CALPINE®
NYSE CPN

A GENERATION AHEAD, today

Seismic Monitoring Advisory Committee Review

18 November 2013
Geothermal Visitors Center
Middletown, California

Reporting Period:
01 April 2013 to 30 September 2013

Craig Hartline
Senior Geophysicist
Calpine Corporation

Reporting Period 01 April 2013 to 30 September 2013

- Seismicity Hotline
- Seismic Monitoring Networks
- Field-Wide Water Injection and Seismicity
- Water Injection Modifications
- Southeast Geysers Water Injection and Seismicity
- Strong Motion Sensor Stations and Data Analysis
- Strong Motion Triggers By Modified Mercalli Intensity and Year
- Historical Seismic Energy Release Analysis
    - Yearly, Monthly, 24 Equivalent Areas

SRGRP #20 Report Summary

- Reporting Period 01 March 2013 to 31 August 2013

3D Visualization and Geological Model Building

Ongoing Seismicity Research Collaborations

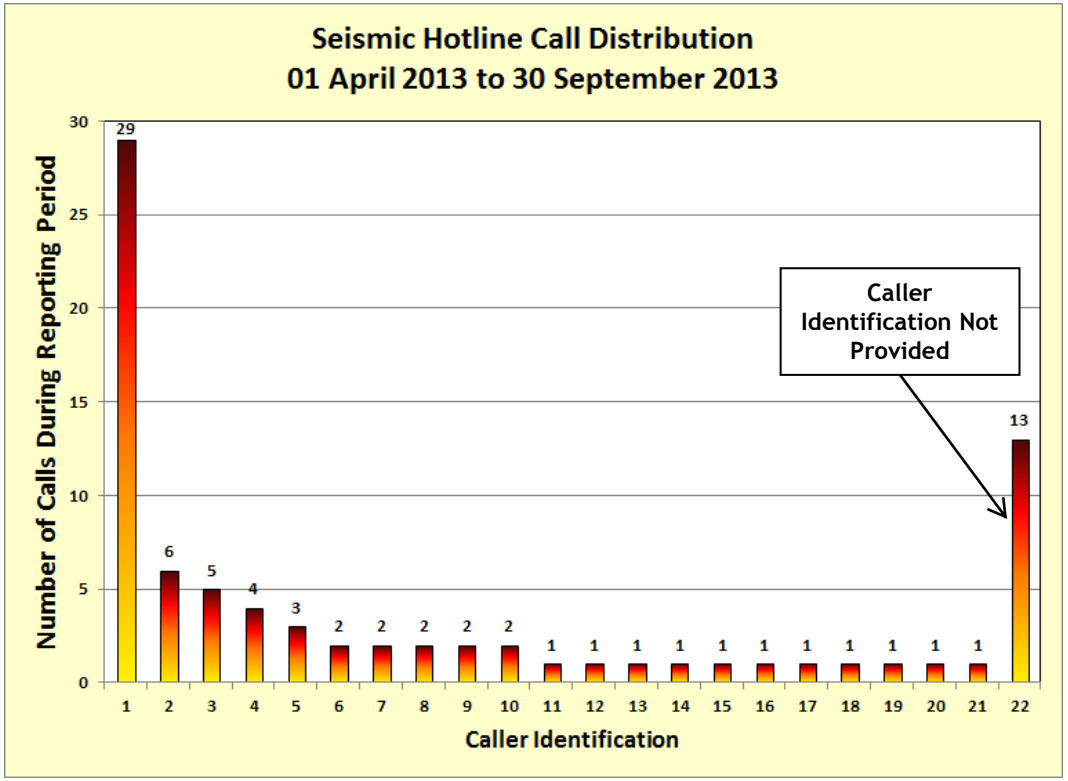
- GEISER Consortium (GFZ Potsdam)
- Lawrence Berkeley National Laboratory

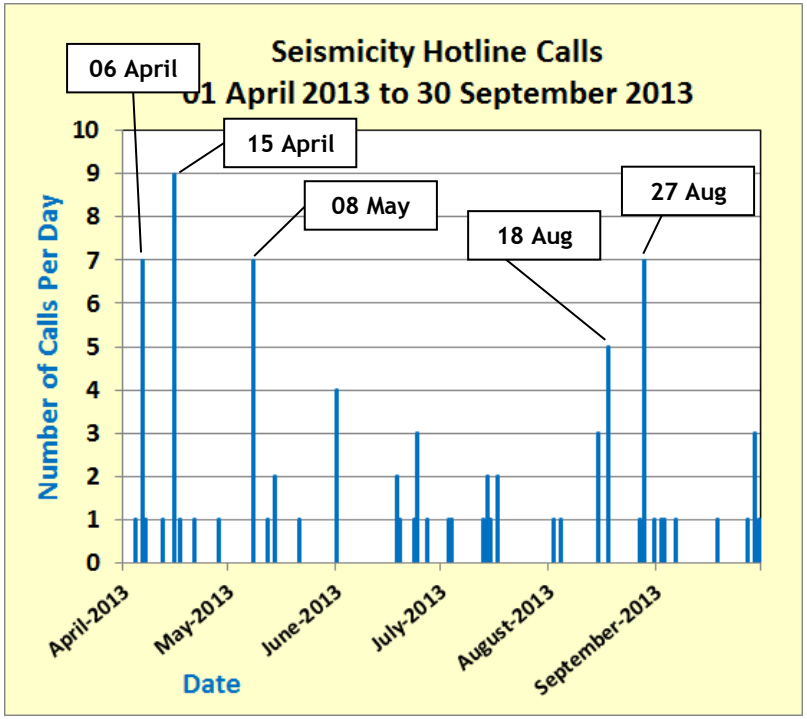
Calpine Community Outreach

Seismic Monitoring Advisory Committee Meeting
Seismicity Hotline (1-877-4GEYSER Toll Free)
Calls Transcribed Daily

- 81 seismicity voicemails transcribed and reviewed from 01 April 2013 to 30 September 2013
  Anderson Springs: 40 calls 3 call-back requests
  Cobb: 41 calls 5 call-back requests

- Calpine Geysers voicemail system failure occurred prior to 27 August 2013 M 3.76 event
- Seismicity Hotline callers received a busy signal
- Calpine set up and distributed an alternate call-in number
- Bruce Carlsen, Director Environmental Services personally telephoned (8) Seismicity Hotline callers of record with event information concerning the M 3.76 seismic event





Seismic Monitoring Advisory Committee Meeting
01 April 2013 to 30 September 2013
Seismic Monitoring Networks

CALPINE NYSE CPN

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)

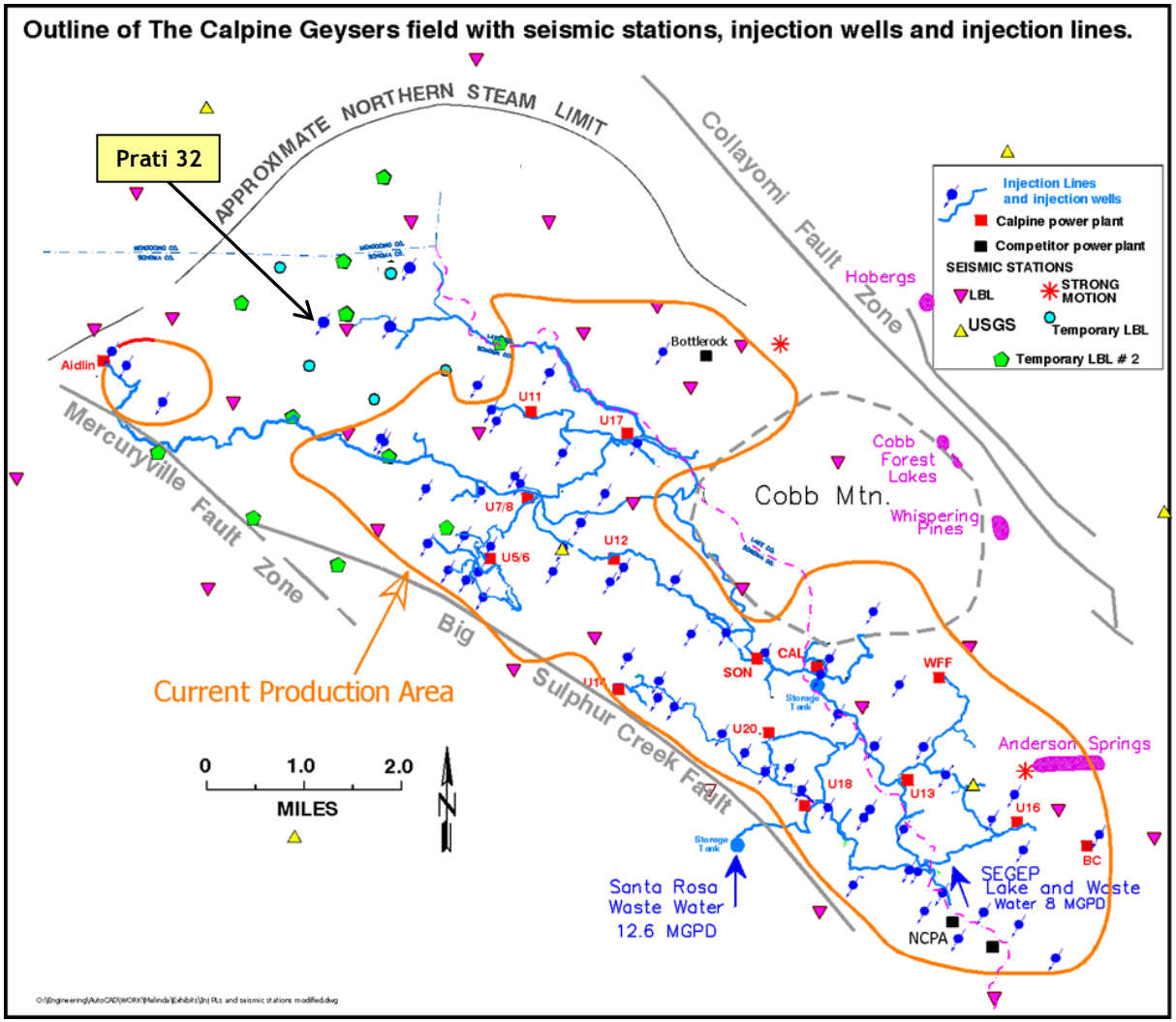
△ **US Geological Survey**
Installed in 1970's; some upgrades
5 stations; M 1.5 threshold
Primary Contact: Dr. David Oppenheimer (USGS)

✳ **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

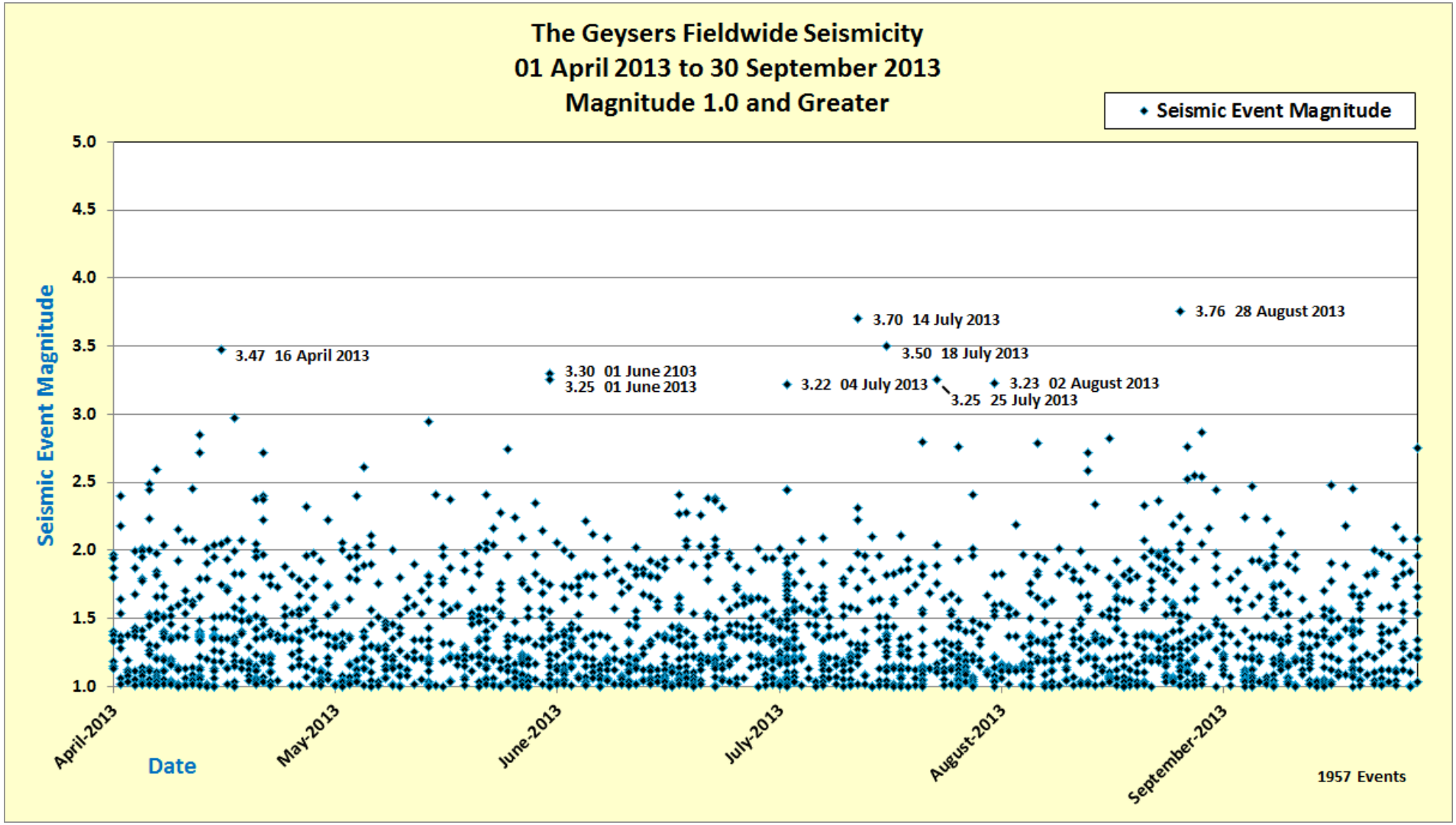
○ **Lawrence Berkeley National Laboratory**
Installed in 2010, ~ M1.0 threshold
5 stations; 4-6 months storage
Primary Contact: Dr. Ernie Major (LBNL)

⬟ **Lawrence Berkeley National Laboratory**
Installed in 2011, ~ M1.0 threshold
9 stations; 3-4 weeks storage
Stations Removed; Data Analysis
Primary Contact: Dr. Lawrence Hutchings (LBNL)

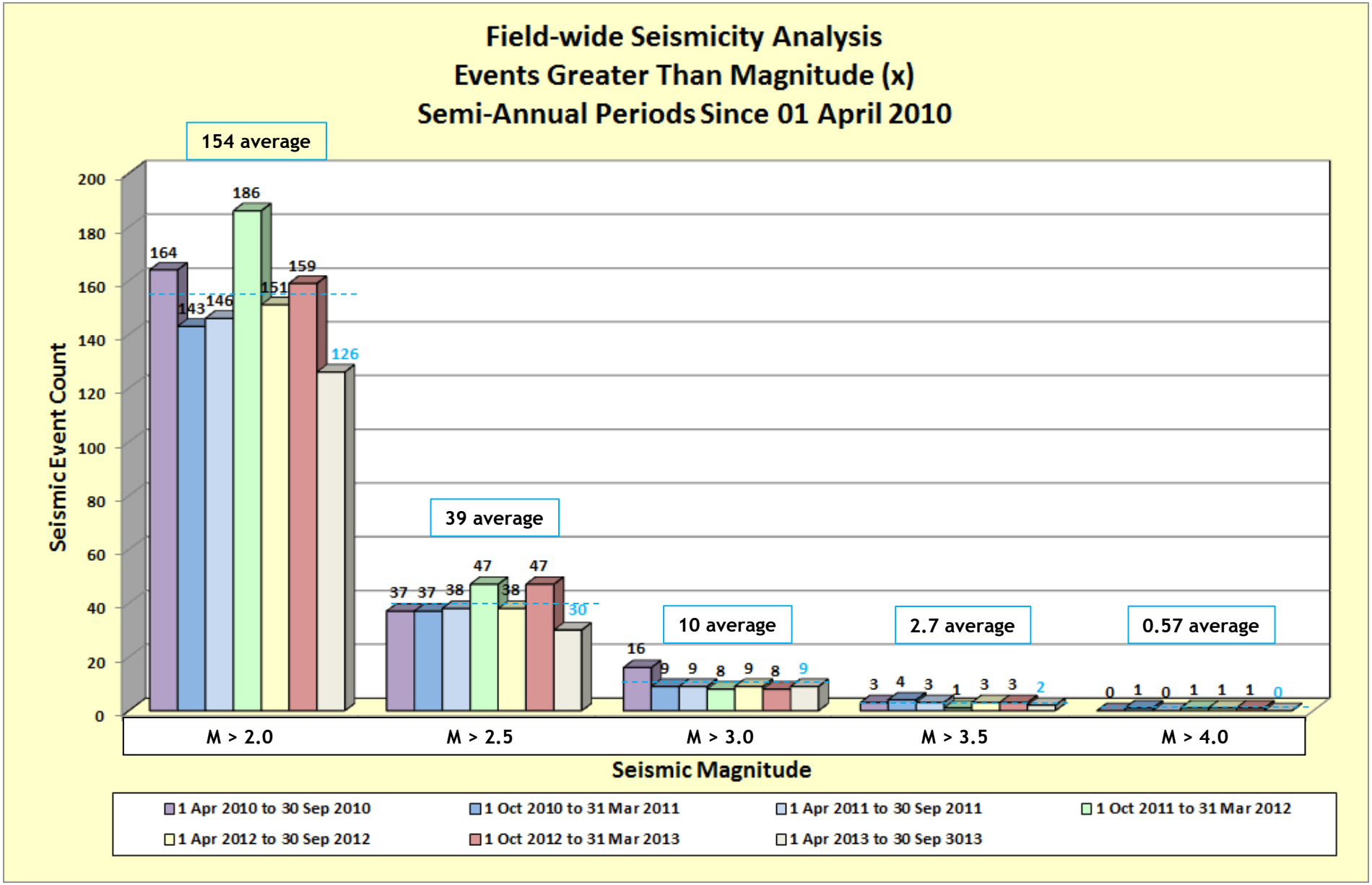


Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
01 April 2013 to 30 September 2013

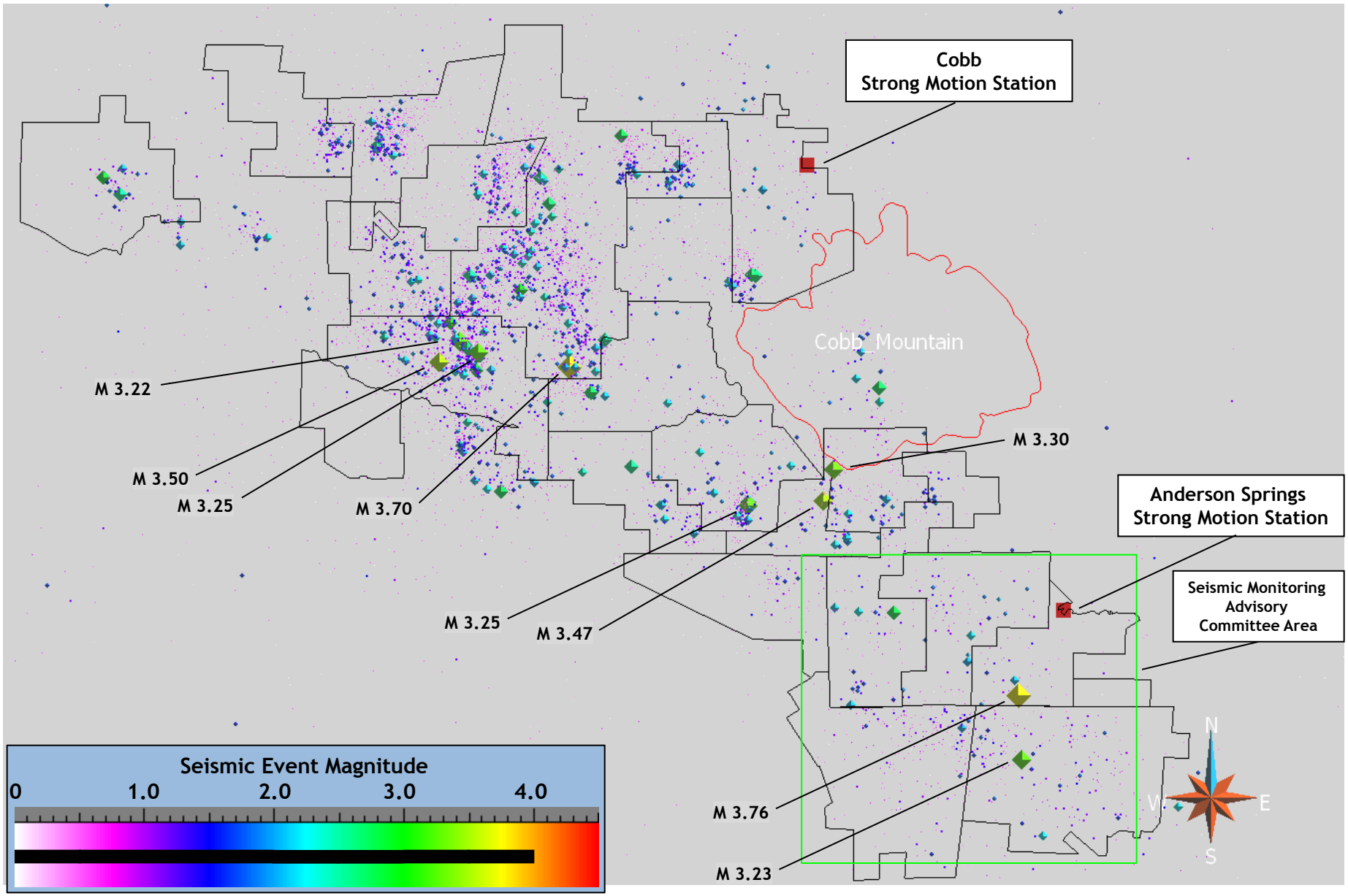
CALPINE NYSE CPN



Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
01 April 2010 to 30 September 2013



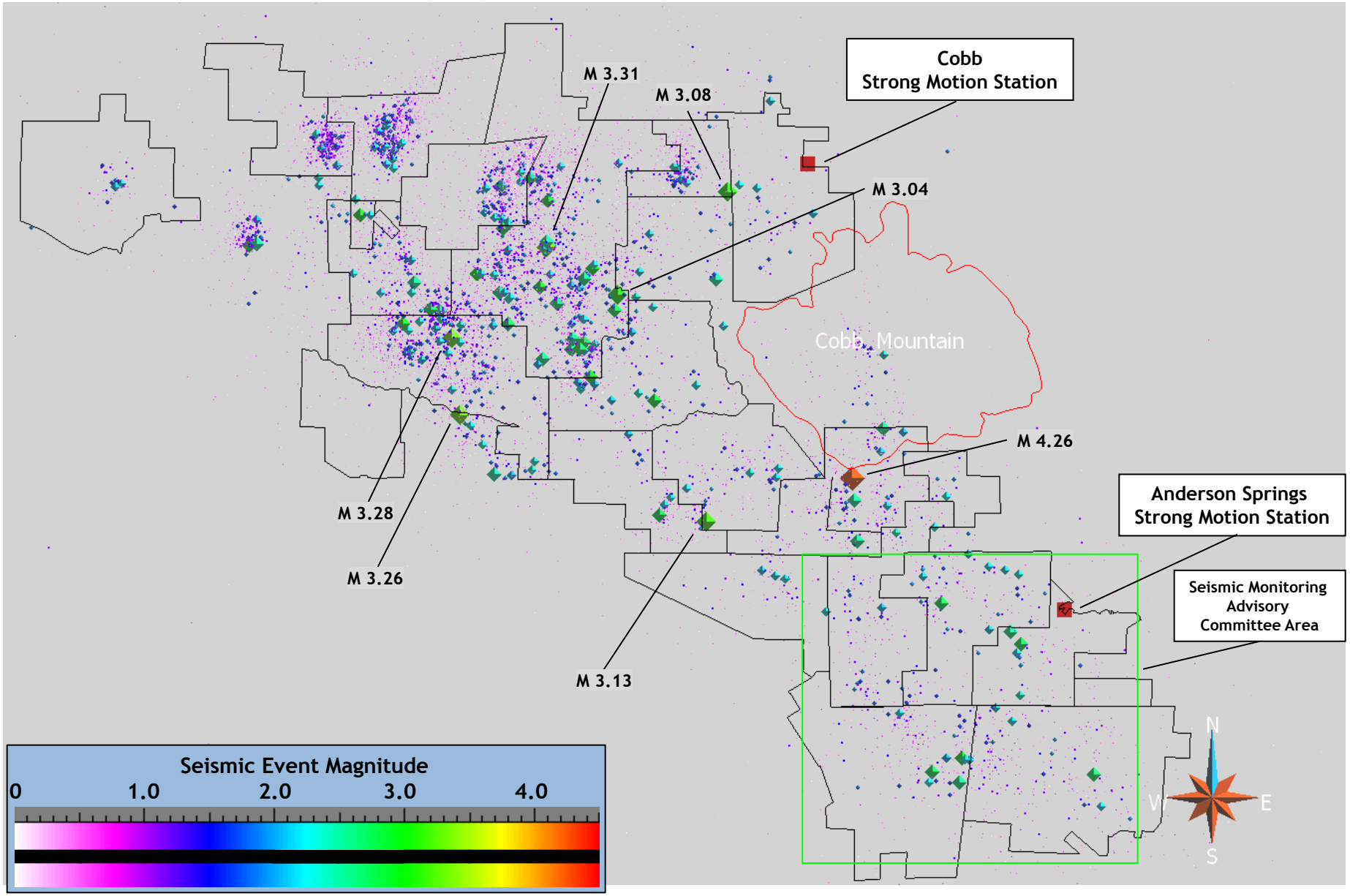
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
01 April 2013 to 30 September 2013



Seismic Monitoring Advisory Committee Meeting

Field-wide Seismicity Analysis

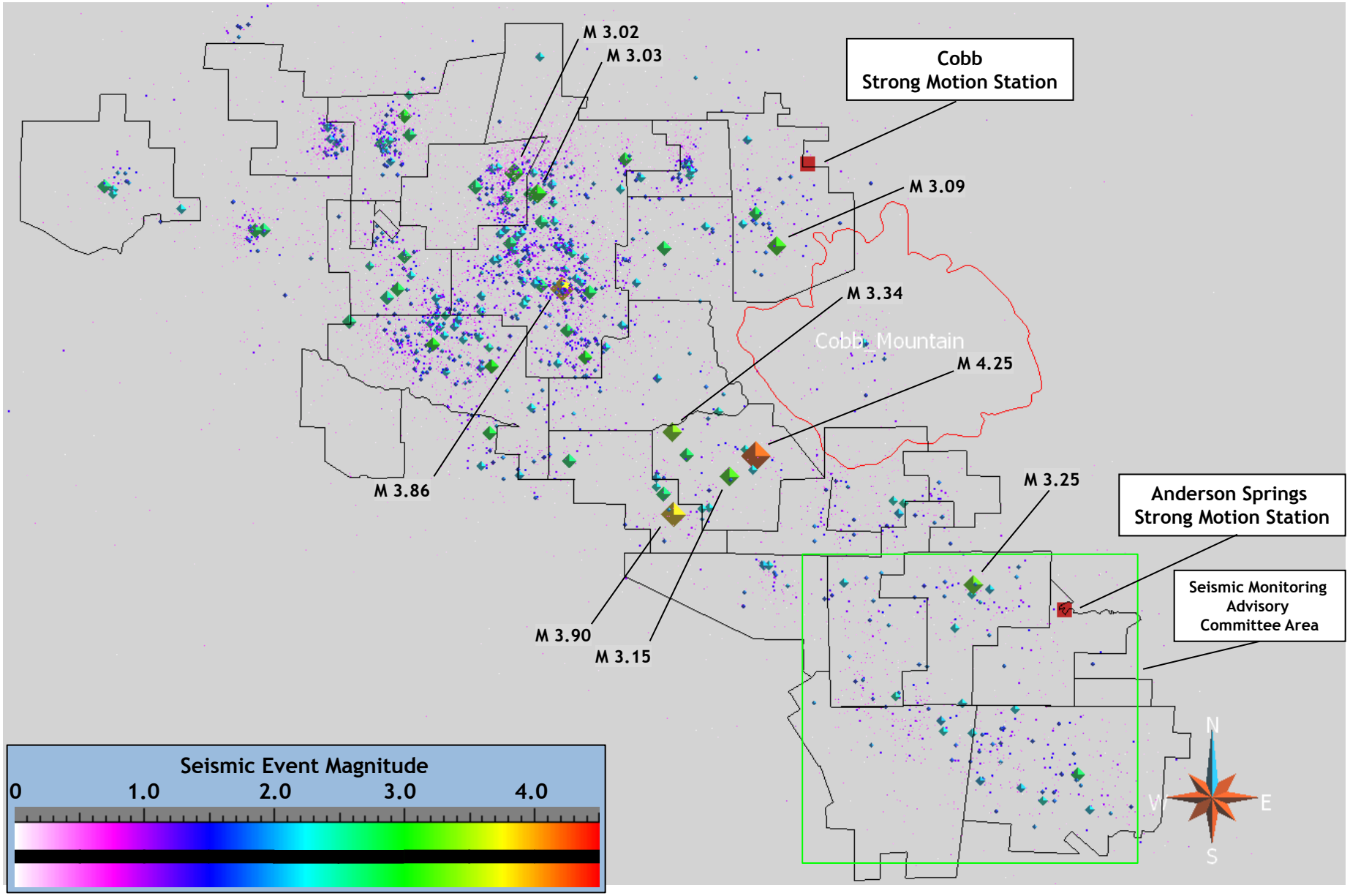
Comparison: Period #1 01 October 2011 to 31 March 2012



Seismic Monitoring Advisory Committee Meeting

Field-wide Seismicity Analysis

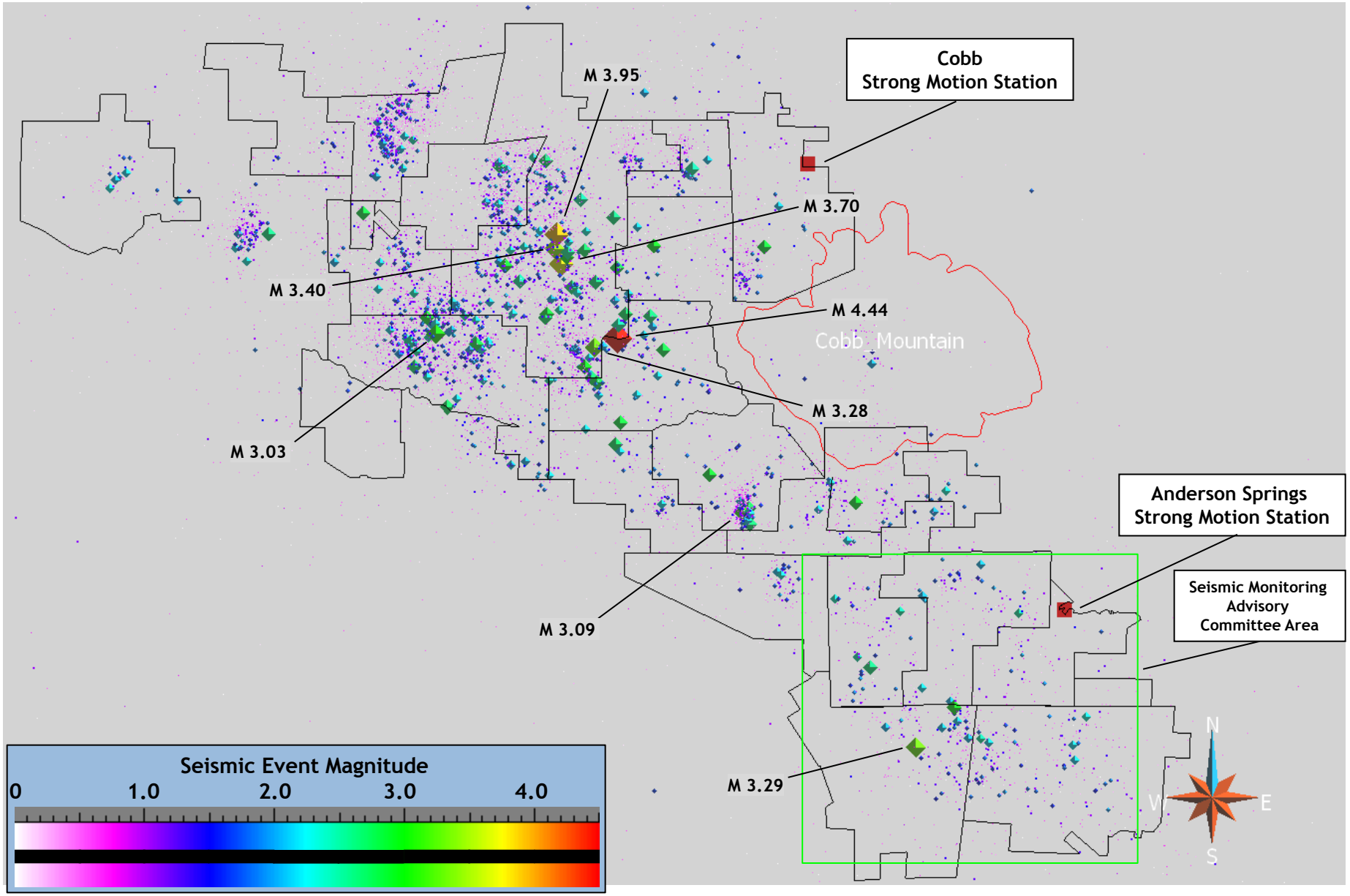
Comparison: Period #2 01 April 2012 to 30 September 2012



Seismic Monitoring Advisory Committee Meeting

Field-wide Seismicity Analysis

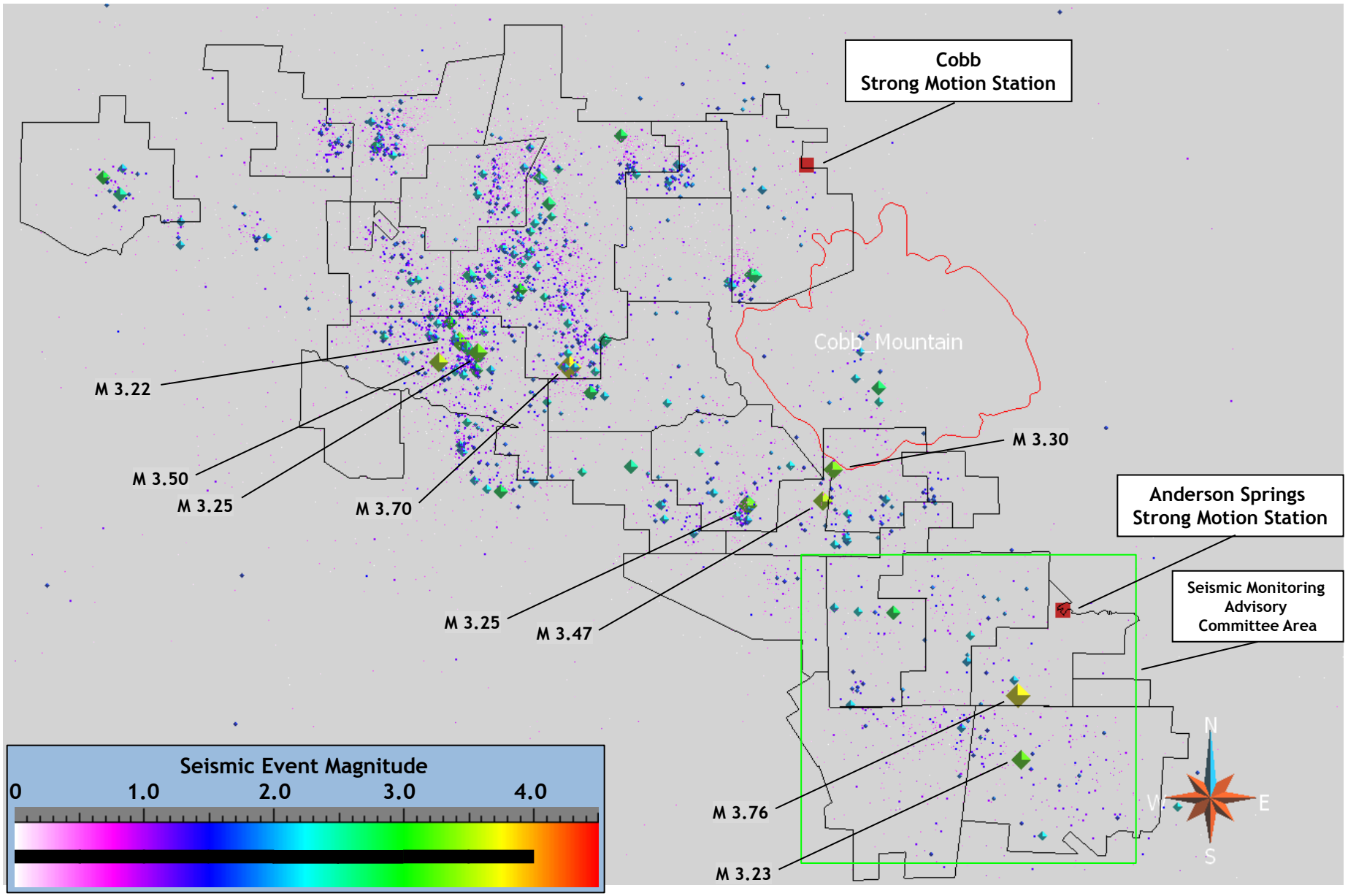
Comparison: Period #3 01 October 2012 to 31 March 2013



Seismic Monitoring Advisory Committee Meeting

Field-wide Seismicity Analysis

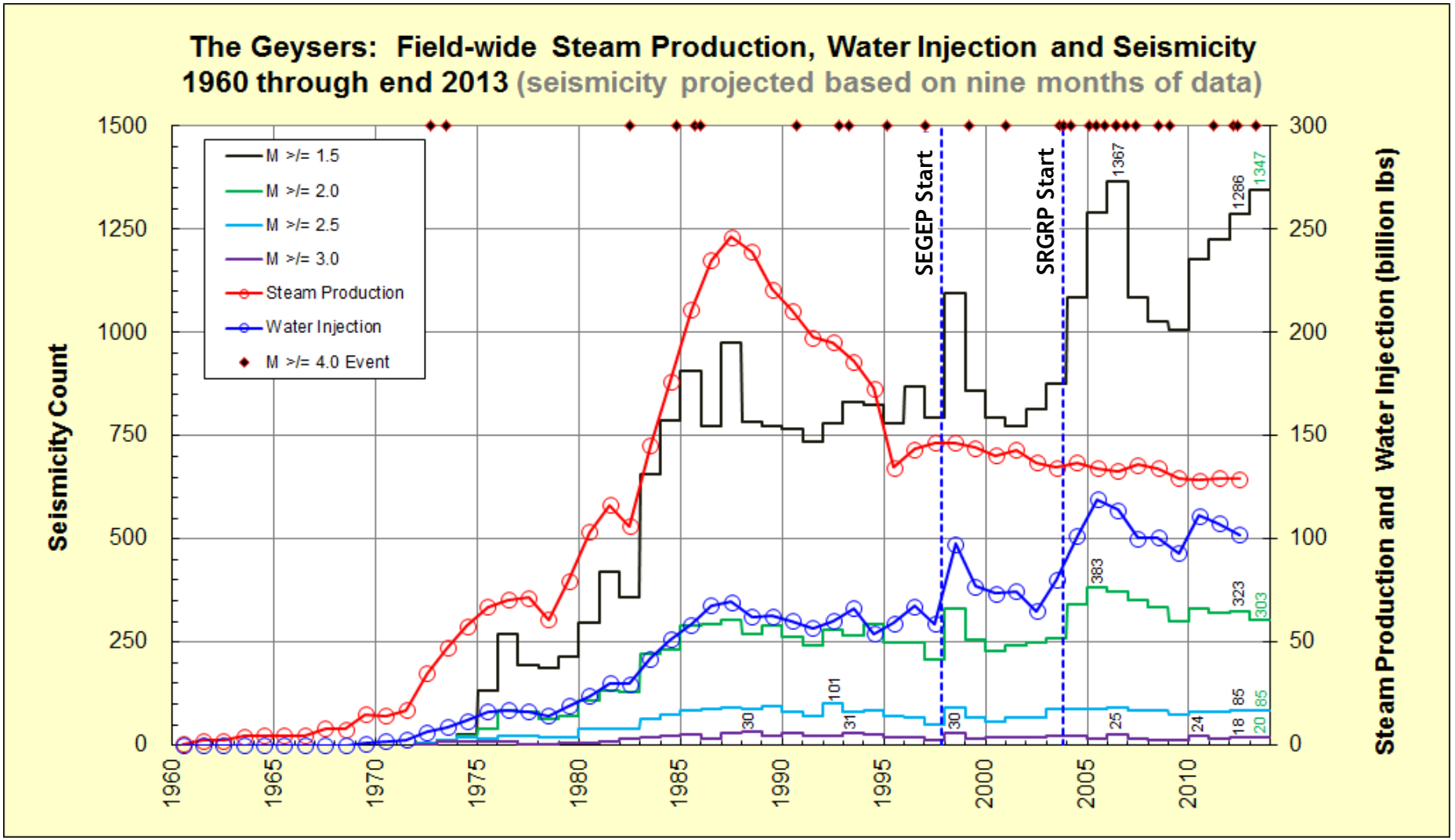
Comparison: Period #4 01 April 2013 to 30 September 2013



Calpine

The Geysers 1960 through end 2013 (projected)

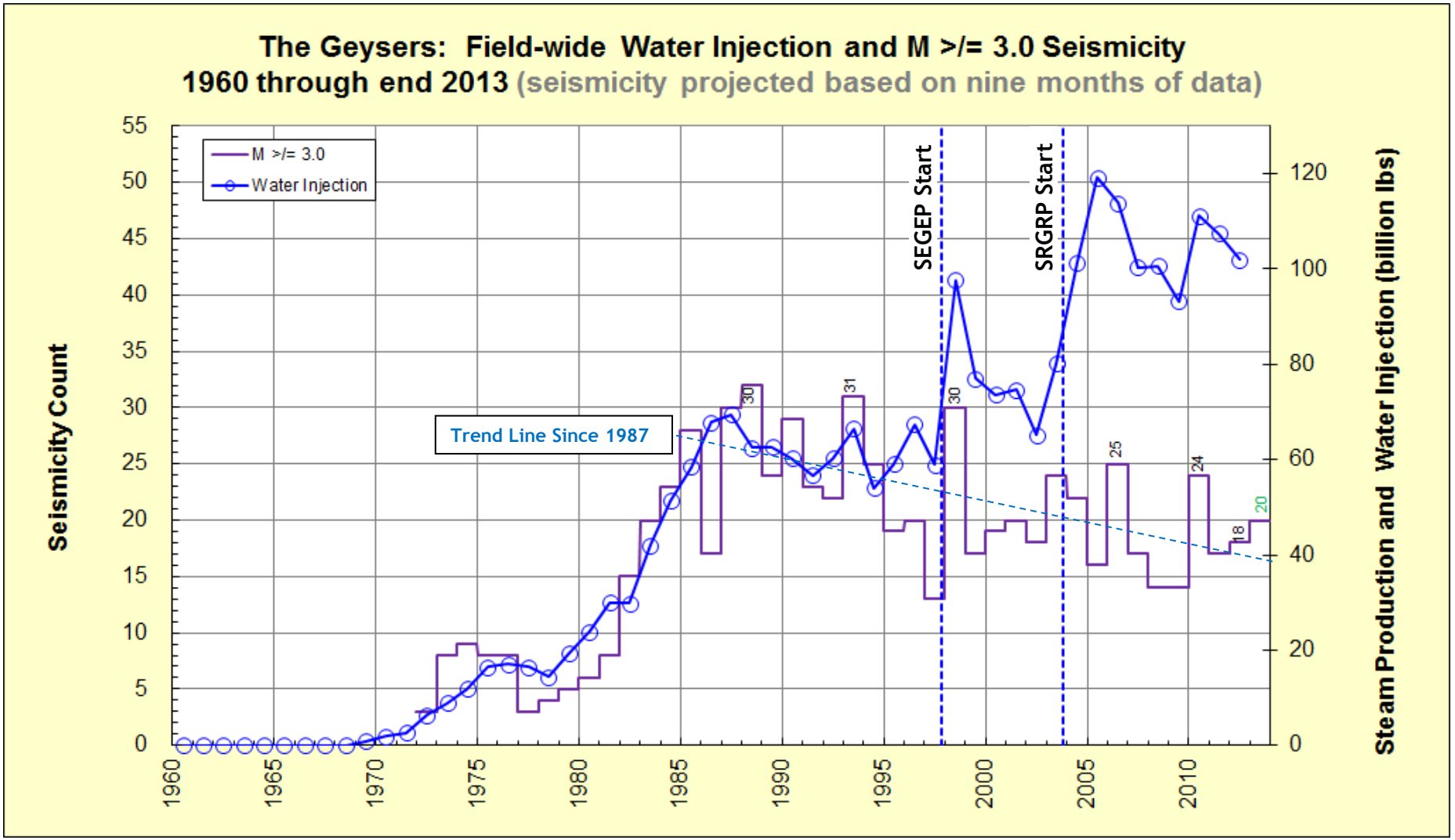
Yearly Field-wide Steam Production, Water Injection and Seismicity



Calpine

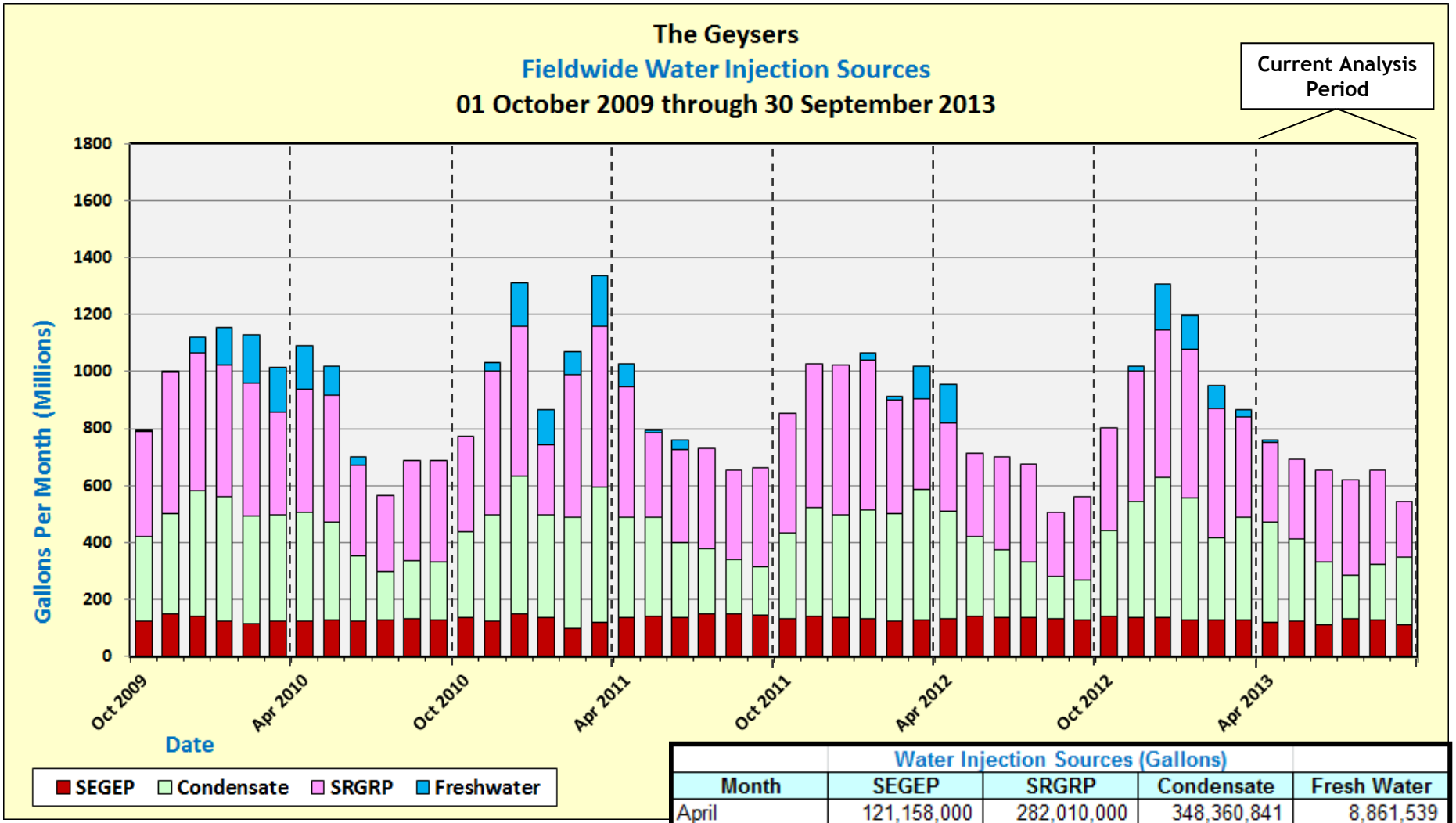
The Geysers 1960 through end 2013 (projected)

Yearly Field-wide Steam Production, Water Injection and Seismicity



Seismic Monitoring Advisory Committee
Field-wide Injection Sources
01 October 2009 to 30 September 2013

CALPINE NYSE CPN



Current Analysis Period

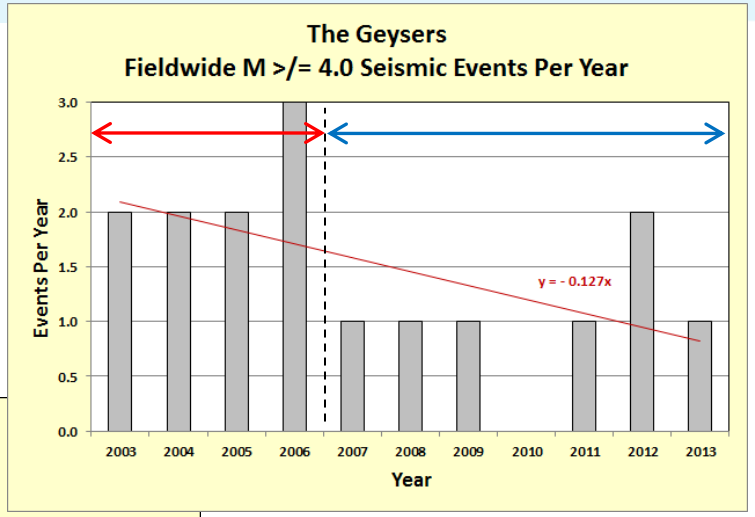
	Water Injection Sources (Gallons)			
Month	SEGEP	SRGRP	Condensate	Fresh Water
April	121,158,000	282,010,000	348,360,841	8,861,539
May	123,077,000	281,670,000	288,322,792	-
June	110,879,619	319,560,000	222,124,970	-
July	130,432,604	332,190,000	156,493,472	-
August	127,824,595	333,670,000	193,824,627	-
September	109,133,867	193,570,000	240,265,177	-

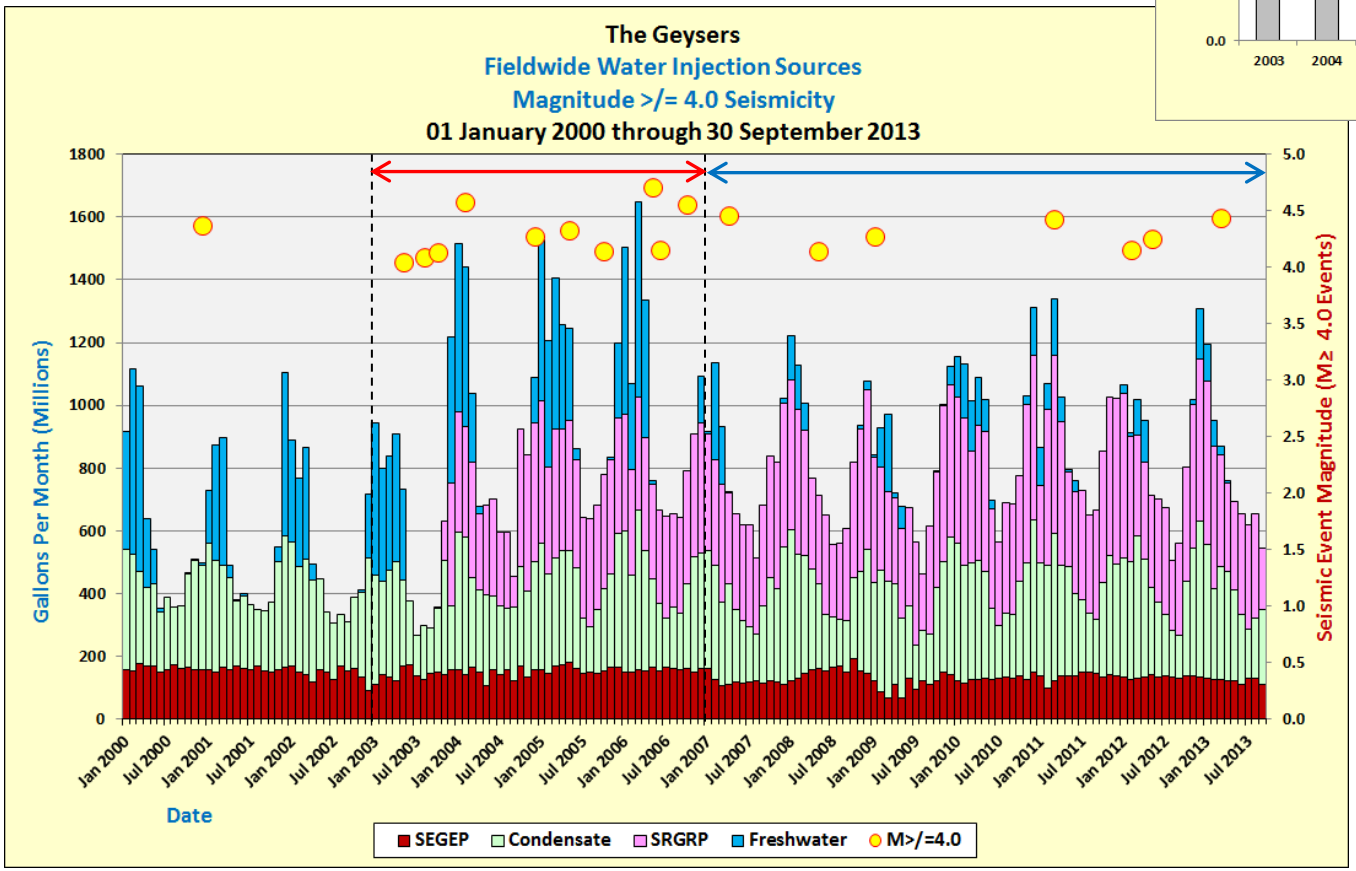
The Geysers
Field-wide Water Injection vs. Seismicity

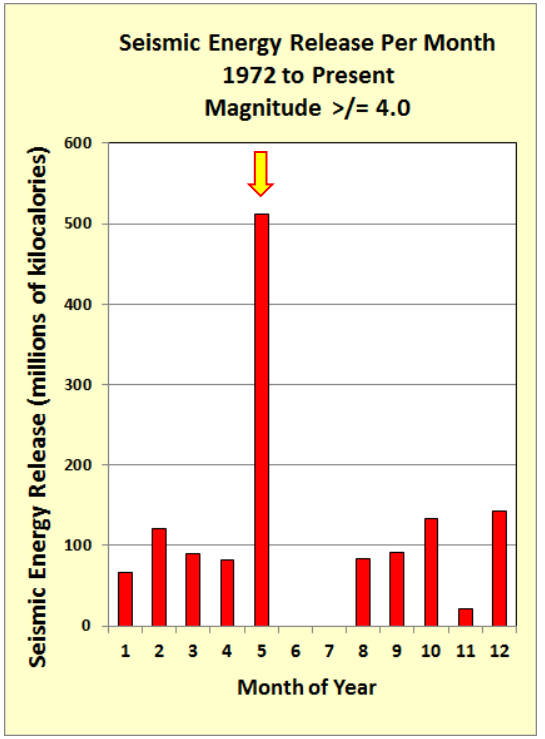
CALPINE
NYSE CPN

Number of Magnitude ≥ 4.0 Events Per Year Decreasing After a 2003-2006 Peak

Time Period	M ≥ 4.0 Seismic Events
2003 through end 2006	~ two events per year (2.25)
2007 through late 2013	~ one event per year (1.02)







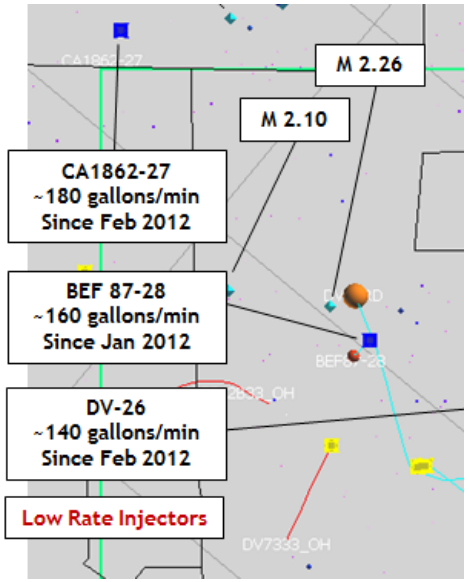
Water Injection Goals

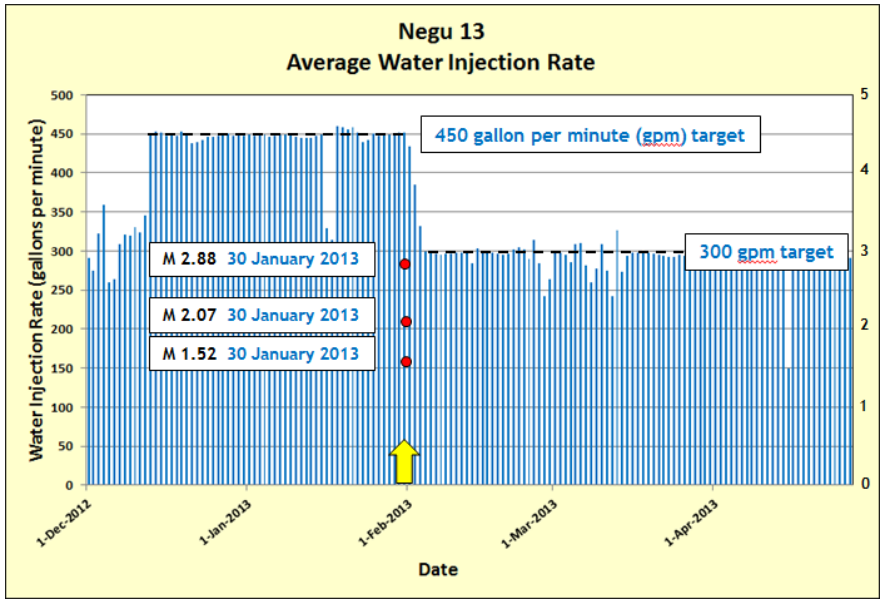
Improve Injection Distribution

- Expansion to northwest and away from communities (Wildhorse-34, Prati-9, Prati-32, Aidlin 11/12)
- Additional injection wells (LF-22 in 2013; Aidlin 13 and McKinley 16 in 2014)
- Shallow low-rate injectors (~150 gallons/minute for CA 1862-27, BEF 87-28, DV-26, 3 more in 2014)

Minimize Injection Rate Variations

- Individual wells and field-wide
- Emphasis on limited variation for wells nearest communities (Negu 13, Thorne 5)
- Lower injection rates per well being evaluated (e.g. 500 gallons/minute)
- Effects of injection rate variability being evaluated far from communities (Prati 32 in NW Geysers)
- Discussions with SRGRP source concerning more gradual transitions



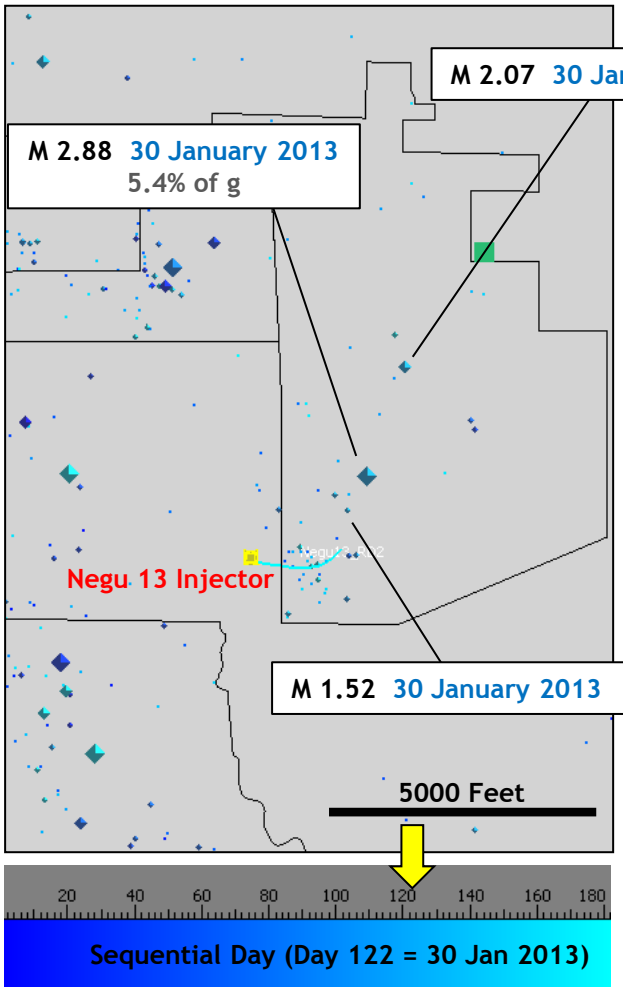


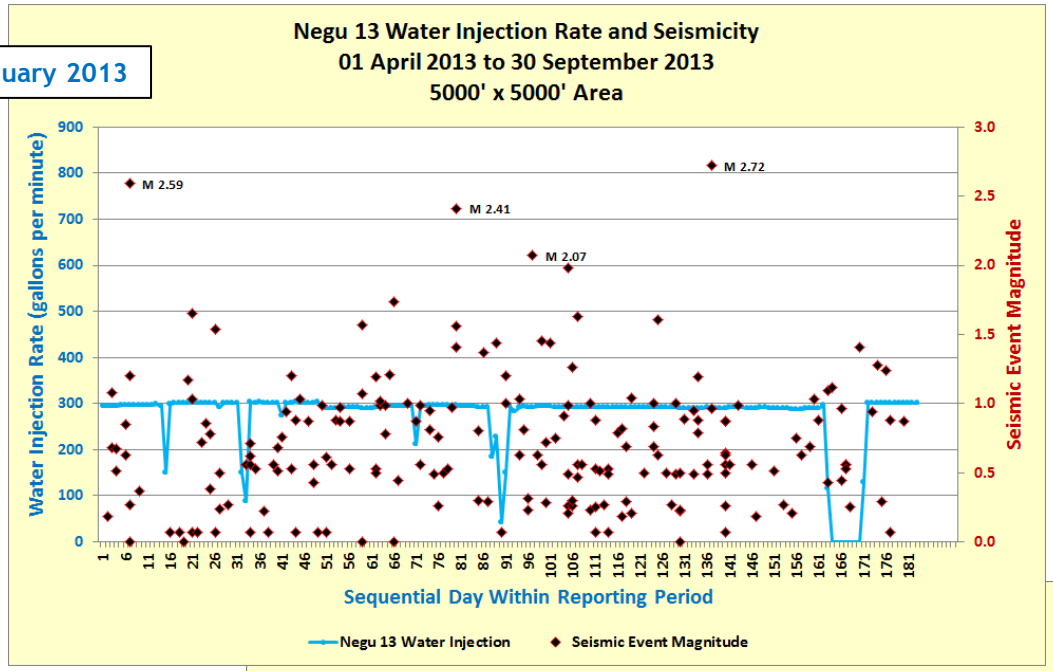
Seismic Monitoring Advisory Committee
Negu 13 Water Injection
Flow Rate Modification in Response to Seismicity

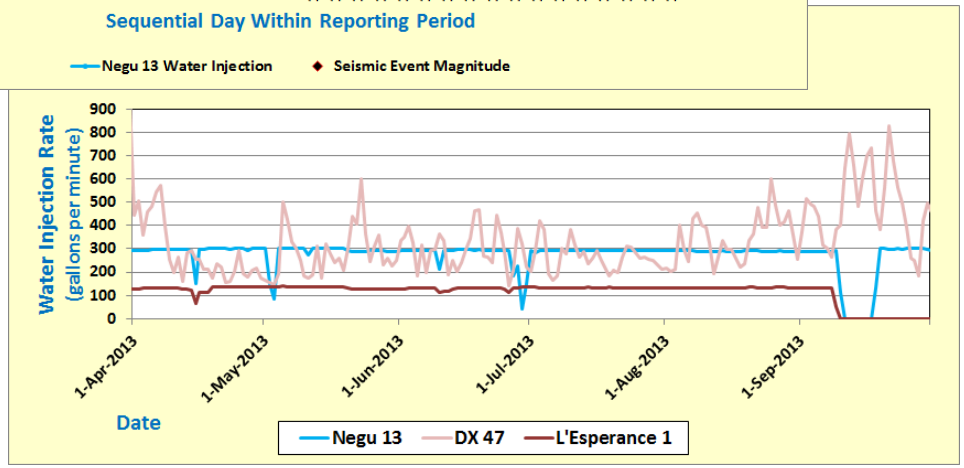
CALPINE
NYSE CPN

The occurrence of three M > 1.5 seismic events on 30 January 2013 (within in the previous reporting period) near an injector in the northeast Geysers prompted a 01 February 2013 flow rate reduction.

Water injection has been targeted at 300 gallons per minute and seismicity is being carefully monitored.

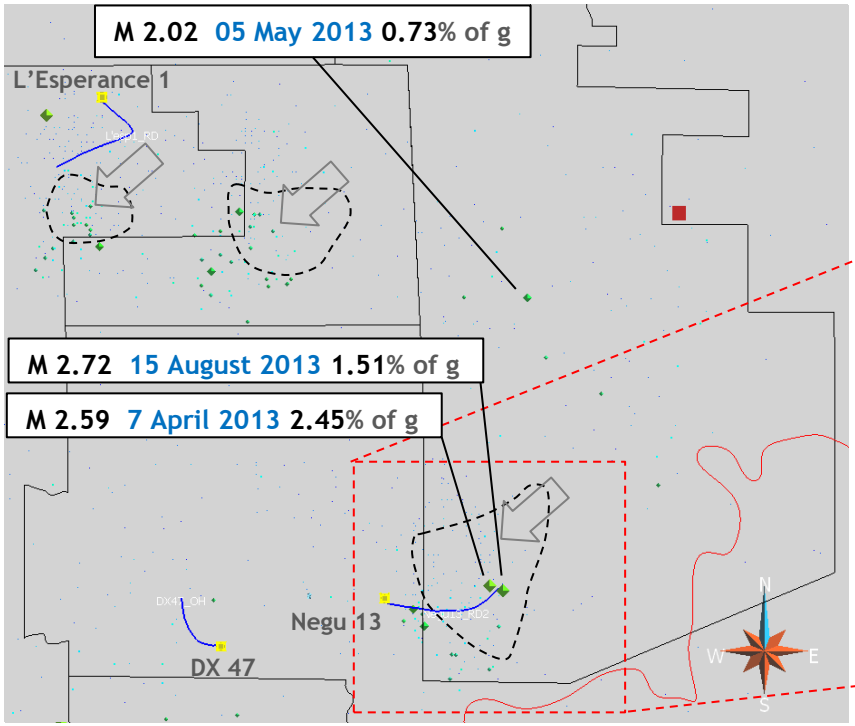


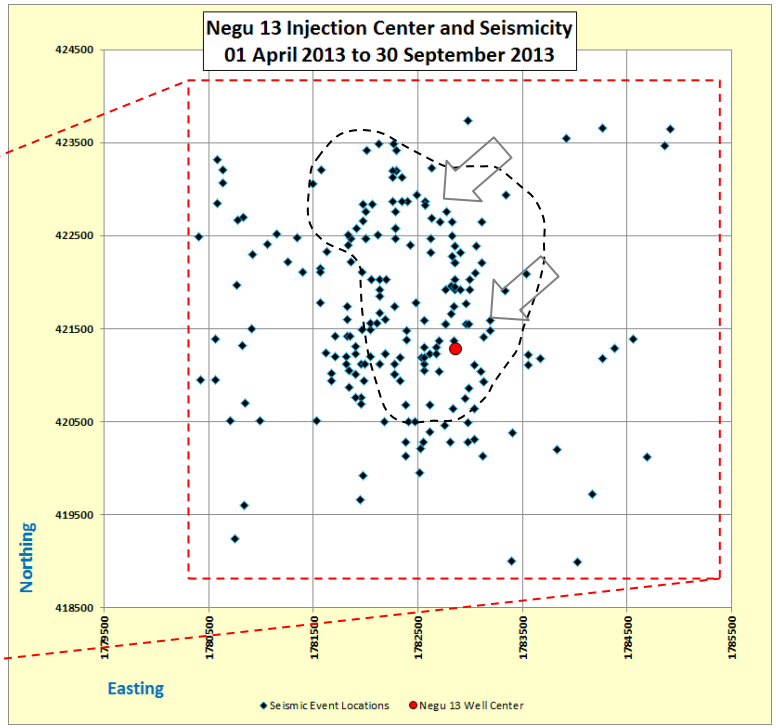




Seismic Monitoring Advisory Committee
Negu 13 Water Injection
Flow Rate Modification in Response to Seismicity

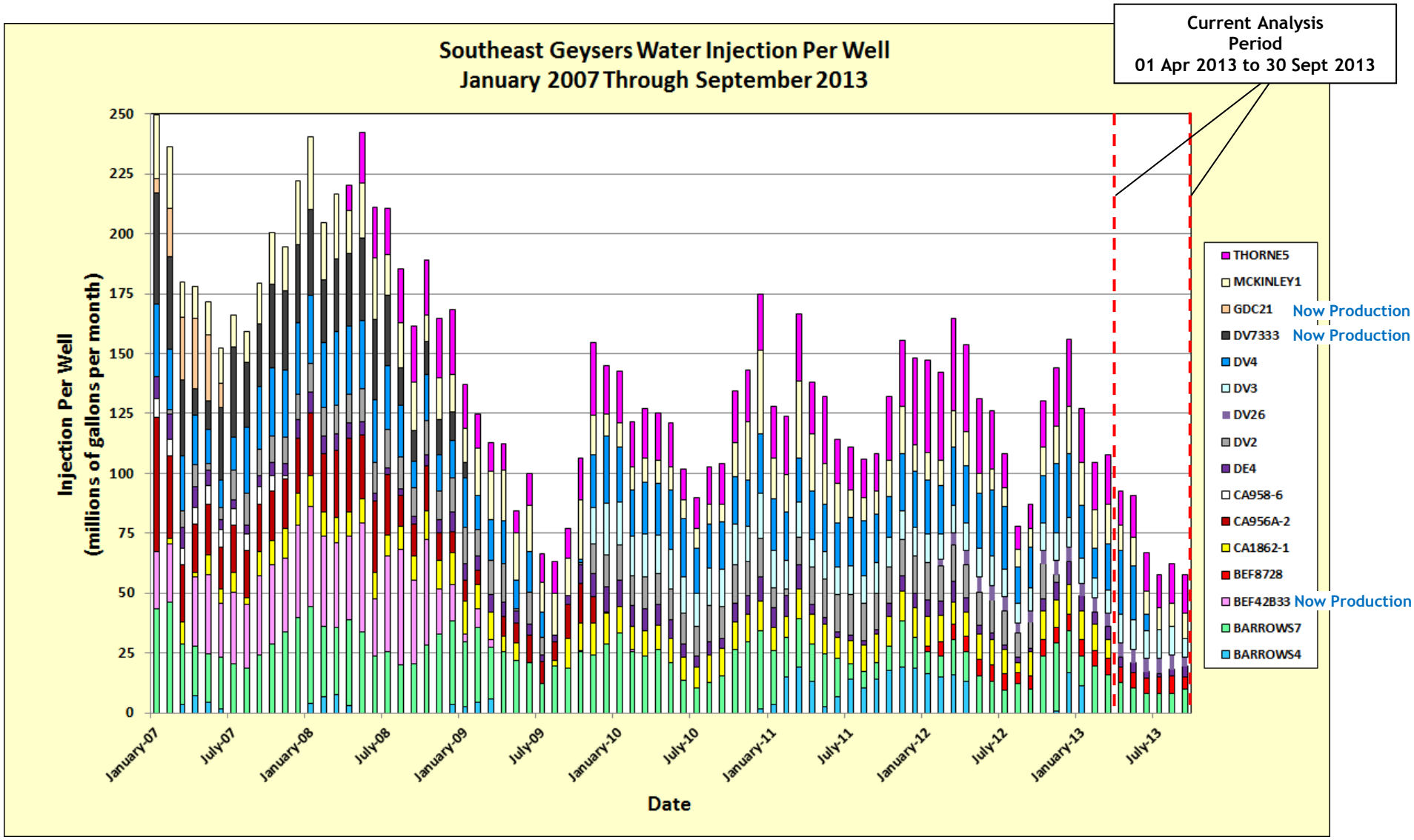
CALPINE
NYSE CPN





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

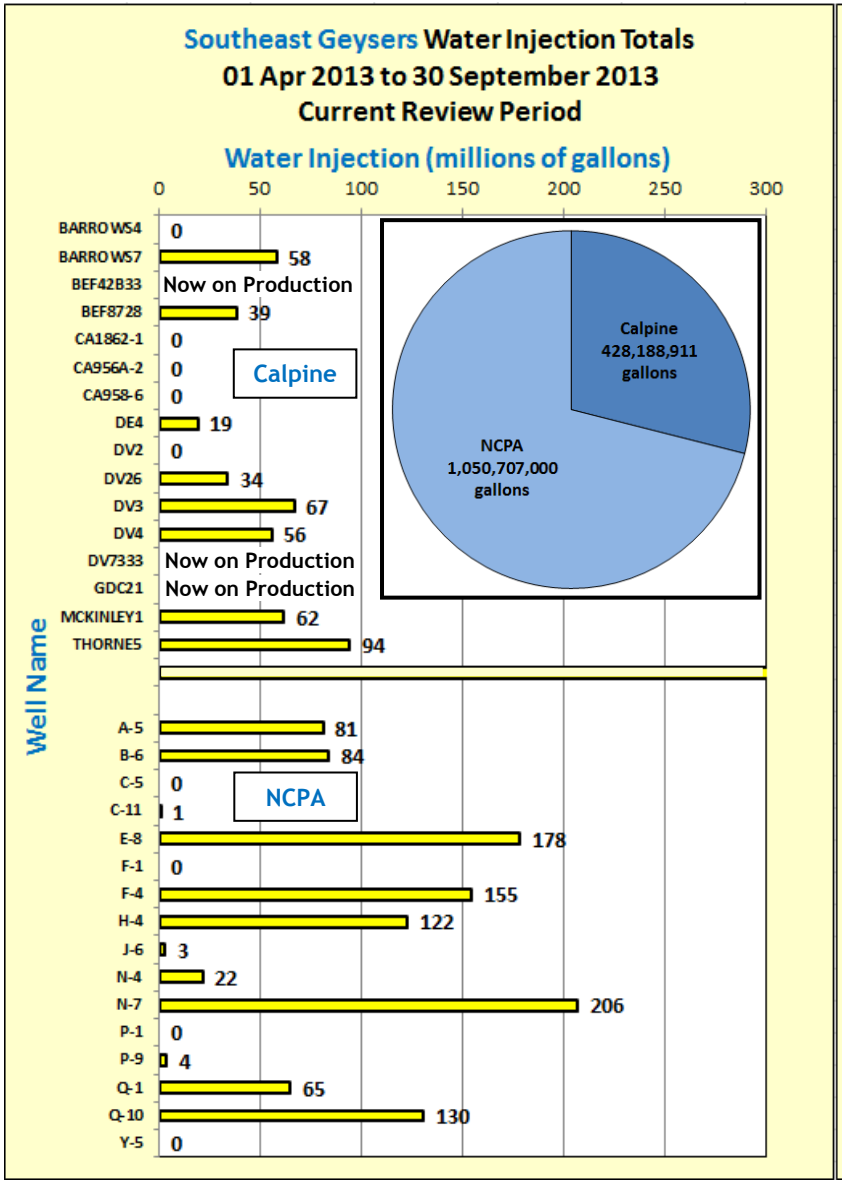
Seismic Monitoring Advisory Committee Meeting
Calpine's Southeast Geysers Injection Wells
01 January 2007 to 30 September 2013



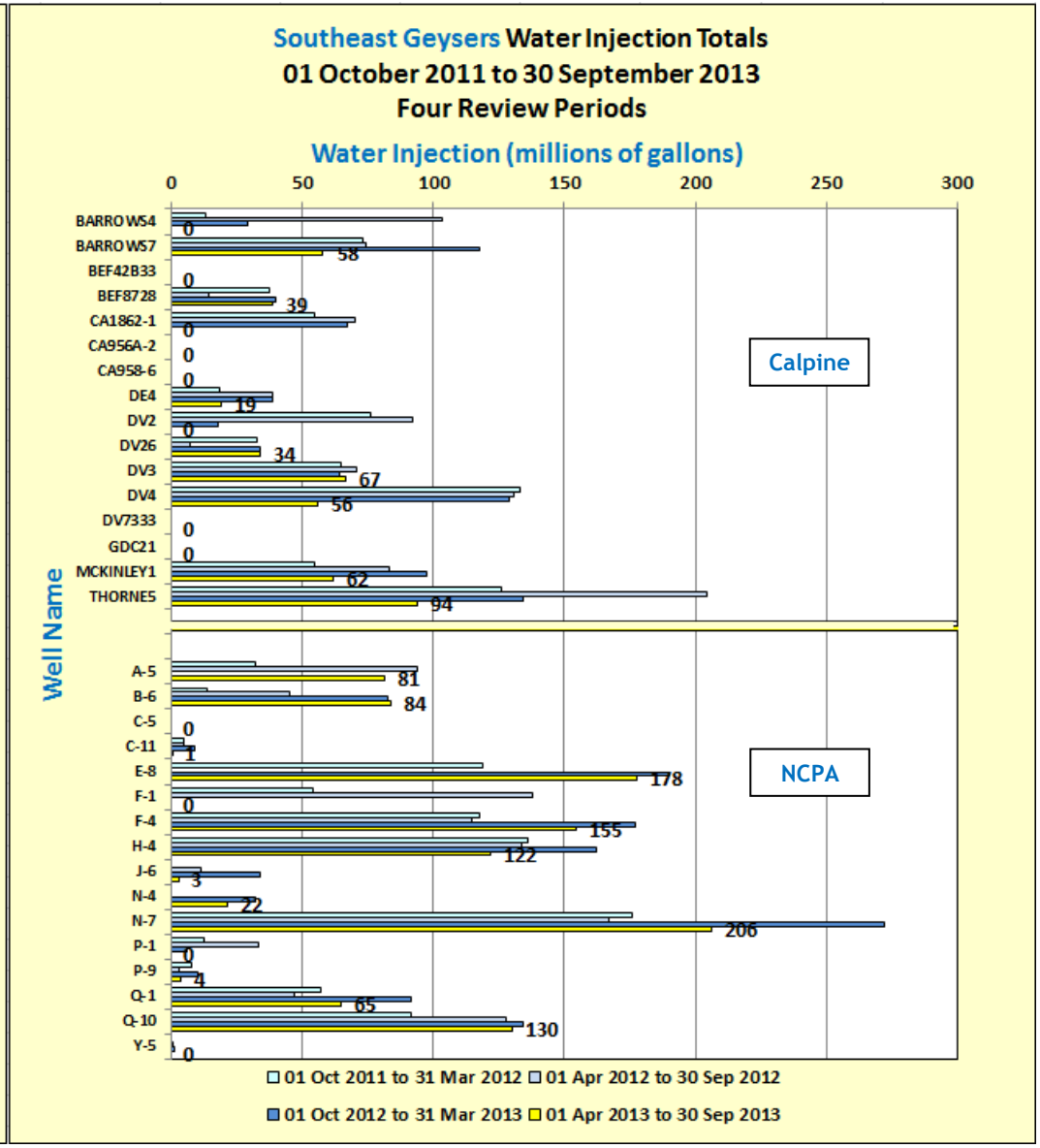
Seismic Monitoring Advisory Committee Meeting
Southeast Geysers Water Injection By Well

CALPINE NYSE CPN

Current Reporting Period



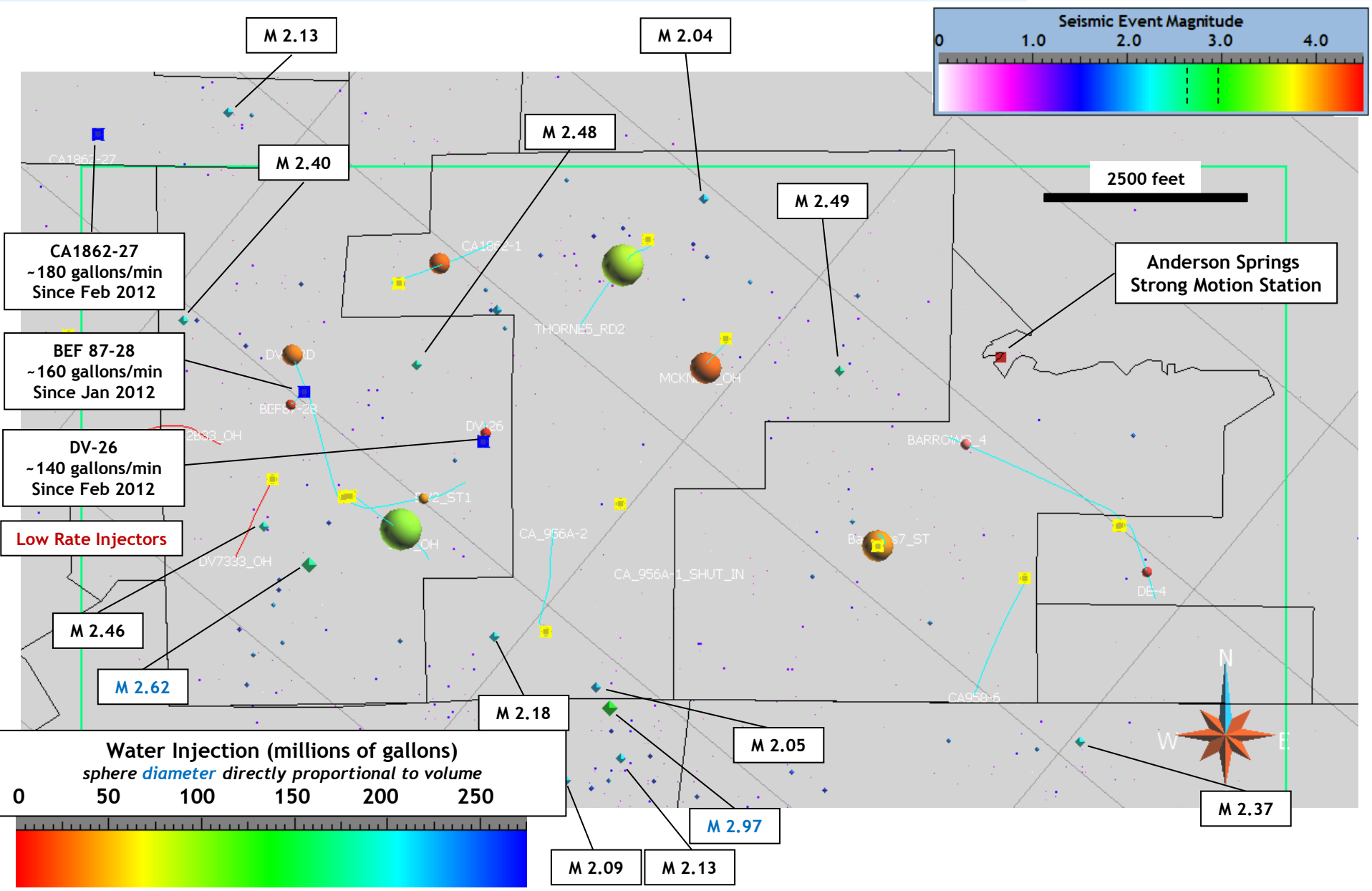
Four Reporting Periods (Two Years Total)



Seismic Monitoring Advisory Committee Meeting

Calpine's Southeast Geysers Water Injection and Seismicity

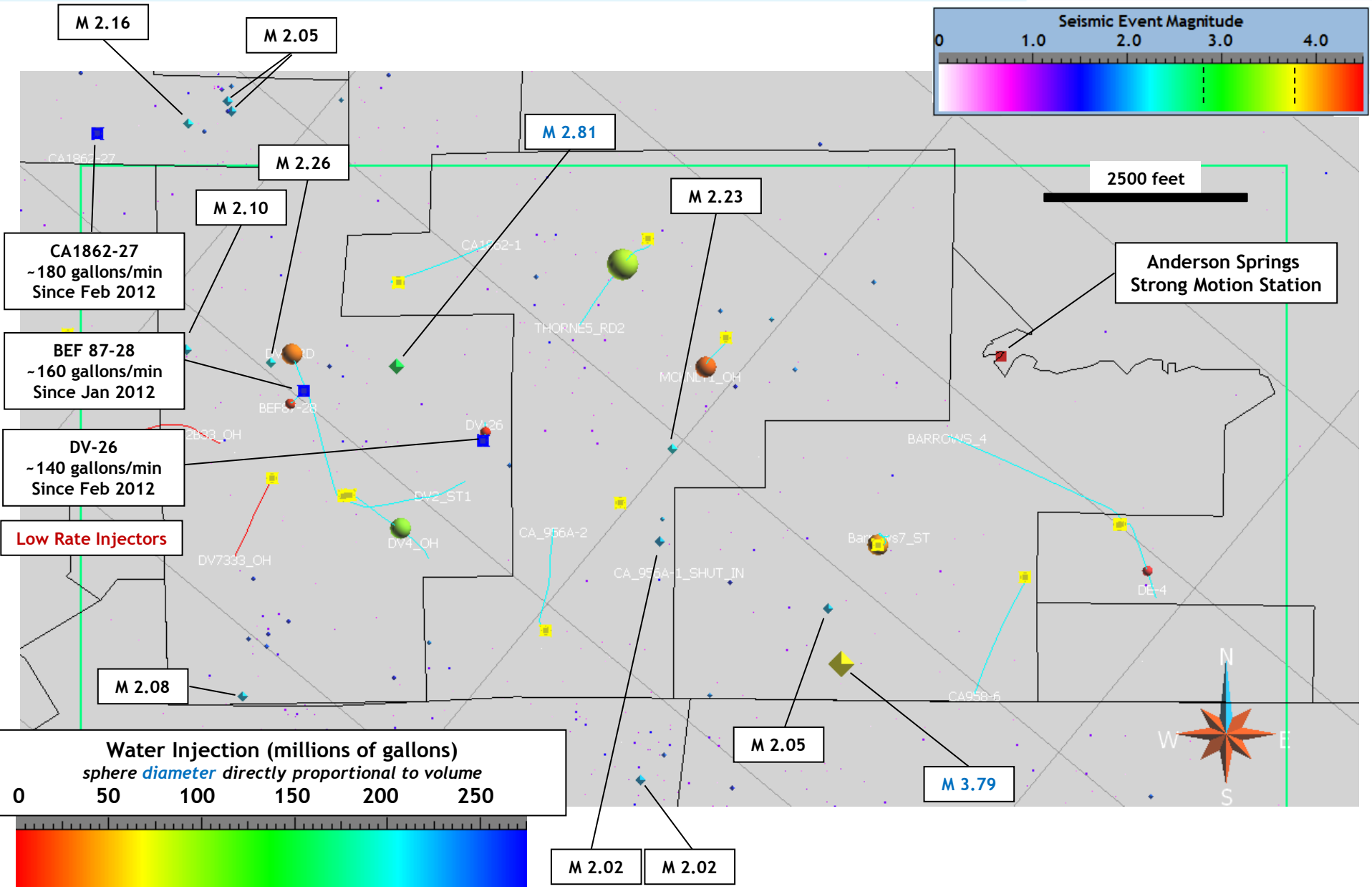
01 October 2012 to 31 March 2013 (Previous Analysis Period)



Seismic Monitoring Advisory Committee Meeting

Calpine's Southeast Geysers Water Injection and Seismicity

01 April 2013 to 30 September 2013 (Current Analysis Period)



CALPINE NYSE CPN

Northern California Seismic Network
Seismicity Data

Southeast Geysers Seismicity Results as of 30 September 2013

Comparison of pre-SEGEP and post-SEGEP (equivalent annual rates in parentheses)

Time Period	Pre-SEGEP	SEGEP	Current Period
Dates	Nov 1995 - Oct 1997	Nov 1997 - Mar 2013	Apr 2013- Sep 2013
Time Span (yrs)	2	15.91	0.5
Seismic Events:			
M>=1.2	330 (165)	4916 (309)	118 (236)
M>=2.0	46 (23)	696 (44)	15 (30)
M>=3.0	10 (5)	39 (2.5)	2 (4)
M Maximum	3.70	4.30	3.79

Seismic Monitoring Advisory Committee Meeting
Strong Motion Sensor Stations
01 April 2013 to 30 September 2013

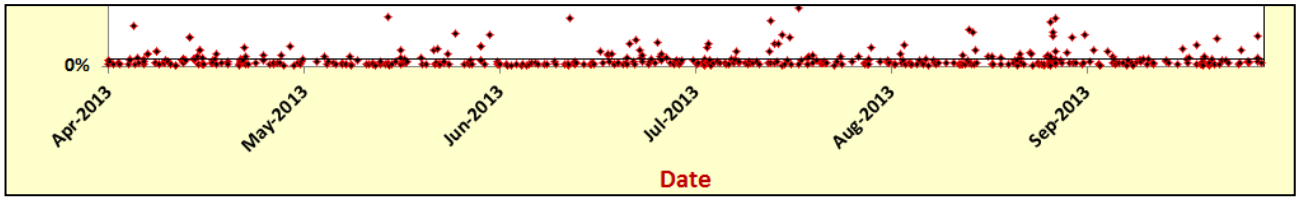
CALPINE NYSE CPN

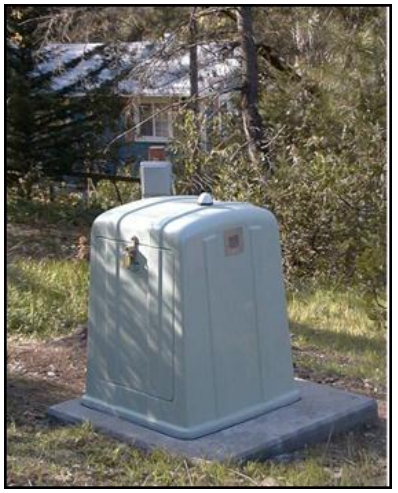
Anderson Springs Strong Motion

No power or communication problems noted for 01 April 2013 to 30 September 2013

Minor triggered event gap for:

Late 15 September 2013 to Early 17 September 2013





Anderson Springs ETNA Strong Motion Station

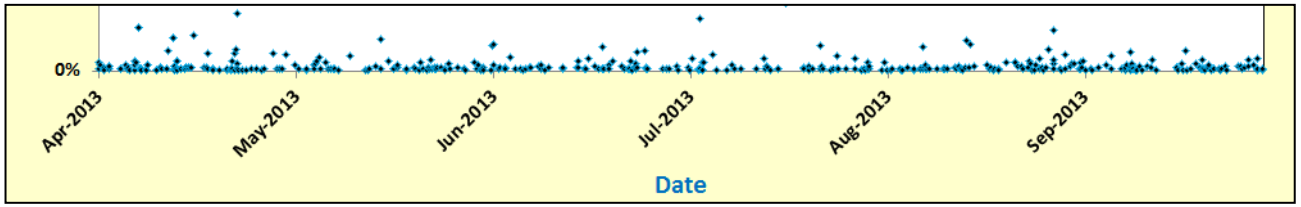
Cobb Strong Motion

No power or communication problems noted for 01 April 2013 to 30 September 2013

Minor triggered event gaps for:

Late 16 July 2013 to Mid 18 July 2013

Early 14 September 2013 to Early 17 September 2013



Reliability Limitations:

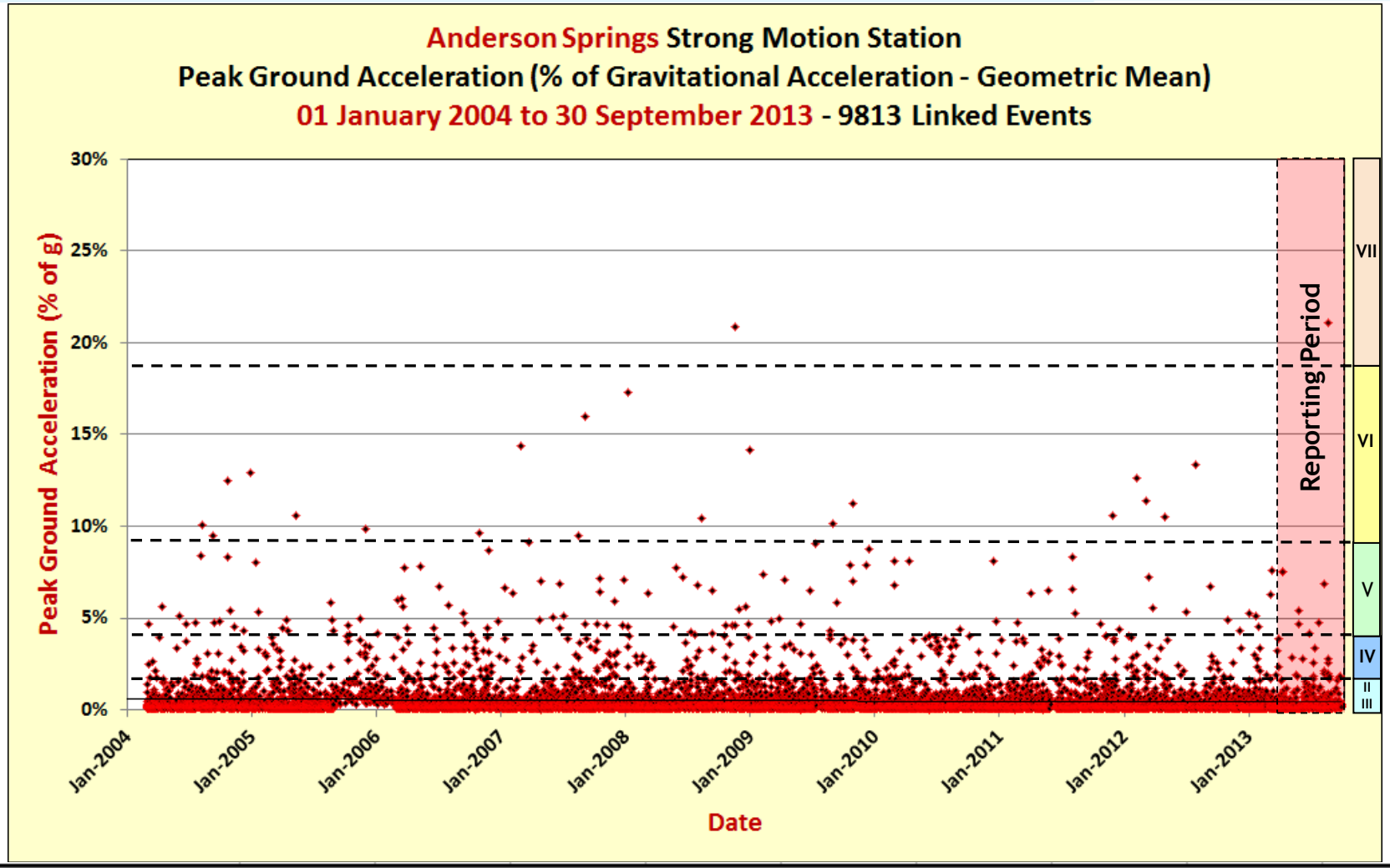
Rural Power
Rural Communications
Lightning Strikes
Downed Lines

Seismic Monitoring Advisory Committee Meeting

Anderson Springs Peak Ground Acceleration

01 January 2004 to 30 September 2013

CALPINE NYSE CPN

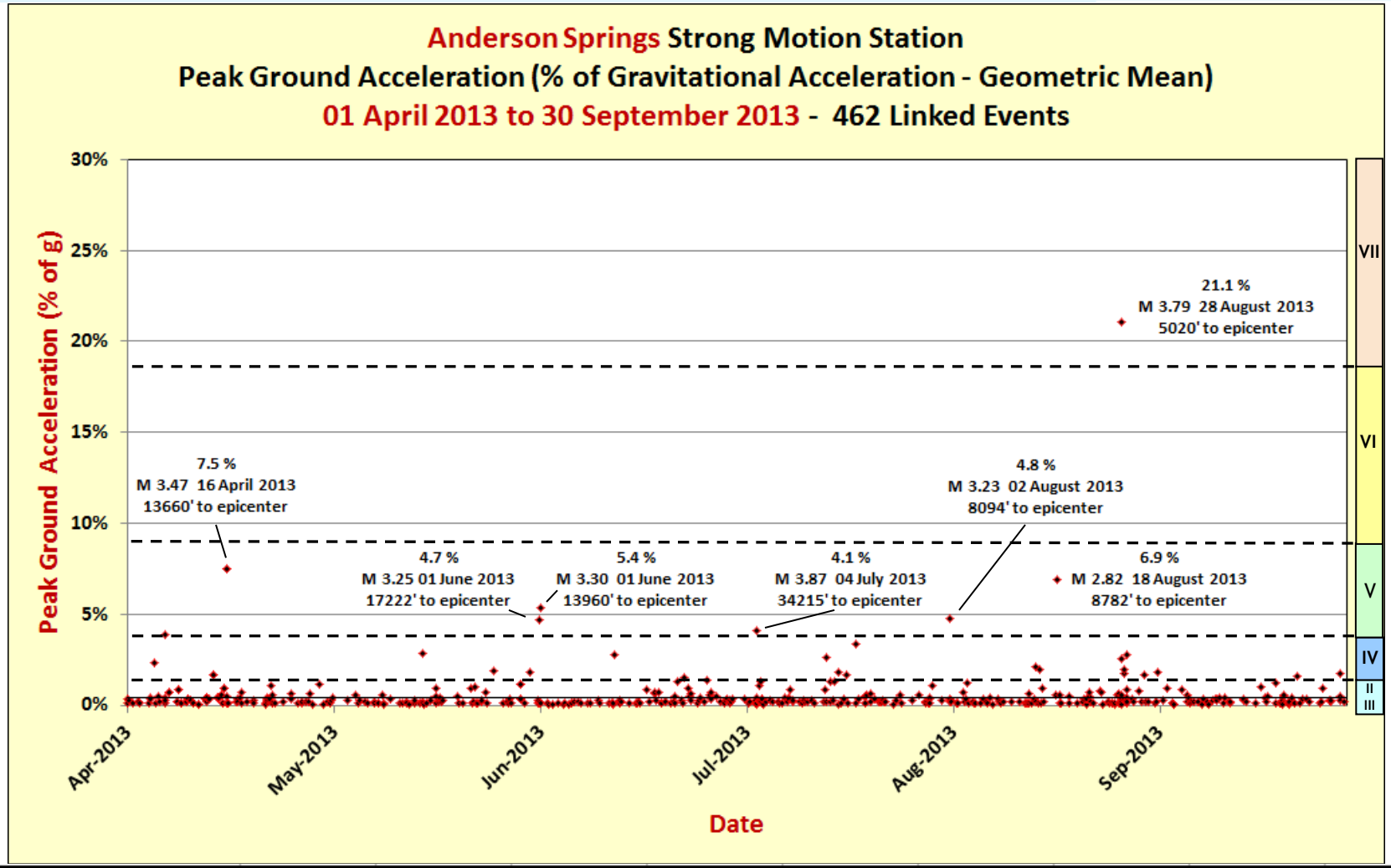


Perceived Shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Damage	None	None	None	Very Light	Light	Moderate	Mod/Heavy	Heavy	Very Heavy
Peak Acceleration (% of g)	< 0.17	0.17 - 1.4	1.4 - 3.9	3.9 - 9.2	9.2 - 18.0	18.0 - 34.0	34.0 - 65.0	65.0 - 124.0	> 124.0
Peak Velocity (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

Seismic Monitoring Advisory Committee Meeting

Anderson Springs Peak Ground Acceleration
01 April 2013 to 30 September 2013

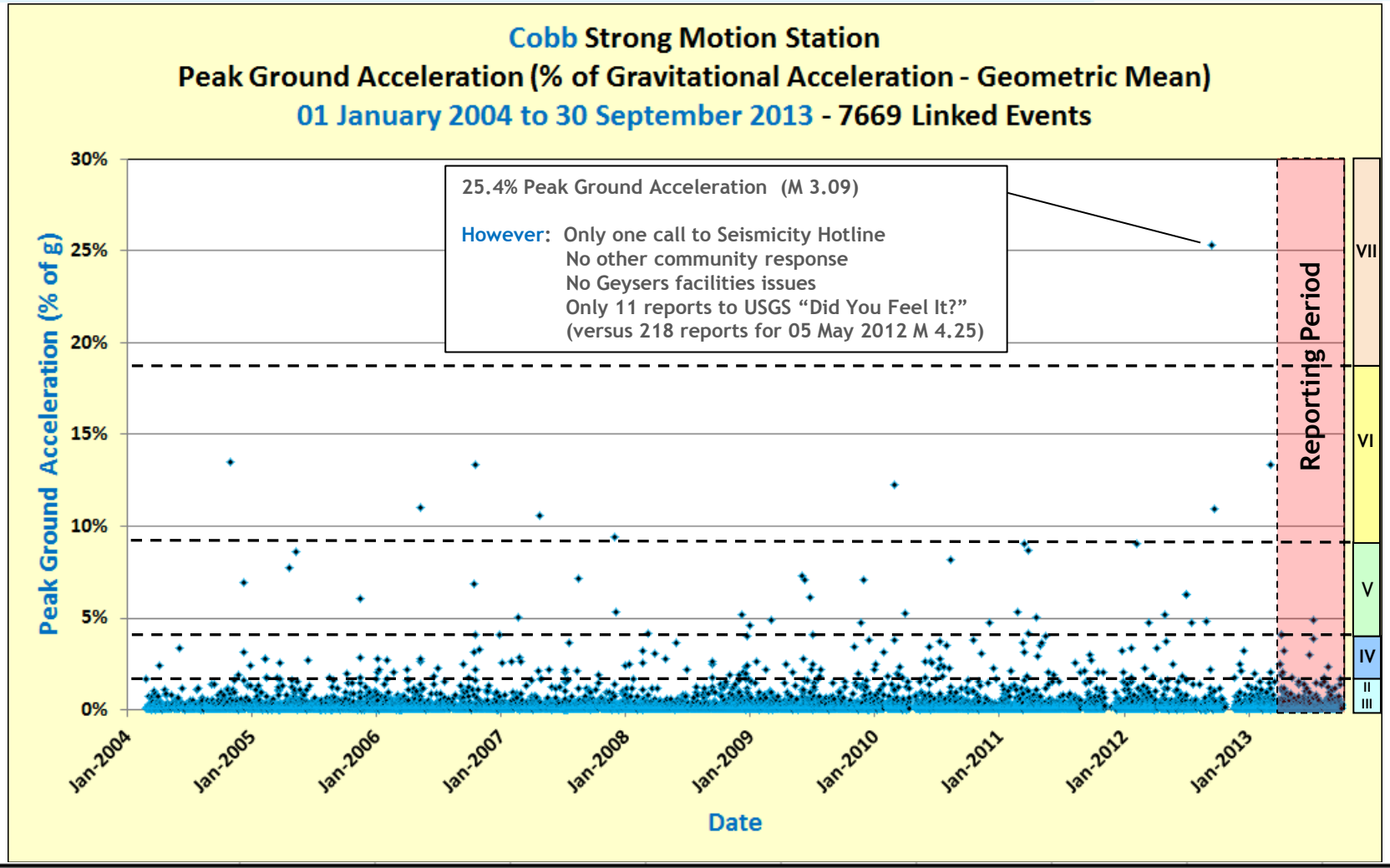
CALPINE NYSE CPN



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

Seismic Monitoring Advisory Committee Meeting
Cobb Peak Ground Acceleration
01 January 2004 to 30 September 2013

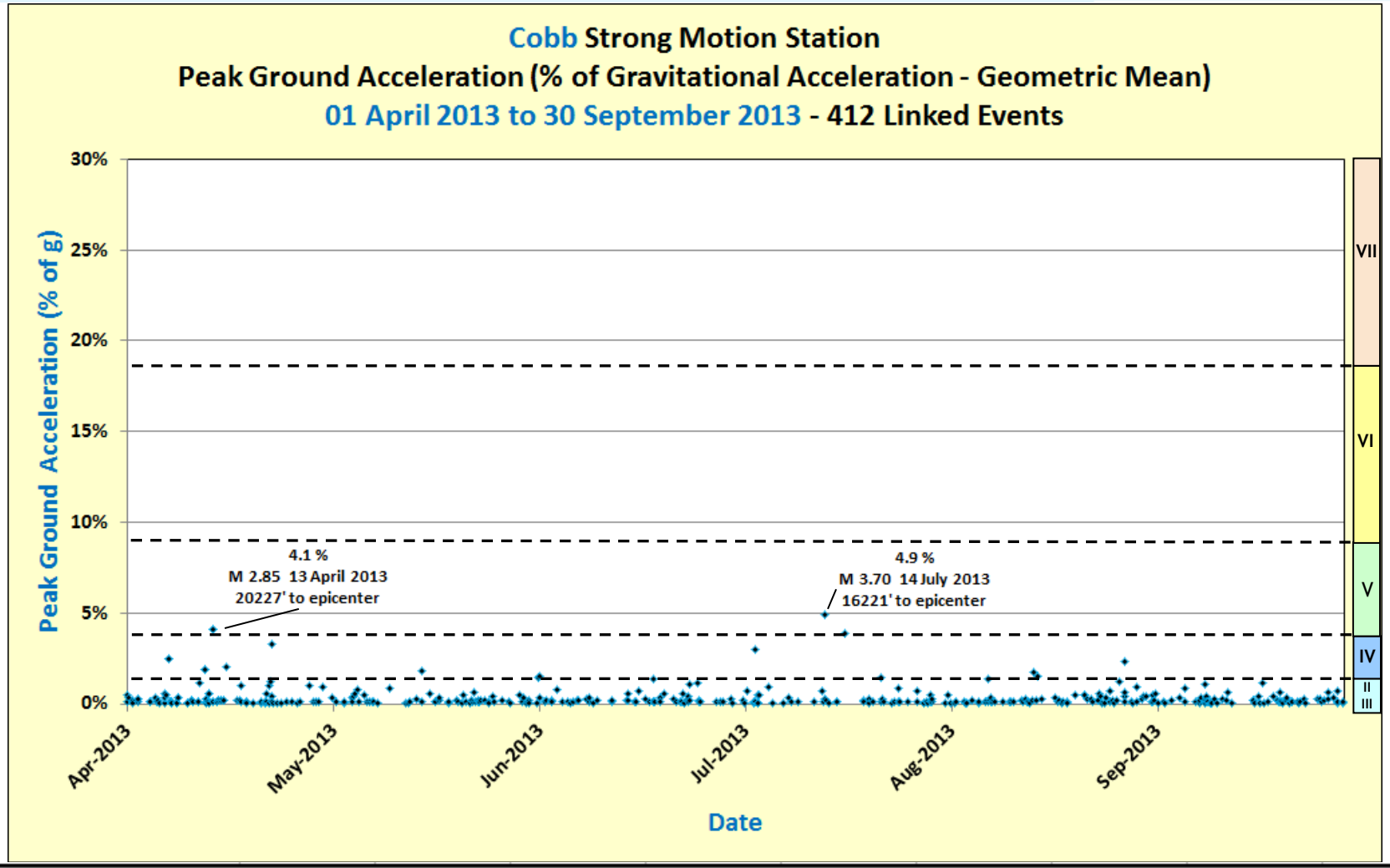
CALPINE NYSE CPN



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

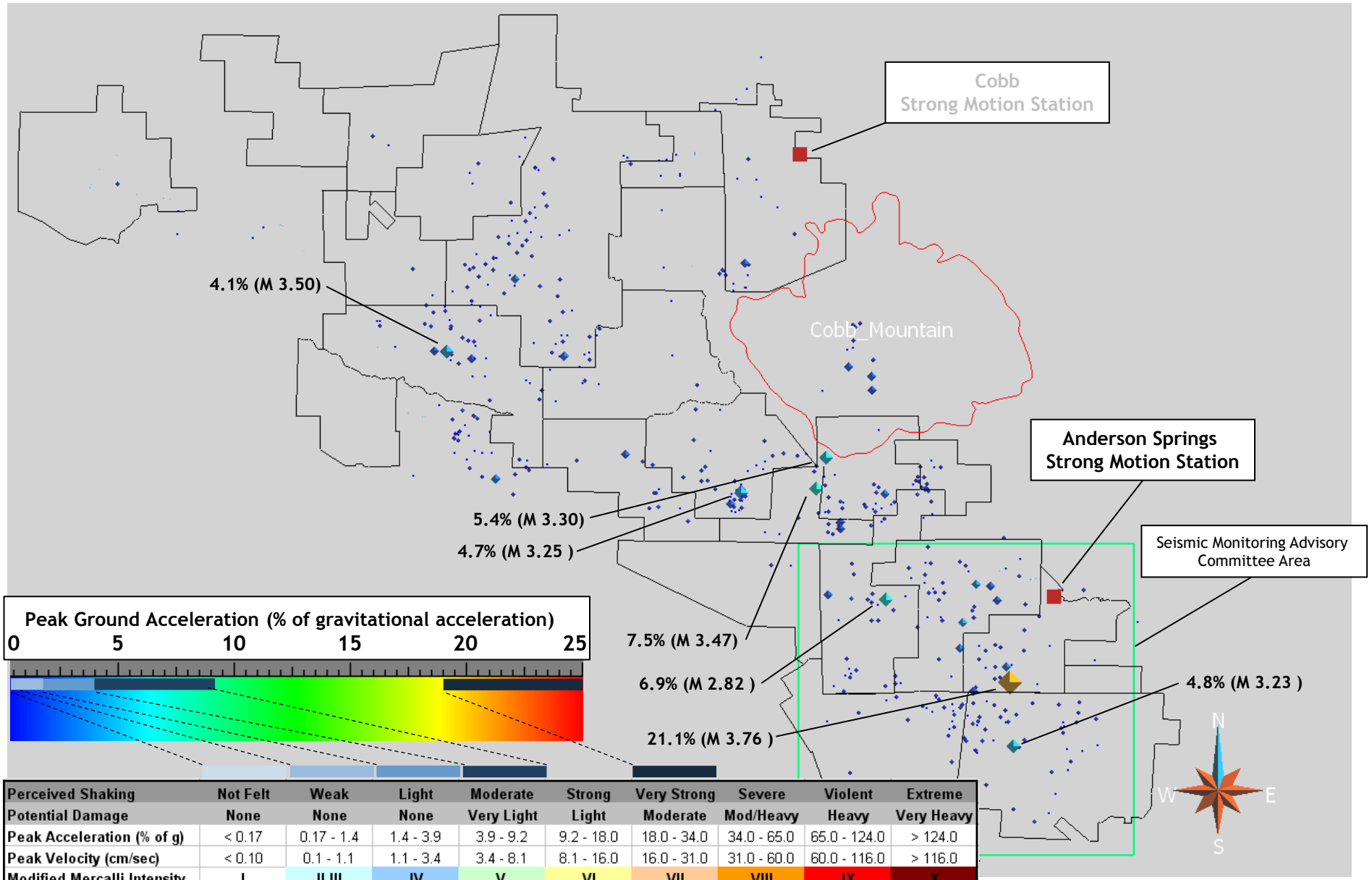
Seismic Monitoring Advisory Committee Meeting
Cobb Peak Ground Acceleration
01 April 2013 to 30 September 2013

CALPINE NYSE CPN



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

Seismic Monitoring Advisory Committee Meeting
Anderson Springs Peak Ground Acceleration
01 April 2013 to 30 September 2013

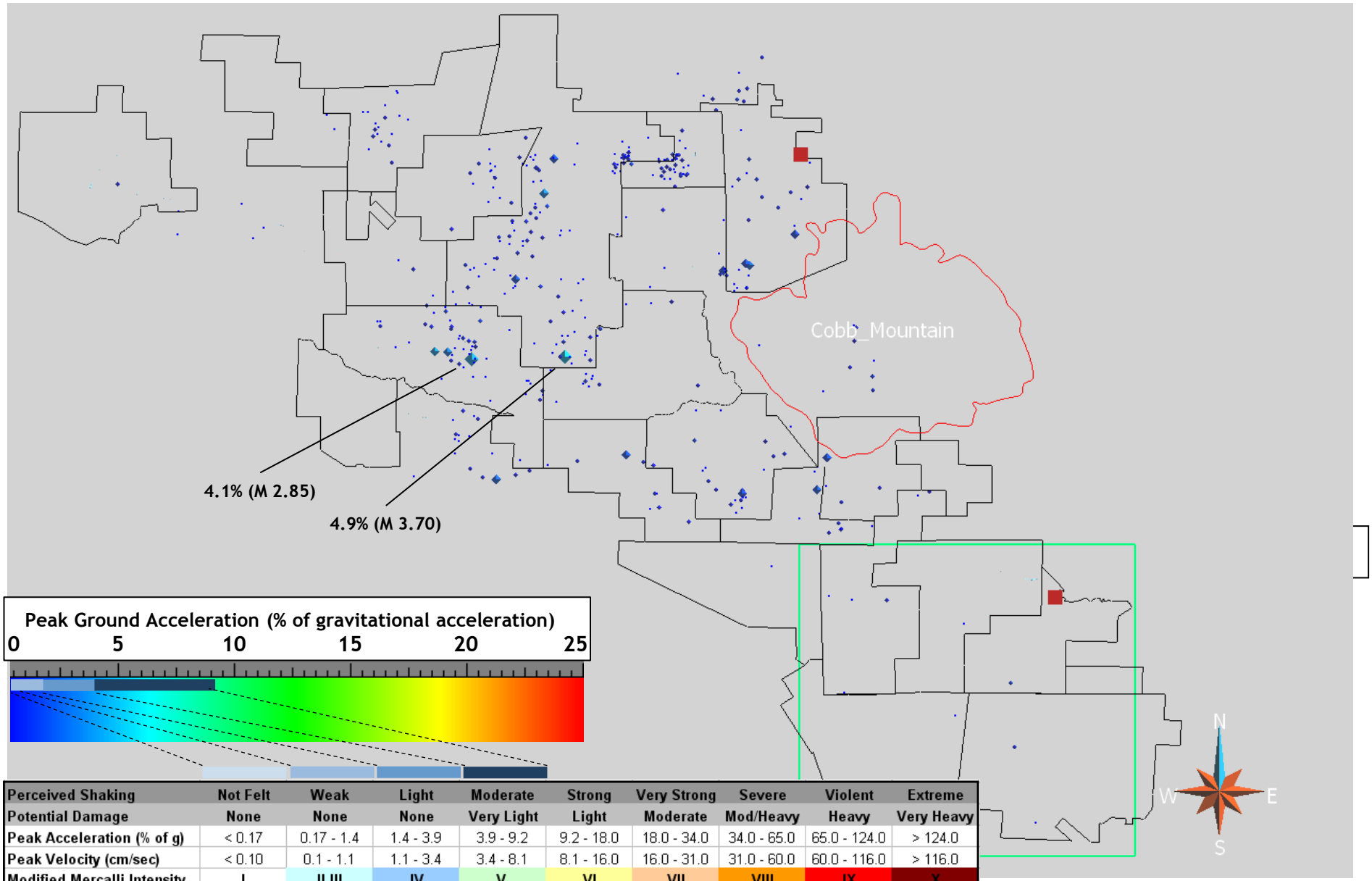


Perceived Shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Damage	None	None	None	Very Light	Light	Moderate	Mod/Heavy	Heavy	Very Heavy
Peak Acceleration (% of g)	< 0.17	0.17 - 1.4	1.4 - 3.9	3.9 - 9.2	9.2 - 18.0	18.0 - 34.0	34.0 - 65.0	65.0 - 124.0	> 124.0
Peak Velocity (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

Seismic Monitoring Advisory Committee Meeting

Cobb Peak Ground Acceleration

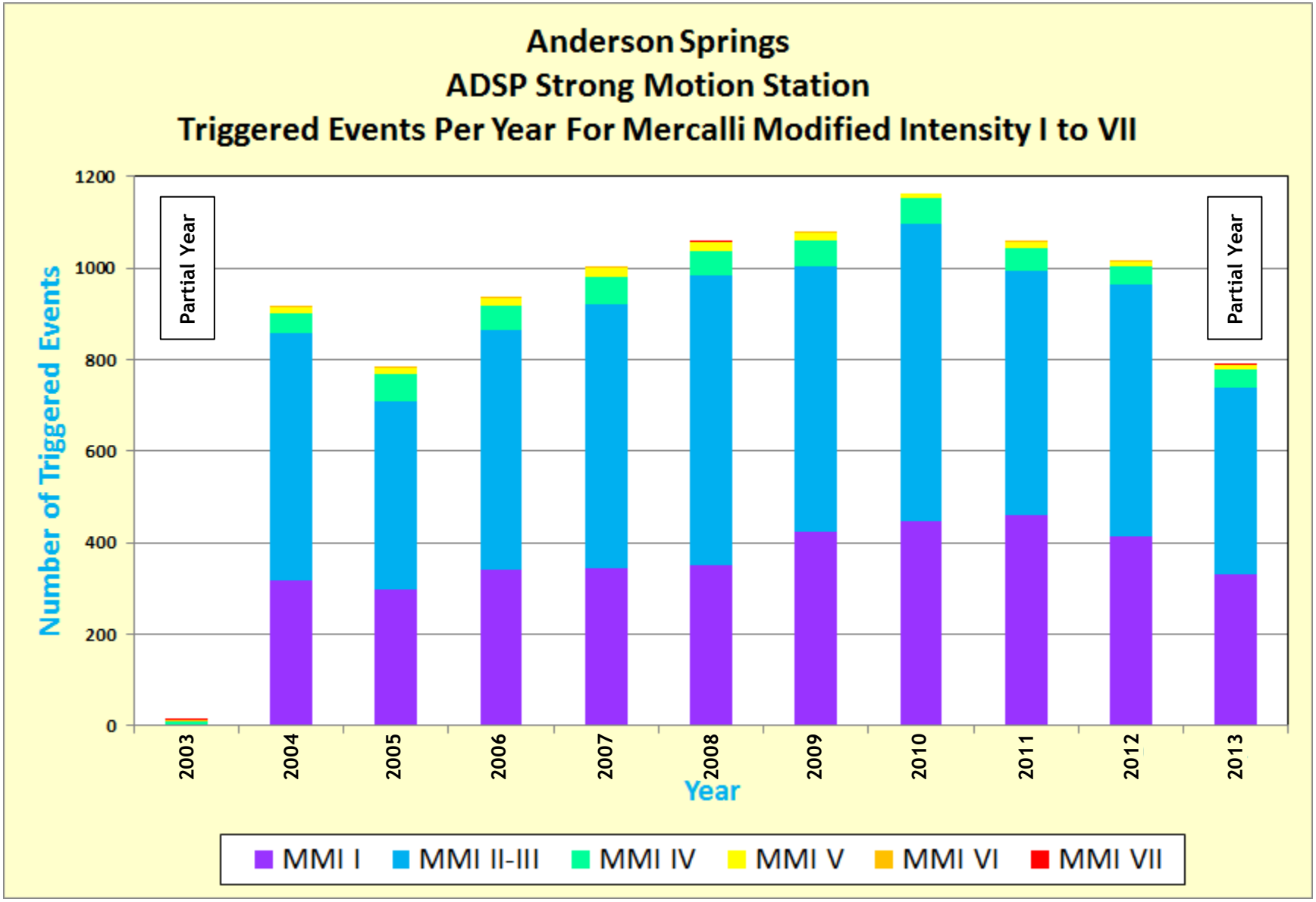
01 April 2013 to 30 September 2013



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

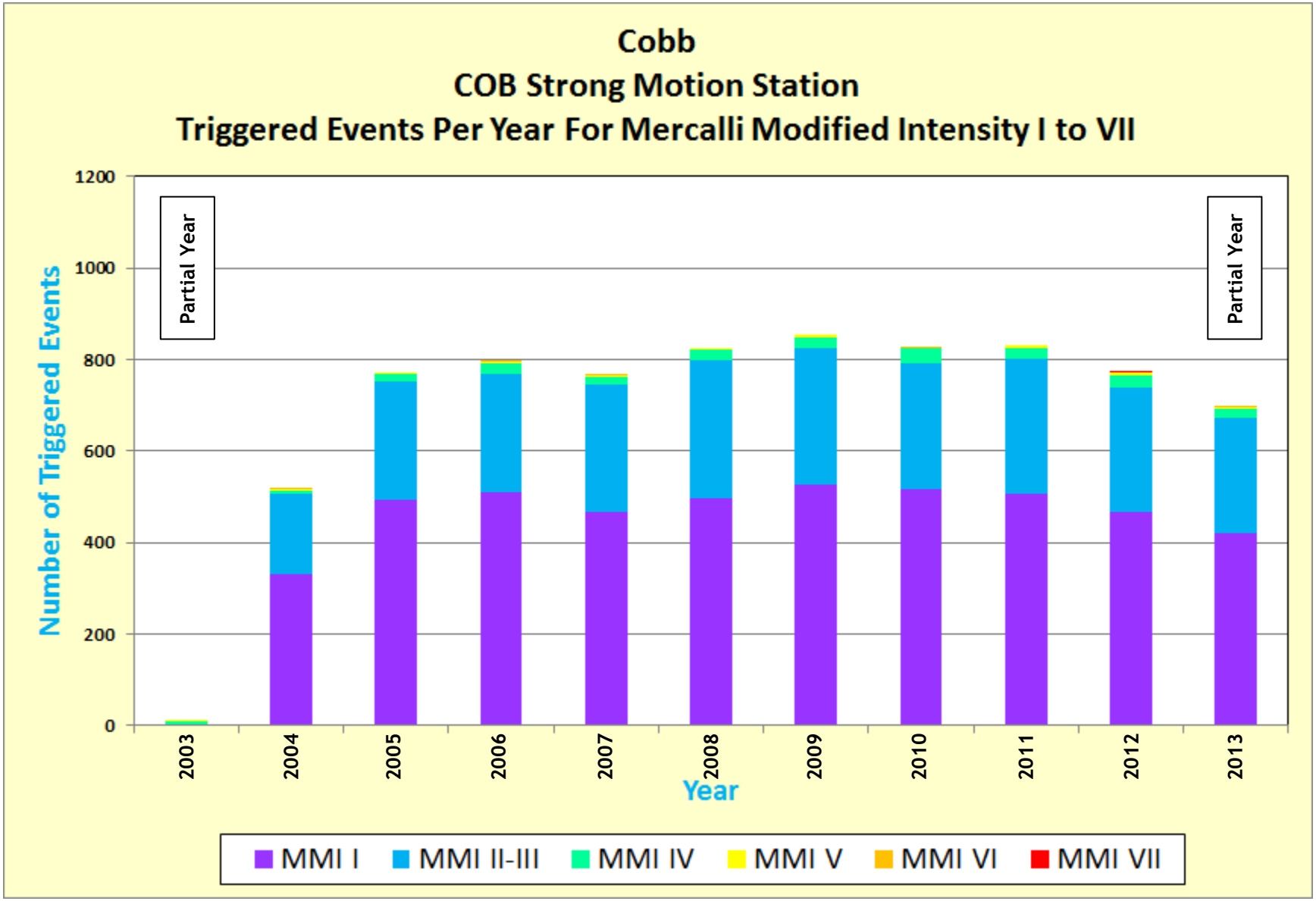
Seismic Monitoring Advisory Committee Meeting

Anderson Springs Peak Ground Acceleration Triggered Strong Motion Events Per Year Since 2003



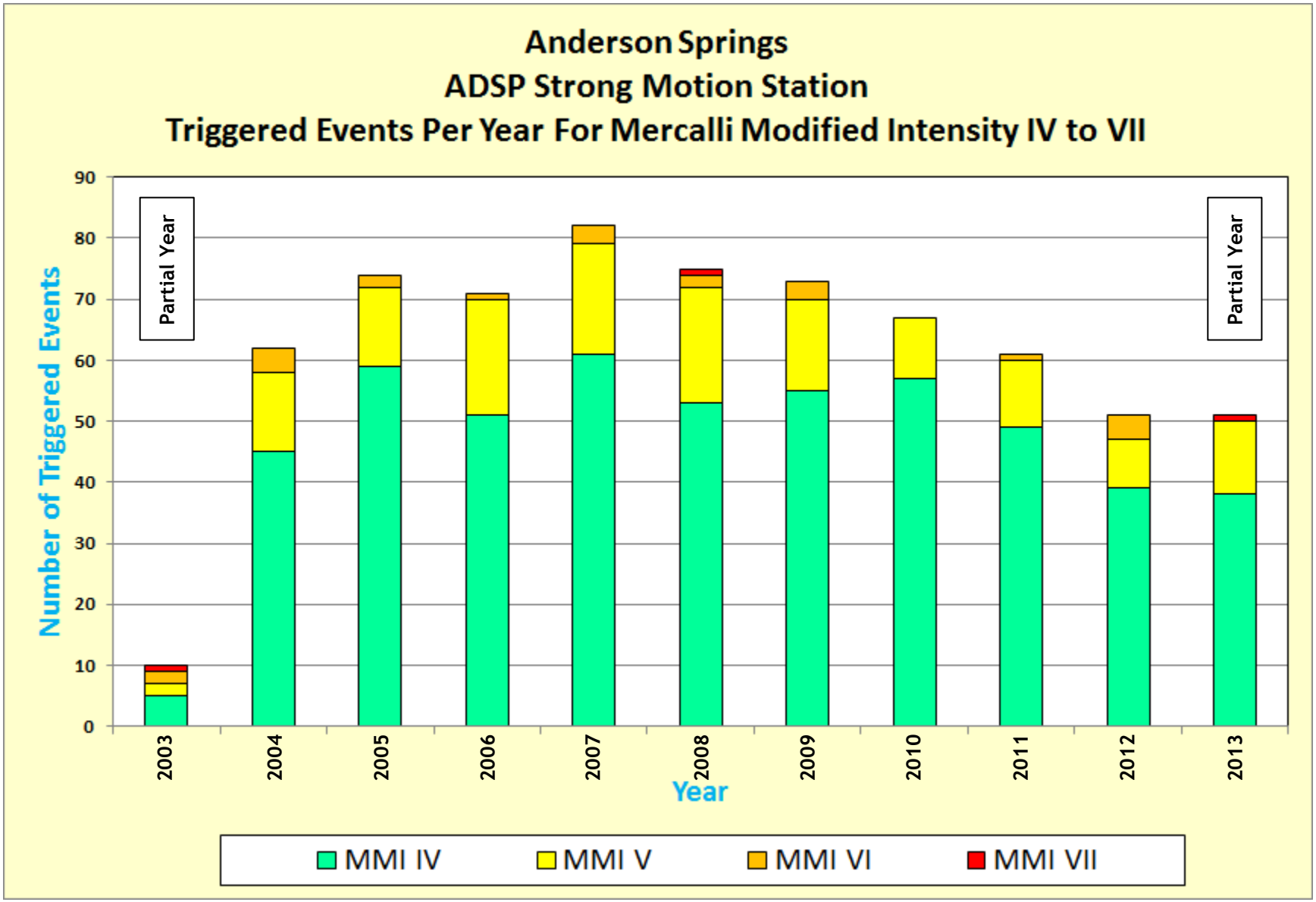
Seismic Monitoring Advisory Committee Meeting

Cobb Peak Ground Acceleration
Triggered Strong Motion Events Per Year Since 2003



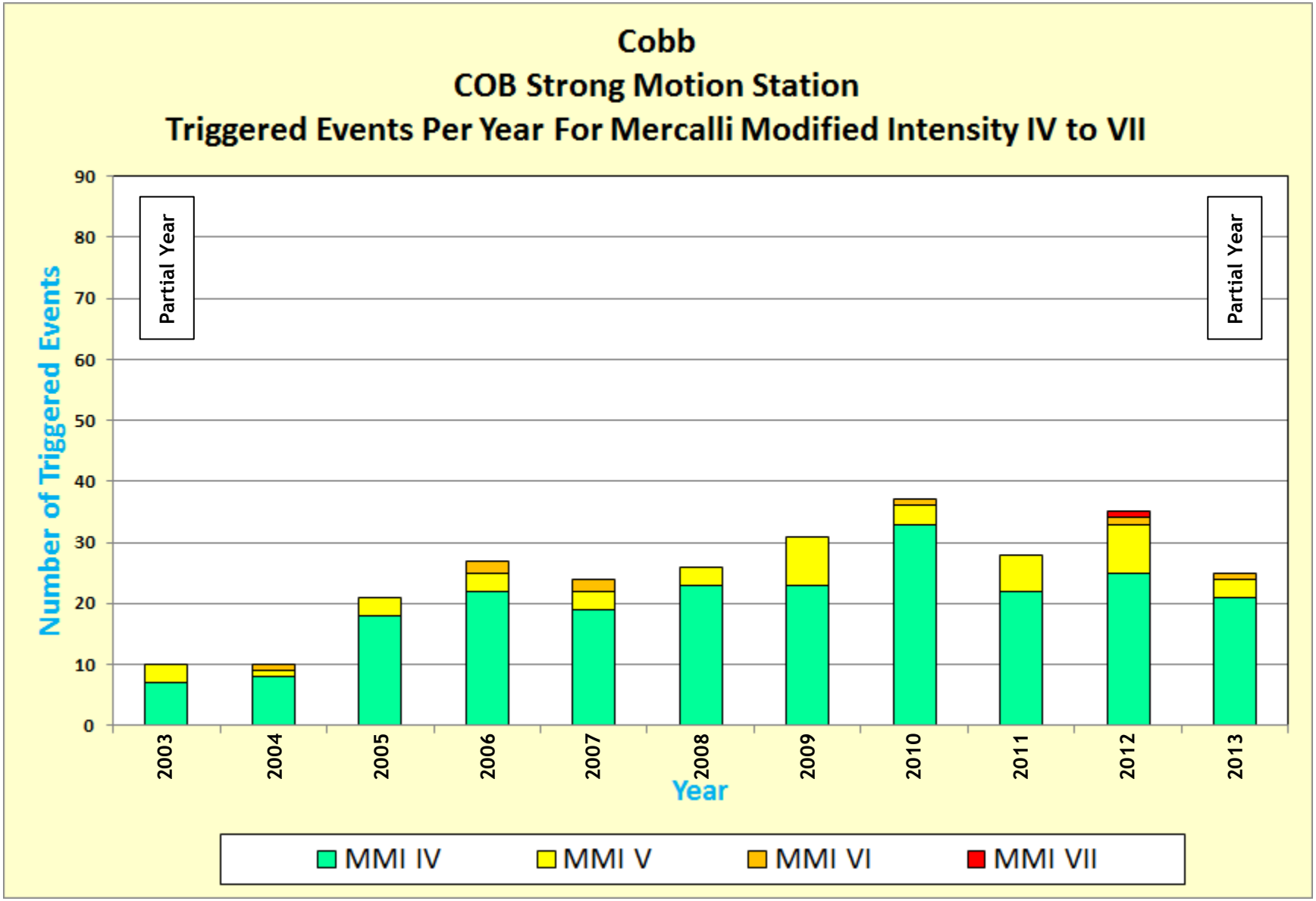
Seismic Monitoring Advisory Committee Meeting

Anderson Springs Peak Ground Acceleration
Triggered Strong Motion Events Per Year Since 2003



Seismic Monitoring Advisory Committee Meeting

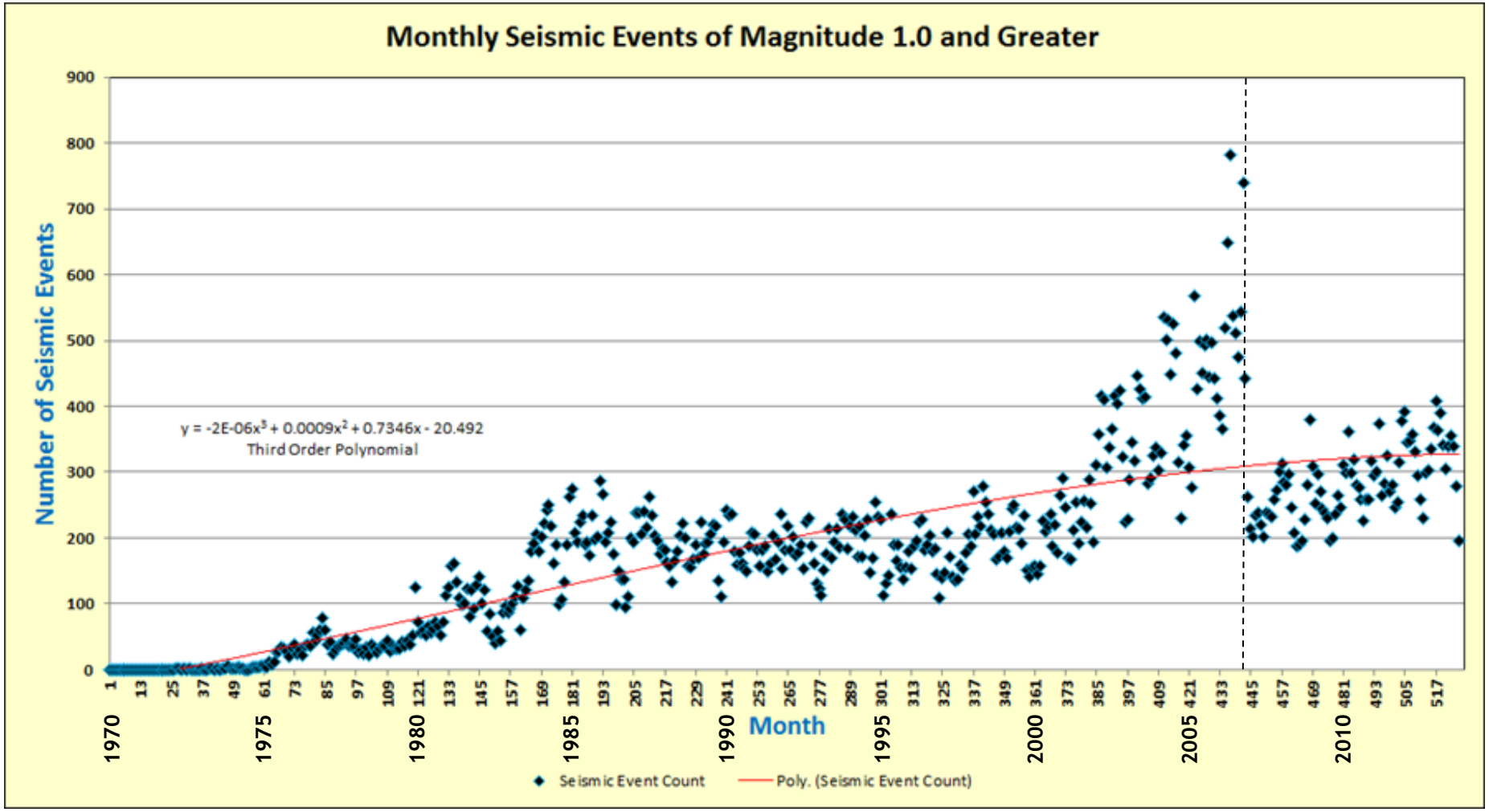
Cobb Peak Ground Acceleration
Triggered Strong Motion Events Per Year Since 2003



Seismic Monitoring Advisory Committee Meeting

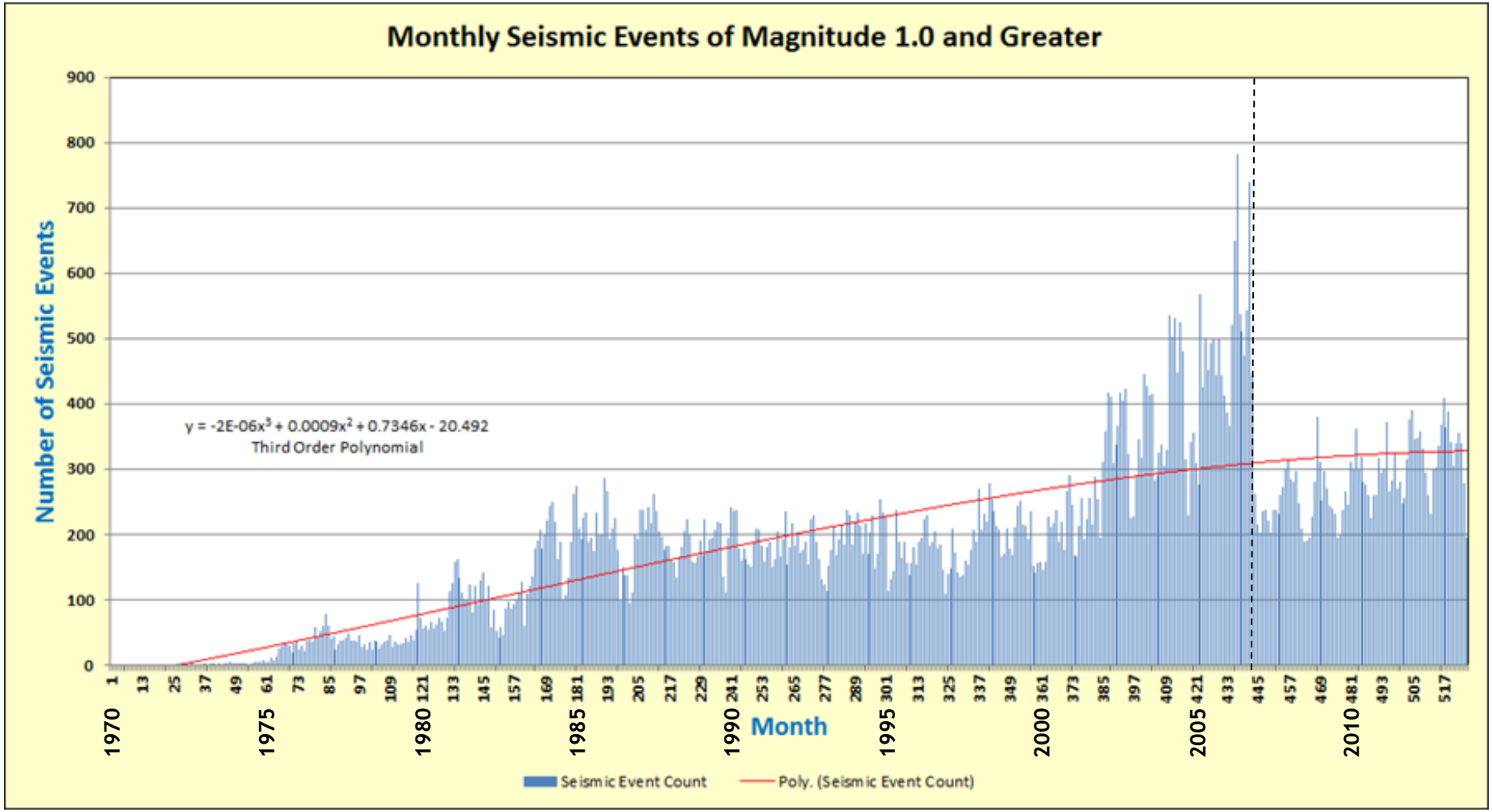
Field-wide Seismicity Analysis

Monthly Seismic Events ≥ M 1.0 Since 1970



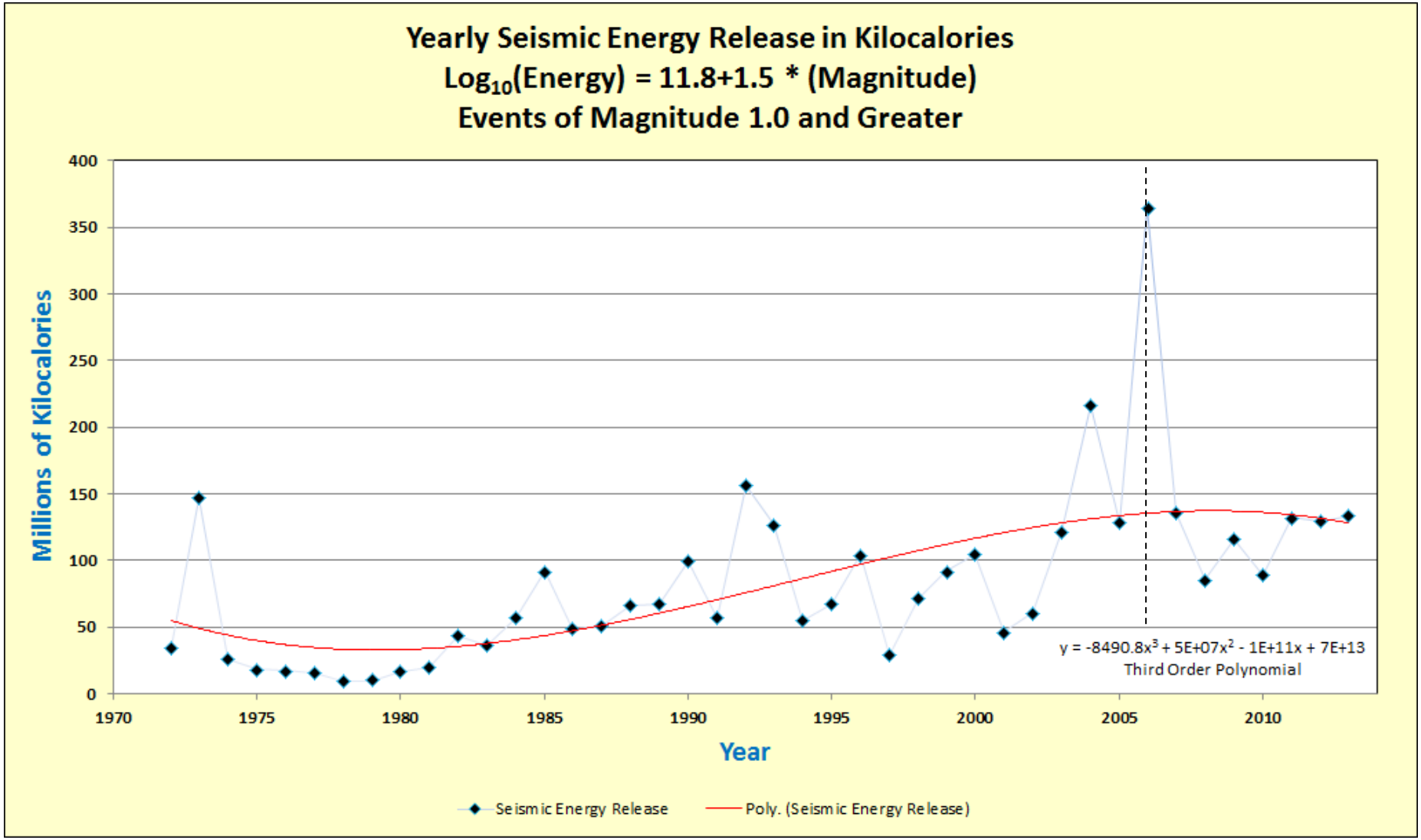
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Monthly Seismic Events ≥ M 1.0 Since 1970

CALPINE NYSE CPN



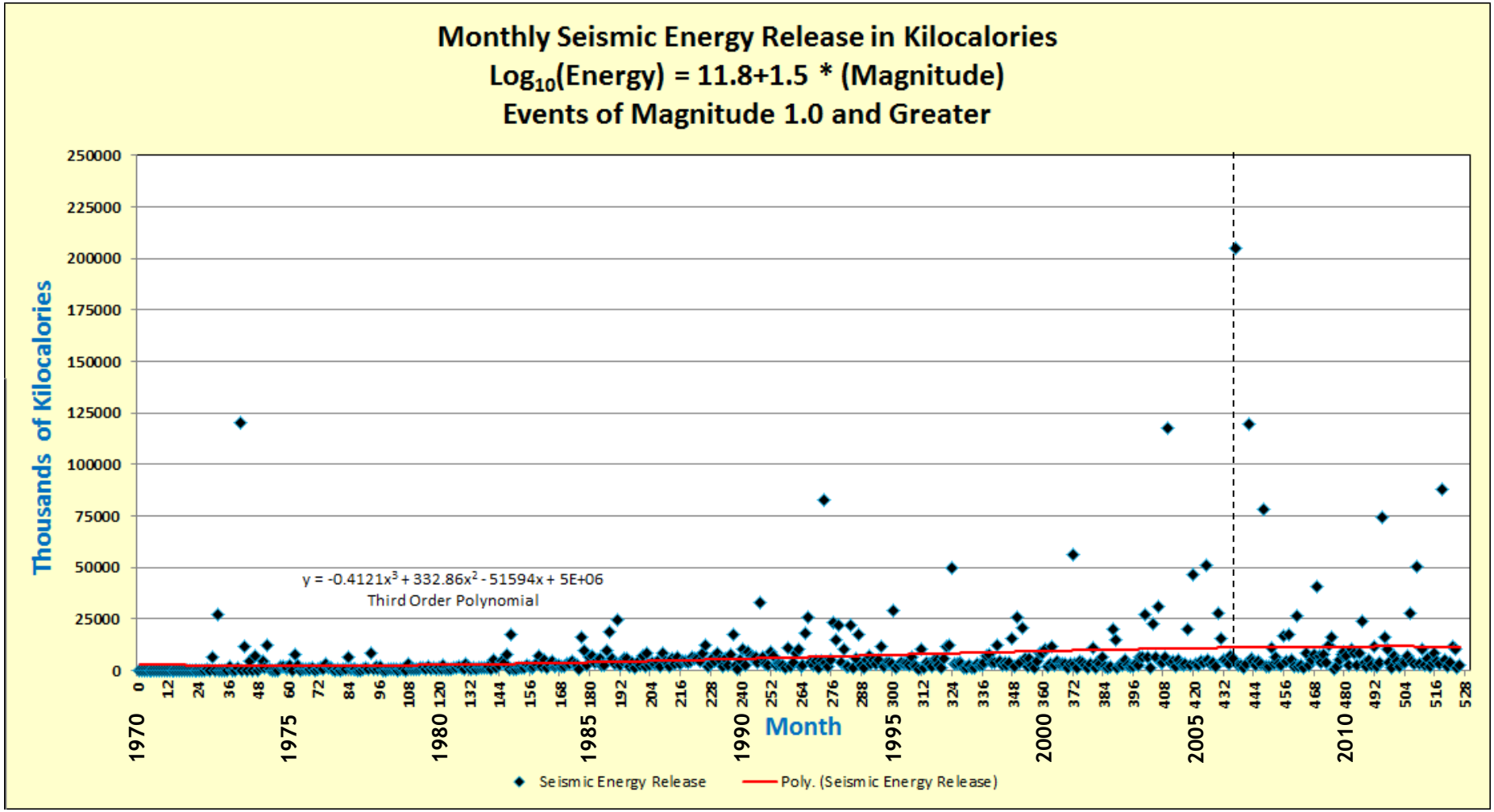
Field-wide Seismicity Analysis

Yearly Seismic Energy Release Since 1972



Field-wide Seismicity Analysis
Monthly Seismic Energy Release Since 1970

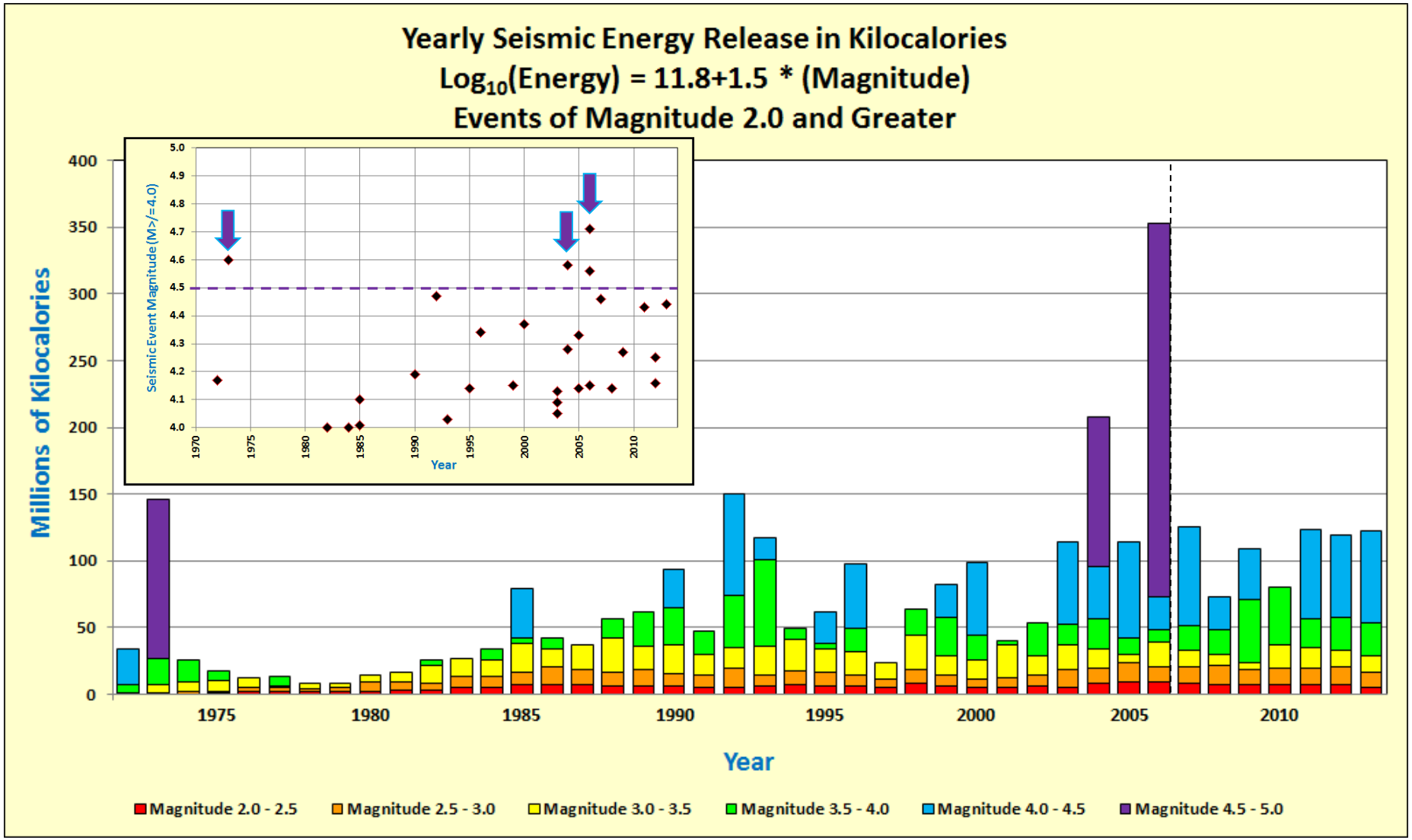
CALPINE NYSE CPN



Field-wide Seismicity Analysis

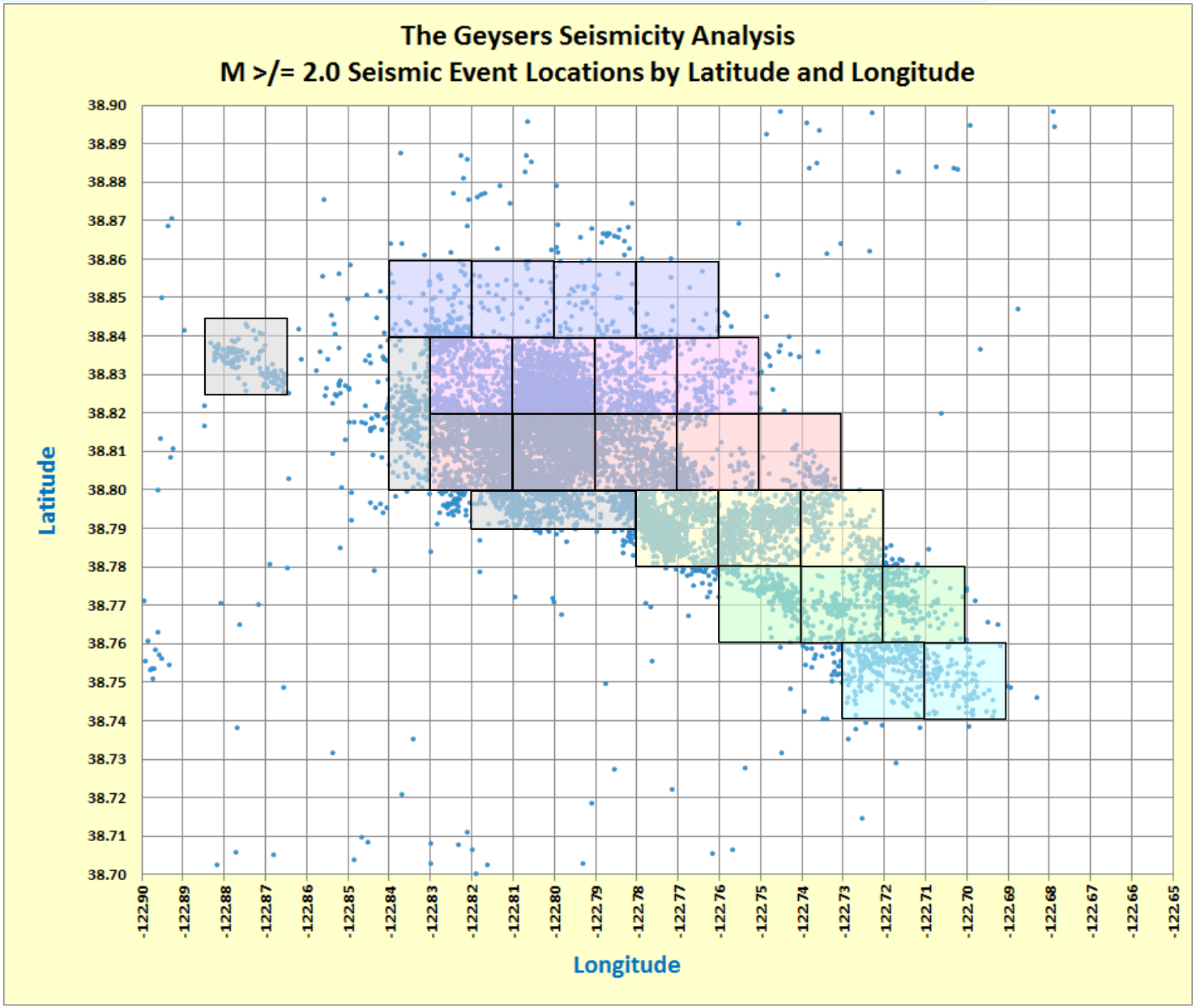
Yearly Seismic Energy Release Since1972 (Historical M ≥ 2.0 Events)

CALPINE NYSE CPN



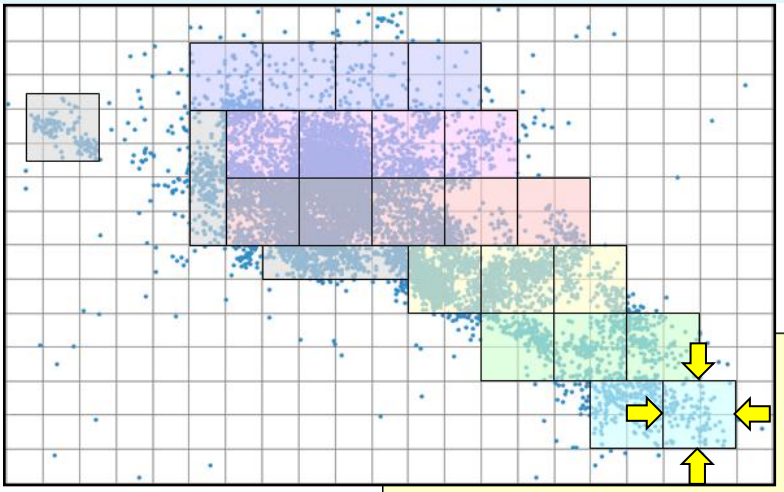
Field-wide Seismicity Analysis

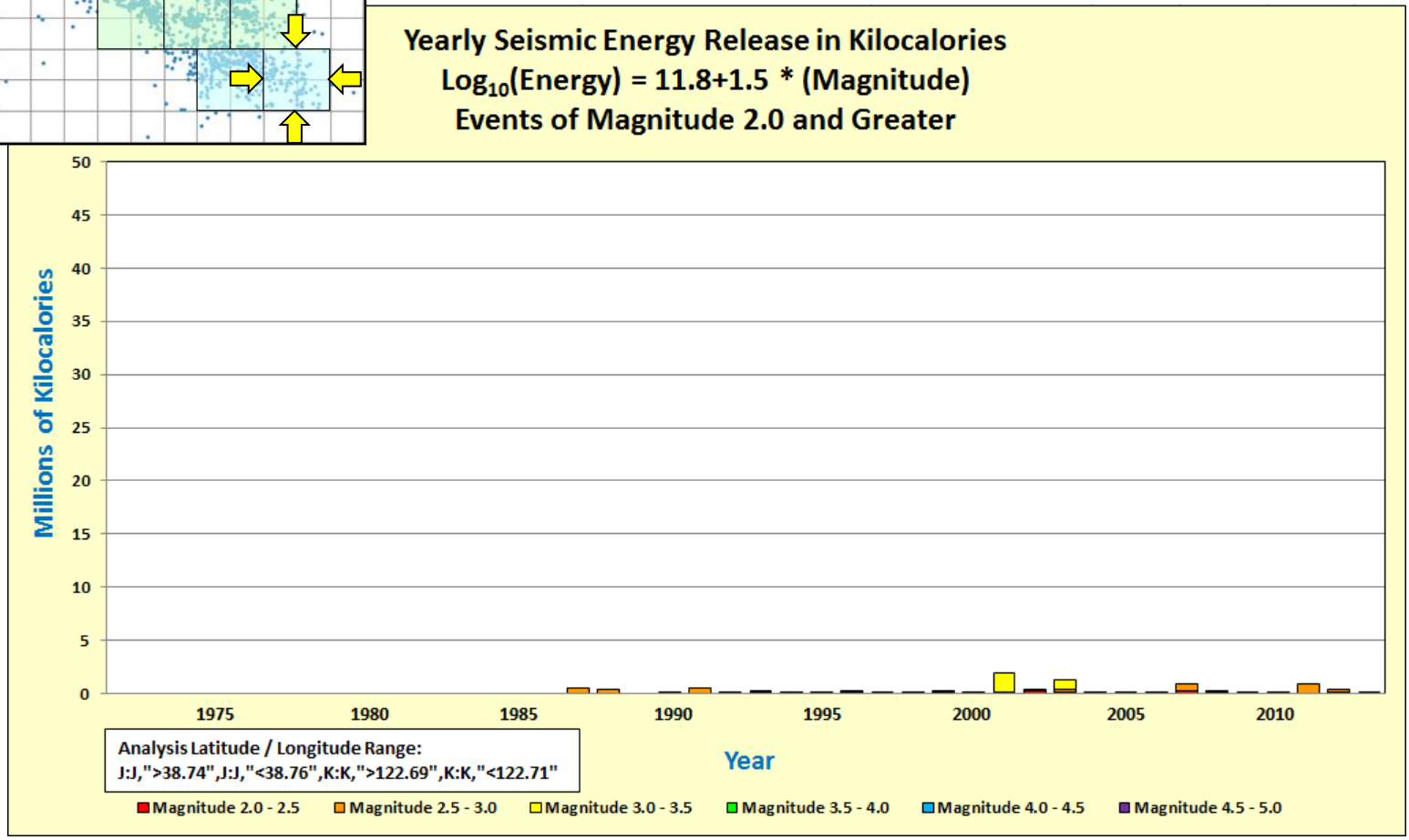
Seismic Energy Release for Equivalent Areas (Historical M ≥ 2.0 Events)



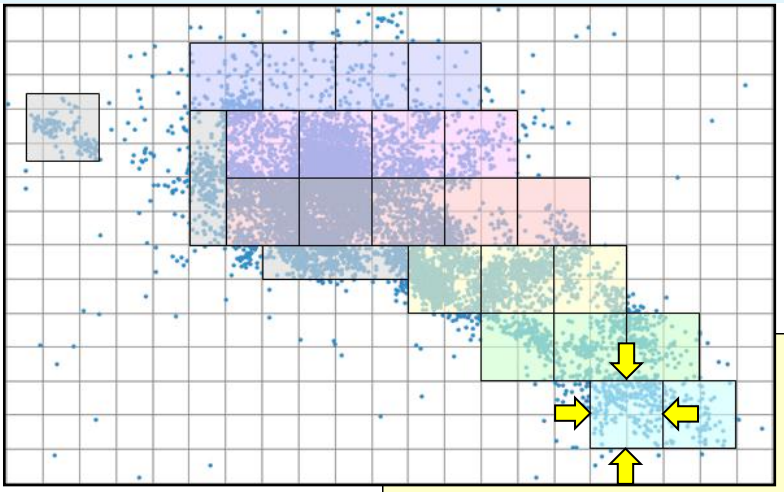
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Equivalent Areas

CALPINE
NYSE CPN

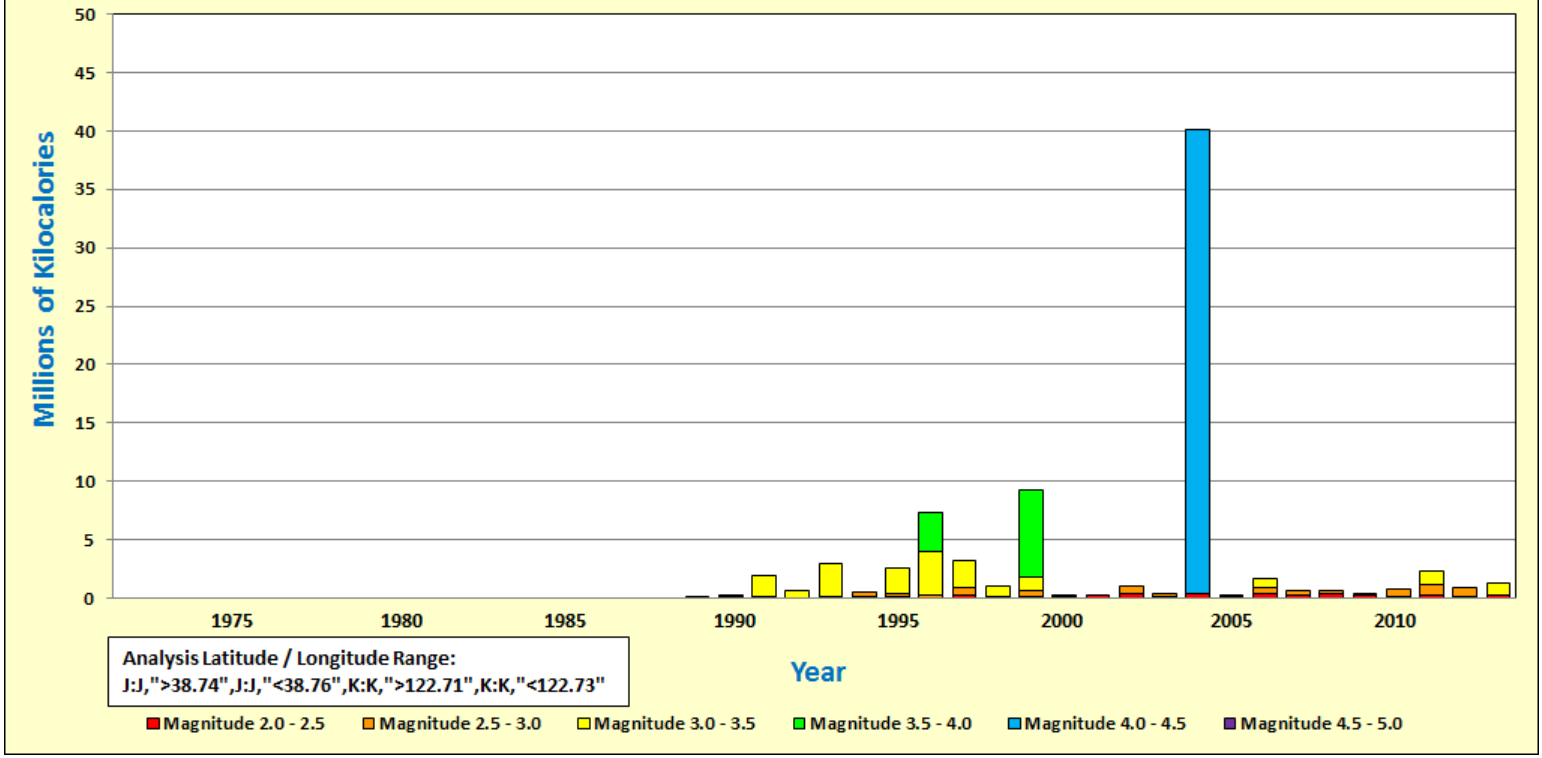




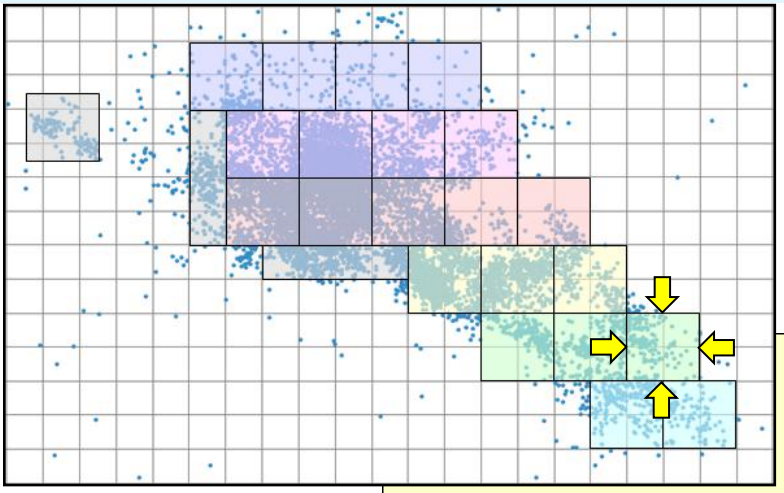
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area

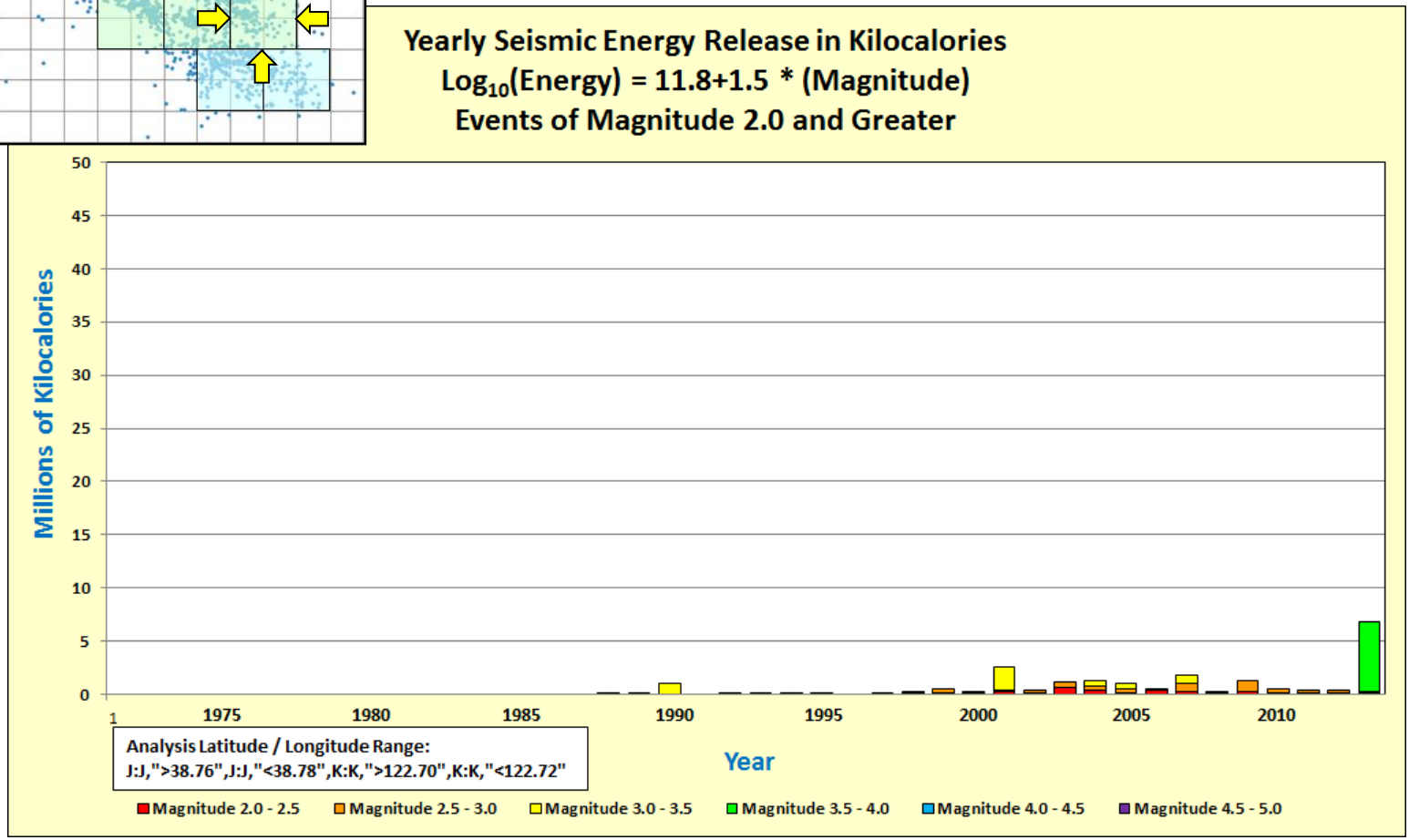


Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater

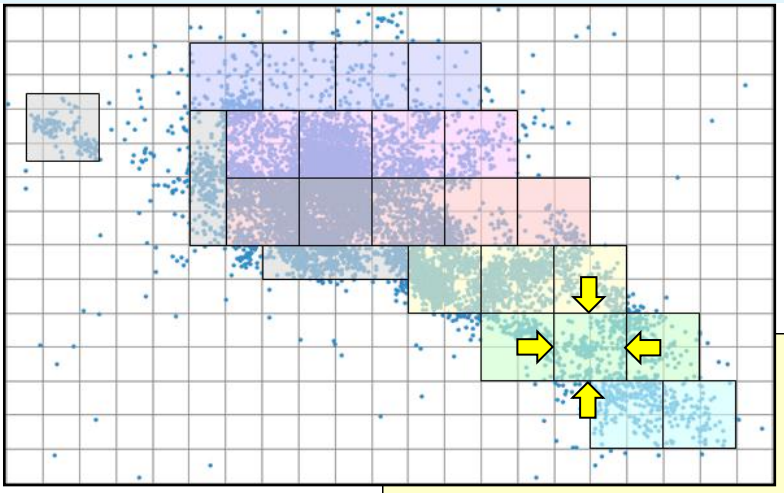


Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area

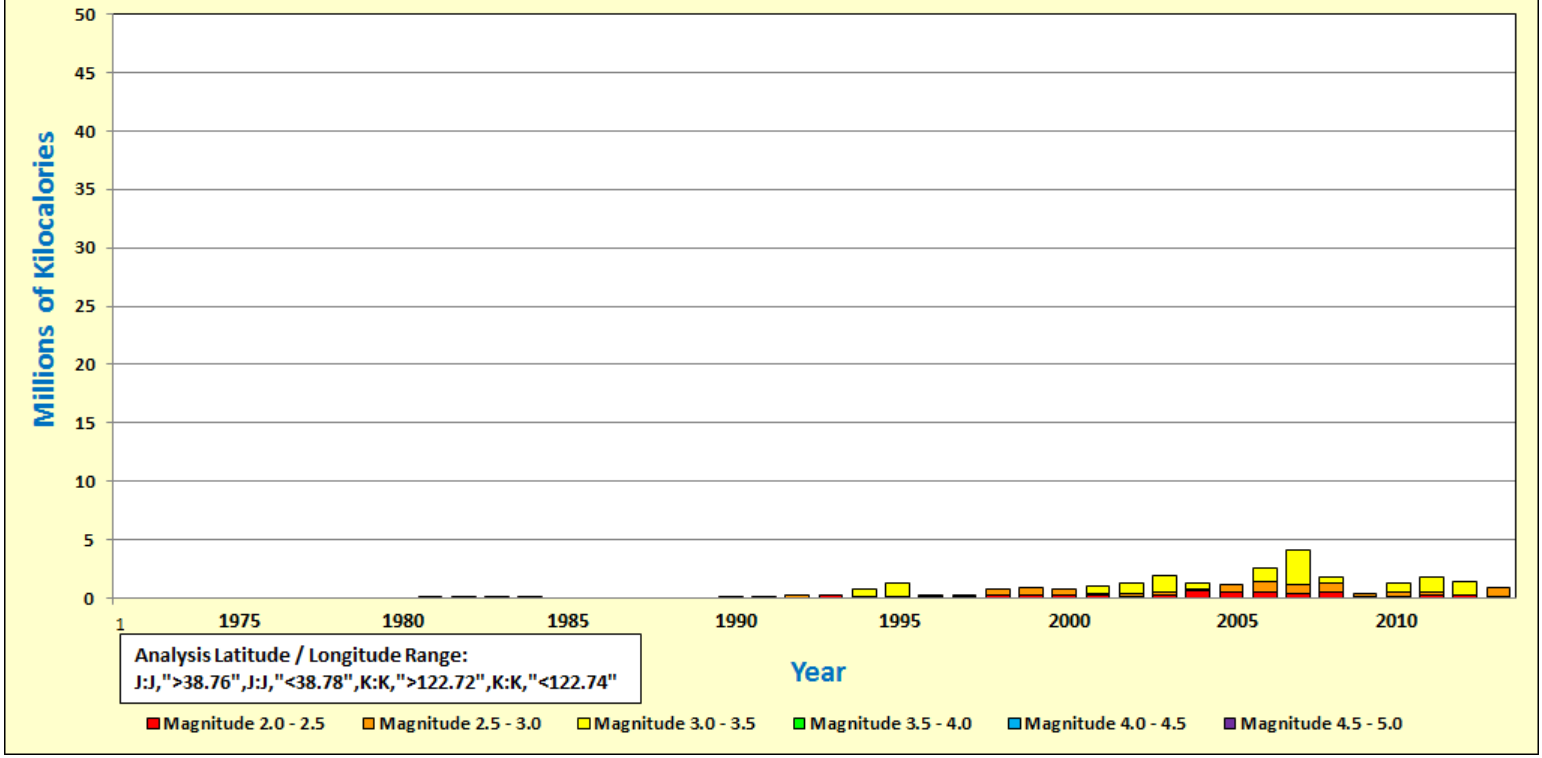




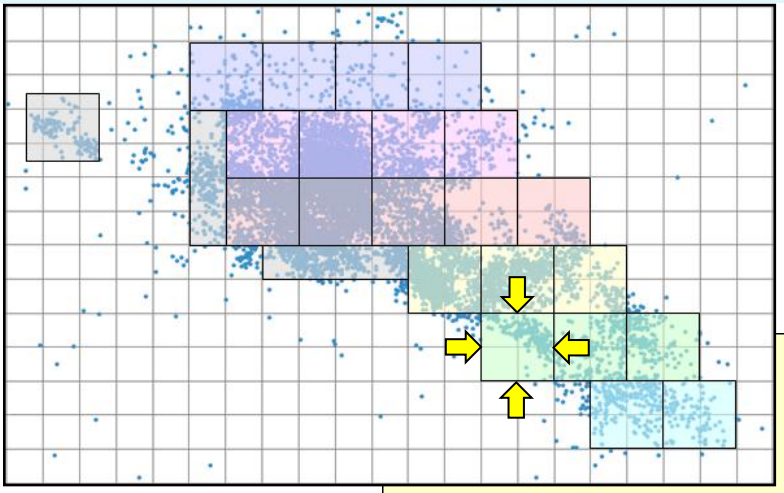
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area



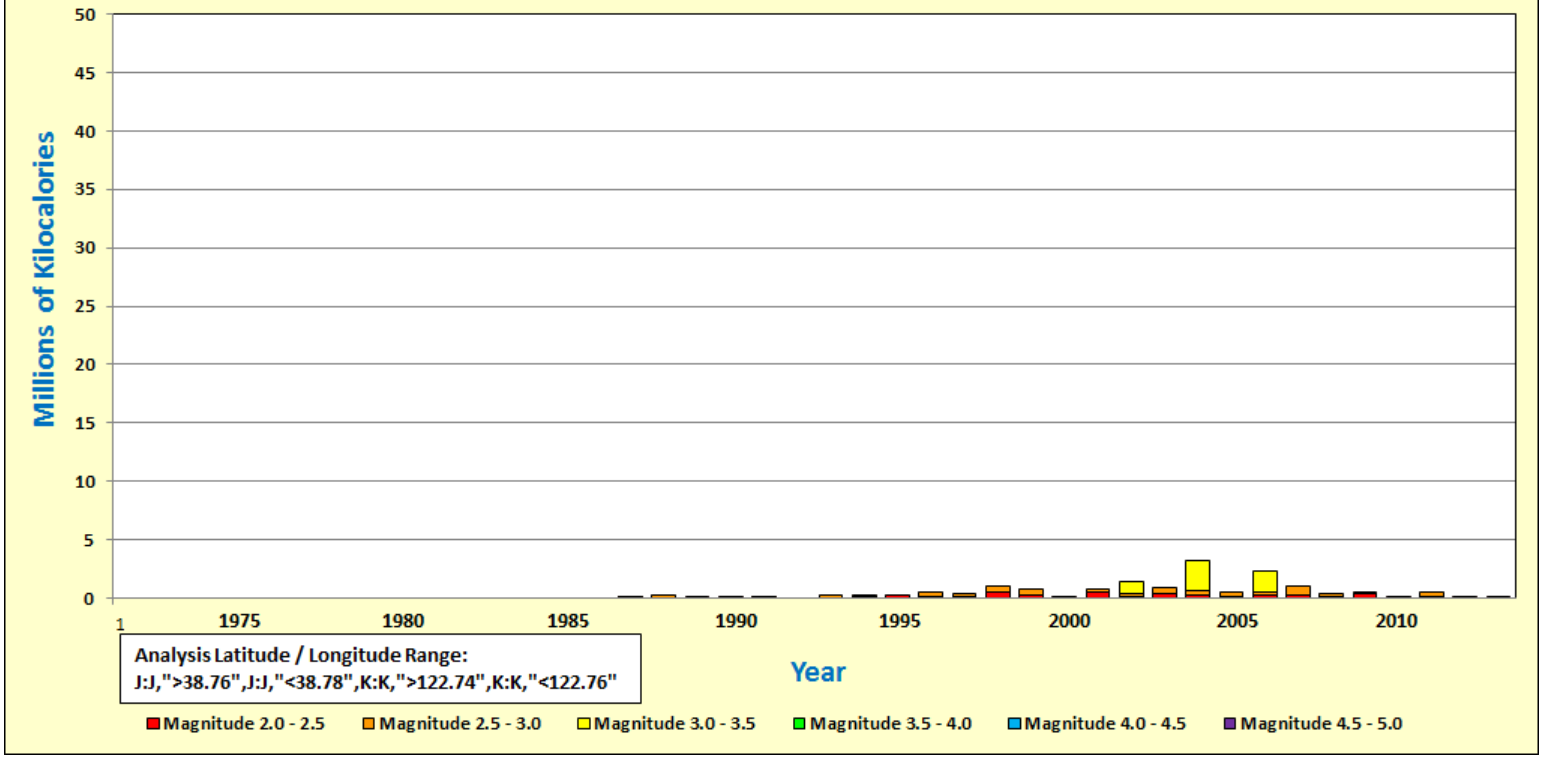
Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater



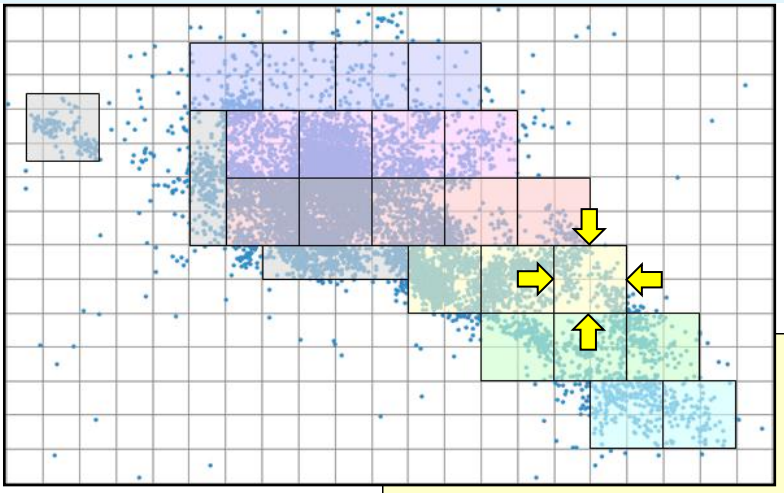
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area



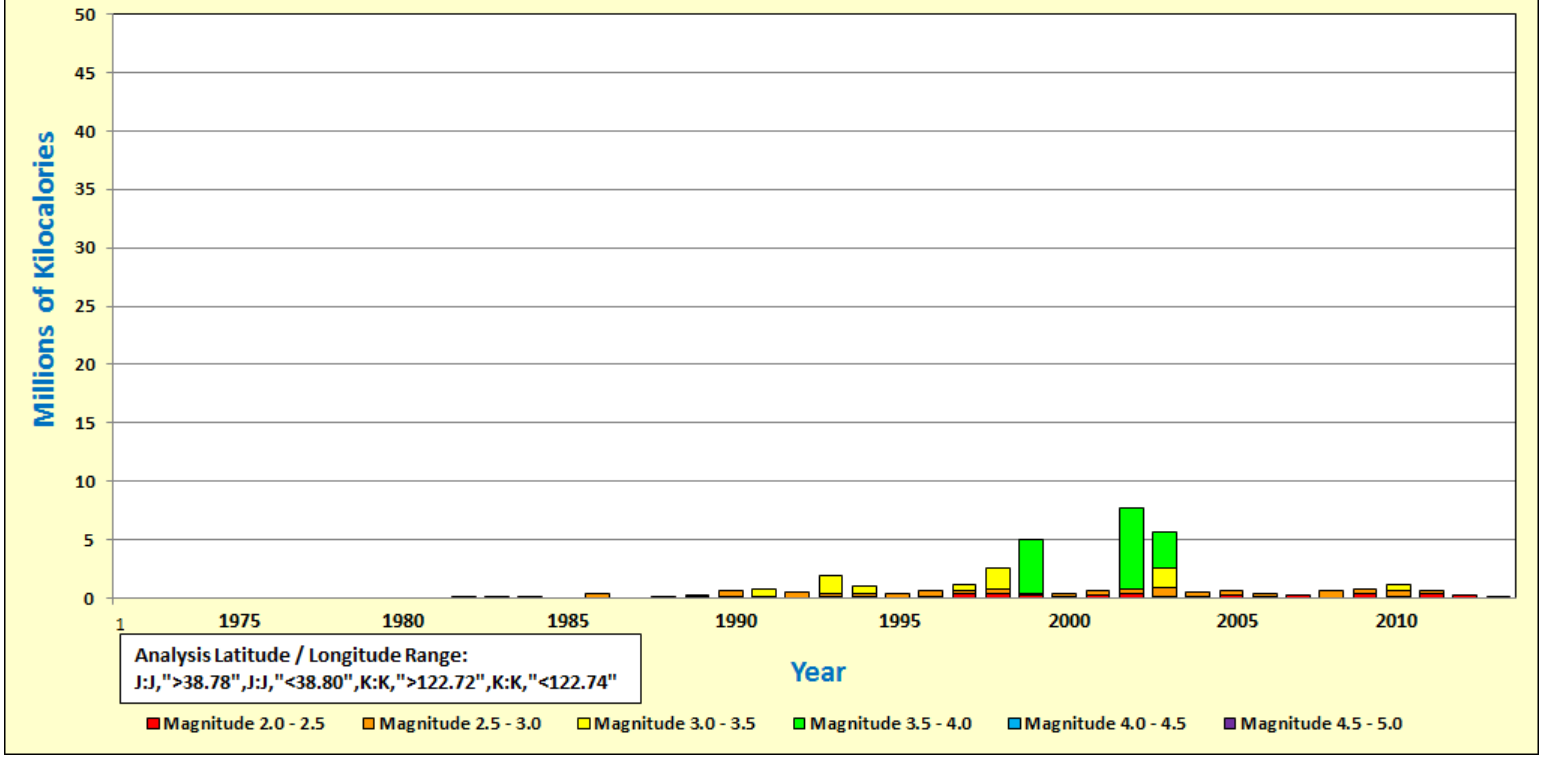
Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater



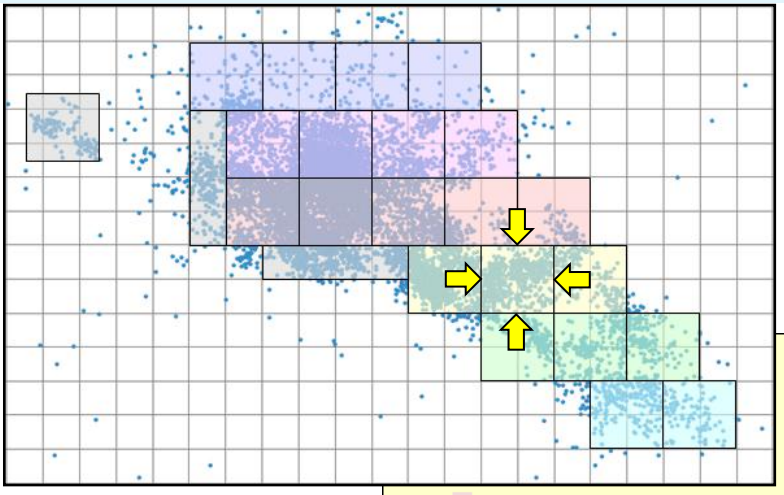
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area



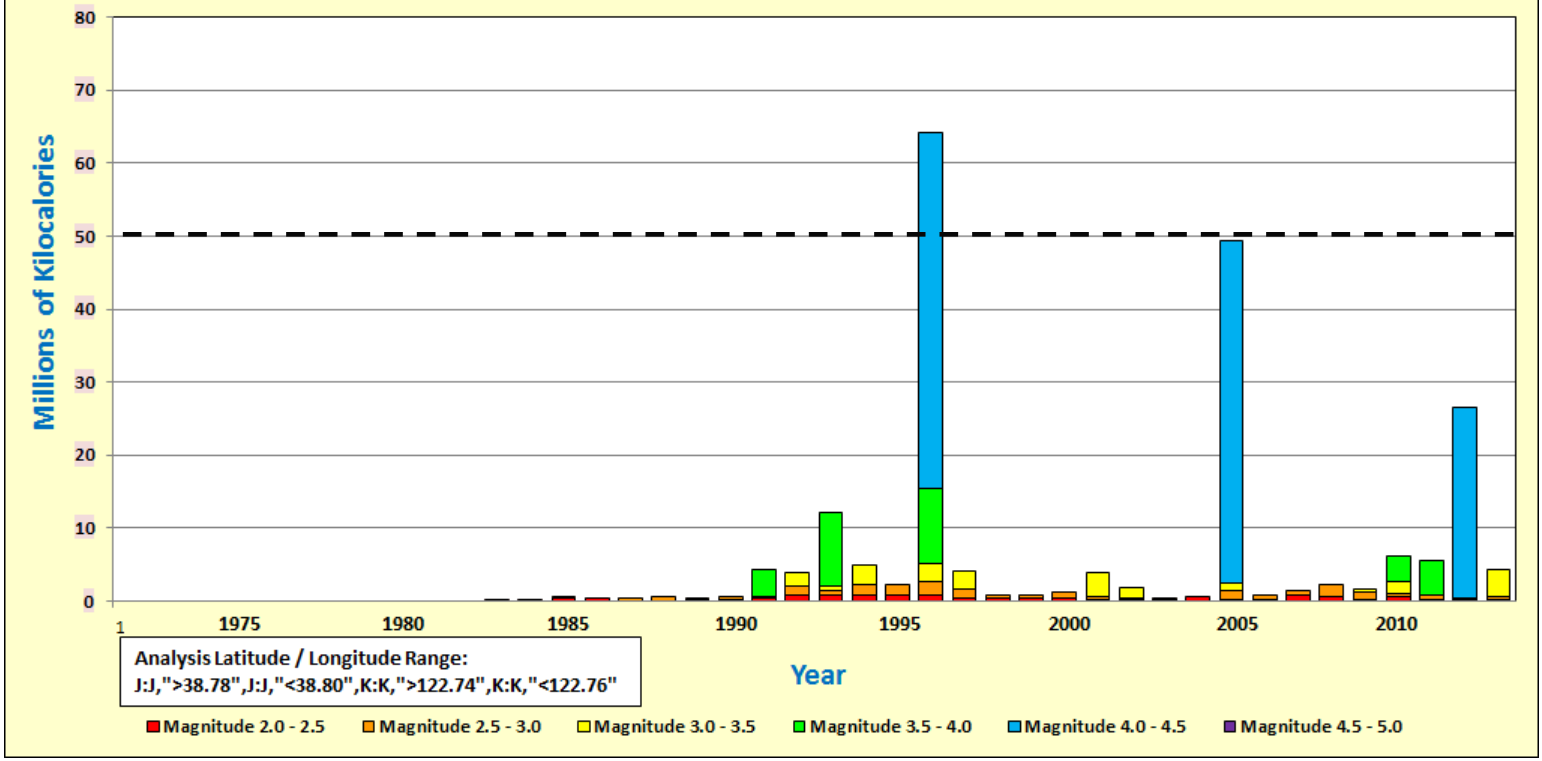
Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater



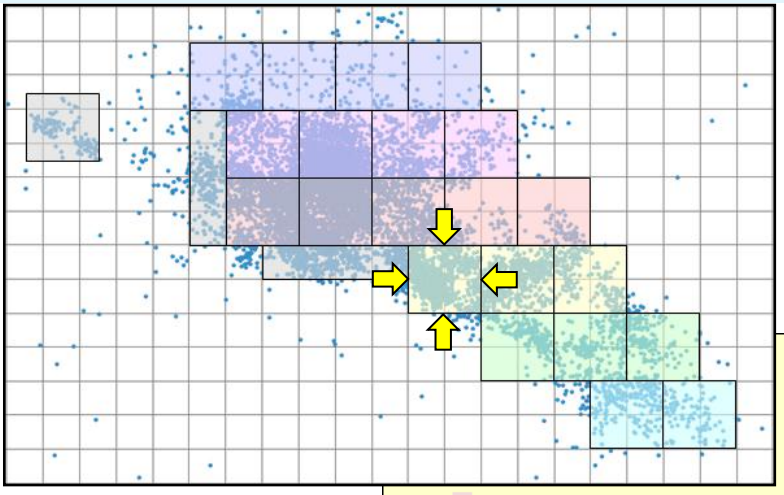
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area



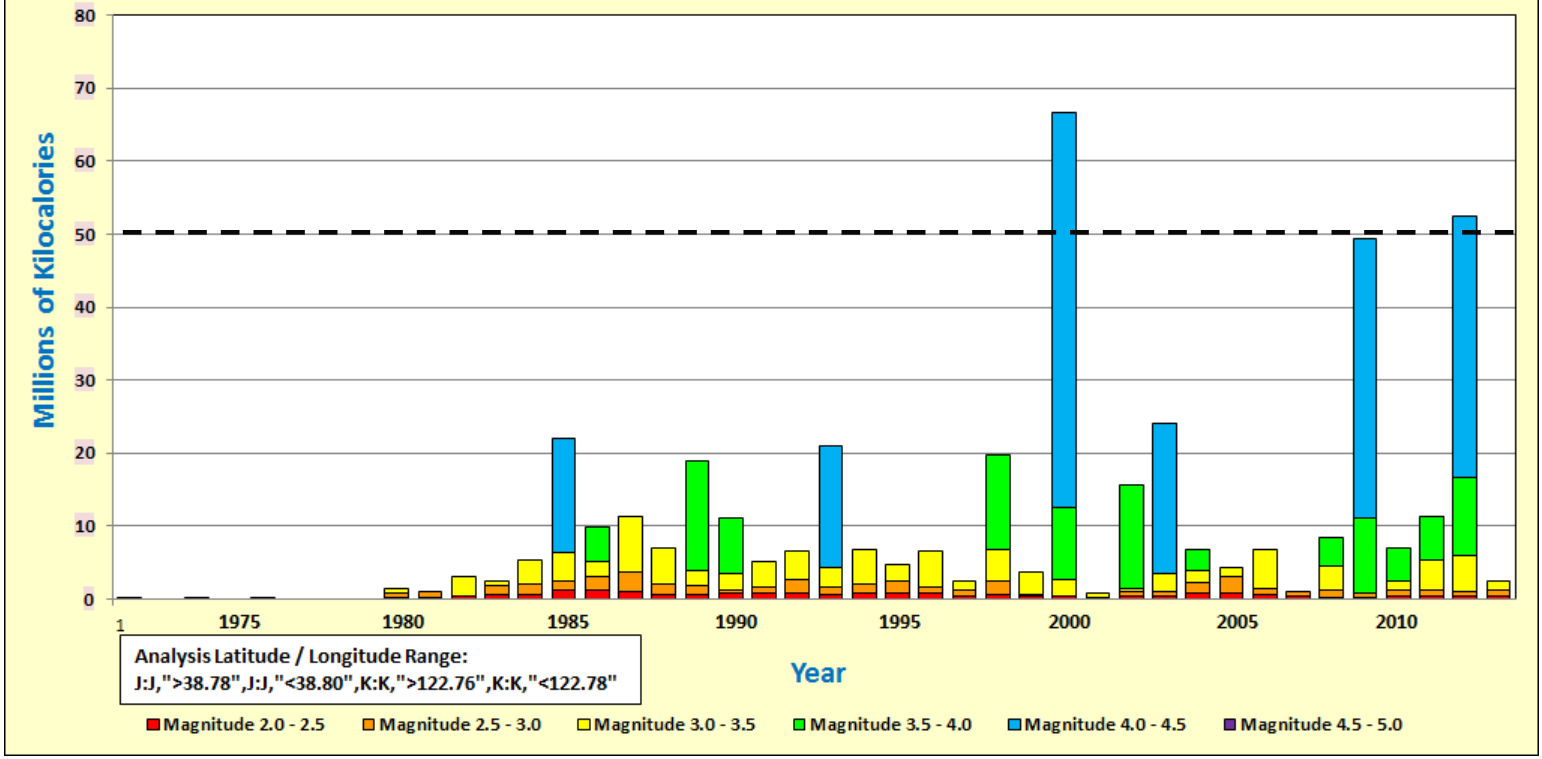
Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater



Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area

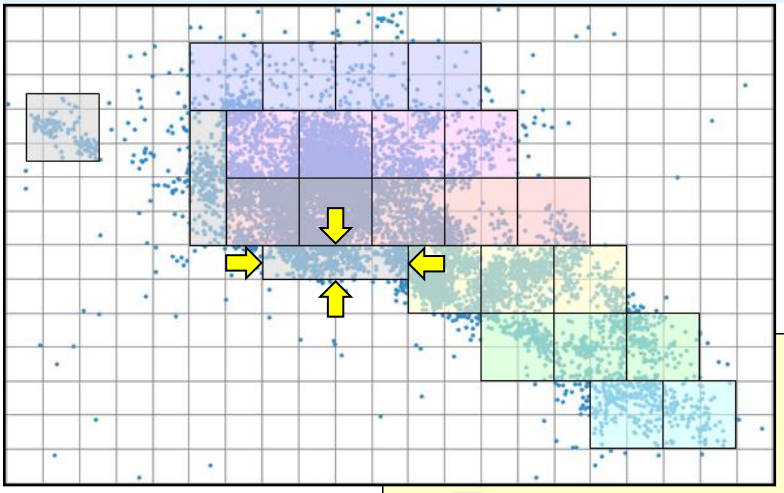


Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater

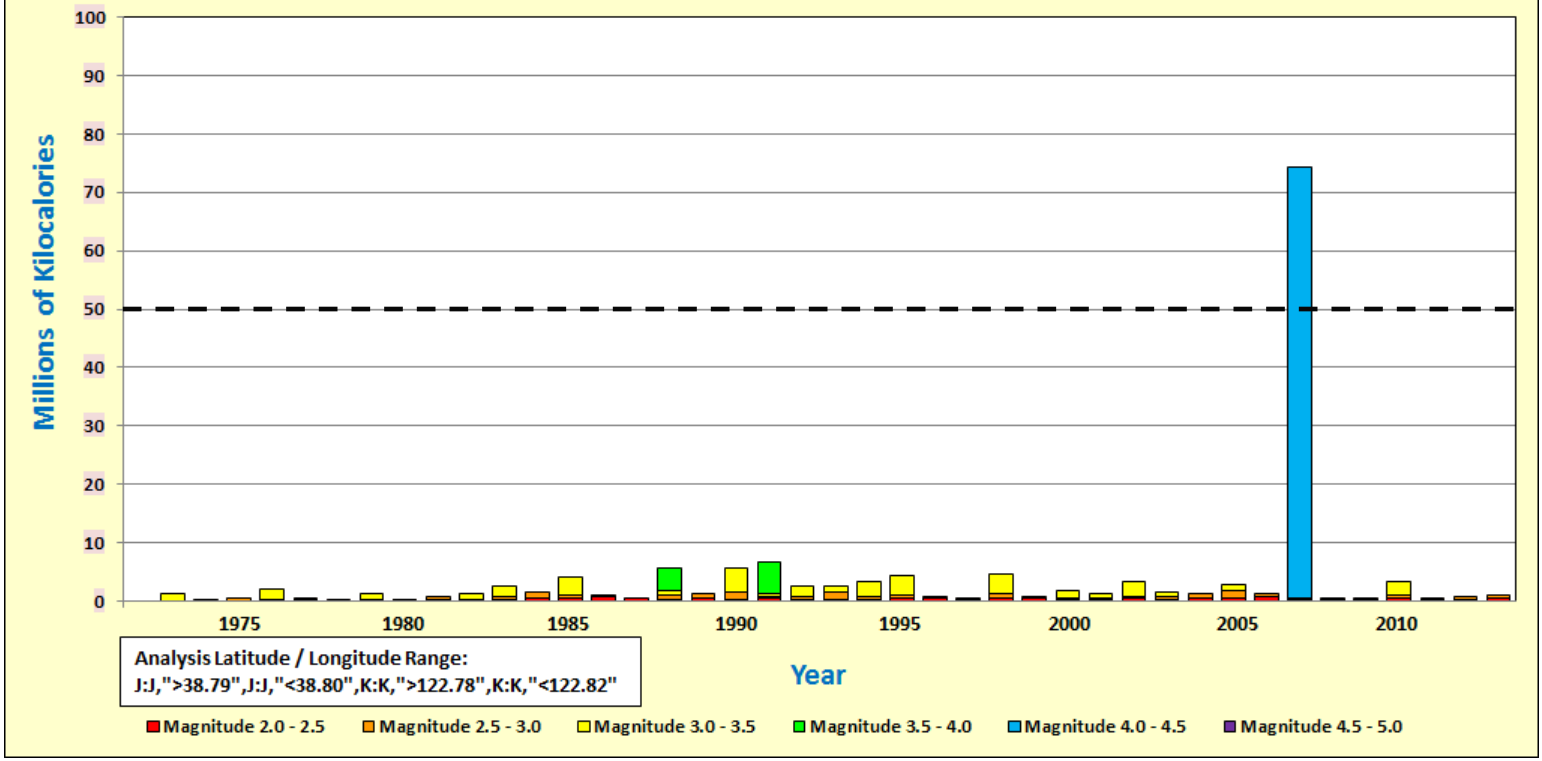


Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area

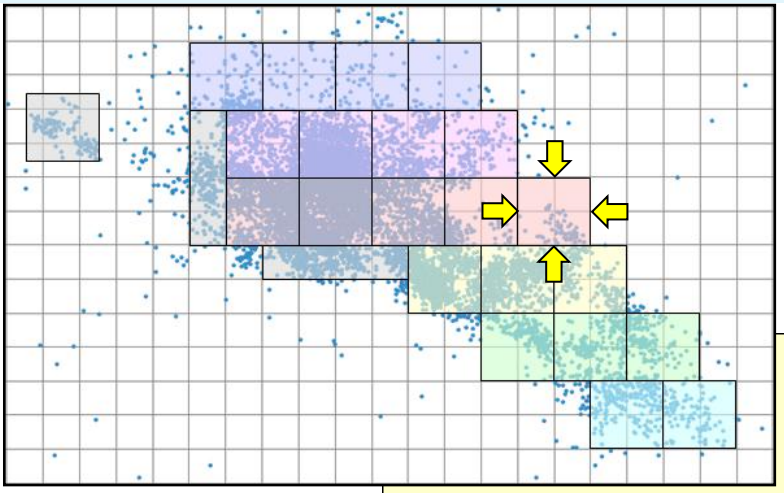
CALPINE
NYSE CPN



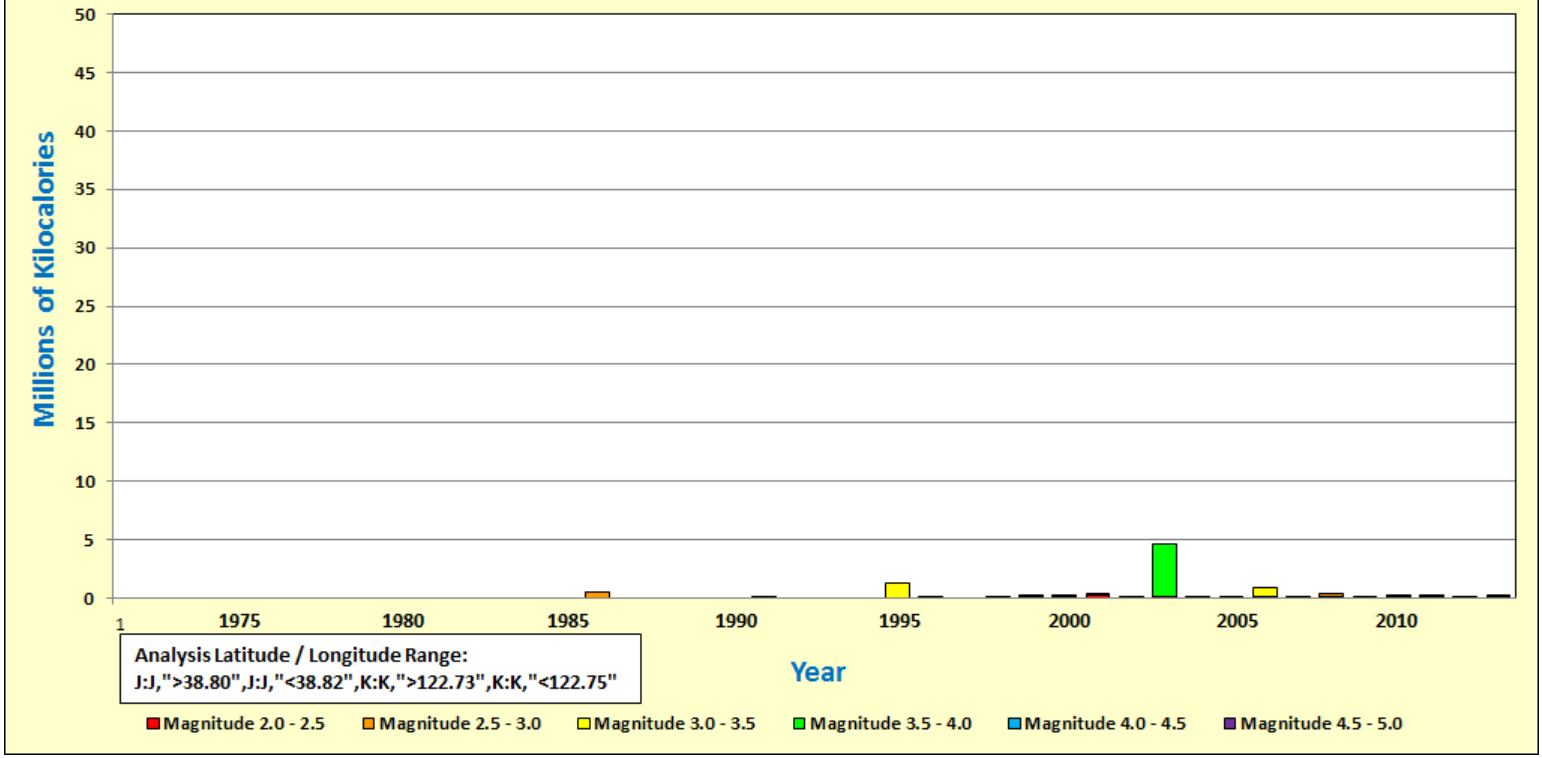
Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater



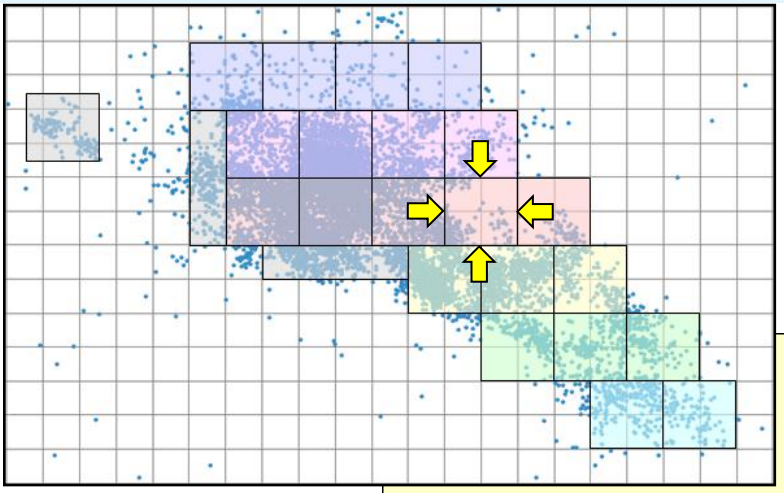
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area



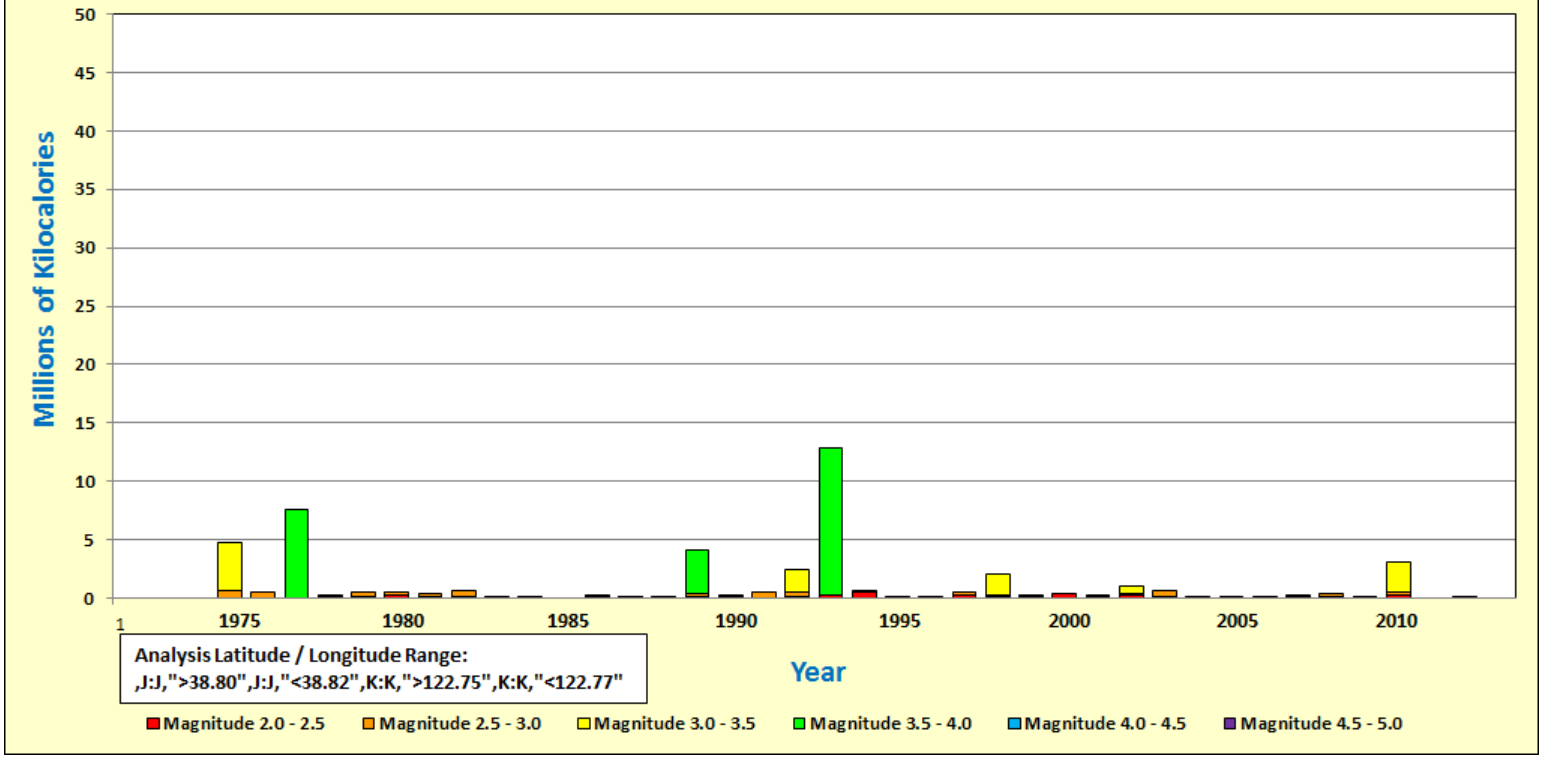
Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater



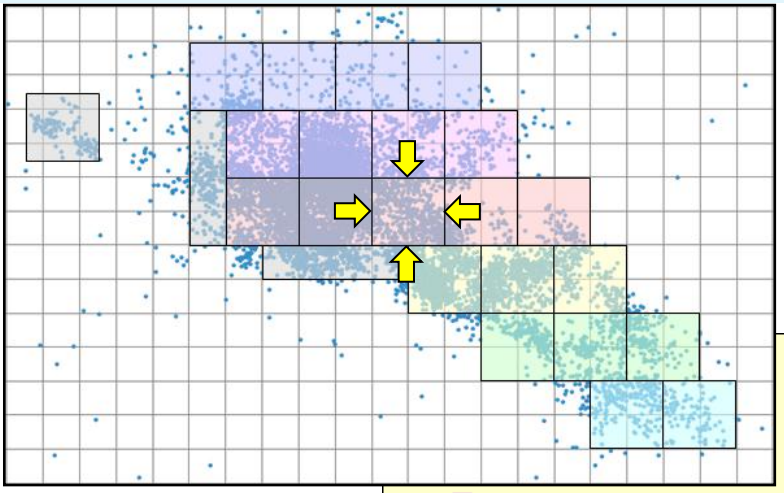
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area

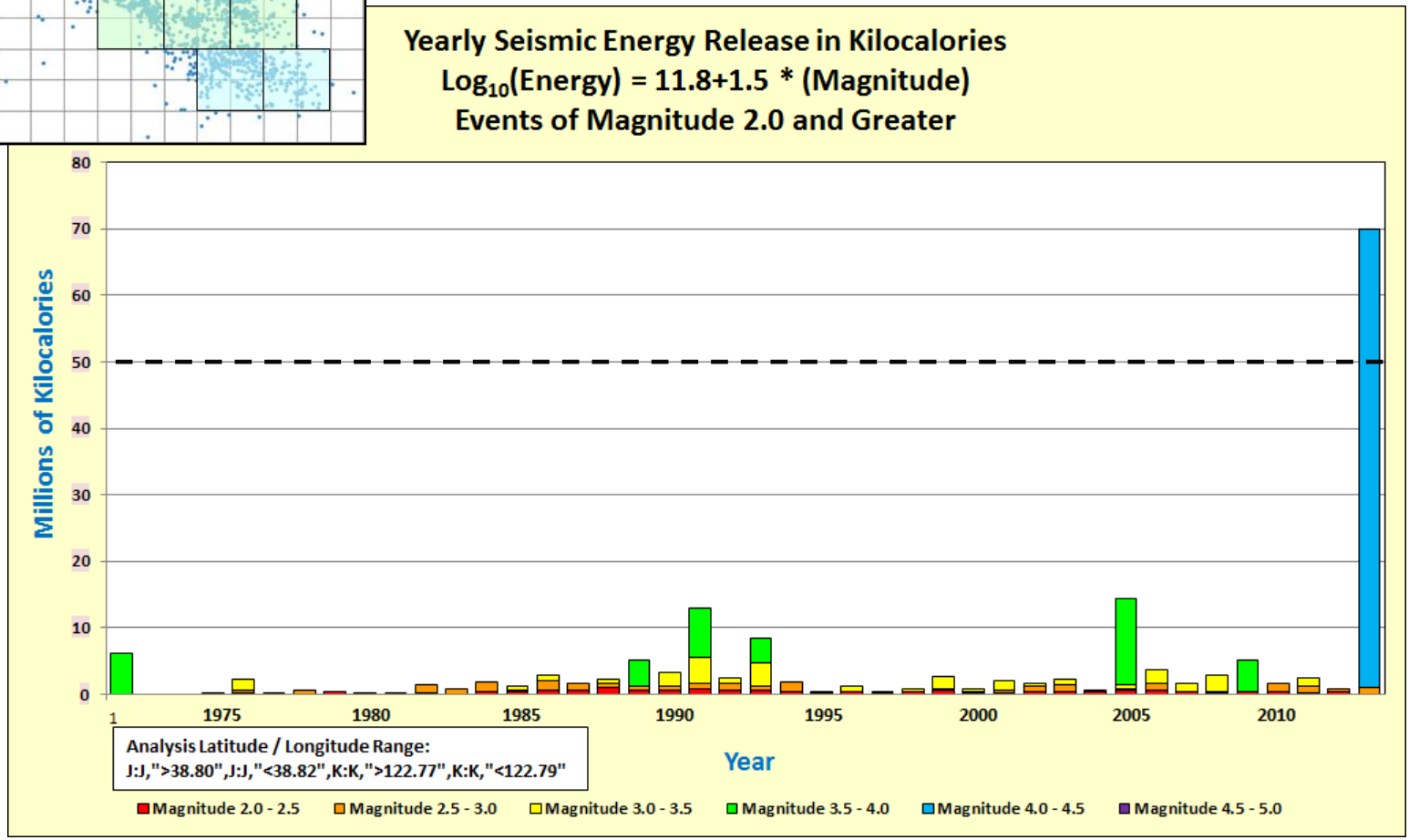


Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater



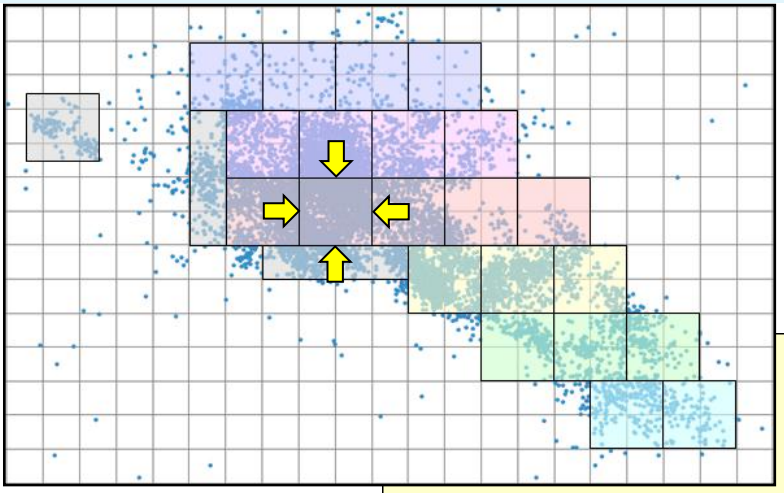
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area



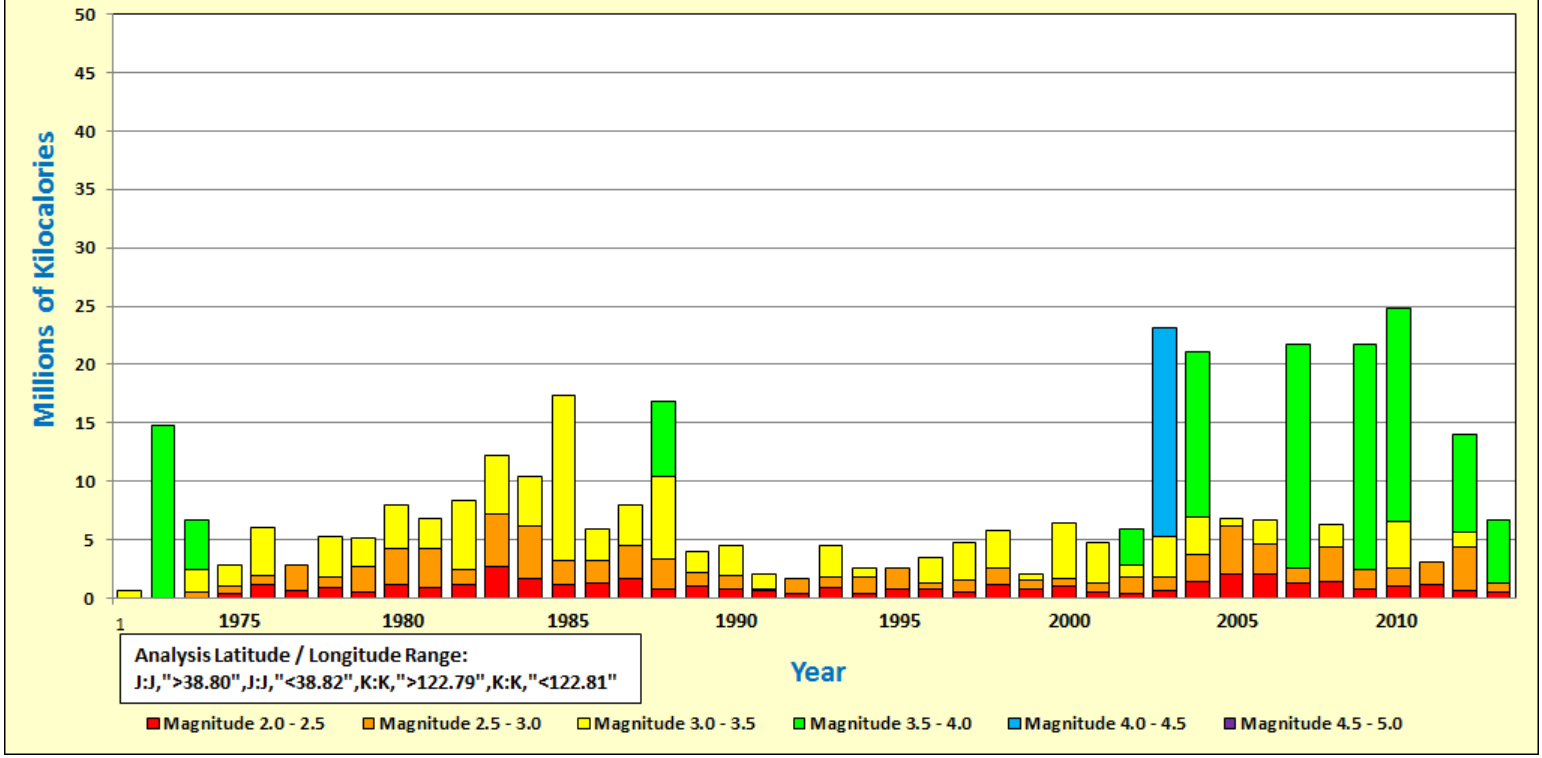


Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area

CALPINE
NYSE CPN

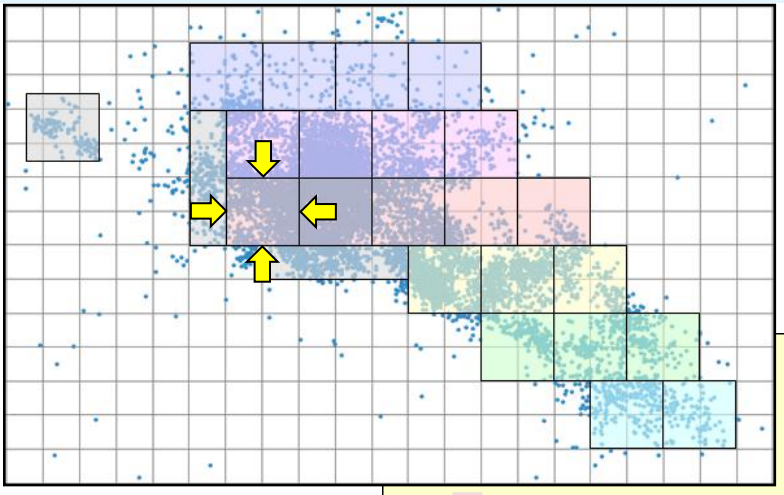


Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater

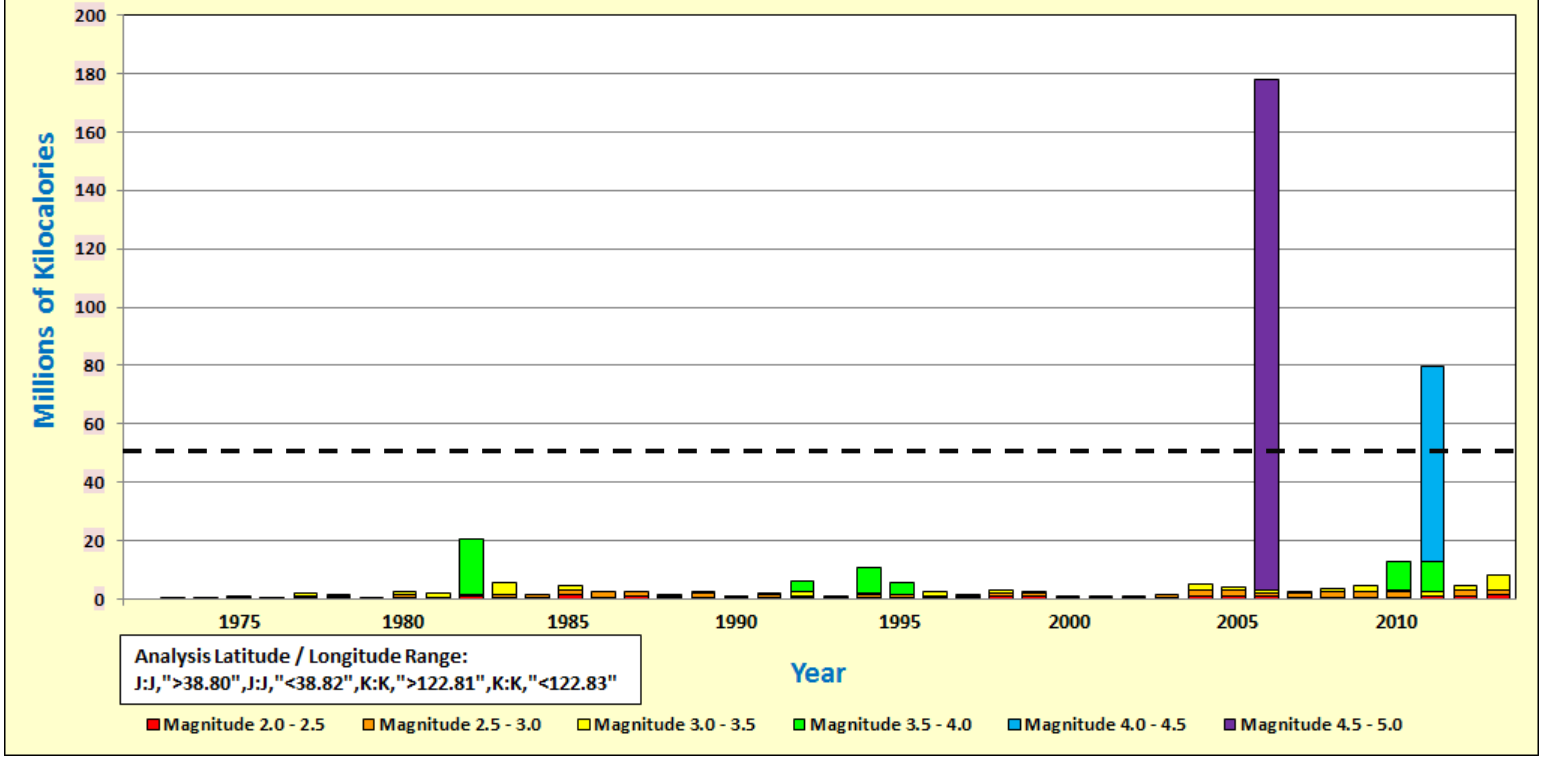


Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area

CALPINE
NYSE CPN

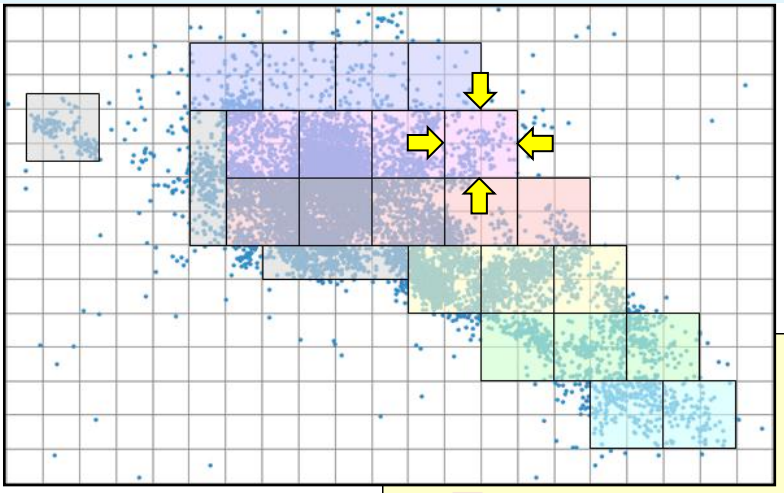


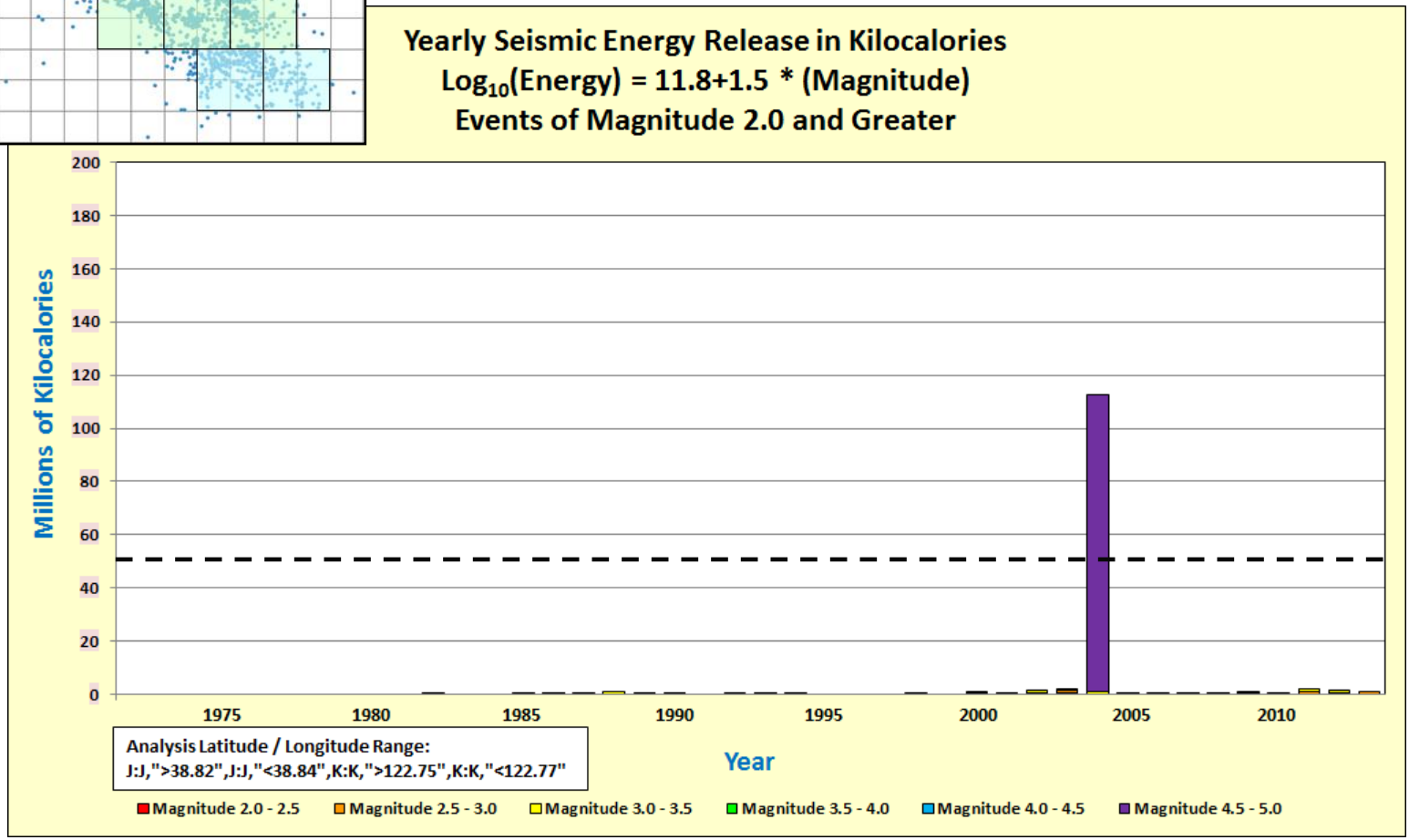
Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater



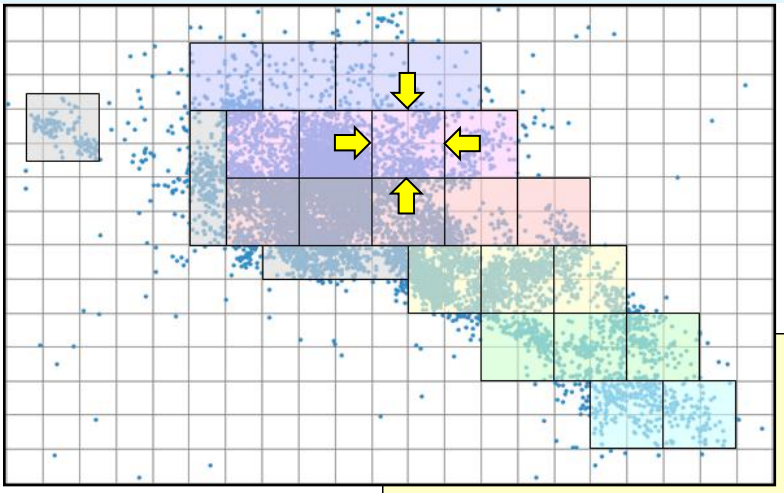
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area

CALPINE
NYSE CPN

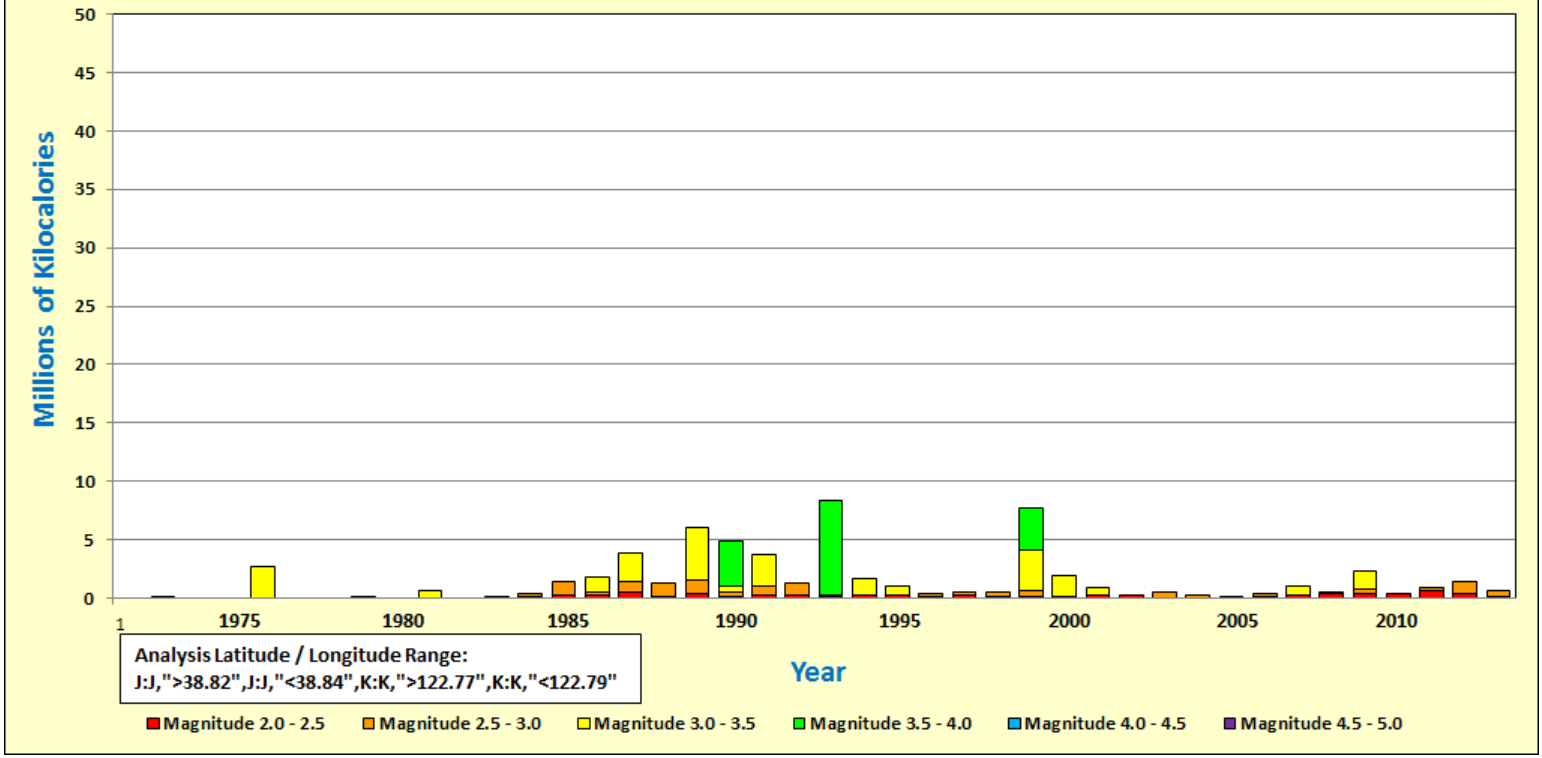




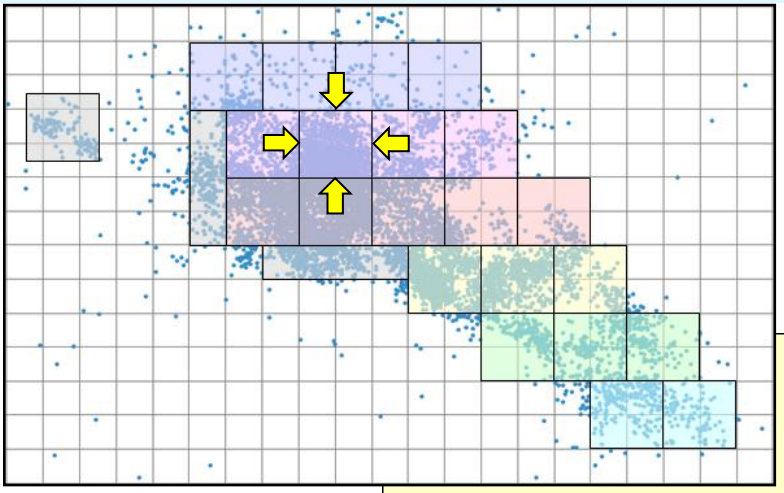
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area



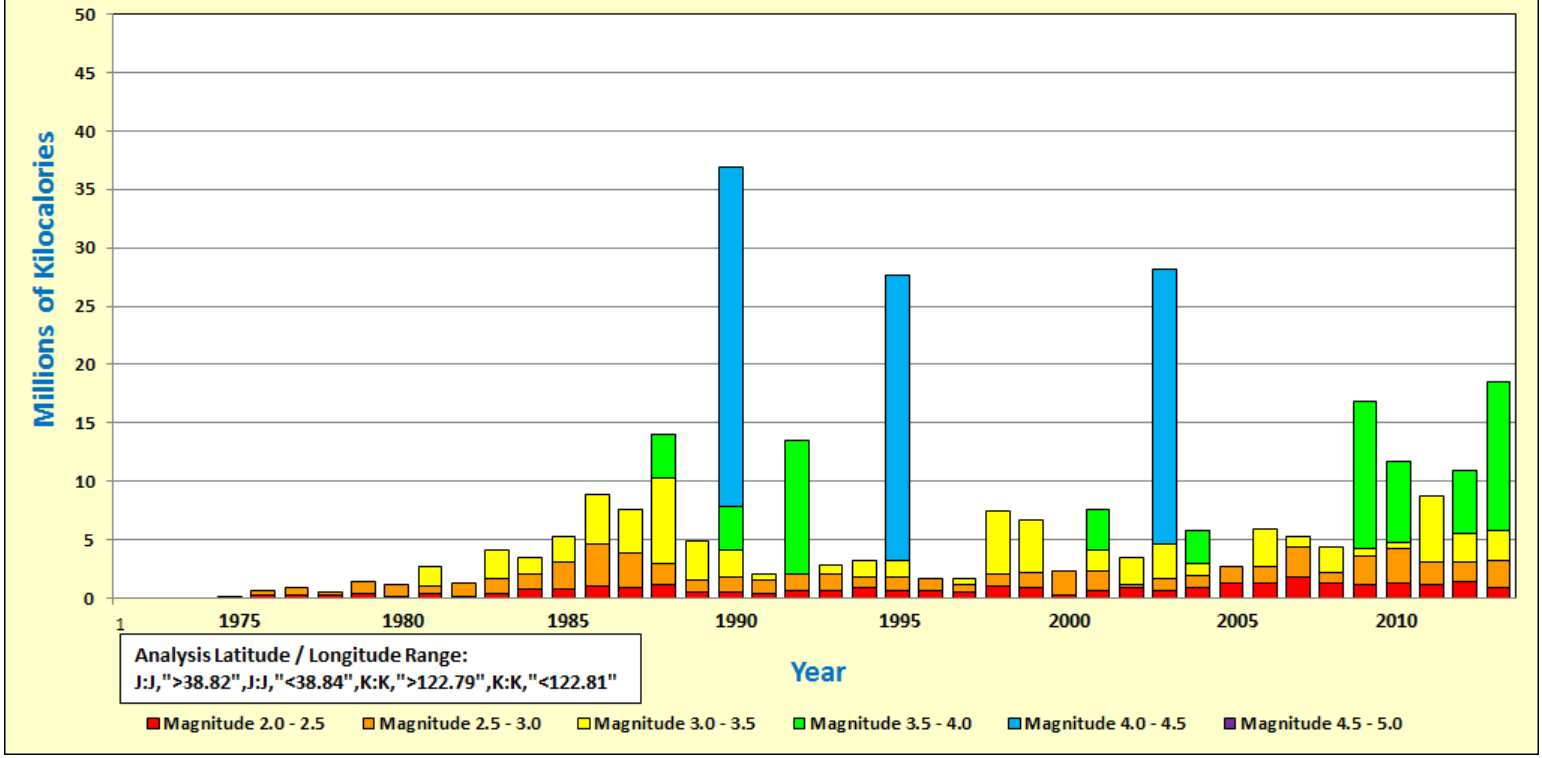
Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater



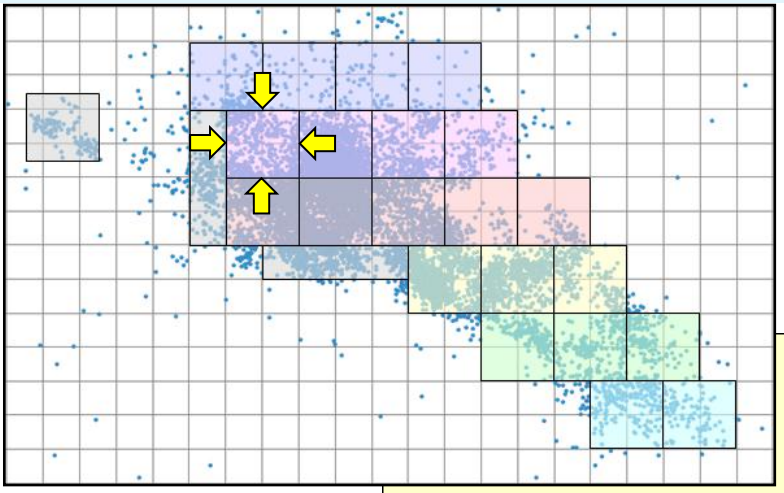
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area



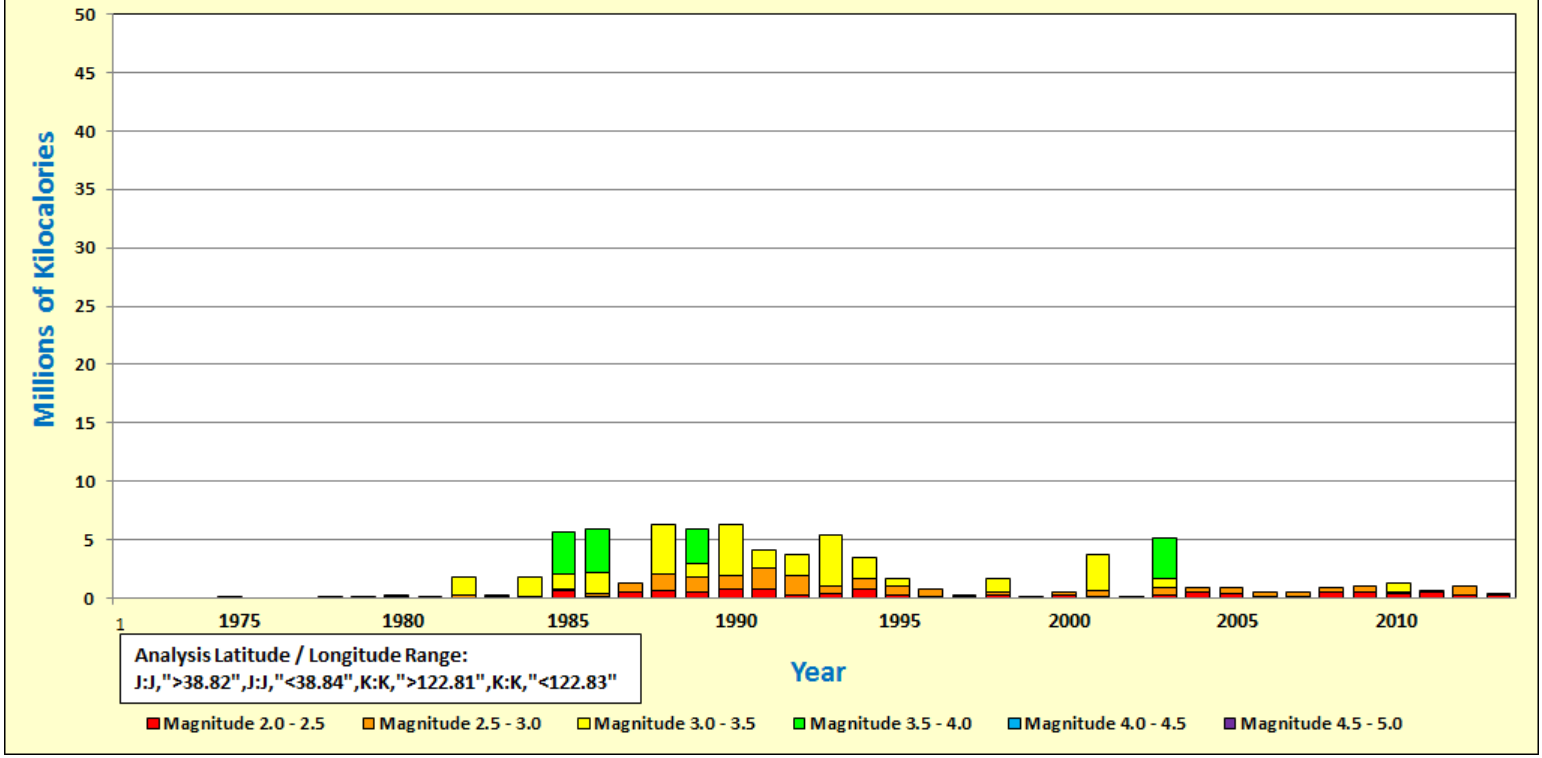
Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater



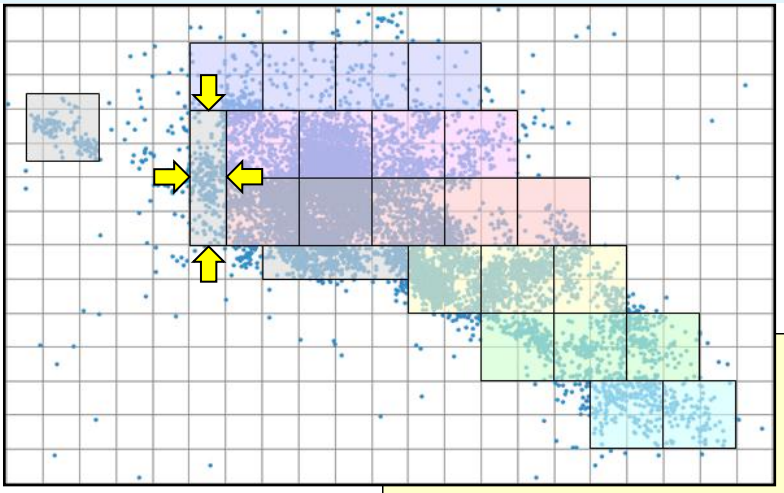
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area



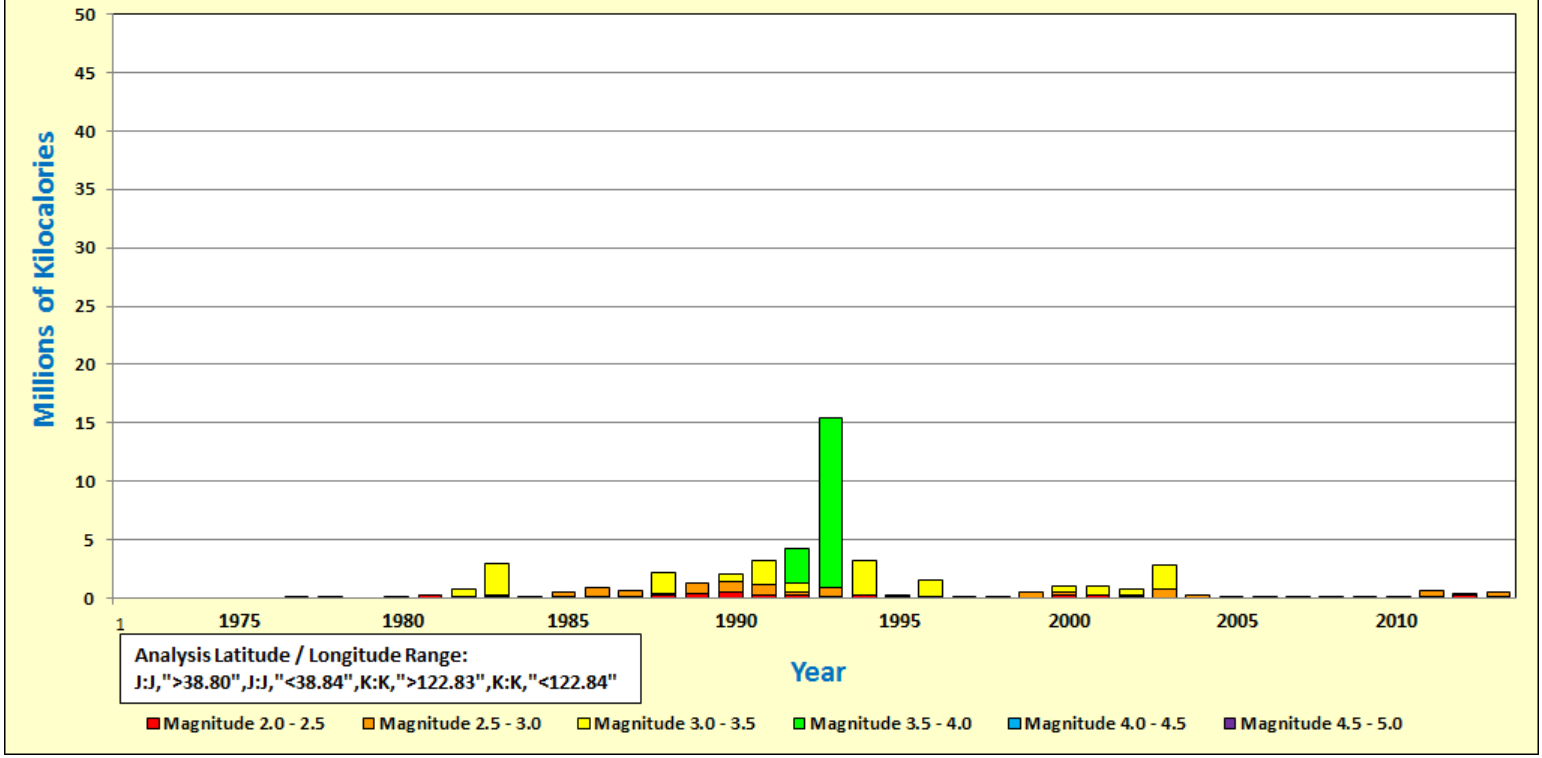
Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater



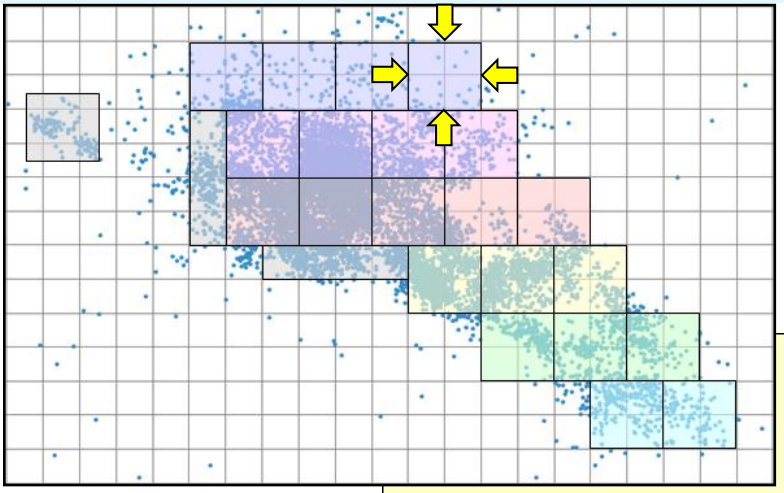
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area



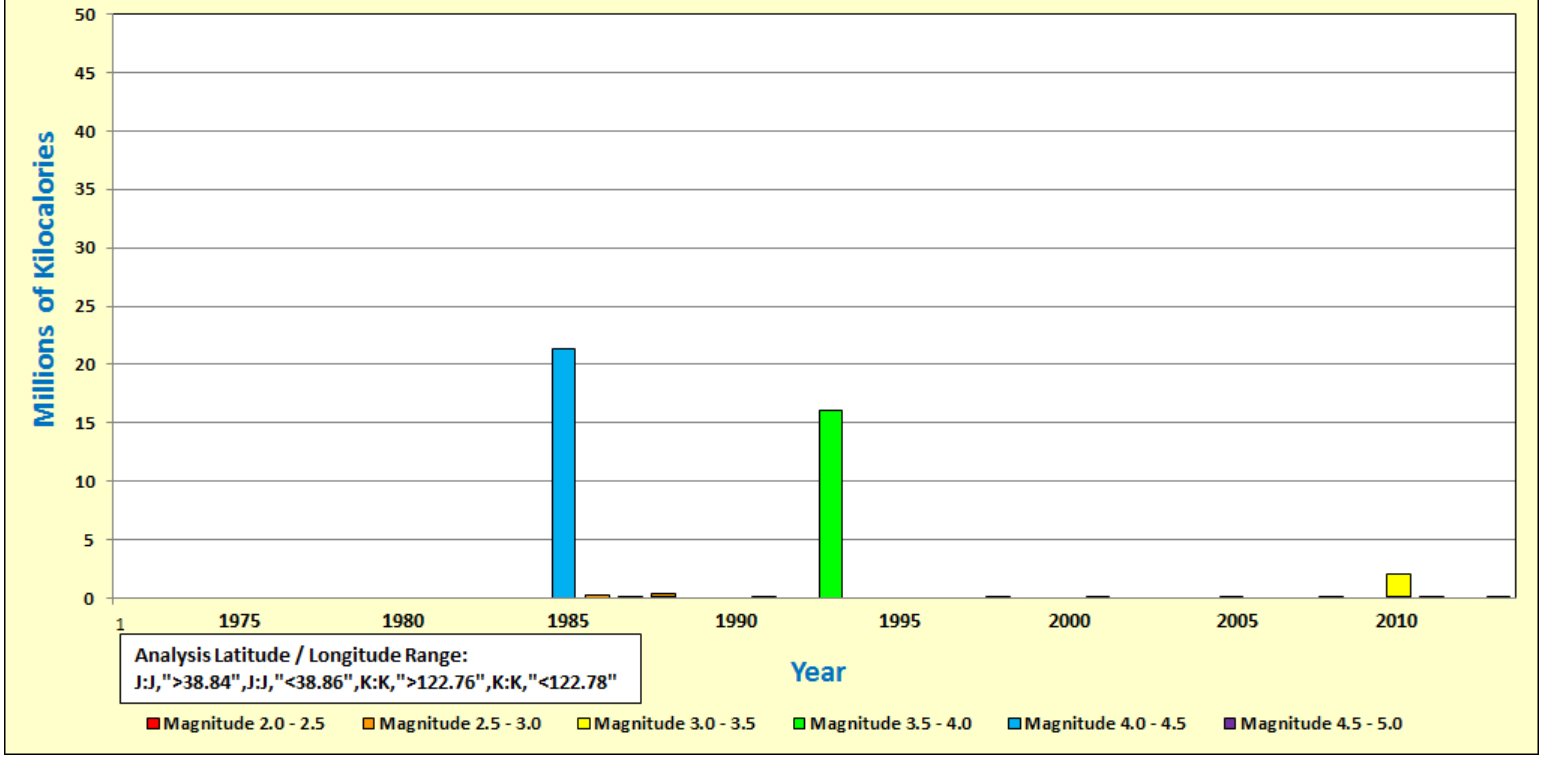
Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater



Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area

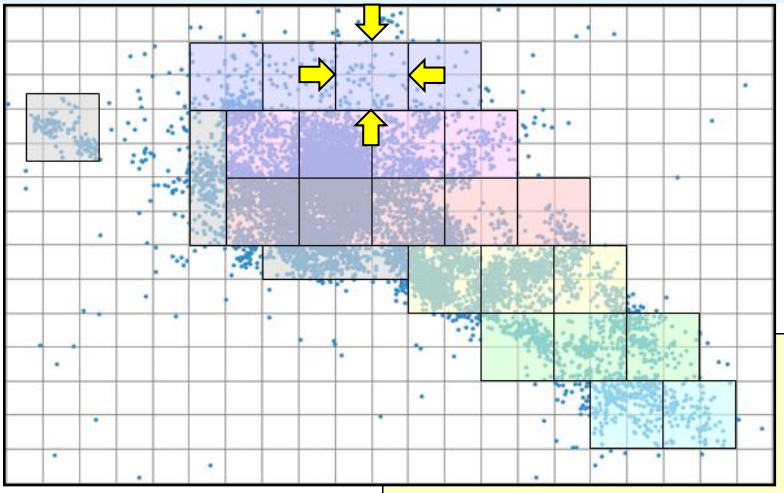


Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater

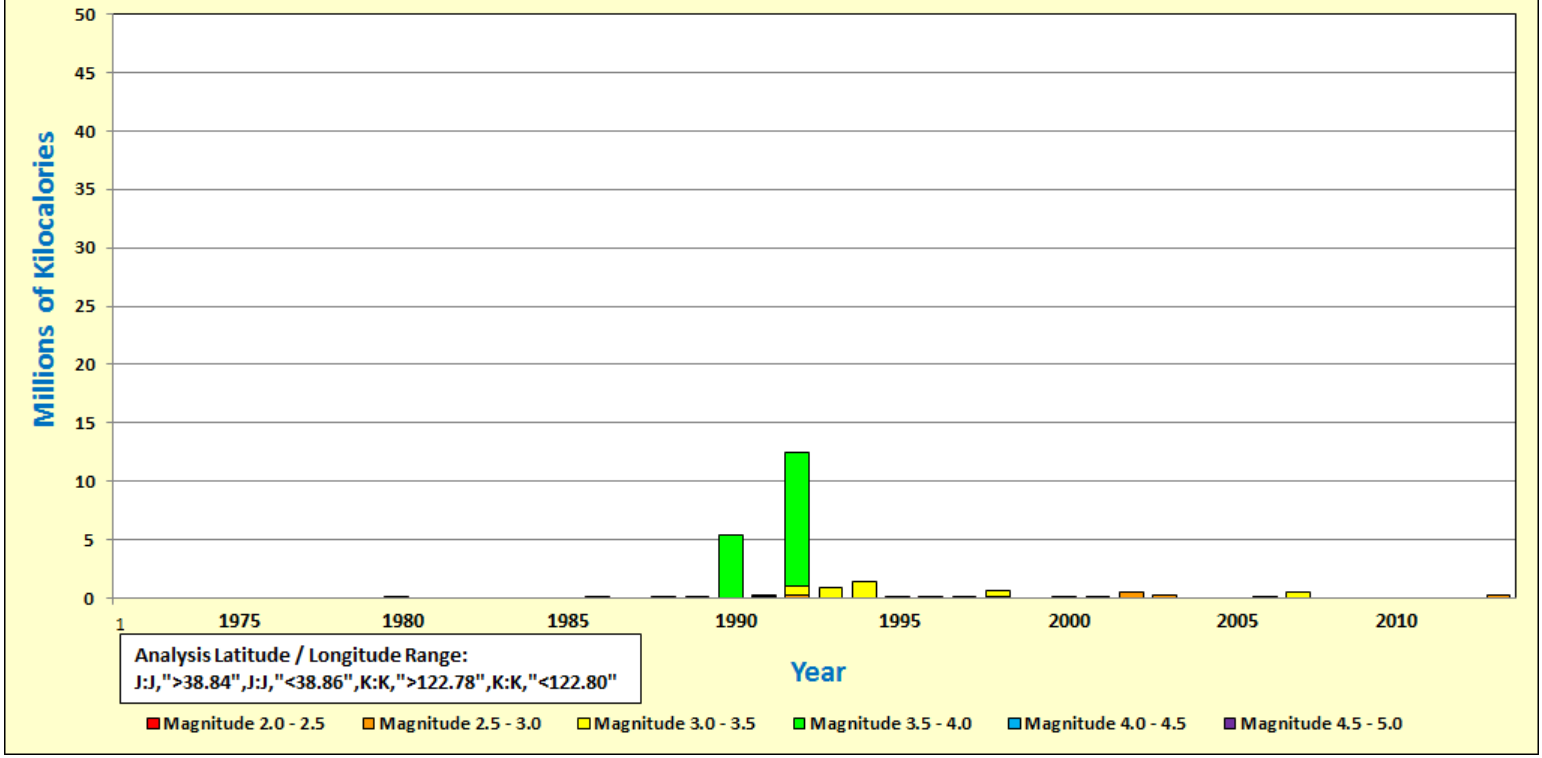


Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area

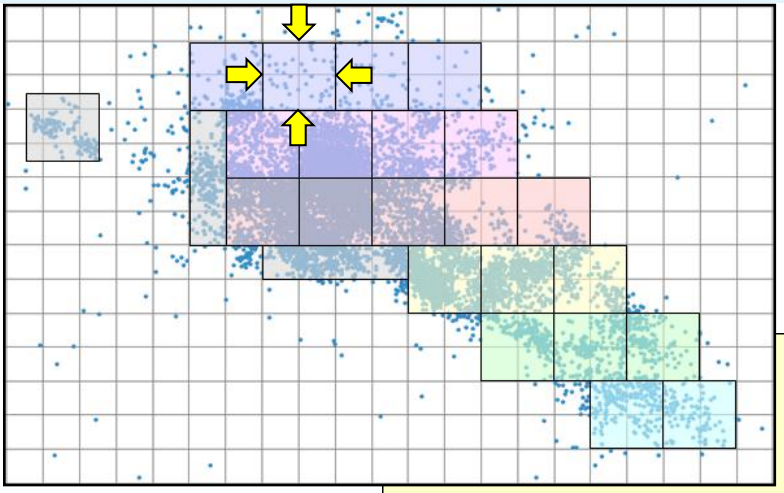
CALPINE
NYSE CPN



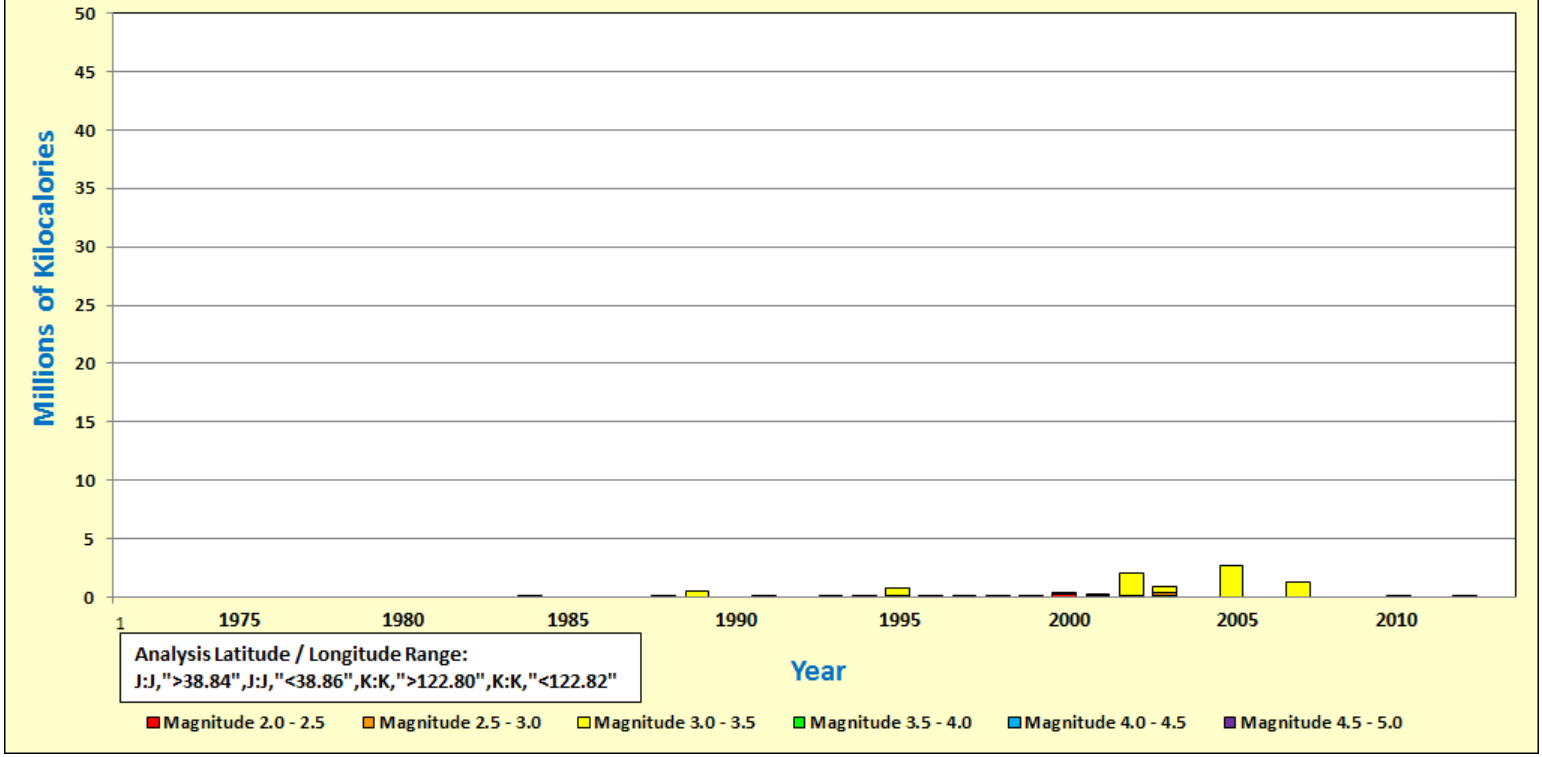
Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater



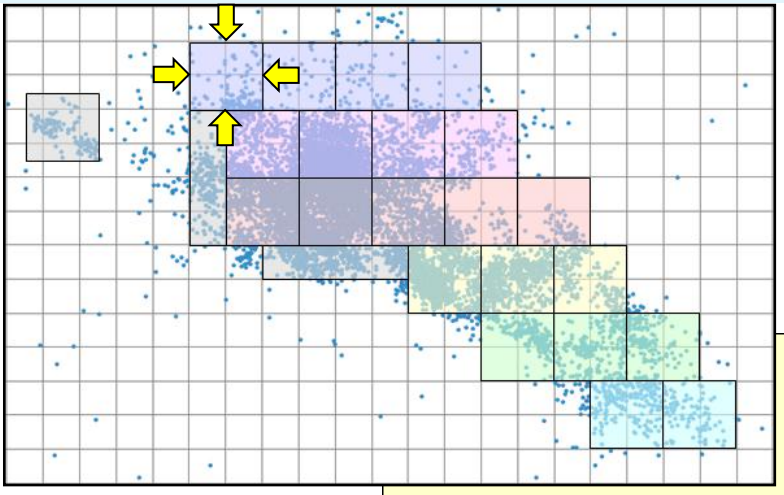
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area



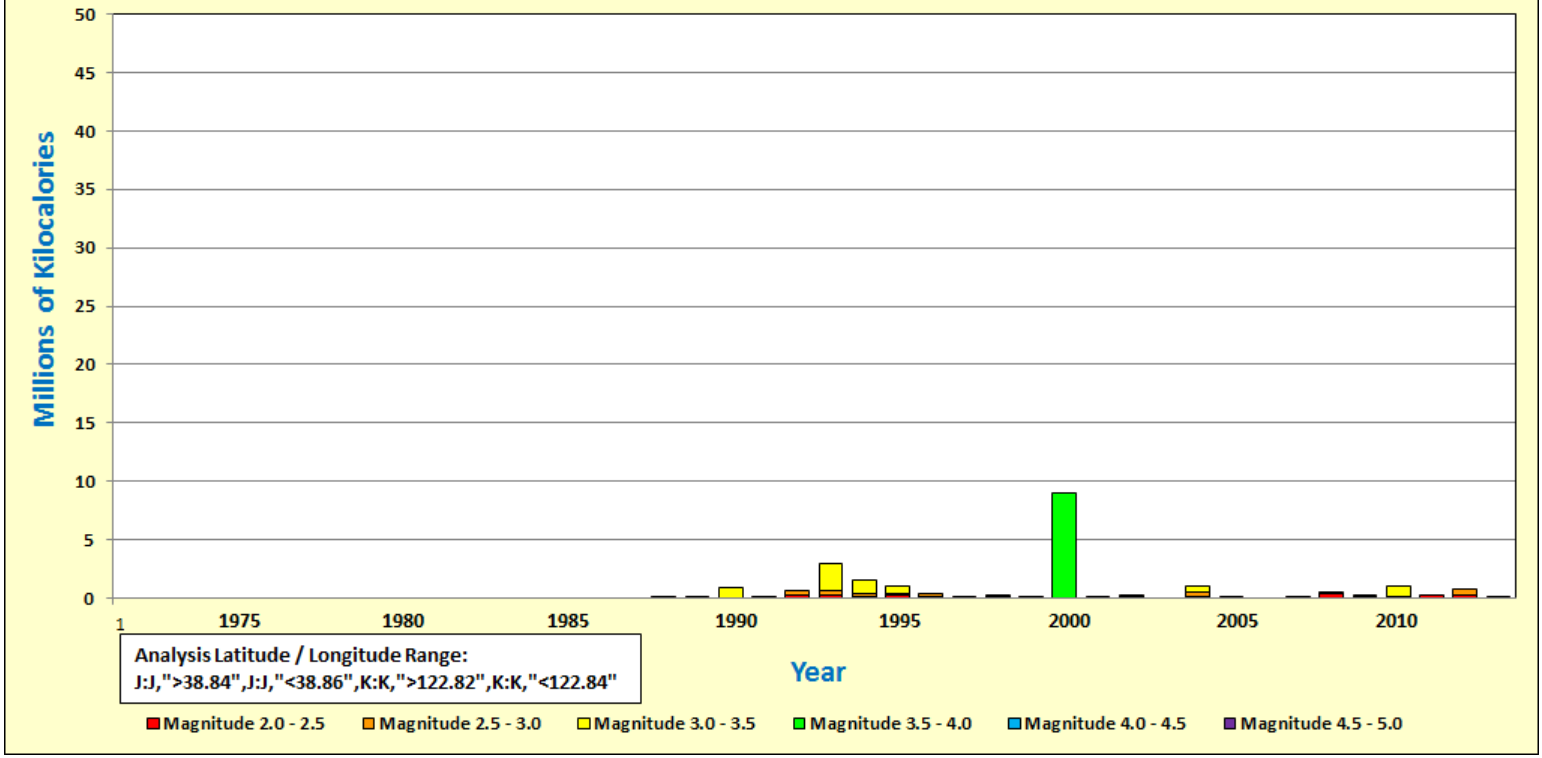
Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater



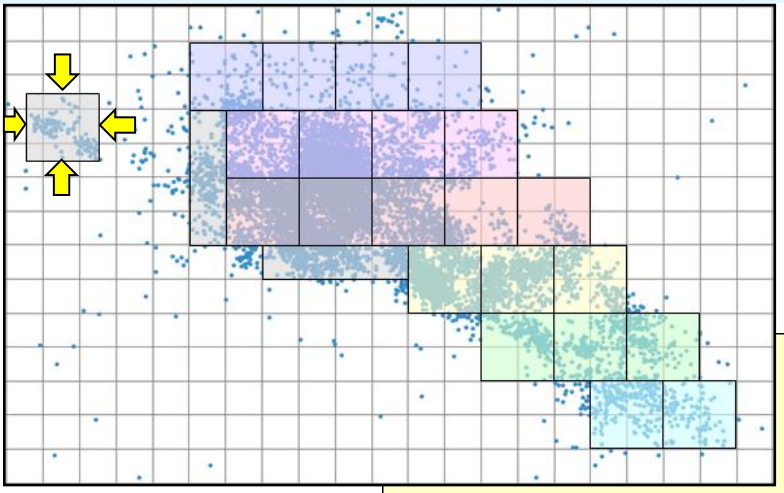
Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area

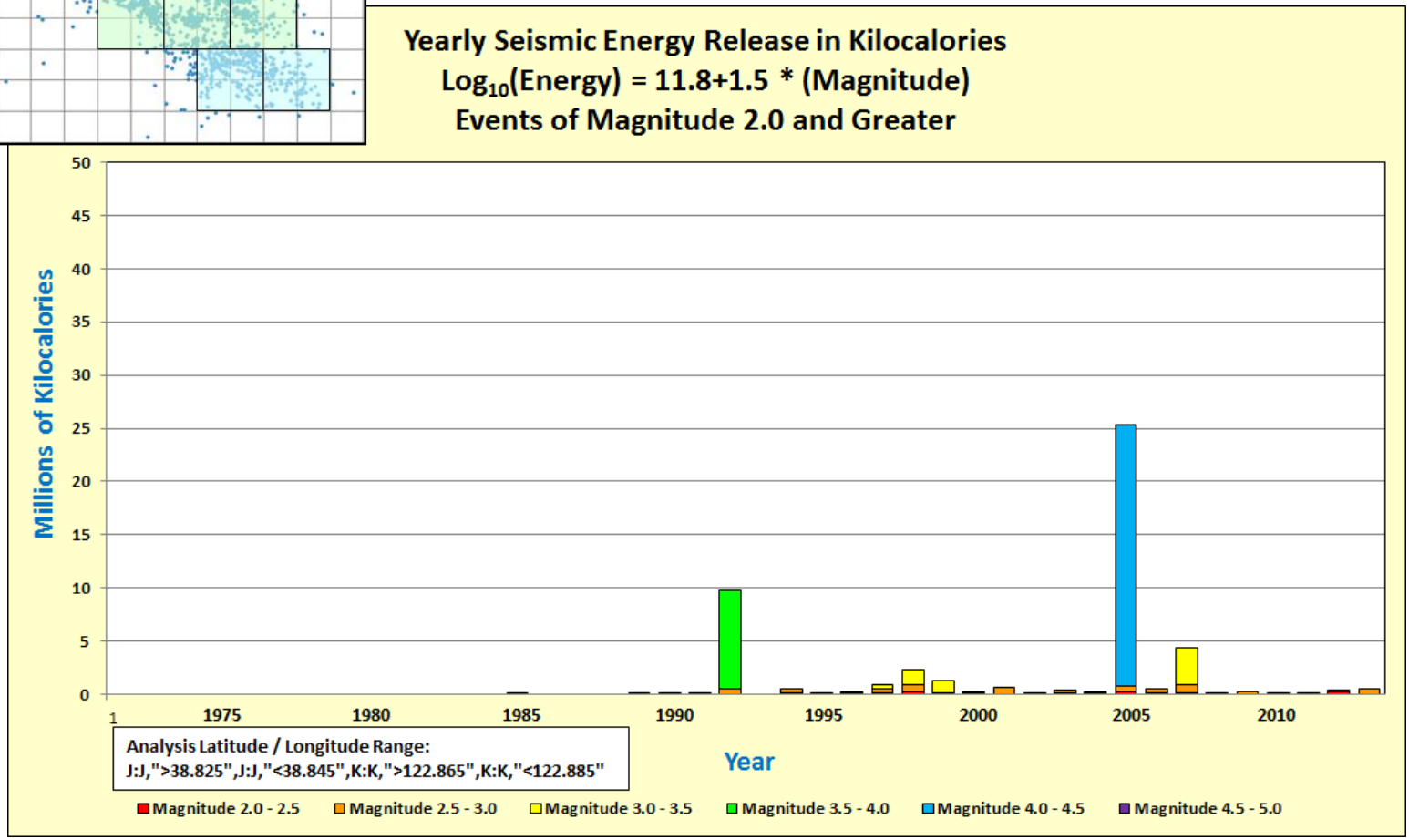


Yearly Seismic Energy Release in Kilocalories
Log_{10}(Energy) = 11.8+1.5 * (Magnitude)
Events of Magnitude 2.0 and Greater



Seismic Monitoring Advisory Committee Meeting
Field-wide Seismicity Analysis
Seismic Energy Release For Limited Area





Seismic Monitoring Advisory Committee
Correlated Strong Motion Trigger Analysis
SRGRP Report for 01 March 2013 to 31 August 2013

CALPINE NYSE CPN

One Month Shift From SMAC Reporting Period

Comparison of Peak Horizontal Acceleration (PGA) incidences during three time periods:

1. Pre-SRGRP (11 July to 18 November 2003)
2. During SRGRP (19 November 2003 to 28 February 2013)
3. Most recent biannual reporting period (1 March 2013 to 31 August 2013)

		MM Intensity→	I	II -- III	IV	V	VI
			PGA (g)	0.0017	0.014	0.039	0.092
Quantity	Station	Time Period	<=0.0017	to 0.014	to 0.039	to 0.092	to 0.18
Seismicity Count	Anderson Springs	Pre-SRGRP	87	207	19	4	1
		During SRGRP	3336	5080	480	136	22
		3/1/13-8/31/13	187	248	23	9	0
Seismicity Count	Cobb	Pre-SRGRP	89	46	6	3	0
		During SRGRP	4216	2445	203	38	7
		3/1/13-8/31/13	252	141	15	3	1
Annualized Seismicity Count	Anderson Springs	Pre-SRGRP	243	577	53	11.2	2.8
		During SRGRP	387**	558	53	14.9	2.4
		3/1/13-8/31/13	388	515	48	18.7	0
Annualized Seismicity Count	Cobb	Pre-SRGRP	266	138	18	9.0	0.0
		During SRGRP	483	280	23	4.4	0.8
		3/1/13-8/31/13	500	280	30	6.0	2.0

Accounts for ADSP station outage 20 July 2009 to 15 August 2009, 5 to 9 August 2010, 3 to 29 June 2011, 26 to 29 Dec 2012, and 8 to 11 February, 2012.

** Corrected for 1 September 2005 to 28 February 2006 when no events were recorded in this category because the ADSP trigger threshold was set at 0.002g.

* Accounts for COB station outage 10 November 2003 to 28 January 2004, 12 October 2009 to 6 November 2009, 3 to 10 February 2010, 18 April 2010 to 3 May 2010, 7 to 10 September, 2010, 3 to 12 September 2011, 20 Novemeber 2011 to 12 December 2011, 15 to 21 April 2012, and 26 October to 27 November 2012.

† Accounts for ADSP station outages for2 March to 10 March 2013.

Field-wide data provided by Calpine to URS Corporation

- LBNL / USGS Seismicity
- Strong Motion Measurements
- SRGRP Well Monthly Injection Volumes
- Seismicity Hotline Reports

Draft report completed by 12 November 2013

Final report with Calpine/URS revisions complete by ~ 21 November 2013

NCSN seismicity results consistent with Environmental Impact Report projections:

Since SRGRP initiation:	M ≥ 1.5	~50% increase
	M ≥ 2.0	~20% increase
	M ≥ 2.5	slight decrease
	M ≥ 3.0	~25% decrease

Days since most recent seismic events of magnitude ≥ 4.0:

- 249 days ago M 4.44 14 March 2013
- 562 days ago M 4.25 05 May 2012
- 644 days ago M 4.26 13 February 2012
- 933 days ago M 4.46 01 March 2011
- 1779 days ago M 4.30 04 January 2009 (nearly five years ago)

Seismic Monitoring Advisory Committee

Seismicity

Calpine 3D Visualization and 3D Model Building

Seismic event magnitude is dependent on:

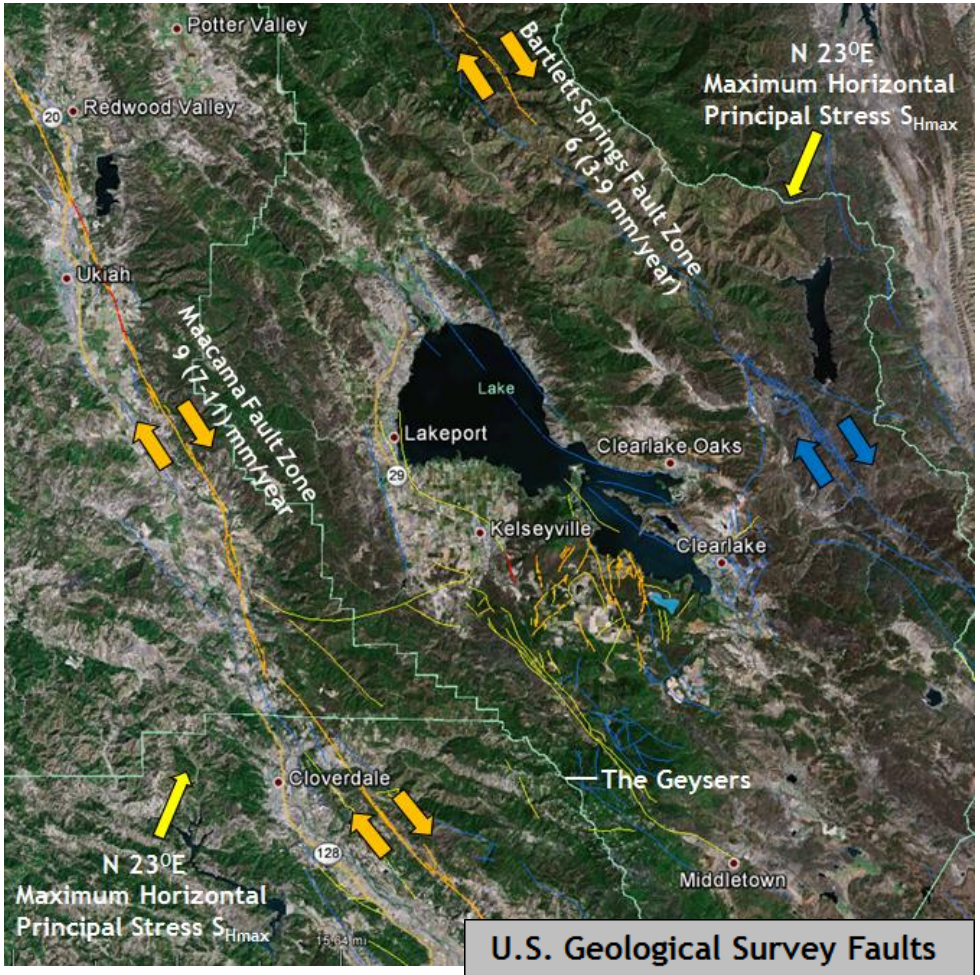
- Fault Area
- Average Slip
- Rock Rigidity

The Earth's crust is crossed by a network of pre-existing faults and fractures of various sizes.

Within The Geysers, CGS/USGS* mapped faults are inactive and restricted in area. This does limit the maximum possible seismic event magnitude.

A three-dimensional geological/geophysical model is currently under development for The Geysers geothermal field.

This 3D structural model (including pre-existing fault zones and fractures) will assist in understanding induced seismicity at The Geysers.

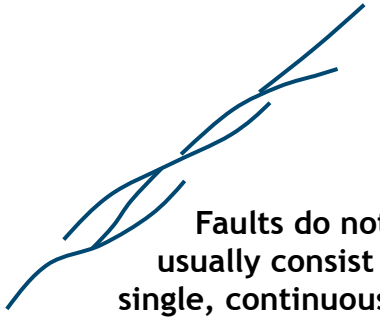


2012 Google Earth

* California Geological Survey, United States Geological Survey

Seismic Monitoring Advisory Committee

Calpine 3D Visualization and 3D Model Building



Faults do not usually consist of a single, continuous fracture.

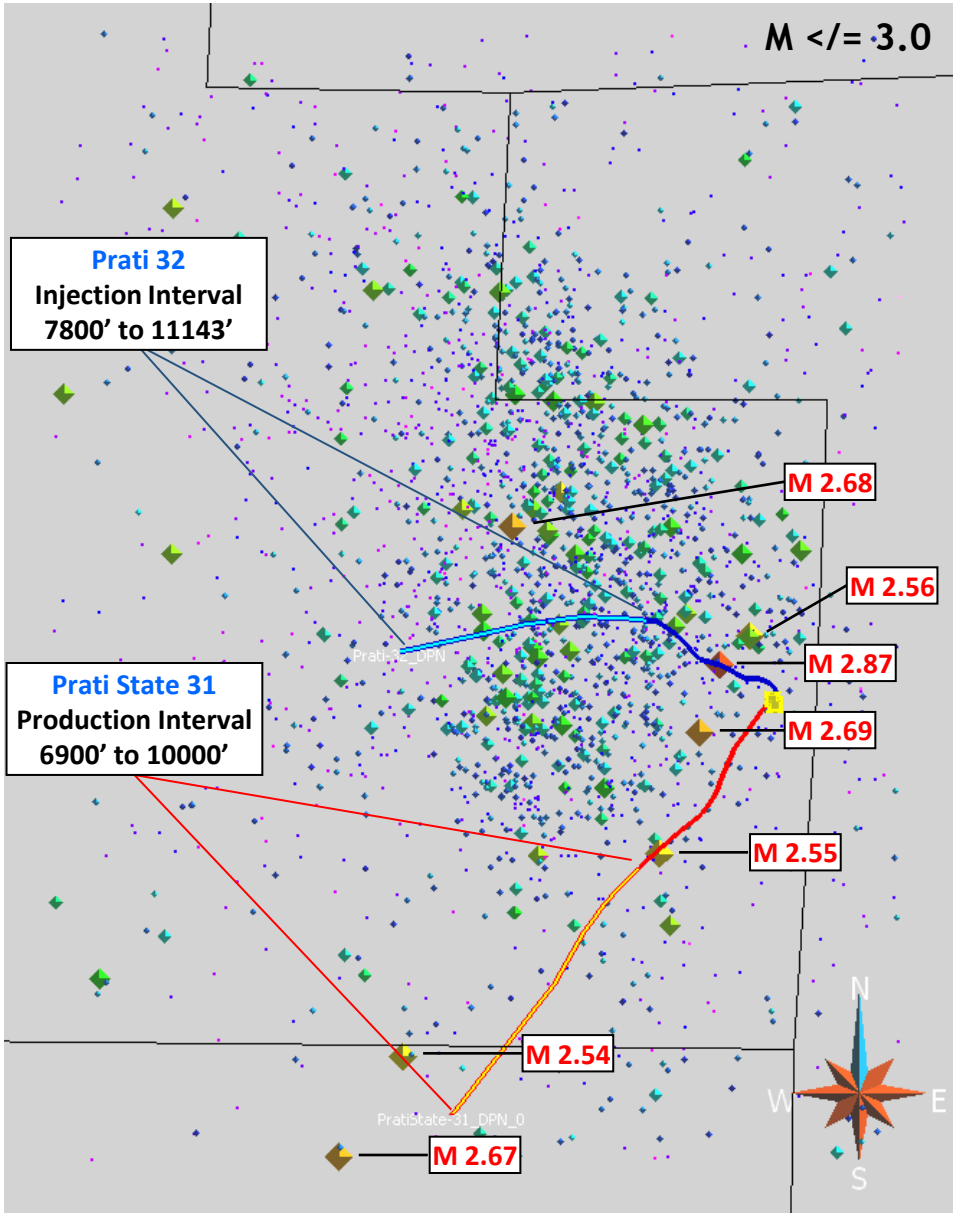
Geologists use the term *fault zone* when referring to the zone of complex deformation.

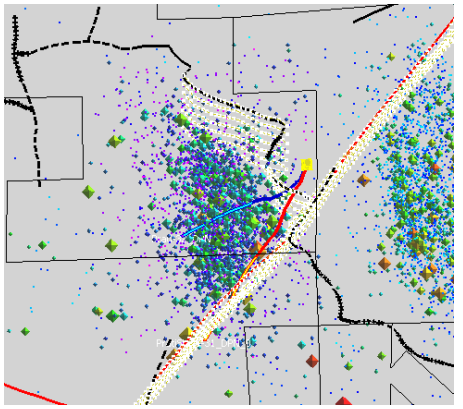
Seismicity analysis can assist in constraining *fault zones*.

Largest Seismic Event Associated with NW Geysers Enhanced Geothermal System

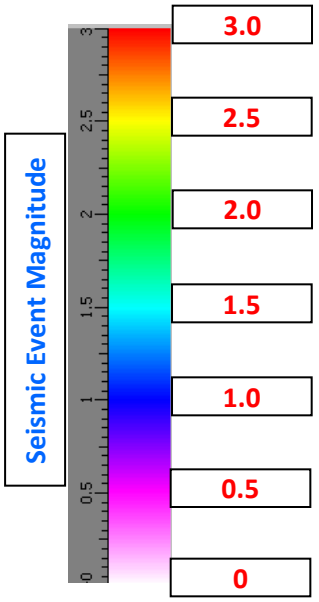
M 2.87

Six of Seven M >/= 2.5 Seismic Events Appear to "Define" SE Boundary



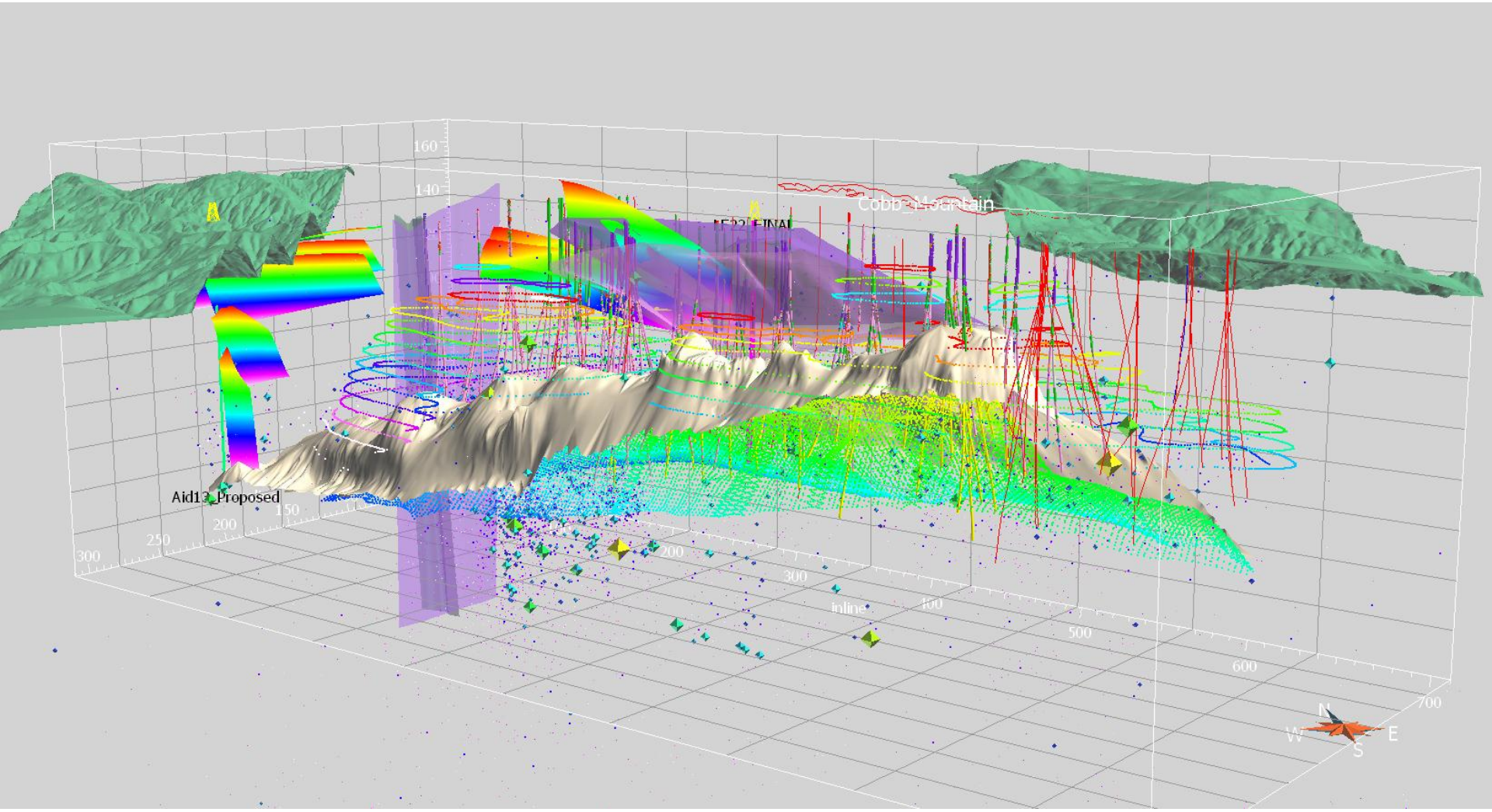


Prati 32 and Prati State 31 Area
Fault Zone Interpretation
Oblique View (west of vertical)



The Geysers
3D Visualization and Model Building

CALPINE
NYSE CPN

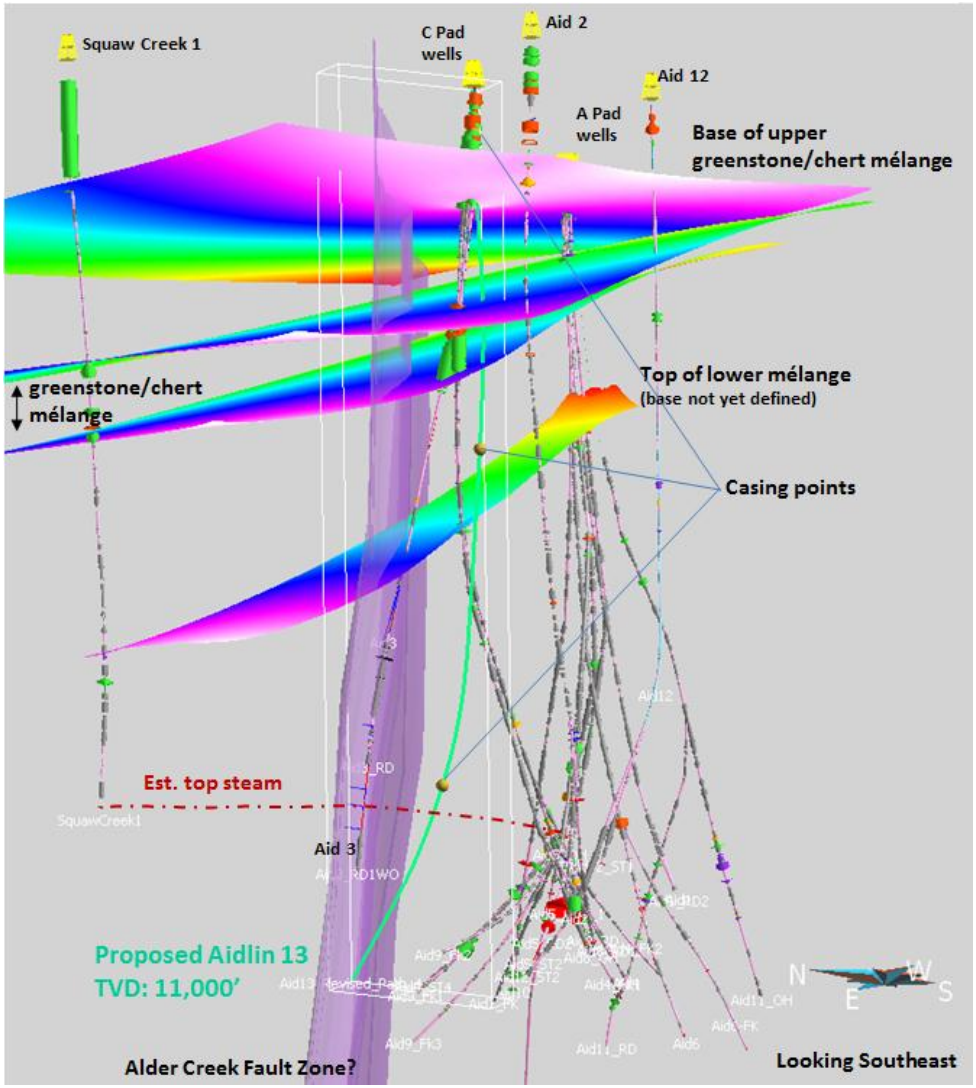


Well Tracks 1042 segments In 3D Project	Lithology and/or Steam Entries for 839 Wells	3D Surfaces (in progress)	3D Contours Top Steam	Fieldwide Seismicity	Fault Zones (in progress)	Well Planning Aidlin-13	Real-Time Drilling Assessment LF-22

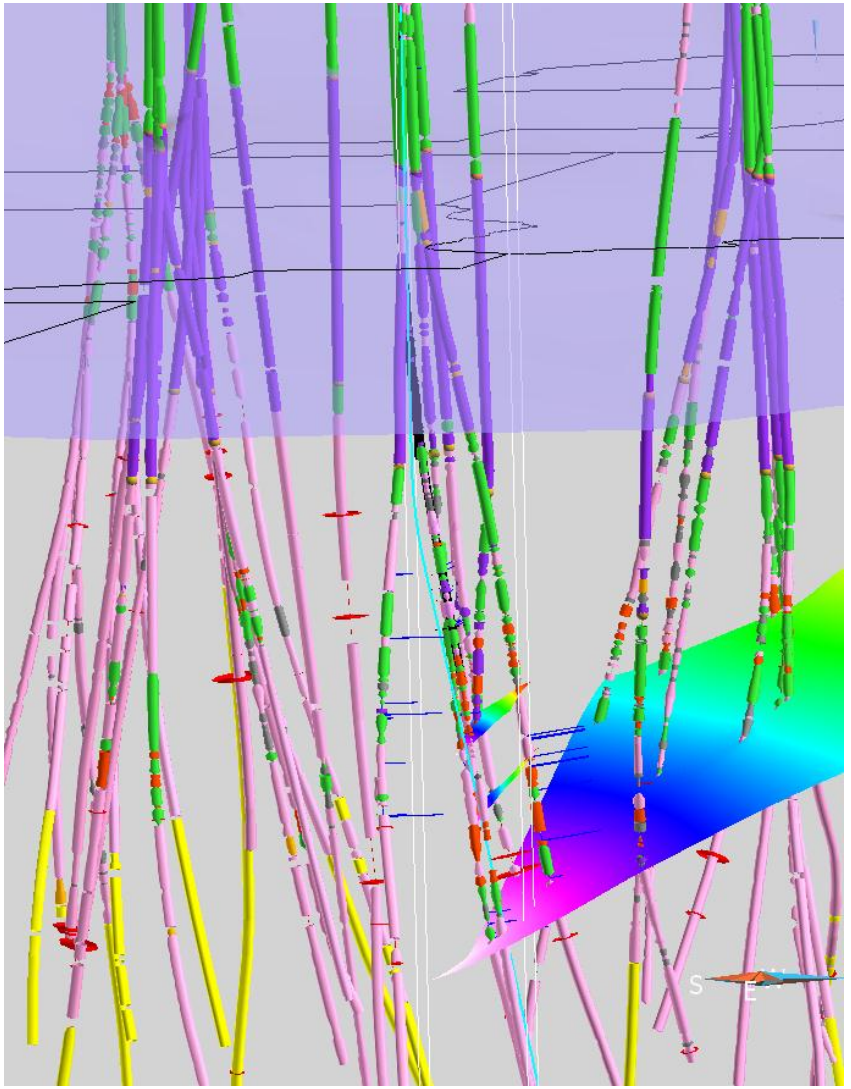
The Geysers
3D Visualization and Model Building

CALPINE
NYSE CPN

Aidlin 13 Well Planning



LF-22 Real-Time Drilling Assessment



Calpine Has Approved Funding For a Second Machine-Based Paradigm GOCAD / SKUA License

Seismic Monitoring Advisory Committee

Additional Seismicity Research at The Geysers

Lawrence Berkeley National Laboratory[1] / Calpine Corporation[2]

Development of a 3D hydrogeological and geomechanical model of an Enhanced Geothermal System using micro-earthquake and ground deformation data from a 1-year injection program

Pierre Jeanne[1], Jonny Rutqvist[1], Donald Vasco[1], Julio Garcia[2], Patrick F. Dobson[1], Mark Walters[2], Craig Hartline[2], Andrea Borgia[1].

(Submittals to American Geophysical Union, Stanford Geothermal Workshop, Geothermics)

Lawrence Berkeley National Laboratory[1] / Stanford University[2]

The Stress State of the Northwest Geysers Geothermal Field and Implication for Fault Controlled Fluid Flow

Katie Boyle[1] and Mark Zoback[2] (August 2013 submittal to Bulletin of the Seismological Society of America)

Lawrence Berkeley National Laboratory[1] / Calpine Corporation[2]

The Northwest Geysers EGS Demonstrations Project, California: Pre-stimulation Modeling and Interpretation of the Stimulation

Jonny Rutqvist[1], Patrick F. Dobson[1], Julio Garcia[2], Craig Hartline[2], Pierre Jeanne[1], Curtis M. Oldenburg[1], Donald W. Vasco[1], Mark Walters[2] (July 2013 submittal to Mathematical Geosciences in Geothermal Energy)*

The Geysers
Additional Seismic Monitoring and Research

CALPINE NYSE CPN

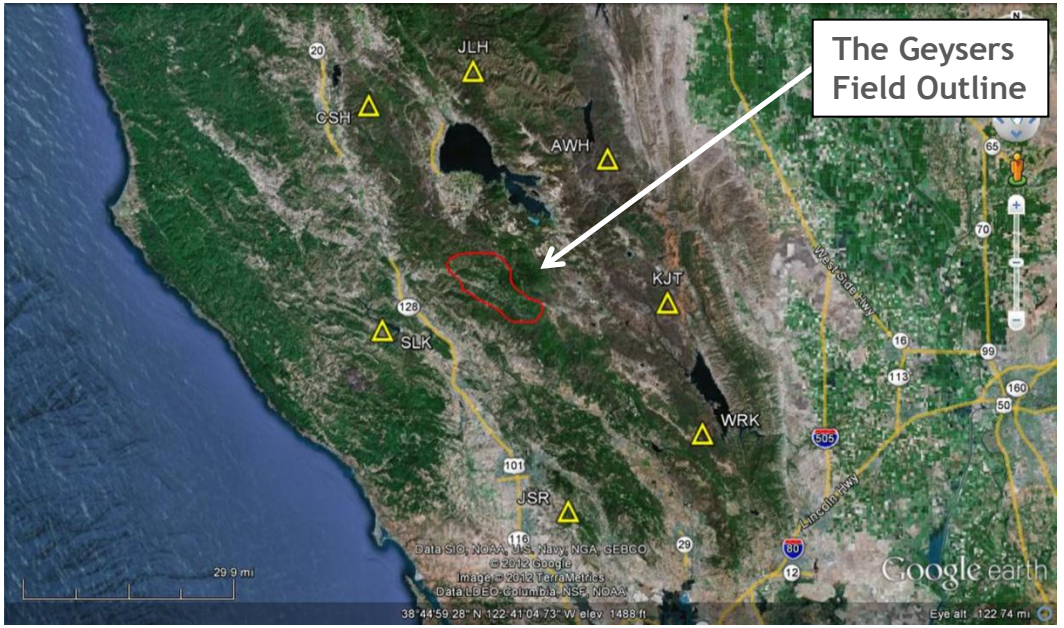
Research Collaboration with European GEISER Project
GFZ Potsdam, Germany
Coordinated with Dr. Roland Gritto; Array Information Technology

GEISER — Geothermal Engineering Integrating Mitigation of Induced Seismicity in Reservoirs

At The Geysers:

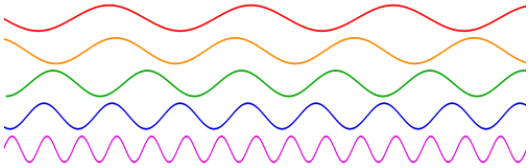
- 33 stations
- Data acquired Jan 2012 to May 2013
- 26 within field boundary
- 7 beyond field boundary

- Continuous monitoring
- Broadband

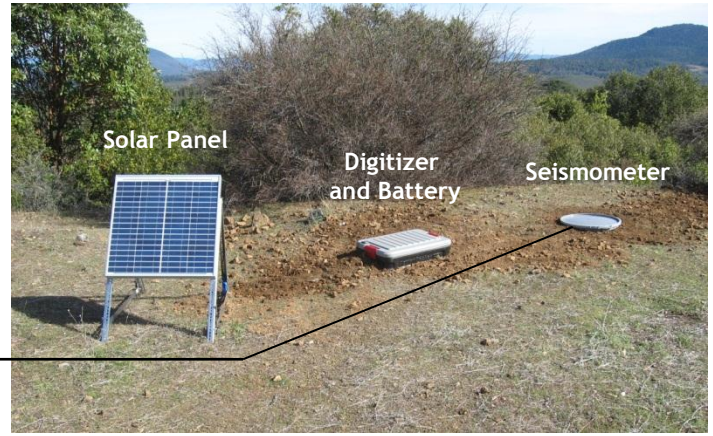


This seismic monitoring network contributes to worldwide GEISER consortium goals:

World-wide acquisition and analysis of induced seismicity data
Understand induced seismicity and geomechanical processes
Understand consequences of induced seismicity
Strategies for the mitigation of induced seismicity



Trillium Triaxial Seismometer
120 seconds per cycle
to
120 cycles per second



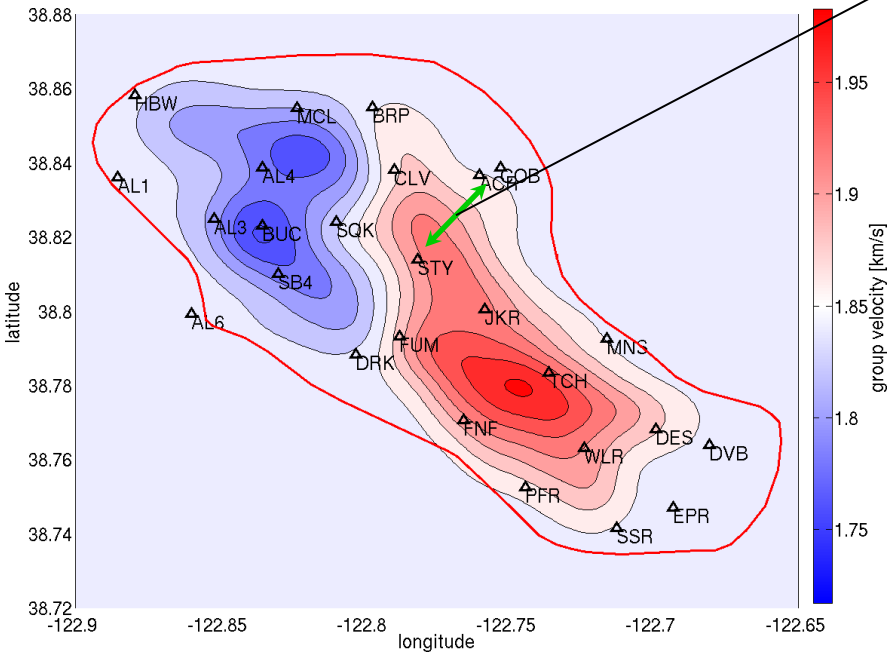
The Geysers
Additional Seismic Monitoring and Research

CALPINE NYSE CPN

Research Collaboration with European GEISER Project
GFZ Potsdam, Germany
Coordinated with Dr. Roland Gritto; Array Information Technology

GEISER

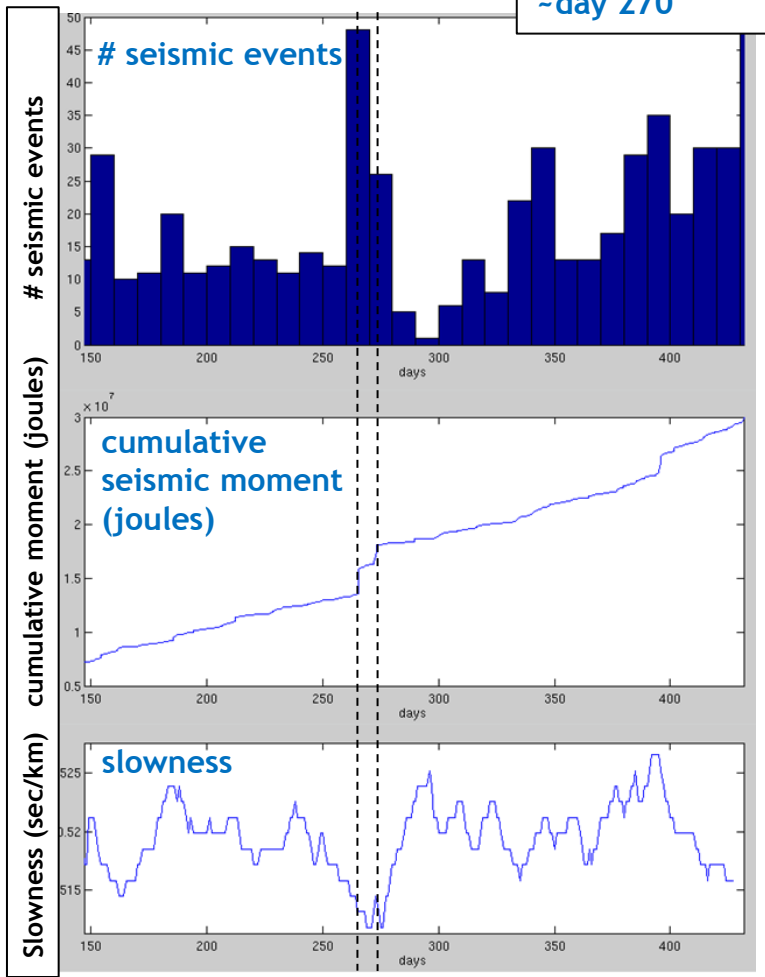
Seismic Data Analysis
Ambient Noise Processing (Cross-Correlation)
Sebastian Specht at GFZ Potsdam



Rayleigh Surface Wave Variation
Group Velocity for 1 Hz (~1km depth)

Station STY to COB
(0.5 Hz)

Seismic event count increase and seismic moment release correlate with *temporary* velocity change at ~day 270



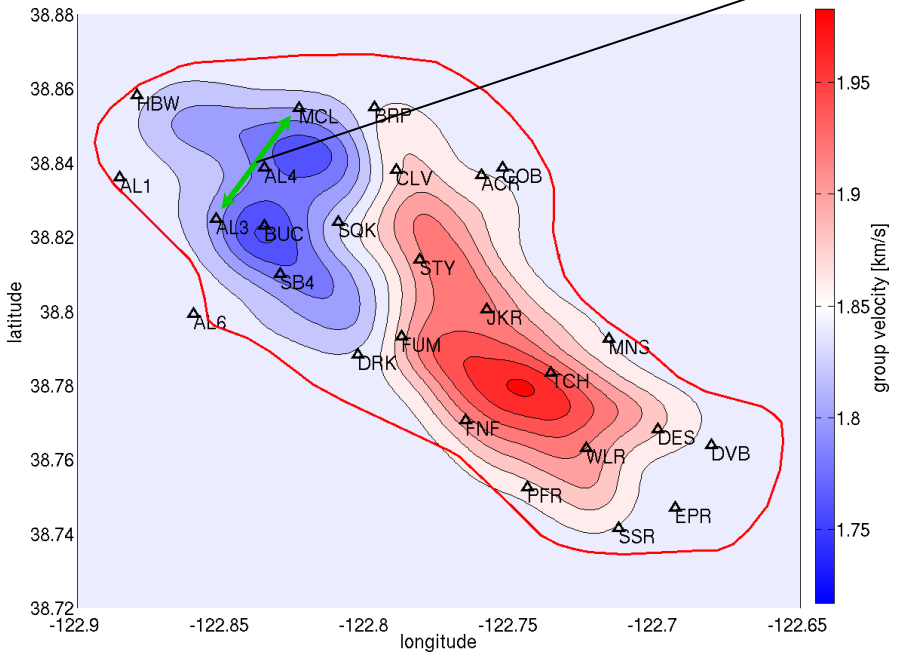
The Geysers
Additional Seismic Monitoring and Research

CALPINE NYSE CPN

Research Collaboration with European GEISER Project
GFZ Potsdam, Germany
Coordinated with Dr. Roland Gritto; Array Information Technology

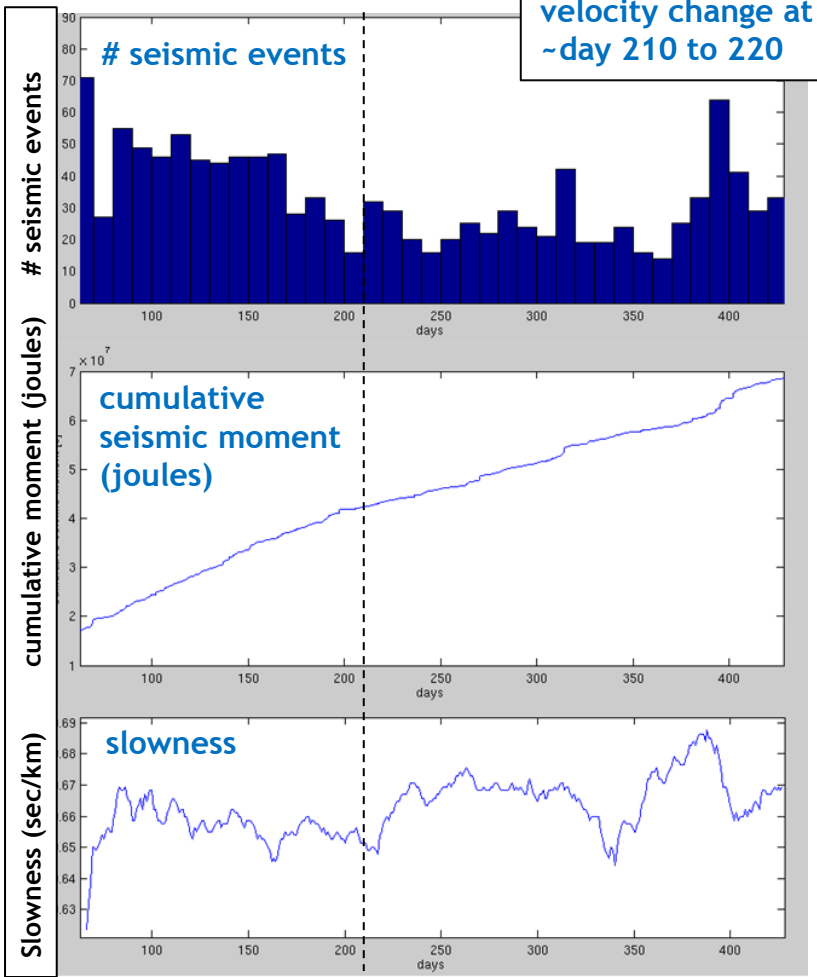
GEISER

Seismic Data Analysis
Ambient Noise Processing (Cross-Correlation)
Sebastian Specht at GFZ Potsdam



Rayleigh Surface Wave Variation
Group Velocity for 1 Hz (~1km depth)

Station STY to COB
(1.0 Hz)



Seismic event count decrease and seismic moment rate change correlate with longer-term velocity change at ~day 210 to 220

The Geysers
Additional Seismic Monitoring and Research
Limited Progress Due To Government Funding Reductions (Sequester)

CALPINE NYSE CPN

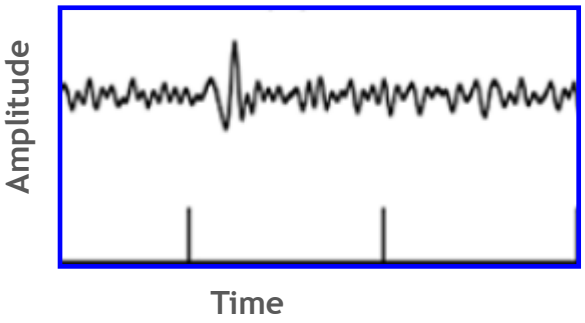
LBNL Sensors – Conversions from Surface to Borehole Monitoring

Several existing boreholes allow recording with limited near-surface noise (wind, rain, machinery, …)

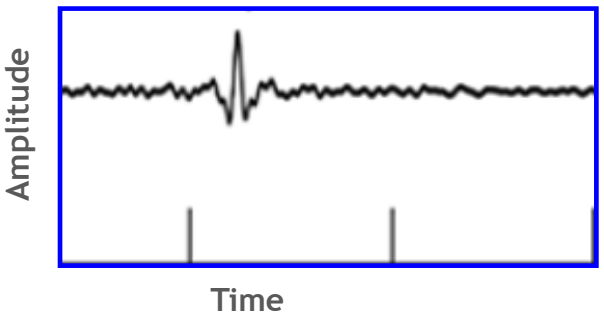
Coordinated with Dr. Ernie Majer (LBNL)

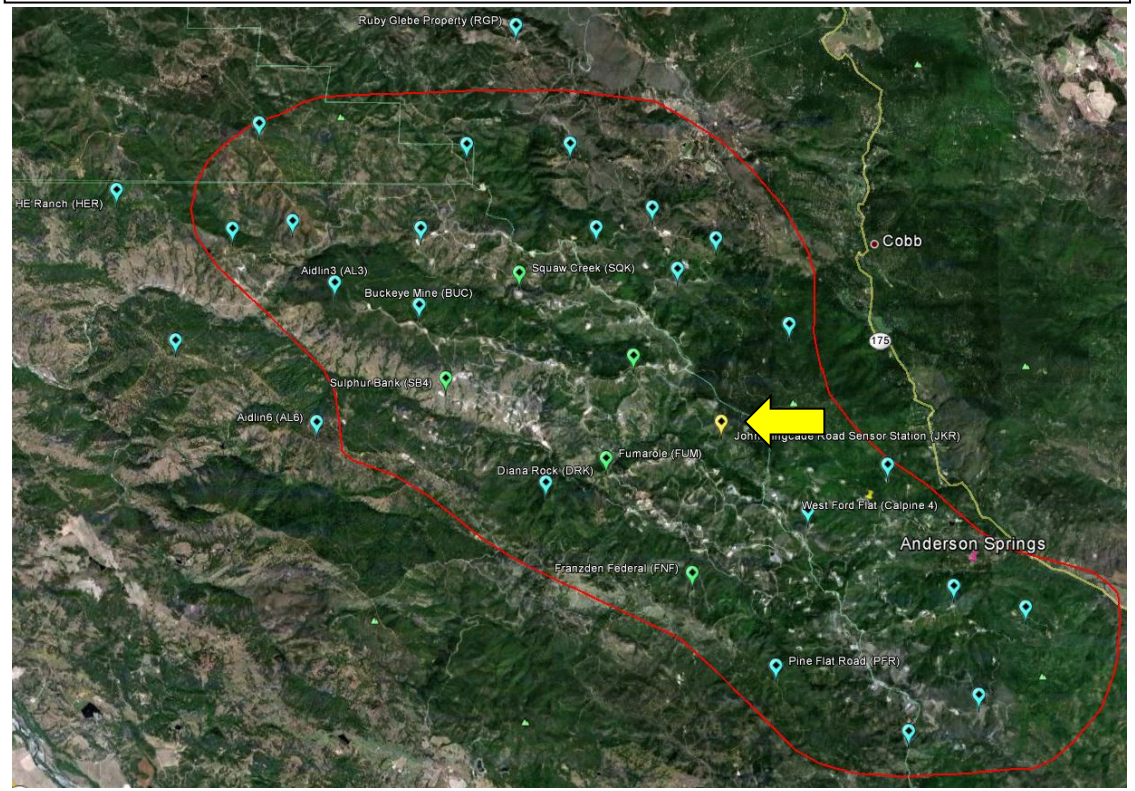
Yellow	Borehole sensor installed and evaluated (John Kingcade Ridge)
Green	Intended conversion to borehole sensor
Blue	Remaining LBNL stations

Surface Sensor – More noise



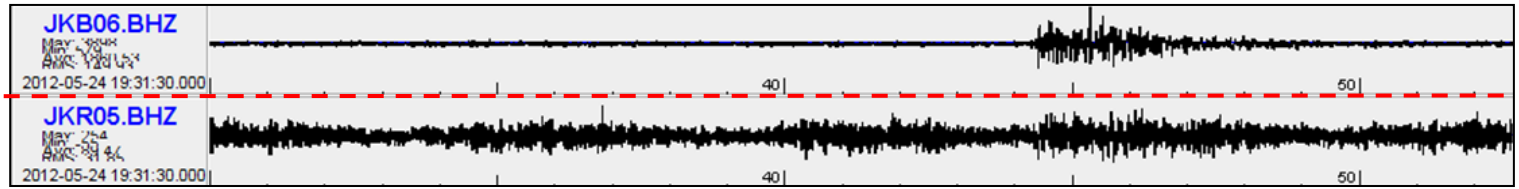
Borehole Sensor – Less noise





JKR Borehole

JKR Surface



The Geysers
Additional Seismic Monitoring and Research
Borehole Transfer Agreement Nearly Completed

CALPINE NYSE CPN

AltaRock Microseismic Array (MSA)

AltaRock will transfer southeast Geysers seismic monitoring boreholes to Calpine.
Calpine will collaborate with LBNL concerning additional borehole seismic monitoring research.

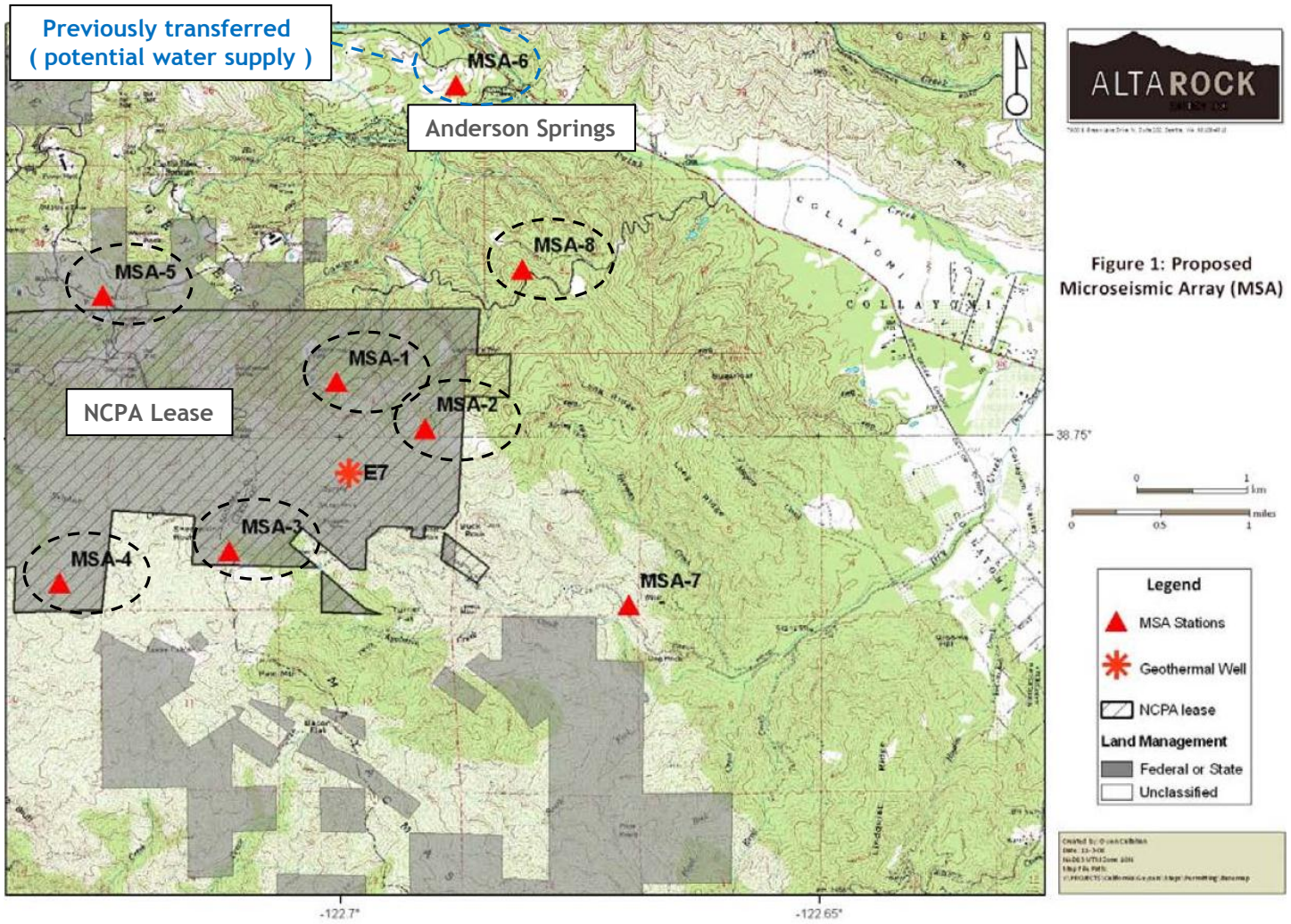


Figure 1: Proposed Microseismic Array (MSA)

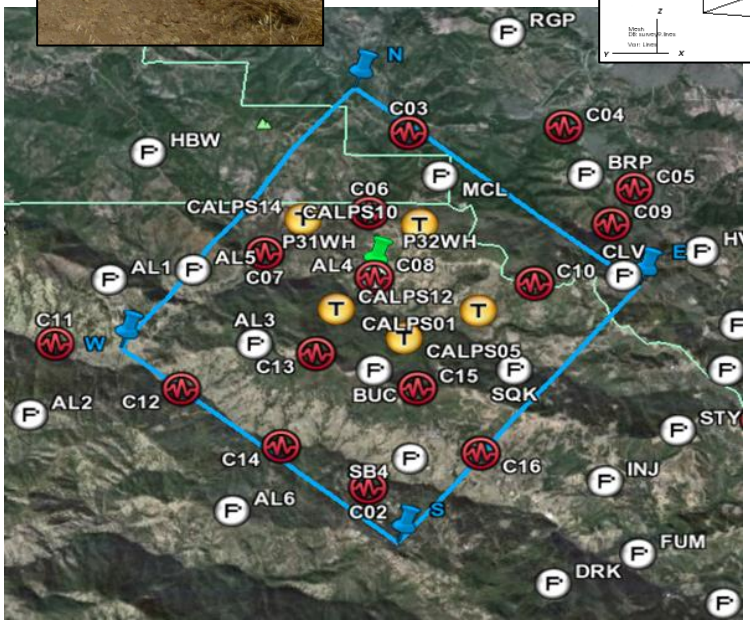
Additional Seismic Monitoring and Research

High Resolution Reservoir Monitoring and Modeling with Micro-earthquake Data and Rock Physics

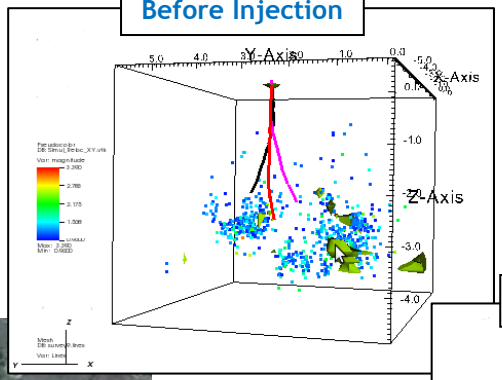
Lawrence Hutchings, Steve Jarpe, Katie Boyle, Brian Bonner, Ankit Sinigh, Gisela Viegas, Aurelie Guilhem, Hunter Philson, and Ernest Majer

23 seismic monitoring instruments (permanent *and* temporary station data processed simultaneously)
Within 6km x 6km area surrounding NW Geysers Enhanced Geothermal System Demonstration Project

15 Stations
Low cost
Easy Installation
Accurate Results

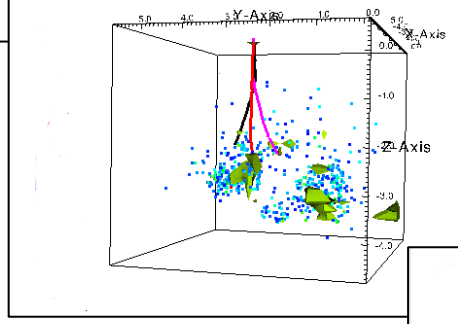


Before Injection

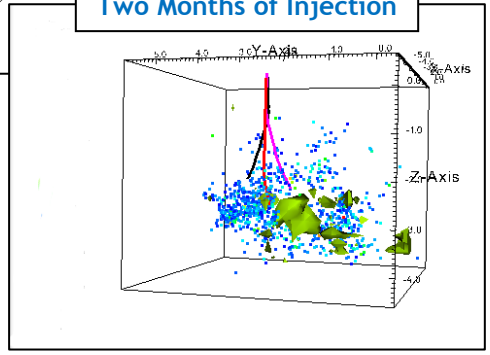


Seismicity Hypocenters (Blue)
Velocity Anomalies (Green)

One Month of Injection



Two Months of Injection



Seismic Monitoring Advisory Committee
Calpine Community Outreach

- **Voicemail Hotline (877) 4-GEYSER**
  Calls now transcribed daily; Hotline active since 16 December 2003
  Compared with strong-motion measurements for Cobb and Anderson Springs stations

- **Detailed Reporting of Events of M>/= 4.0 (or M >/=3.5; MMI >/= 5; PGA >/= 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
  Updated expansion including Enhanced Geothermal System (EGS) exhibits

- **Geysers Field Tours**
  Free group tours approximately monthly spring through fall (www.geysers.com)

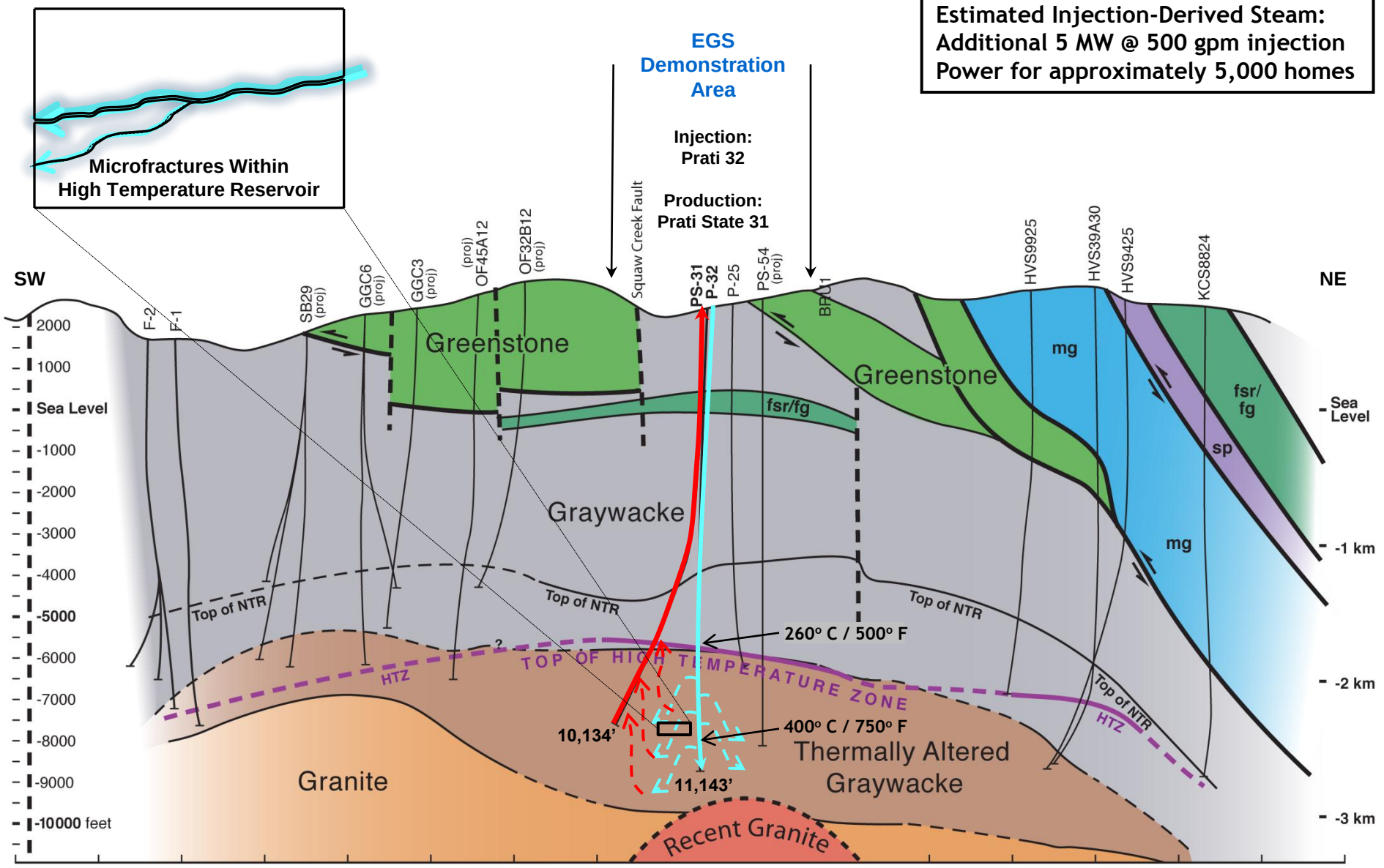
- **Community Newsletter**
  2-3 publications yearly by email and posted to www.geysers.com

- **Northwest Geysers ENHANCED GEOTHERMAL SYSTEM Demonstration Community Updates**
  Six community updates since Oct 2011 project start

The Geysers
Northwest Geysers Enhanced Geothermal System Demonstration
Location and Technique

CALPINE NYSE CPN

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



The Geysers
Northwest Geysers Enhanced Geothermal System Demonstration
Successful Research Collaboration with the U.S. Department of Energy

CALPINE
NYSE CPN

- Prati State 31 and Prati 32 were recompleted as a production-injection well pair in September 2011 (respectively).
- Injection into Prati 32 began on October 6, 2011 and has been continuously monitored.
- Continuous injection of water at rates of 400, 700 and 1000 gallons per minute into 750^{O}F rock at a depth of 11,000 feet.
- A microseismicity "cloud" began to form almost immediately with the Prati 32 water injection.
- An Enhanced Geothermal System has been created in hot dry rock. The evidence for this comes from the analysis of:
  - Microseismicity data
  - Chemical isotope data
  - Temperature data
  - Pressure data
  - Prati State 31 flow response
- A connection has been established between the deep, hot-dry rock reservoir and the overlying normal temperature reservoir.

Selected Wells:

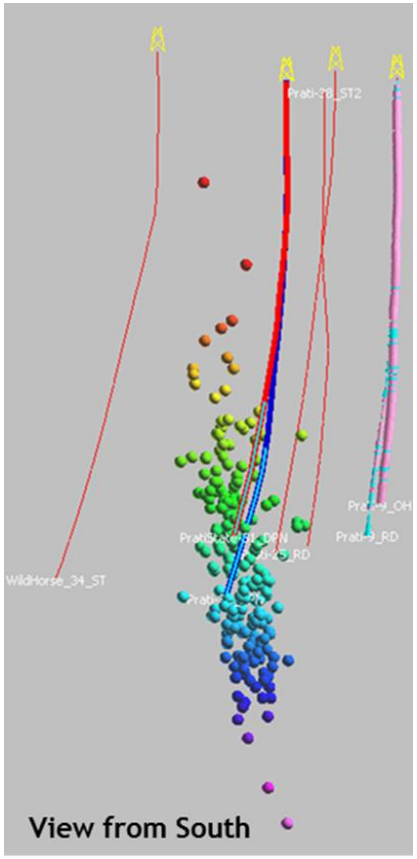
Prati State 31

656 ^{O}F 1983

Prati 32

600 ^{O}F 1985

750 ^{O}F 2010 - Deepened

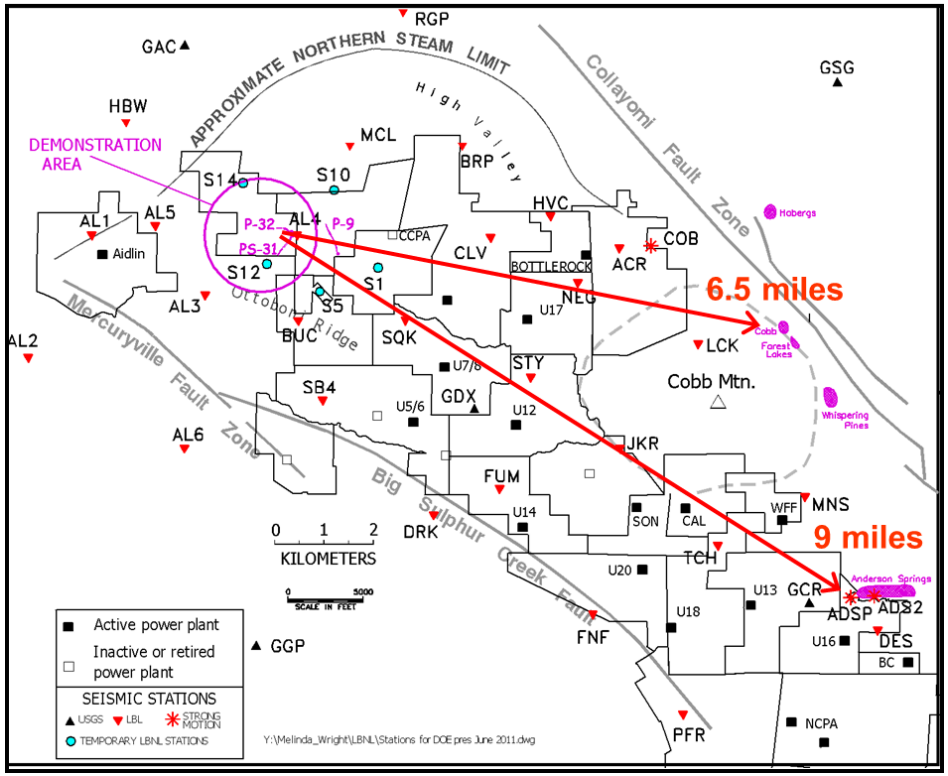


Negligible Strong Motion Instrument Responses at Anderson Springs and Cobb From Maximum Seismic Event (M 2.87)

Magnitude 2.87 Event
31 May 2012, 05:31:26 UTC

<u>Anderson Springs:</u>
Geometric Mean (Horizontal Components):
1.53 cm/sec^2 = 0.16% of gravitational acceleration
Modified Mercalli Intensity: I
Not Felt; No Potential Damage

<u>Cobb:</u>
Geometric Mean (Horizontal Components):
1.38 cm/sec^2 = 0.14% of gravitational acceleration
Modified Mercalli Intensity: I
Not Felt; No Potential Damage



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