

AGENDA

SEISMIC MONITORING ADVISORY COMMITTEE

May 11, 2015 @ 9:30 a.m.
Calpine Geothermal Visitors Center
15500 Central Park Road, Middletown

Call In: 1-888-449-6492; Participant Passcode: 226083

- I. Introductions
- II. Approval of SMAC report to the Board of Supervisors of November 17, 2014 meeting.
- III. Anderson Springs Report, (Jeff Gospe) and Input
- IV. Cobb Area Public Input
- V. General Public Input
- VI. Update of SE Geysers pipeline operations (Voge, Drake)
- VII. Summary of Seismic Data from USGS Network (Voge, Drake)
- VIII. Report by Calpine on Strong Motion Seismic Sensors (Hartline)
- IX. Report by Calpine on Santa Rosa Pipeline Operations (Hartline)
- X. Calpine EGS (Hartline)
- XI. Report on LBNL Seismic Array (Majer) and Induced Seismicity Update
- XII. Report by Lind Gee Seismic Data
- XIII. Report on Bottle Rock Power Co. Operations
- XIV. Coordination with Santa Rosa
- XV. Schedule Next Meeting for Monday, November 16, 2015
- XVI. Adjournment

SEISMIC MONITORING ADVISORY COMMITTEE (SMAC)

Monday, November 17, 2014, 9:30 a.m.
Calpine Geothermal Visitors Center
15500 Central Park Road
Middletown, California

FINAL MINUTES

Meeting called to order by Mark Dellinger, Committee Chairman (Lake County Special Districts) at 9:35 a.m. Minutes were recorded by tape recorder and transcribed to Draft Minutes. Dellinger initiated introductions.

Present: Mark Dellinger, Committee Chairman (Lake County Special Districts), Lester Drake (Northern California Power Agency - NCPA), Ed Voge (NCPA), Craig Hartline (Calpine), Bruce Carlsen (Calpine), Danielle Matthews Seperas (Calpine), Brian Harms (Bottle Rock Power), Rick Coel (Lake County Community Development Department), Mike Sherman (City of Santa Rosa), Melinda Wright (Calpine), Jody Spooner (Calpine), Joe Austin (Department of Conservation, Division of Oil, Gas & Geothermal Resources - DOGGR), Cheryl Engels (Anderson Springs), Ben Minks (DOGGR), Bob Young (NCPA), Meriel Medrano (Anderson Springs), David Oppenheimer (United States Geological Survey - USGS, via phone), Jeff Gospe (Anderson Springs)

I. **May 12, 2014 Meeting Minutes for Approval:** Mark Dellinger

Mr. Dellinger presented the Draft Minutes for approval and they were approved by consensus.

II. **Cobb Area Public Report:** Mark Dellinger reported that there were no residents from Cobb present anywhere. No comments from general public.

III. **Northern California Power Agency (NCPA) Report:** Ed Voge

Voge's presentation covered the operations in the South East Geysers pipeline, the effect of the drought and the operating seismic activity that has been observed for the past 6 months. The presentation covered three main areas: 1) Operations at The Geysers and the impact the drought has had; 2) Focus on the South East Geysers and the seismic activity observed, and 3) Segway into Craig's discussion on overall Geysers and the seismic activity observed.

i. Pipeline Operations:

- a. The Southeast Geysers Effluent Pipeline (SEGEP) has been in operation for 17 years and has delivered approximately 48.2 billion gallons of water at an average rate of 5,384 gpm to The Geysers steam fields for injection. That averages about 7.75 million gallons per day.
- b. During the more recent 6 month period from April – Sept. 2014, the SEGEP Pipeline has been in operation almost every day. Due to drought conditions, pipeline delivery rates were reduced on May 1, 2014 from an average of 8.11 million gallons per day to an average of 3.02 MGD. This reduction in flow remains in effect until further notice. It is dependent on the water levels in Clear Lake.
- c. The Rumsey gauge needs to be at 3.5 or higher by May 1, 2015 before additional water can be taken from the lake to supplement wastewater being pumped to The Geysers. Current level is -.83 feet.
- d. Steam production is up slightly from the previous 6 months because water in the reservoir is boiling off faster, which explains the slight up-tick in our steam production.

- e. Decline rate in steam production will start dropping off if we do go into a 2nd year drought. Currently, things are still in the range of normal.
- ii. Observed Seismicity / South East Geysers
 - a. The USGS recorded a total of 79 seismic events of magnitude 1.5 and greater within the SE Geysers area from 4/1/14-9/30-14. Voge noted that this is down about 20% quite a bit from the previous 6 months.
 - b. There was one seismic event that measured a 4.8 magnitude right on the NCPA/Calpine lease line that occurred 27 seconds after the Napa earthquake. It is considered to be an overlapping event.
- iii. Seismic Activity in the Geysers Known Geothermal Resource Area
 - a. There have been 489 events of magnitude of 1.5 and greater recorded by USGS for the past 6 months.
 - b. There were 2 earthquakes events of magnitude 3.0 and greater, one already mentioned earlier. The other was a magnitude 3.29 located in the central Geysers about 6.2 miles from AS instrument and occurred 3/8/14. Voge noted again that this number was down quite a bit.
 - c. In 2014, the cumulative total of EQ events greater than 1.5 is projected to be 1,038 which is down from 1,344 recorded in 2013.

IV. Calpine Corporation: Craig Hartline

Craig Hartline discussed the 6.02 South Napa earthquake. He focused on the Cobb Strong Motion Station which he found the strong motion values to be 8 to 10 times of what might be expected based on the energy and the distance from the South Napa Earthquake. USGS and David Oppenheimier provided an initial determination that AS stations were contaminated by local interferences.

- i. Seismicity Hotline: The Community Hotline is checked, reviewed, transcribed daily. During this current period we had 18 calls from April 1 to September 30, 2014. Four of these calls occurred on the day of the South Napa earthquake in the morning. During the previous period, 81 calls were received between April 1 to September 30, 2013 and 57 calls between October 1, 2013 to March 31, 2014. The number of calls to the hotline is down.
- ii. Yearly Field-Wide Water Injection: Hartline reports steam production is down which relates to seismicity count.
 - a. Water injection vs. Magnitude 1.5 and greater is at 1080 events, which is significantly down from the past reporting period.
 - b. Magnitude 2.0 and greater are down to 225 events from 320 events during the past reporting period.
 - c. Magnitude 2.5 and greater showed only 49 events which is a very low number.
 - d. Magnitude 3.0 and greater are on the decline field wide since about 1985.

- iii. Strong Motion Sensor Analysis: The strong motion instruments have been used to evaluate the ground acceleration during the past reporting period. During this period, there were a limited amount of events. Hartline provided information on estimated Cobb magnitude 2.83 and estimated Anderson Springs magnitude 4.38 as the biggest contributors.
- iv. 3D Visualization and 3D Structural Model Building: A three-dimensional geological/geophysical model is currently under development for The Geysers geothermal field.
 - a. This 3D structural model (including pre-existing fault zones and fractures) will assist in understanding induced seismicity at The Geysers.
 - b. Minor pressure variations that result from sub-surface fluid flow are indicated by the seismicity thus these fluid flow pathways and barriers are important constraints on development of the 3D structural model.
 - c. Software advances for seismicity analysis, along with 3D modeling constraints from lithology logs, surface geology, temperature logs, pressure logs, tracer analysis, heat flow and reservoir history matching are improving Calpine's ability to develop a 3D Structural Model for The Geysers.
 - d. The developing 3D structural model (including existing fault zones and fractures) will assist in understanding and potentially mitigating induced seismicity at The Geysers. The goal is to better manage water injection flow rates with local steam reservoir conditions.
- v. Calpine Surface Geology Mapping Project: Hard copy surface geology maps with varying creation dates, formats and scales were compiled, refined with surface investigations, and merged digitally using ArcGIS Mapping Software.
 - a. Work was completed by Calpine 2014 Summer Intern under the guidance from Calpine. This recently completed surface mapping project is being used as an additional constraint on the development of The Geysers 3D Structural Model.
- vi. Additional Seismic Monitoring and Research:
 - a) Seven AltaRock Microseismic Array (MSA) Boreholes have been transferred to Calpine Corporation;
 - b) Working "Towards the Understanding of Induced Seismicity in Enhanced Geothermal Systems" R. Gritto, D. Dreger, O. Heidbach and L. Hutchings;
 - c) The team of Bjorn Paulsson, Ernie Majer, Craig Hartline submitted a proposal to the California Energy Commission and was awarded nearly \$900,000 for the borehole seismic monitoring two high temperature North Geysers wells project.
 - d) Calpine is determining a suitable borehole for a limited test program with high temperature three-component fiber optic sensors developed by United States Seismic Sensor Systems Incorporated.
 - Seismic Warning Systems: Primary Goal – Automated Control (and shutdown) of natural gas, electricity and water supply for refineries, chemical plants, public schools medical facilities. Two test sensors installed at The Geysers Prati 32 Well Pad and tied in to Calpine Power and communications. Geysers project goals are

to refinement of event detection software to: avoid false positives; and, Distinguish between smaller seismic events and large seismic events (earthquakes) triggering automated warnings and shutdowns)

Follow Up Comment/Question: "We appreciate all that you have done and continue to do; that is just great. I have one question. The calls from Anderson Springs that are in the numbers, is that just for earthquakes or does it include noise too?"

Hartline responded that Calpine made a determination about a year ago, to distinguish between seismicity calls and all other community calls, including noise. Only seismicity calls are included in the SMAC meetings.

Comment from David Oppenheimer, USGS in follow up to Hartline's presentation: The main shock of an earthquake is traveling away, and the others are riding on top of it. It is not known if the magnitude is ever going to get refined. A fair amount of work was done on it and that it is thought that it will probably be the best estimate available on it. It is in the "4" range. Otherwise, said he did not have much to add other than a personal comment that he is retiring in February. Lind Gee will take over the project. Some of you may know her from when she was at UC Berkeley running the network there. She is capable and currently participating in represent the USGS and will likely connect with the SMAC in mid-January. Oppenheimer stated that it has been a pleasure working with everybody. Personally and professionally, it's good to see all this work going forward at The Geysers. It's unique that industry, government, partnership work together so well and he congratulated everyone you for making that happen. Committee comments of congratulations followed.

V. Lawrence Berkeley National Laboratories Report: Craig Hartline for Ernie Majer

- i. Mr. Hartline summarized that LBNL has 32 permanent 3-C stations at The Geysers as well as 5 temporary stations that are around EGS well, the enhanced geothermal system well at Prati 31, 32 and those are still in place that EGS project is still continuing.

The SE part of the array is being augmented with former 500 ft. deep Alta Rock boreholes. All five in by the end of the year (LBNL equipment)

- ii. Napa earthquake, at first look may have triggered some seismic events in The Geysers. Assistance was given by Katie Boyle and Ernie at LBNL to give us some understanding with the relationship between the main seismic event and the triggered event. Ernie has requested that we put some equipment down hole in the Northwest Geysers.
- iii. LBNL has been working with United States Seismic Sensors, Inc. and moving forward with event detection. Planning new sensor test for increasing resolution of fracture imaging and MEQ detection.
- iv. Two new initiatives that Department of Energy (DOE) has concerning seismicity called FORGE (Frontier Observatory for Research Geothermal Engineering). This will be a 10- year effort with a significant amount of funding dedicated to this program and the idea being that they will have a dedicated field site for understanding enhanced geothermal systems.

Another program – SubTER (Grand challenges in subsurface engineering). This is another 10-year effort and it's going to involve fossil energy programs- geothermal, carbon sea crustation – where they take the output from power plants, things that burn fossil fuels and try to isolate and inject carbon dioxide into the sub-surface or dispose of it in some other manner.

The Department of Energy has put these programs out there and companies, research groups are applying for this funding that will move forward the issues concerning geothermal and other energy technologies.

VI. Anderson Springs Report: Jeff Gospe

Mr. Gospe passed around a map showing where the events were located (relative to the Magnitude 4 event). Gospe noted that it is known that events can be triggered by natural outside events but what are the implications in terms of liability, in terms of mitigation. Is there mitigation that can be done or not. Gospe invited Cheryl, Joan or Meriel who live in Anderson Springs to share afterwards what was felt but the main question he posed is what mitigation or planning really could be done for outside earthquakes that trigger something in the field. While it may never be known what would have happened had there not been 30-40 years of geothermal, Gospe commented that the development may have altered things. Anderson Springs tends to relate to the modified Mercalli scale developed but are told that it is not very accurate. Gospe asked if there is there something that could better relate to modified Mercalli intensity and that would be useful. Gospe mentioned that the methodology was designed for large magnitude distant earthquakes but not shallow short district micro-earthquakes.

Gospe states that it would be valuable to have at least one hole sensor in the community, possibly in an old, abandoned well, whether for water or steam that could be used. He asked if there would there be any value that to understanding what's happening down hole rather than at the surface for ground acceleration on the data collected.

David Oppenheimer (via phone) commented, noting that one question to be asked is: Is there anything, any mitigation techniques that can be done. The Geysers, as well as many geothermal and volcanic areas around the world have seen many triggered events. Typically, these events are triggered as Hartline (Calpine) presented -- by what is called the surface wave which follows the shear wave. The best way to think about it is that the area is loaded up and that earthquake would have occurred and so now with a little bit of shaking, you have just advanced the time in which the event occurred. That analysis has not been done but if you look at the data you may see that there was a decrease in seismicity in the next day to week or so as opposed to those advanced earthquakes from the shaking systems where not enough stress accumulation to come back to the stress levels where seismicity normally would have occurred. It has just been advance of the clock.

Jeff Gospe asked if there anything that should be considered to be done to reduce the possibility of a triggered event. David Oppenheim commented that he thinks those triggered earthquakes are normal, just part of the normal background activity at The Geysers. He did not think that there are any mitigating activities other than the kind of work that Calpine is doing in trying to understand what the physical conditions are that are inducing seismicity and altering injections, location of injections, lines of injections and that kind of thing.

VII. Report on Bottle Rock Power Company: Brian Harms Nothing to report

VIII. Report on Coordination with Santa Rosa: Mike Sherman

City of Santa Rosa and Utility Department are in constant discussions with Calpine and it appears that SRGRP will fulfill 90-93% of its Geysers contract. Discussions are also underway with urban and agricultural users of the water.

Next meeting: The next SMAC meeting will be **May 11, 2015** at the Calpine Geothermal Visitors Center. Meeting was adjourned by Chairman Dellinger at 11:47 a.m.

Meeting Agenda and Full Presentations are available online at:
<http://www.geysers.com/smac.aspx>