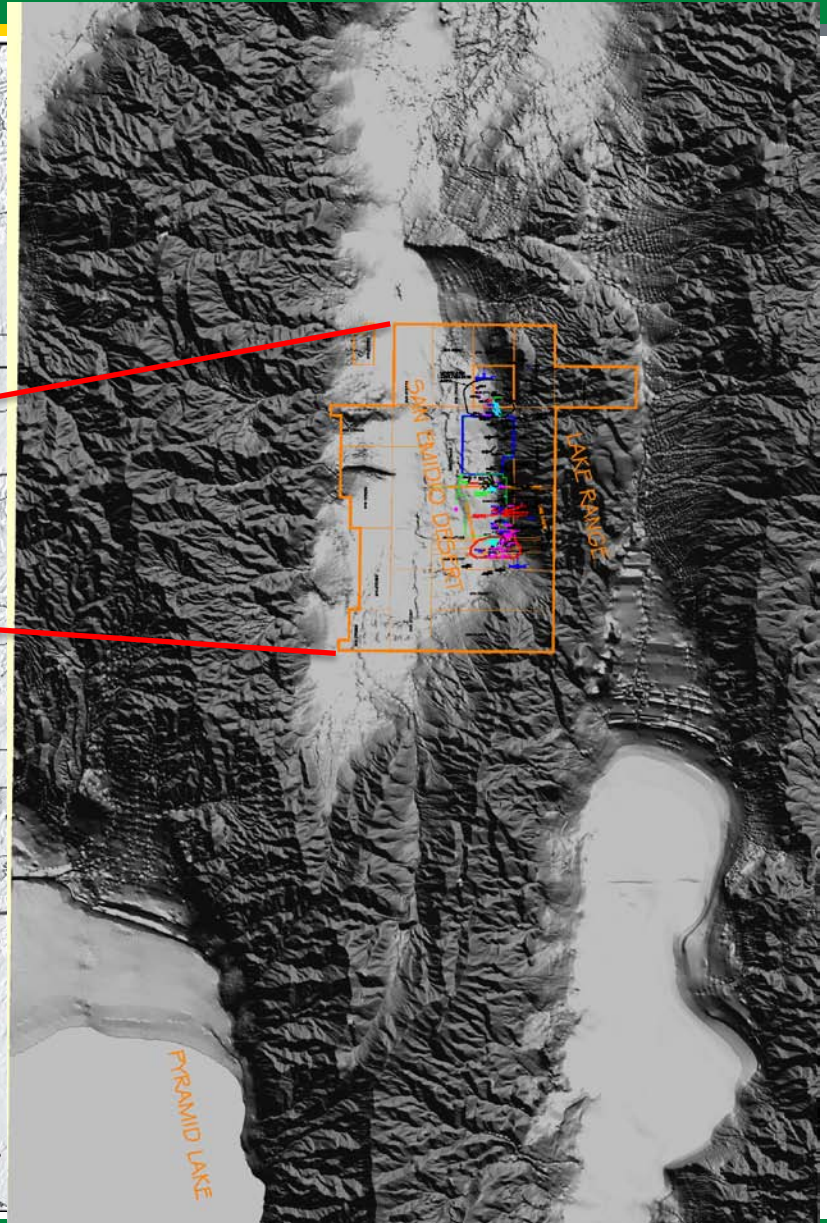
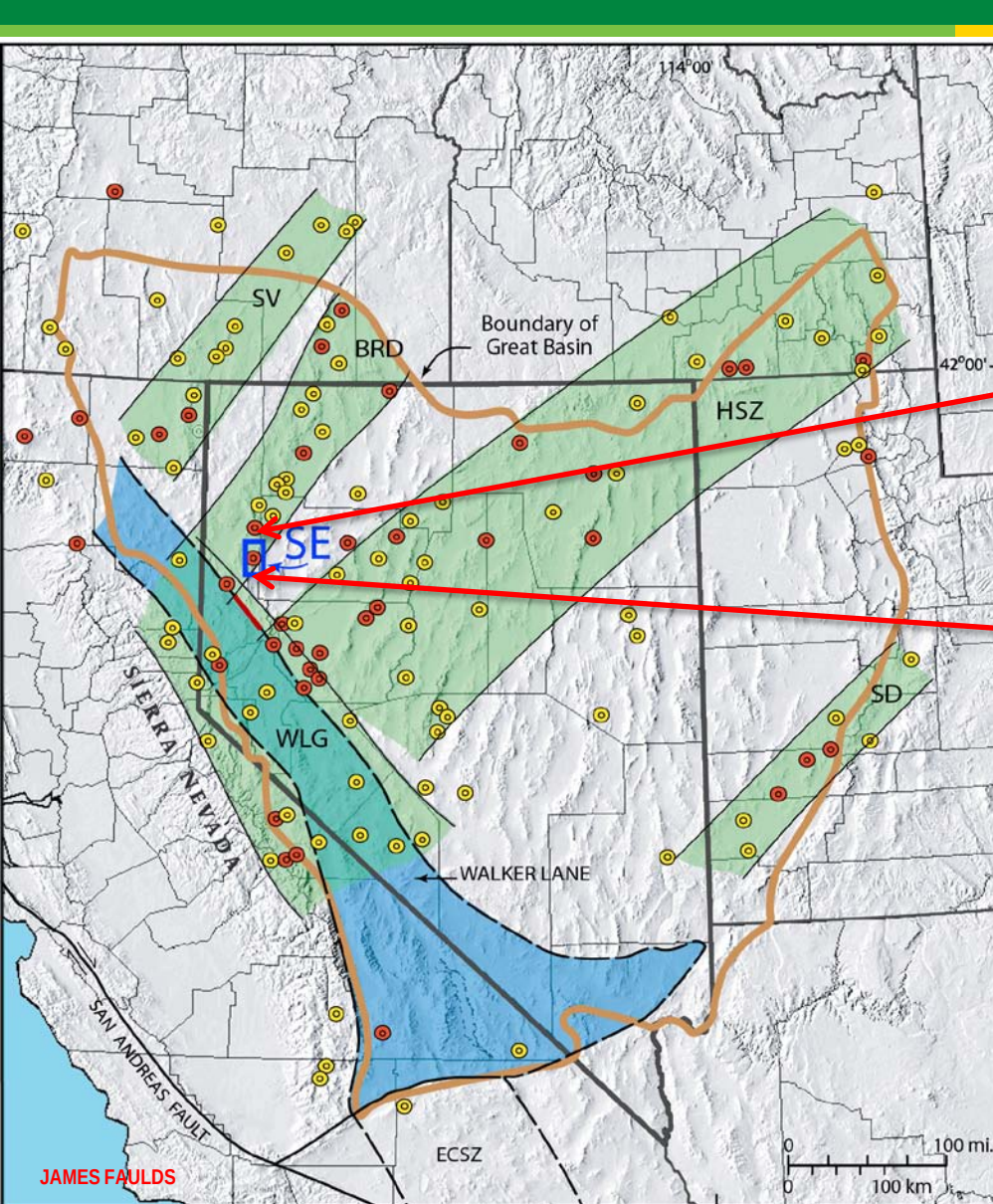
Principal Investigator :
William Teplow, US Geothermal, Inc.
Presenter:
Ian Warren, US Geothermal, Inc.

INNOVATIVE EXPLORATION TECHNIQUES

SAN EMIDIO GEOTHERMAL PROJECT

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy



- San Emidio Program Objectives:
 - Develop and test an integrated suite of geophysical/geological techniques to identify and map Large Aperture Fractures (LAFs) in a tensional tectonic environment.
 - Drill production/exploration wells targeted to intersect LAFs identified in this program.
 - Perform well and reservoir tests to quantify the production characteristics of wells drilled for this program.
- Expected Impacts of Program:
 - Reduce dry hole risk
 - Increase per-well productivity
 - Reduce parasitic pumping loads
 - Reduce environmental impacts by minimizing the number of wells for a given geothermal field capacity.
 - Expand wellfield extent and capacity.
 - Integrated geophysical/geological exploration program applicable to other Basin and Range prospects.

- Innovative Aspects
 - Integrated finite element structural kinematic analysis with measurement of ongoing surface deformation, detailed gravity, and magnetics.
 - Used 3-component long-offset seismic refraction to image LAFs.
 - Used 3-component Vibroseis source.
 - Used modified small-truck-mounted rig to drill deep temperature gradient/exploration/production wells at minimum cost.
 - Optimized exploration well design for maximum productivity at minimum cost.
- GTO Goals Met:
 - Generated well-defined production targets in Phase 1.
 - Drilled and tested targets in Phase 2.
 - Drilling Results:
 - Added wellfield capacity to existing project.
 - Expanded resource base
 - Reduced drilling cost.
 - Established successful integrated exploration strategy that is highly applicable to other Basin and Range prospects.

Integration of advanced geological, geophysical, and remote sensing techniques to identify zones at depth conducive to LAF formation. Confirm those zones by drilling and flow testing. Working hypothesis: A combination of active tensional tectonics plus embrittlement due to silicification are essential for occurrence and maintenance of LAFs. These features were expected to have a unique combination of correlative geophysical and geological characteristics.

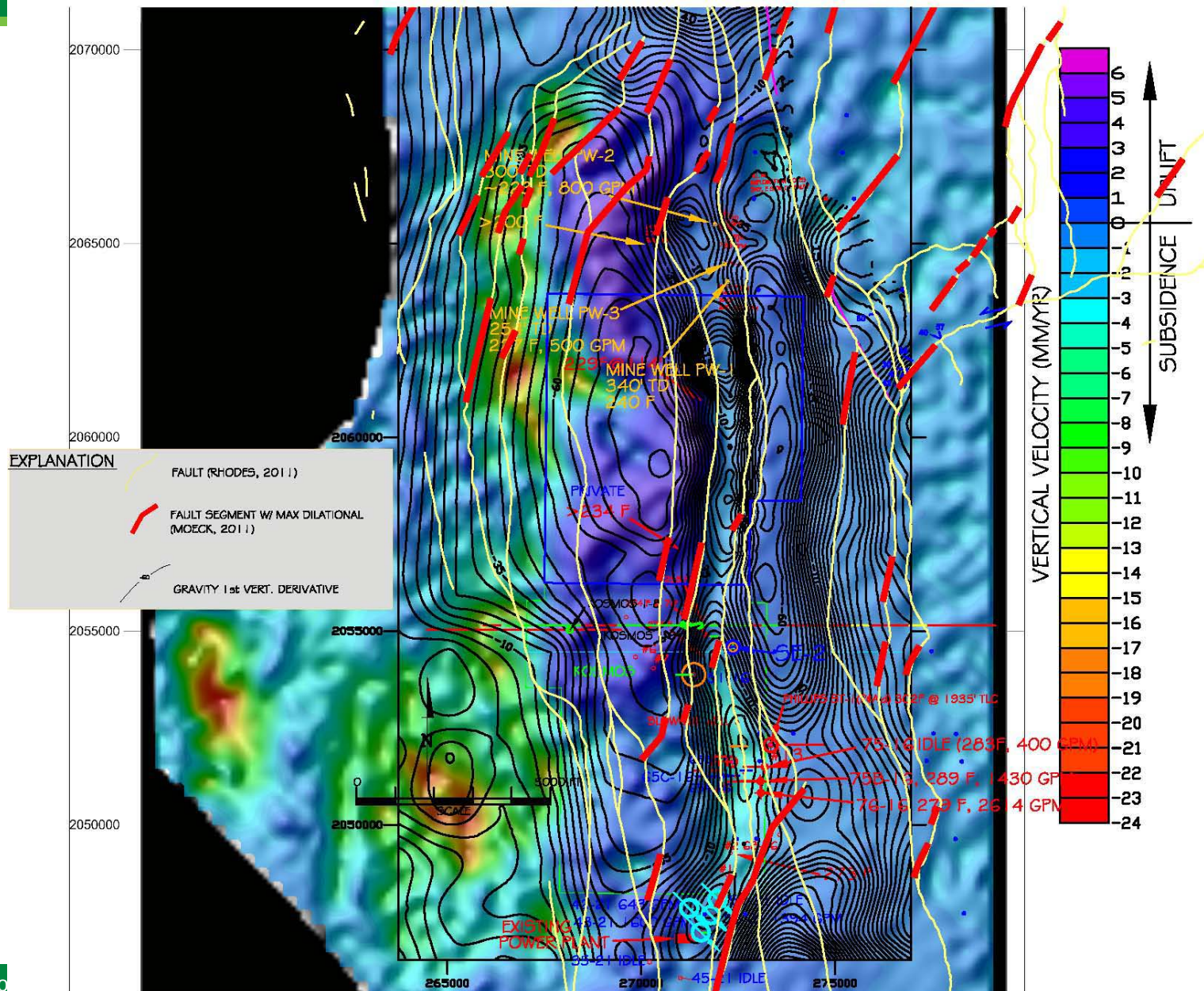
- **Highlights of Project Design:** Phase 1 exploration was executed as planned. Flexibility demonstrated by USG and DOE in Phase 2 drilling allowed modification of the program to maximize Phase 1 successes. Additional benefit of program modification: reduced drilling cost and reduced risk for expanding resource base.
 - **Rigor of scientific/technical research methods applied:** High data density. Strong correlation between datasets. Empirical characterization of and correlation to known production zones. Work from known to unknown in small increments.
 - **Logic and reasonableness of milestones and steps:** Use techniques with maximum 2-D and 3-D resolution at minimum cost.
 - **Technical feasibility:** All surveys were successfully executed within budget. Targets derived from Phase 1 were successfully drilled and tested in Phase 2 within the budget. The drilling program was a commercial success.
- **Identify key issues being addressed and their significance.**
 - Maintain program flexibility in well siting.
 - Definitive well test with rig on hole.
 - Real time geologic, P/T logging, and flowtest analysis to determine next rig move. No standby or demob cost.
 - Maintain 3-D geologic model on site with daily updates.
 - Requires pre-siting and permitting of wells to cover all high quality targets.
- **Describe how well the approach has been executed in project tasks.**
 - Immediately capitalize on success and avoid future failures.
 - Reservoir model was significantly revised as result of drilling program.
 - Approach led to discovery of higher temperature resource and 1-sq. mi. expansion of production area.

- **Accomplishments/Progress to date.**

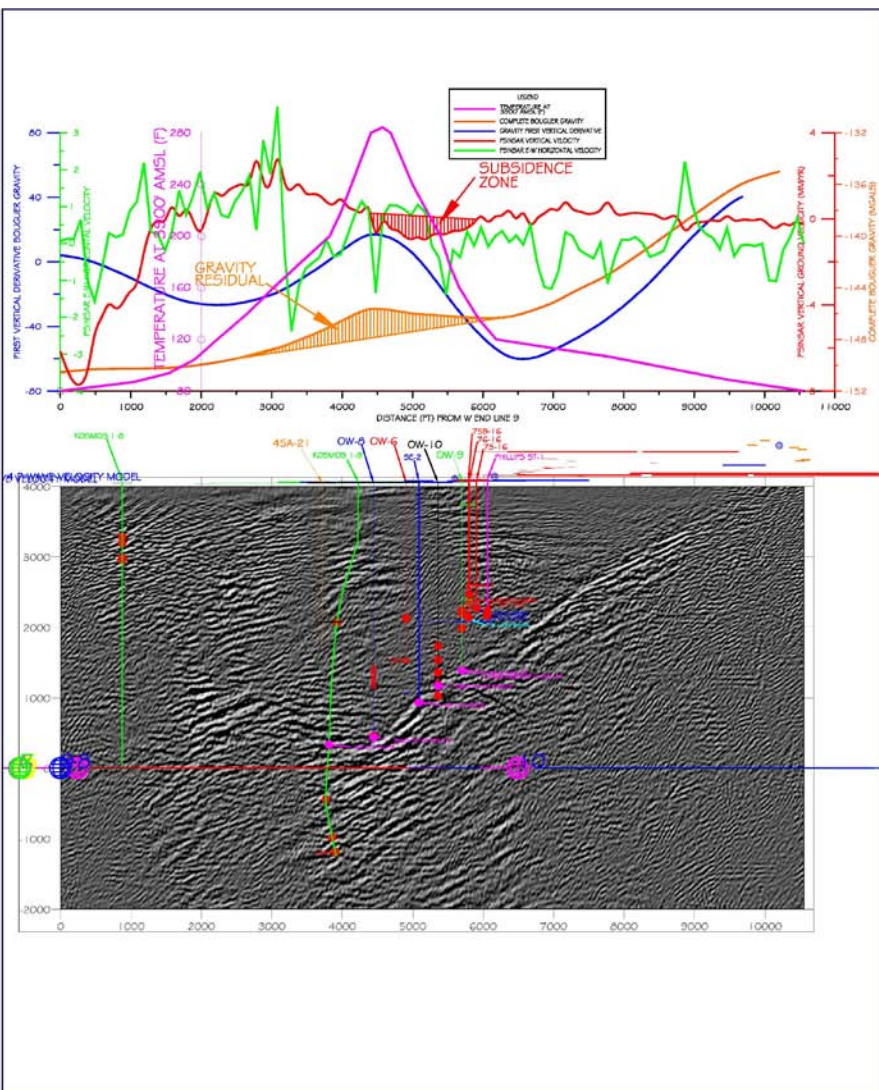
- Established a high degree of correlation between active ground movement, gravity 1st vertical derivative, P-wave velocity model, magnetics, dilational fault tendency, and productive fracturing at depth. Methodology applicable to numerous Basin and Range geothermal sites. Demonstrated that active shallow hydrothermal systems with massive subsurface silica deposition are not in isostatic equilibrium.
- Slimhole production well drilling proved the efficacy of the exploration strategy.
- A majority of the geophysical methods can be executed by remote sensing, thus greatly reducing environmental impacts and permitting requirements.
- Technical Challenges: Tight control of drilling costs starting with rig modification to match drilling conditions, optimized well design to drill and test maximum number of targets at minimum cost, well testing on the fly, and P/T logging capabilities onsite.
- The geophysical program employed state of the art commercial contractors, readily available to any developer.

Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Utilize state of art geophysical suite to characterize known productive fractures, then use to generate new targets.	Numerous production targets identified	5/31/2011
Drill 5 slimhole exploration wells to test geophysical targets.	5 wells drilled; 4 were productive; expanded field by 1 sq.mi.; found 10-15 °F higher T.	5/31/2012

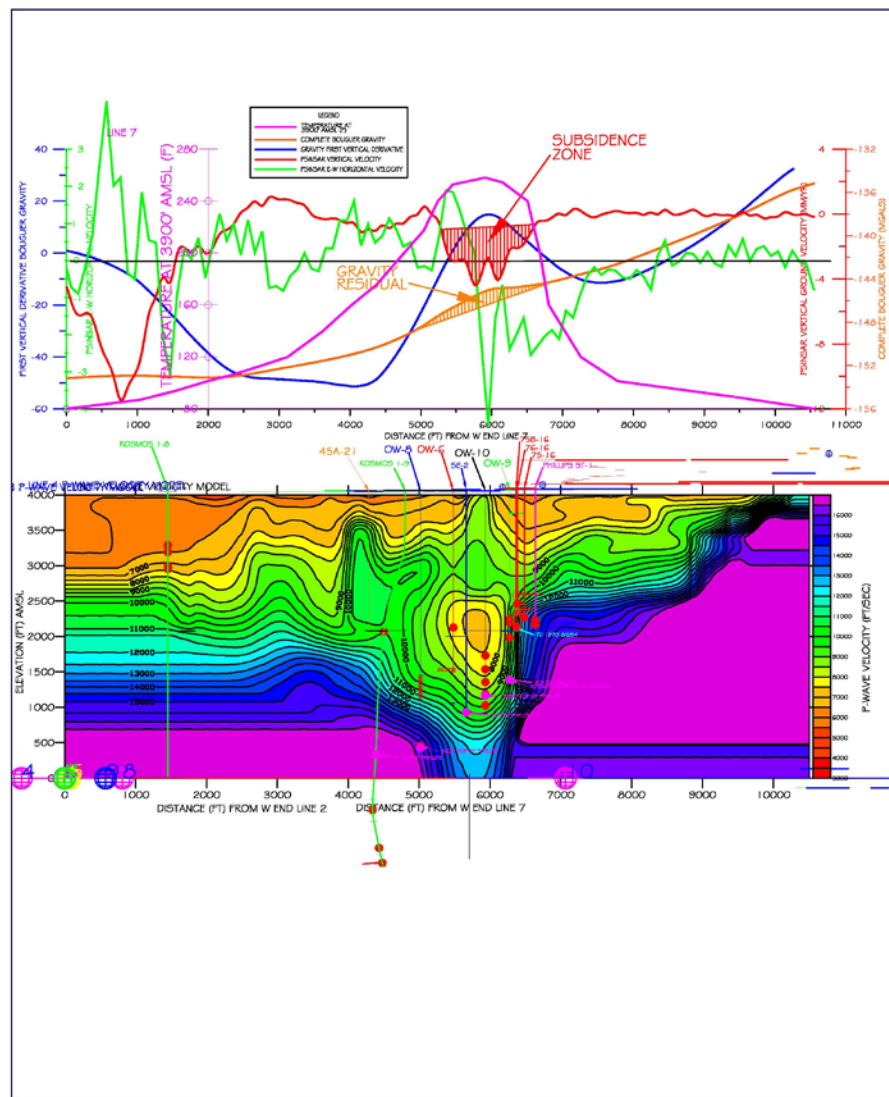
PHASE 1 CORRELATIONS: GRAVITY, SUBSIDENCE, DILATIONAL TENDENCY



Phase 1 Geophysical Correlations



EXPLANATION	SAN EMIDIO GEOTHERMAL PROJECT	US Geothermal Inc.	FIGURE 5
○ LOST CIRCULATION ZONES	SEISMIC REFLECTION PROFILE 9 AND GEOPHYSICAL PROFILES		BY: WM. TEPLOW DATE 5/8/2012



EXPLANATION	SAN EMIDIO GEOTHERMAL PROJECT	US Geothermal Inc.	FIGURE 4
○ LOST CIRCULATION ZONES	Vp VELOCITY MODEL, SEISMIC PROFILE 7 AND GEOPHYSICAL PROFILES		BY: WM. TEPLOW DATE 5/8/2012

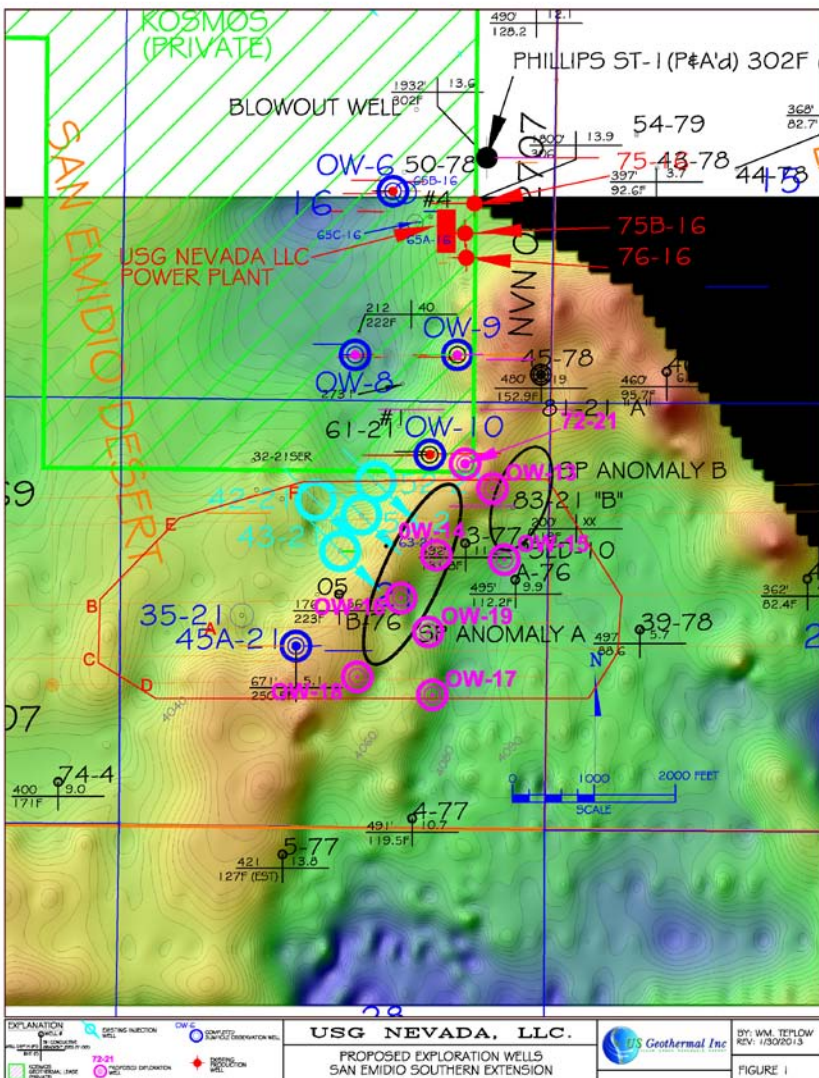
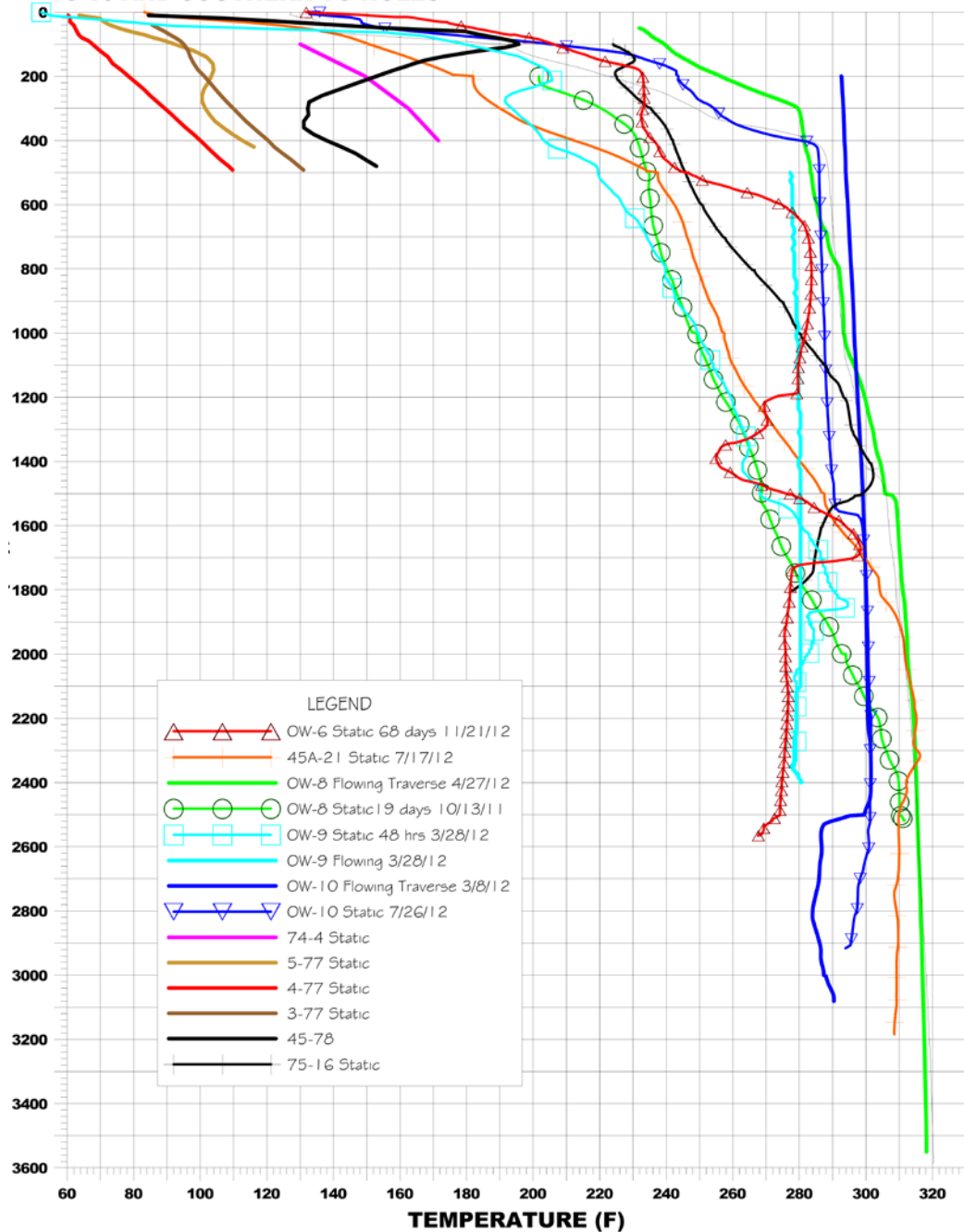
Phase 2 Drilling Results

Well No.	Total Depth (ft)	Maximum Temperature (F)	8" Casing Depth (ft)	Permeable Zones Depths (ft)	Estimated Productivity (Mwe-net)	Cost
OW-6	2542	298	400	1930, 2480	2.0	\$575,237.80
OW-8	3990	318	412	2800	0.5	\$902,910.63
OW-9	2686	279	427	1835, 1880, 2090	2.0*	\$607,824.05
OW-10	3050	302	420	2325, 2520, 2700, 3030	2.0	\$690,194.84
45A-21	3186	316	836	n/a	0	\$720,970.74
TOTAL	<u>15454</u> <u>\$226/ft</u>				<u>6.5</u>	<u>\$3,497,138.05</u>

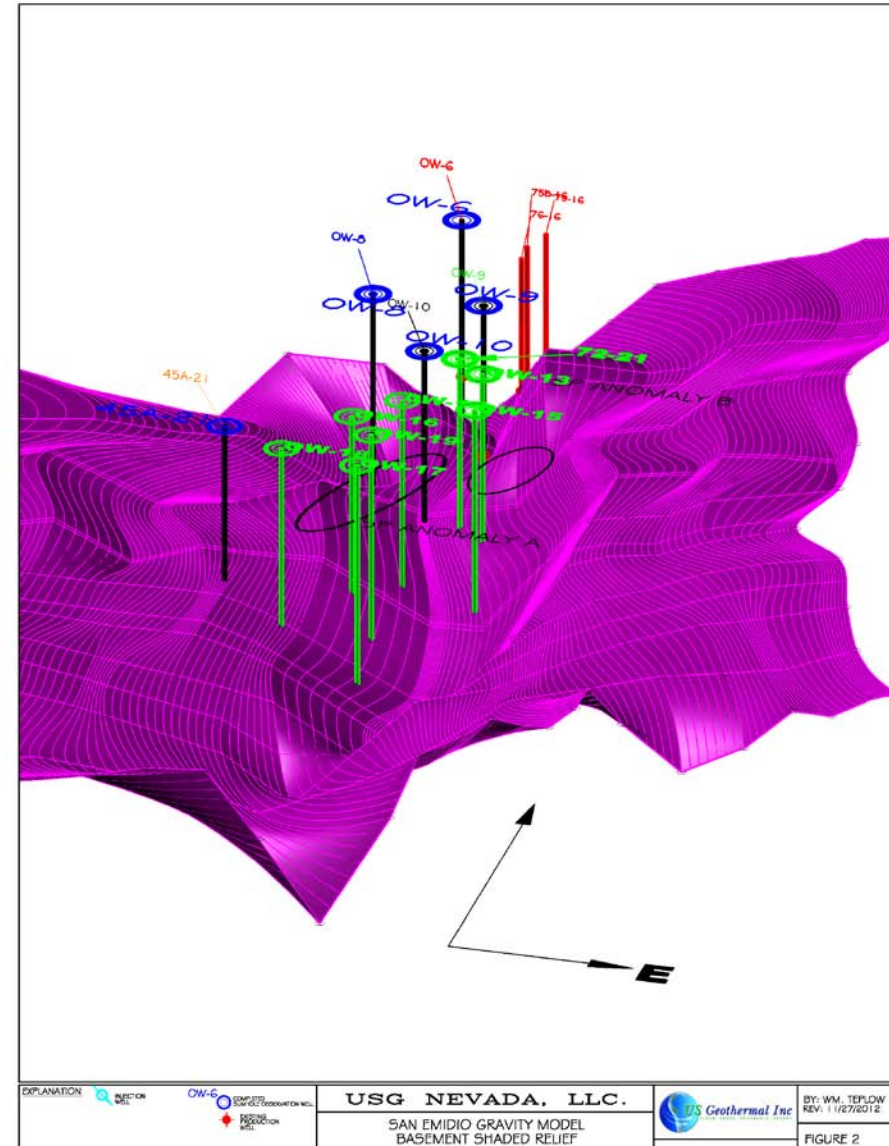
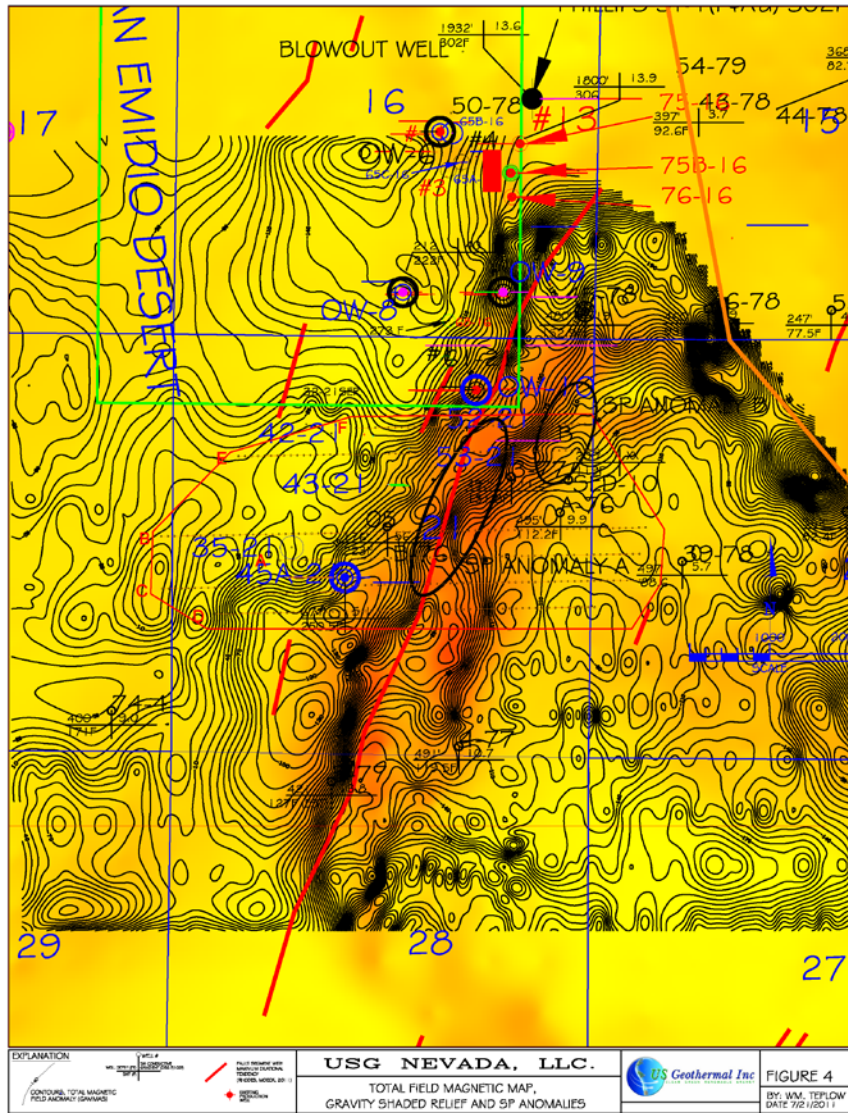
* Damaged casing requires rework

SAN EMIDIO TEMPERATURE PROFILES

TEMPERATURE PROFILES, OW-6, OW-8, OW-9, OW-10, 45A-21, 75-16 AND SOUTHERN TG HOLES



SAN EMIDIO RESOURCE SOUTHERN EXTENSION



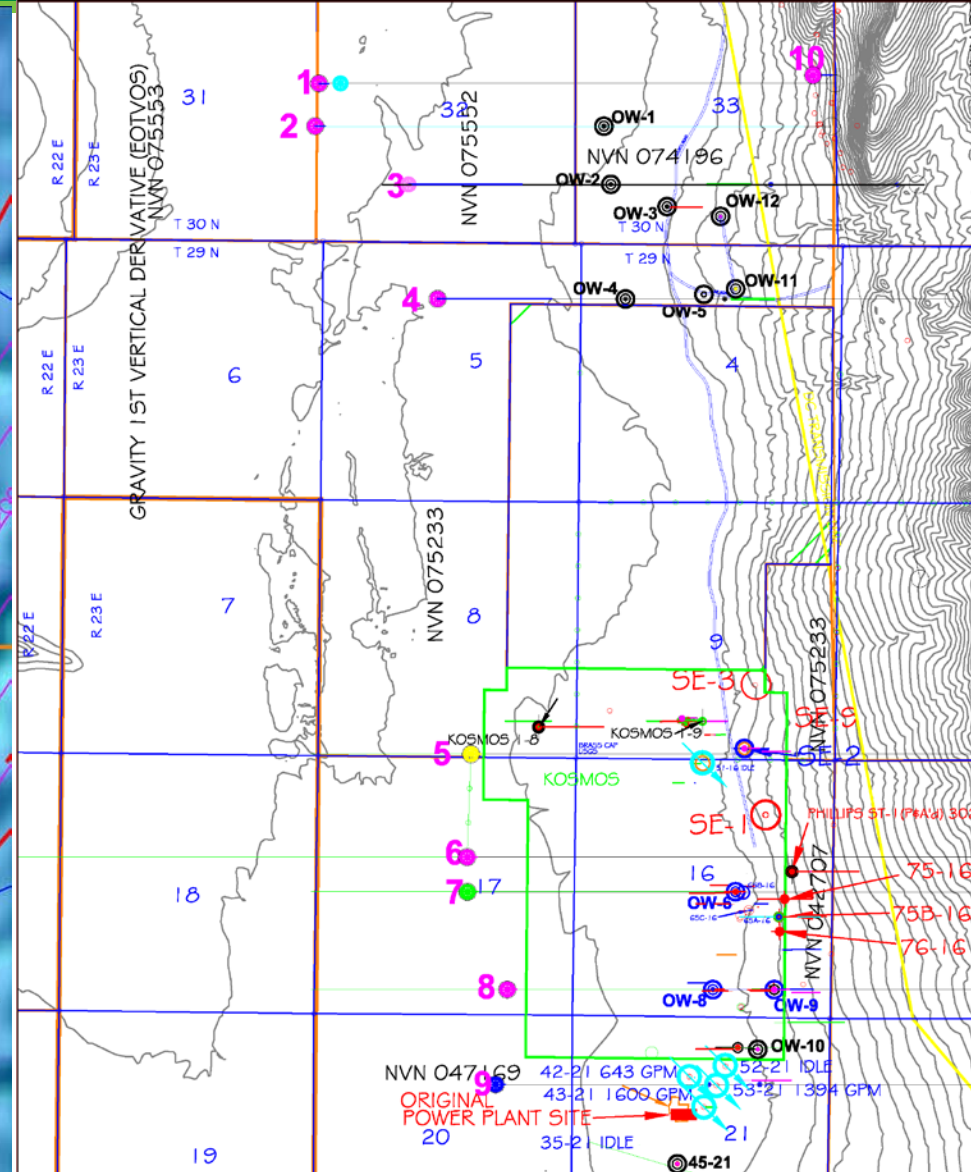
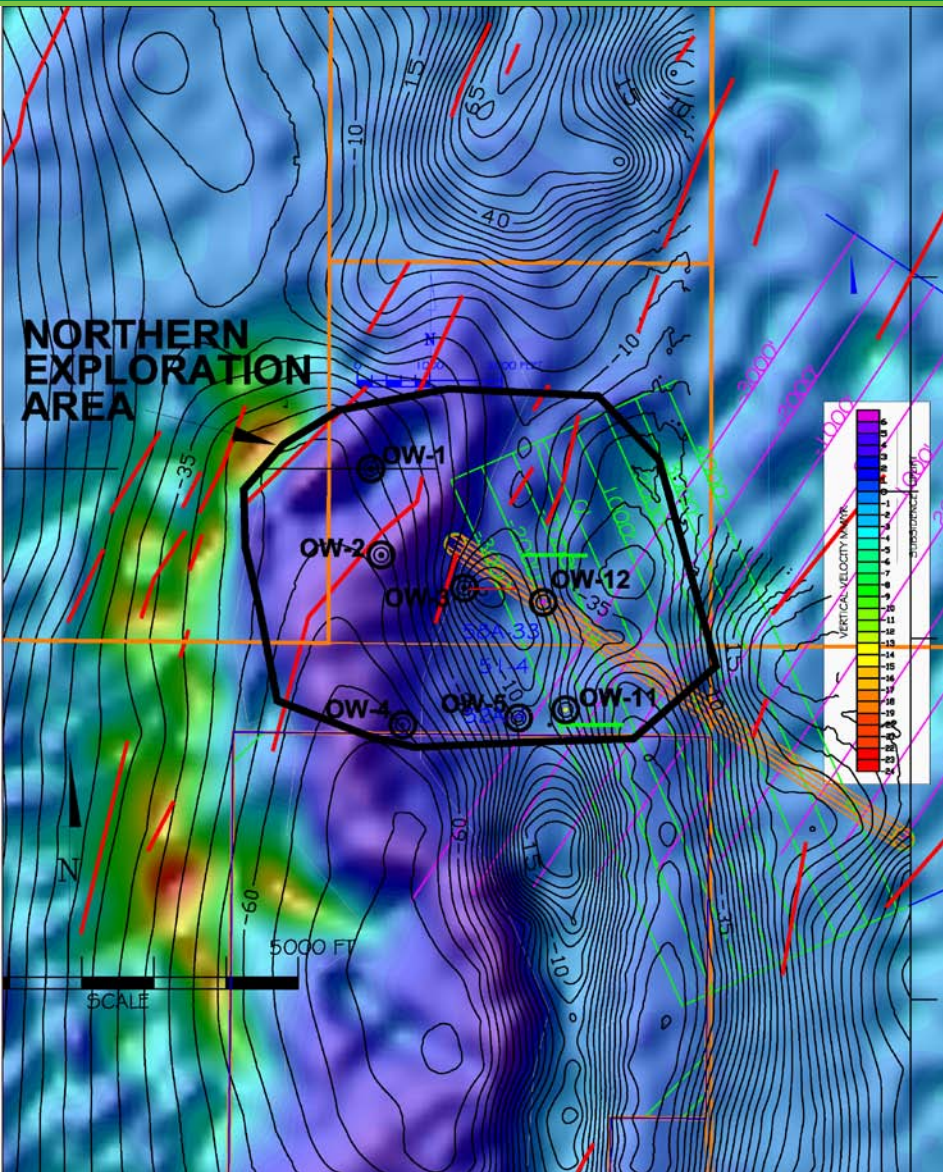
- Repeat drilling strategy in San Emidio Northern Exploration Area.
 - Drill up to 5 slimhole exploration/production wells.
 - Log and flowtest.
 - Design and start procurement of additional 9 MW net power plant to expand current San Emidio capacity.
 - If Northern Exploration Area does not contain a commercial reservoir, complete drilling of Southern Extension and add capacity to existing power plant.
 - Apply the San Emidio model for integrated geophysical/geological exploration and slimhole drilling to additional US Geothermal properties.

Milestone or Go/No-Go	Status & Expected Completion Date
Drill and test northern exploration area targets.	Permitted, drill ready, complete by 9/1/2013

SUMMARY OF DOE COST SHARE GEOTHERMAL EXPLORATION AT SAN EMIDIO

- Phase 1 exploration program generated numerous well-defined drilling targets.
- Phase 1 established integrated, cost-effective geophysical and geological exploration program universally applicable to Basin and Range resources.
- Phase 2 drilled and tested Phase 1 targets.
- 4 out of 5 wells encountered commercially exploitable permeability and temperature.
- Added 2 MWe to currently operating wellfield.
- Expanded possible southern resource area by 1 sq mi.
- Found resource with temperatures 15 to 20° F higher than previously observed at San Emidio.
- Drilling strategy will be repeated in Northern Exploration Area by September, 2013.

DRILL SITES, NORTHERN EXPLORATION AREA



Timeline:

PHASE	TASK	Planned Start Date	Planned End Date	Actual Start Date	Actual End Date
1	Seismic Refraction, PSInSAR, Kinematic Structural Analysis	4/1/2010	3/31/11	4/1/2010	5/31/11
2 Southern Area	Drilling & Reservoir Testing	6/1/2011	9/30/2011 (1 Well)	8/1/2011	5/30/12 (5 Wells)
2 Northern Area	Drilling & Reservoir Testing	10/1/2011	11/30/2011	5/1/2013	8/31/2013
3	Data Dissemination	10/1/2011	3/31/13	5/1/2013	9/30/2013

PHASE	Federal Share	Cost Share	Planned Expenses to Date	Actual Expenses to Date	Value of Work Completed to Date	Funding needed to Complete Work
1	\$500,000	\$173,000	\$679,318	\$673,000	n/a	\$0
2: Southern Area	\$2,281,543.36	\$633,795	\$4,406,500	\$2,915,338		\$0
2: Northern Area	\$991,000	\$3,415,500	\$4,406,500	\$0	n/a	\$4,406,500
3	\$0	\$7,500	\$0	\$0	n/a	\$7,500



PROJECT MANAGEMENT: OBJECTIVES AND METHODS

- Employ industry leaders for each element of Phase 1 exploration. (James Faulds, Greg Rhodes, Inga Moeck for structural analysis; Imageair (Mariana Eneva) for PSInSAR; Optim Software for seismic survey).
- Calibrate exploration techniques on known production zones, then extend surveys to prospective areas.
- Integrate and correlate all datasets to generate well defined drilling targets.
- Drill and test several targets at minimum cost while maintaining option for commercial production.
- Maintain target flexibility to immediately exploit data from each completed well.
- Closely coordinate with operating USG power plant for timely commercial exploitation of discoveries.
- Project delays are due to limitations of company resources while simultaneously commissioning two geothermal power plants.