



America's Premier Competitive Power Company  
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# Seismic Monitoring Advisory Committee Meeting

01 April 2022 to 30 September 2022 Reporting Period

Calpine Geothermal Visitor Center

Thursday 10 November 2022

Craig Hartline  
Senior Geophysicist  
Geysers Power Company, LLC



# Seismic Monitoring Advisory Committee Meeting

## Presentation Agenda

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- Seismic Monitoring Networks
  - LBNL / Geysers Power Company Seismic Monitoring Network
  - LBNL / Geysers Power Company Strong Motion Network
  - USGS / Northern California Seismic Network
  - Upgrades to Radio Telemetry Systems
- Fieldwide Induced Seismicity Analysis
  - Water Injection and Induced Seismicity Animation
- 3D Structural Model
- Strong Motion Data Analysis
  - Peak Ground Acceleration vs. Hypocentral Distance
- Community Hotline
  - Seismic Events of Concern
  - 28 June 2022 Magnitude 4.19 Seismic Event Series

# Geysers Geothermal Field, Nearby Communities and Seismic Monitoring Networks

● Lawrence Berkeley National Laboratory  
2003 installation; continuing upgrades  
34 stations

Magnitude 0.8 Threshold \*

Primary Contacts: Dr. Seiji Nakagawa  
Dr. Ernie Majer

● Strong Motion Accelerometers

● 2017/18 Nanometrics installation (2)

● 2020 Q1 Nanometrics installation (2)

0.1% of Gravitational Acceleration Threshold

Primary Contacts: Ramsey Haught  
Jarpe Data Solutions

● US Geological Survey Regional Network

1970's installation; several upgrades

7 contributing stations

Magnitude 1.5 Threshold \*

Primary Contacts: Dr. Lind Gee / Lynn Dietz  
Dr. David Oppenheimer

Productive Steam Reservoir Outline

"Major" Roads

**Northwest Geysers**  
Radio Repeater Relocation/Upgrade  
Q4 2021 to Q4 2022

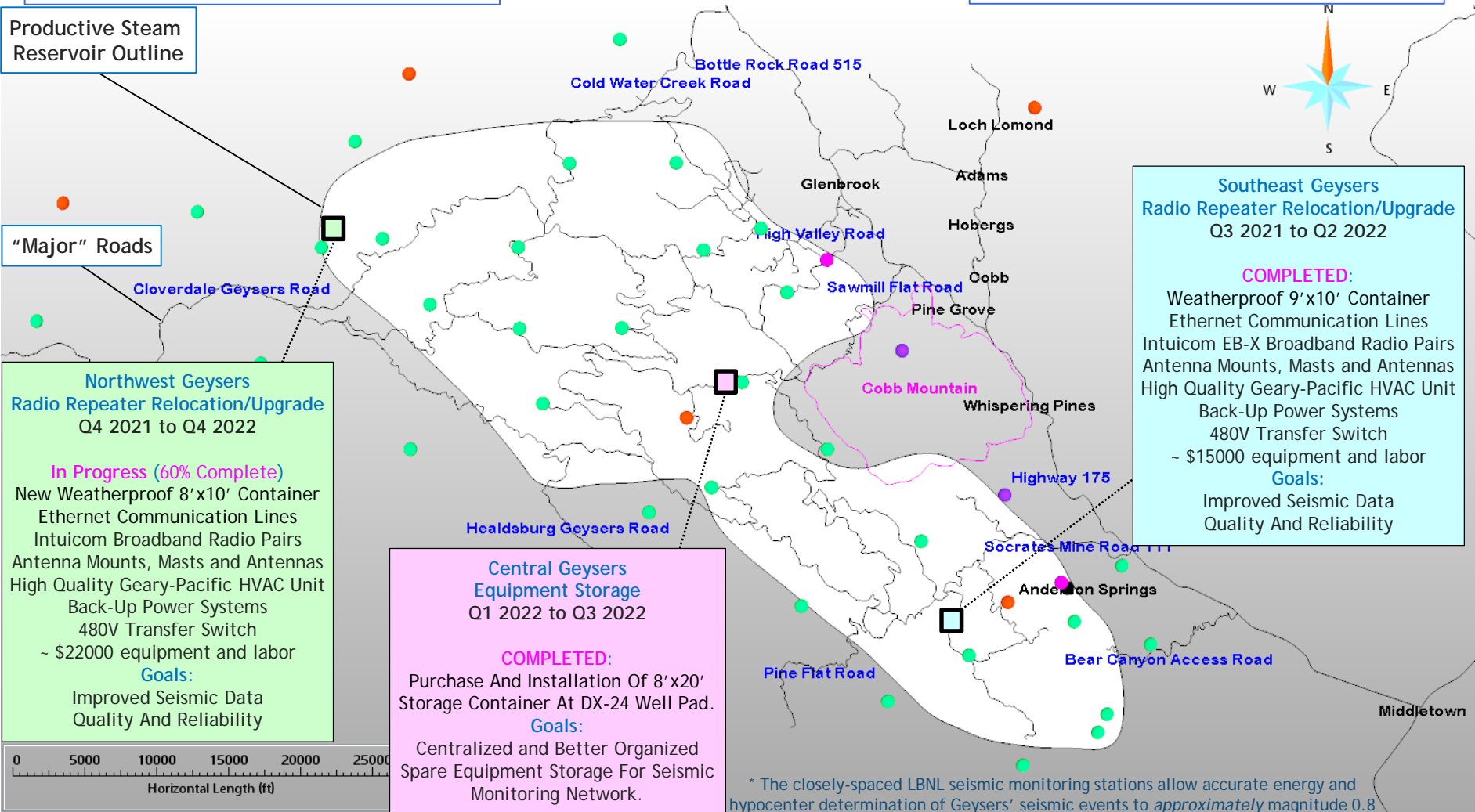
**In Progress (60% Complete)**  
New Weatherproof 8'x10' Container  
Ethernet Communication Lines  
Intuicom Broadband Radio Pairs  
Antenna Mounts, Masts and Antennas  
High Quality Geary-Pacific HVAC Unit  
Back-Up Power Systems  
480V Transfer Switch  
~ \$22000 equipment and labor  
**Goals:**  
Improved Seismic Data  
Quality And Reliability

**Central Geysers**  
Equipment Storage  
Q1 2022 to Q3 2022

**COMPLETED:**  
Purchase And Installation Of 8'x20'  
Storage Container At DX-24 Well Pad.  
**Goals:**  
Centralized and Better Organized  
Spare Equipment Storage For Seismic  
Monitoring Network.

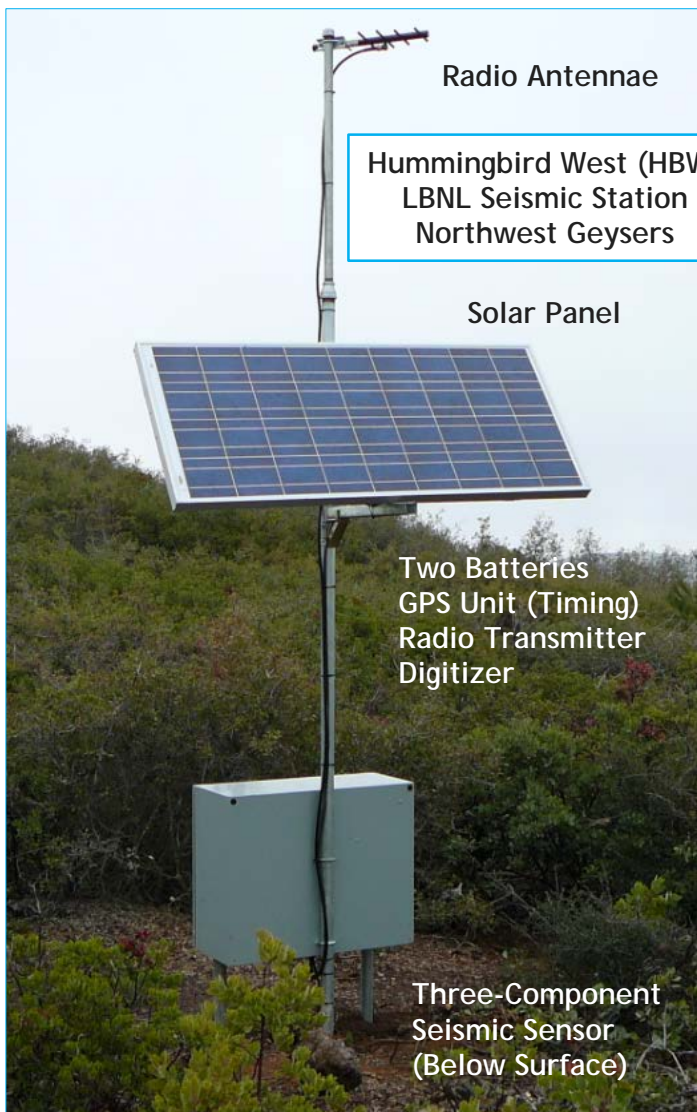
**Southeast Geysers**  
Radio Repeater Relocation/Upgrade  
Q3 2021 to Q2 2022

**COMPLETED:**  
Weatherproof 9'x10' Container  
Ethernet Communication Lines  
Intuicom EB-X Broadband Radio Pairs  
Antenna Mounts, Masts and Antennas  
High Quality Geary-Pacific HVAC Unit  
Back-Up Power Systems  
480V Transfer Switch  
~ \$15000 equipment and labor  
**Goals:**  
Improved Seismic Data  
Quality And Reliability



\* The closely-spaced LBNL seismic monitoring stations allow accurate energy and hypocenter determination of Geysers' seismic events to approximately magnitude 0.8





Intuicom Radios  
Transmitter-Receiver  
Pairs

Taurus Digitizer  
Analog-to-Digital Data

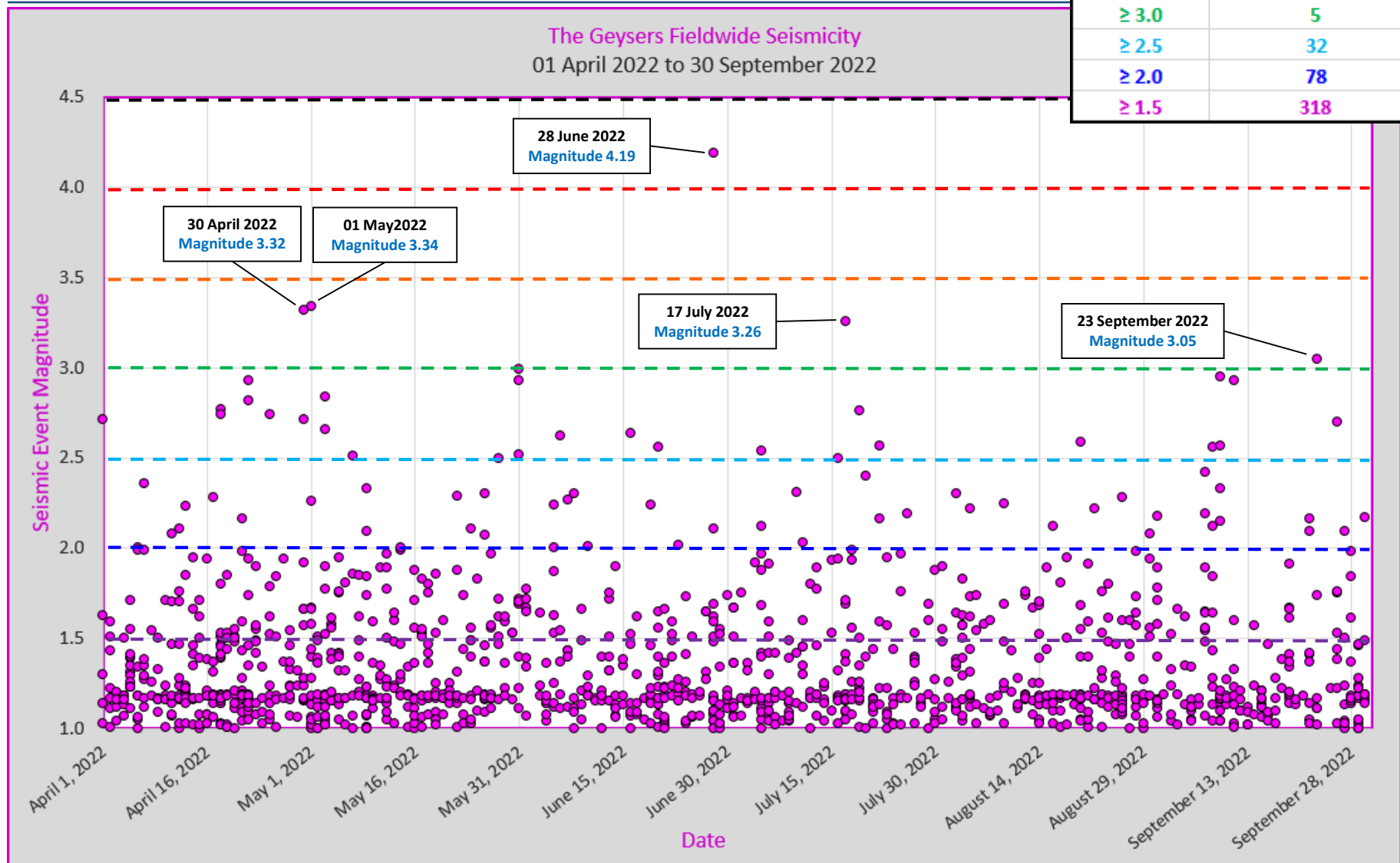


Nanometrics Titan  
Three-Component  
Accelerometer  
Strong Motion

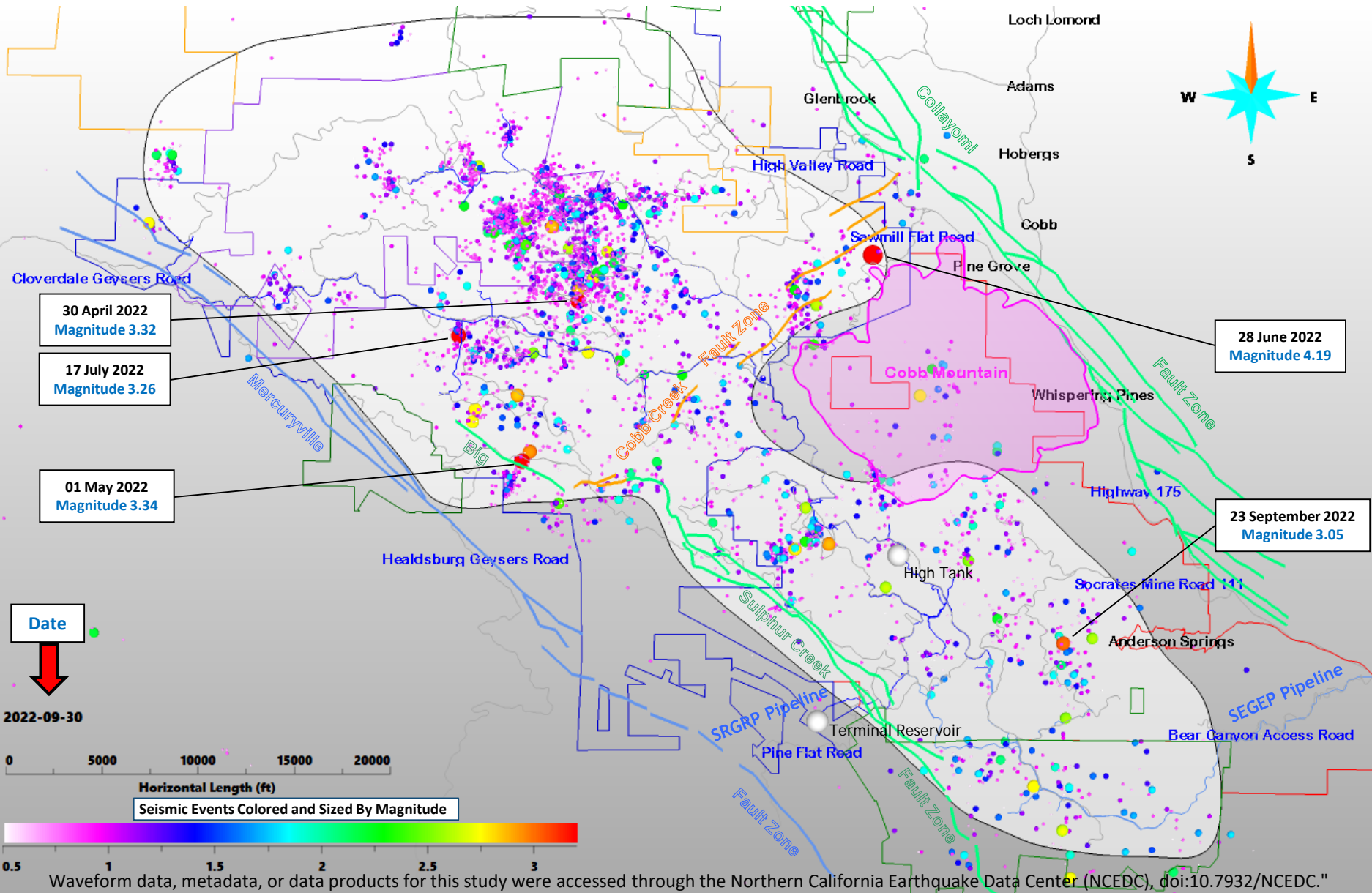
Geospace Three-Component 2 Hz Sensor  
Conventional

# Field-wide Seismicity Analysis From 01 April 2022 to 30 September 2022

Magnitude	Number Of Events
≥ 4.5	0
≥ 4.0	1
≥ 3.5	1
≥ 3.0	5
≥ 2.5	32
≥ 2.0	78
≥ 1.5	318



# Field-wide Seismicity Animation At Two Week Interval - Color Scaled By Magnitude



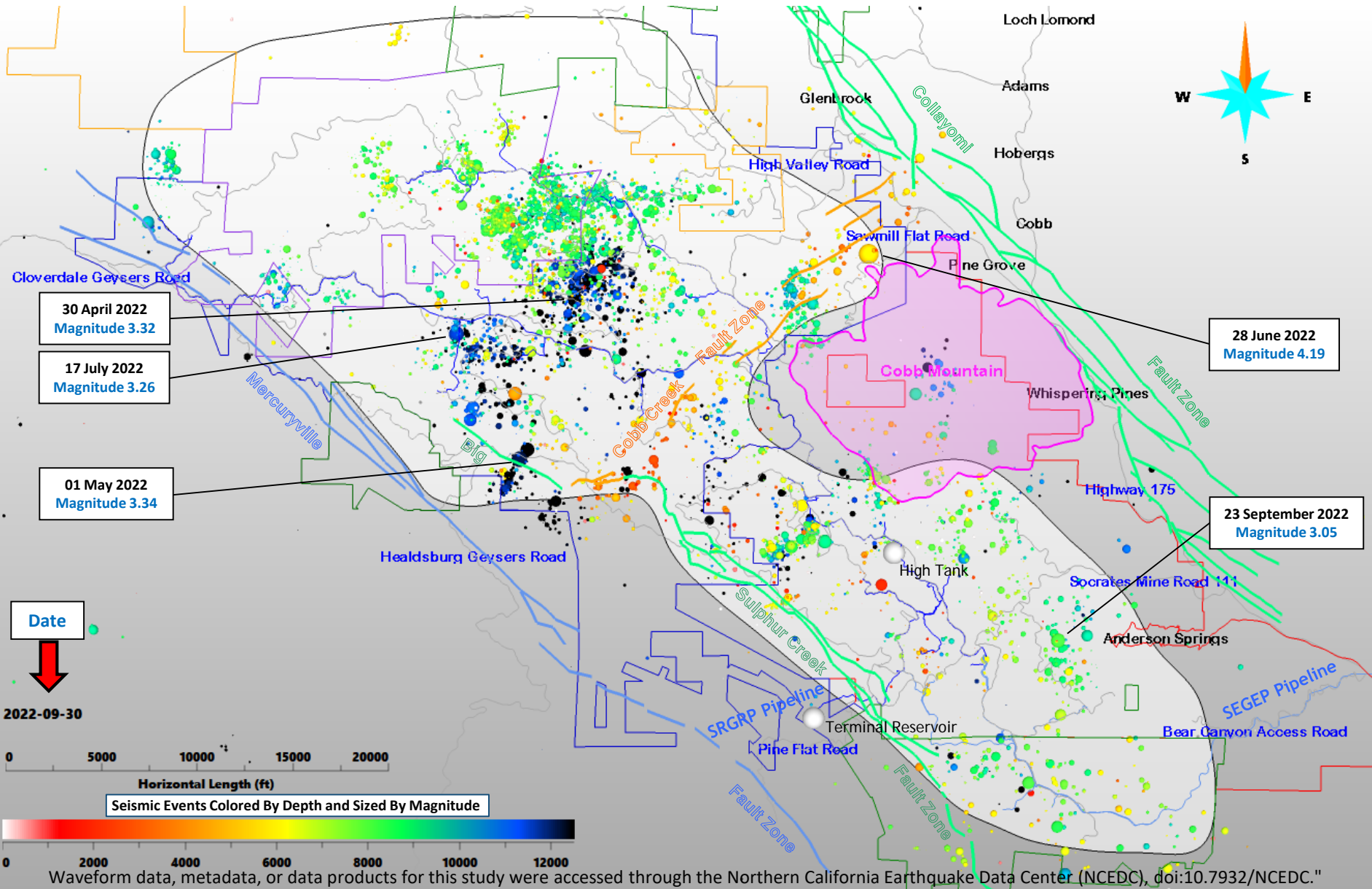
Waveform data, metadata, or data products for this study were accessed through the Northern California Earthquake Data Center (NCEDC), doi:10.7932/NCEDC."



Seismic Monitoring Advisory Committee Meeting  
 01 April 2022 to 30 September 2022 Reporting Period Craig Hartline Senior Geophysicist



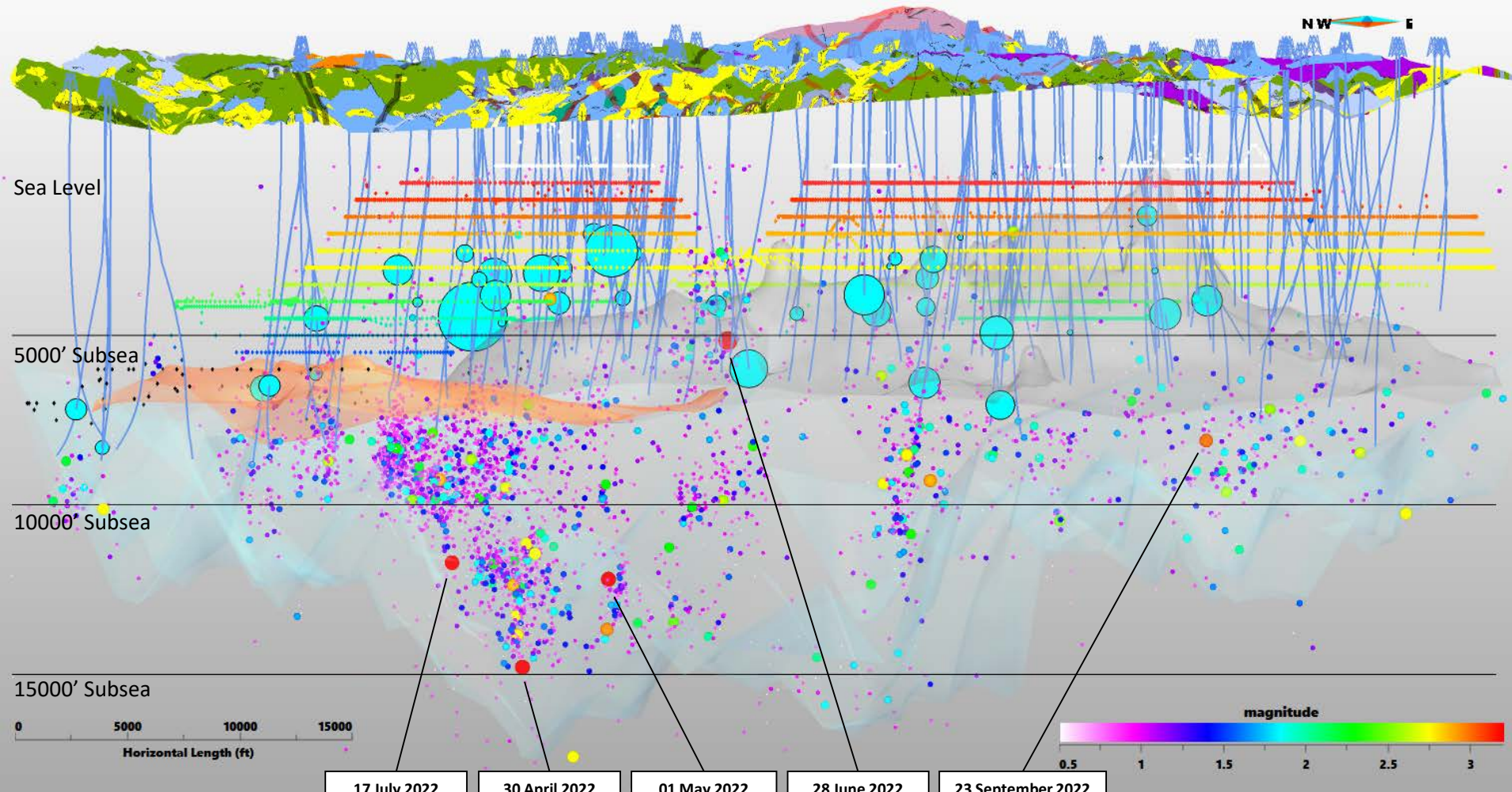
# Field-wide Seismicity Animation At Two Week Interval - Color Scaled By Magnitude



# Monthly Water Injection And Induced Seismicity Animation From 01 April 2022 Through 30 September 2022

View From Southwest

Date  2022-09-30



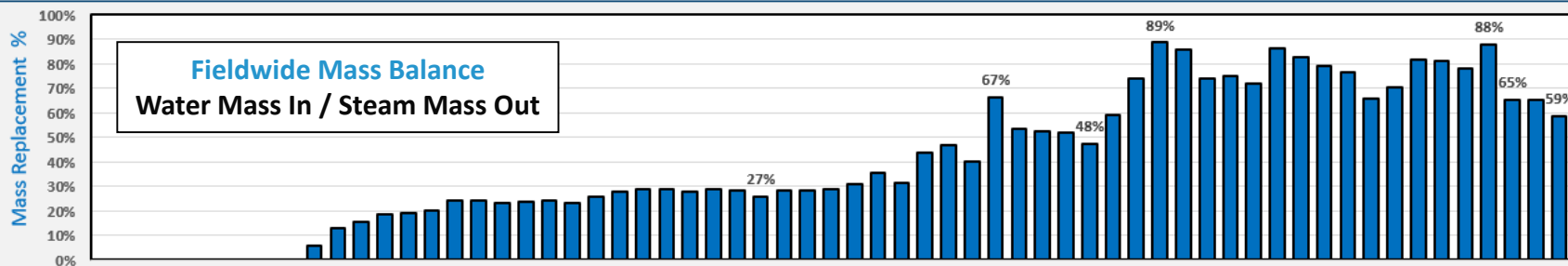
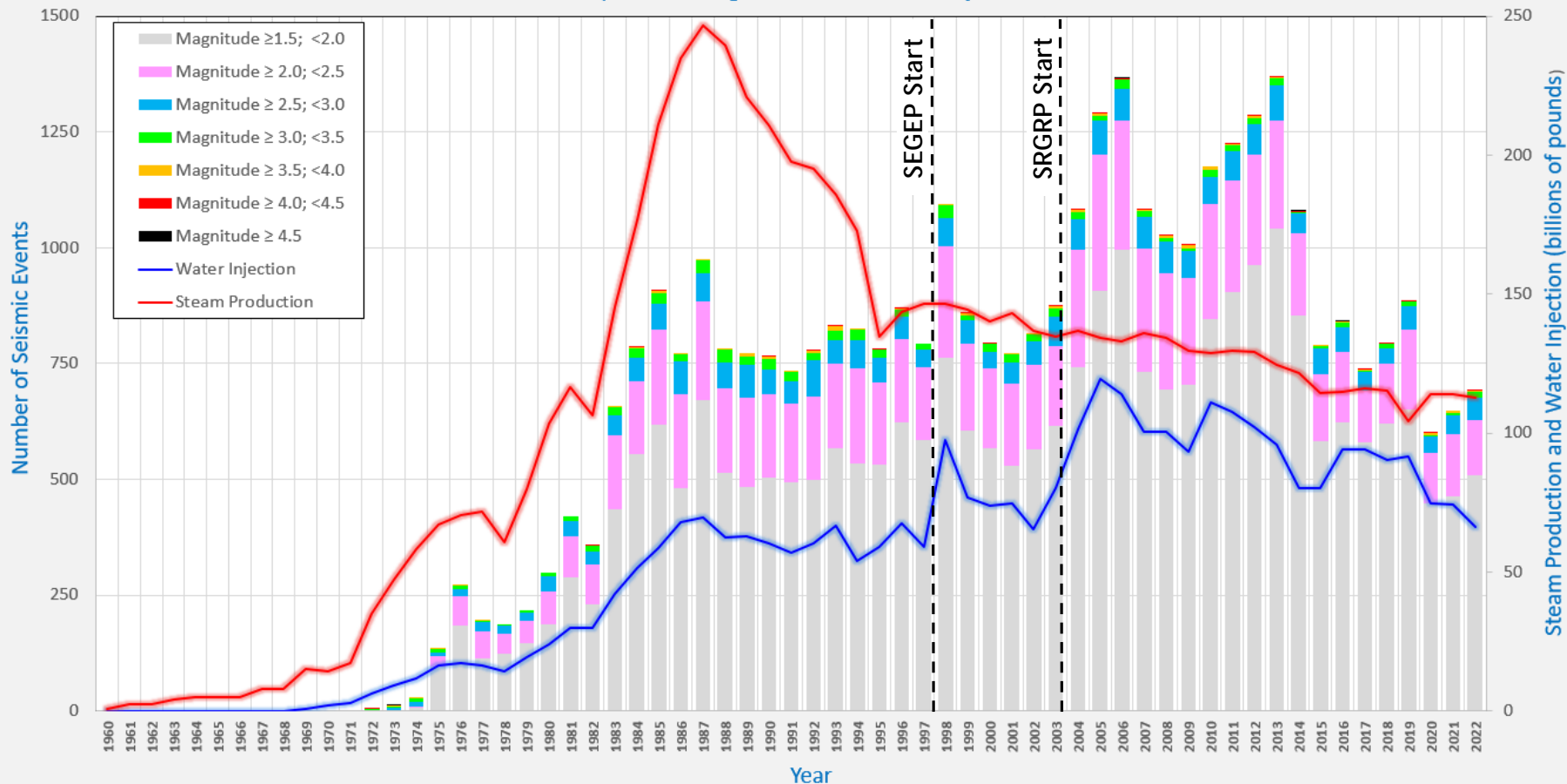
- 17 July 2022  
Magnitude 3.26
- 30 April 2022  
Magnitude 3.32
- 01 May 2022  
Magnitude 3.34
- 28 June 2022  
Magnitude 4.19
- 23 September 2022  
Magnitude 3.05





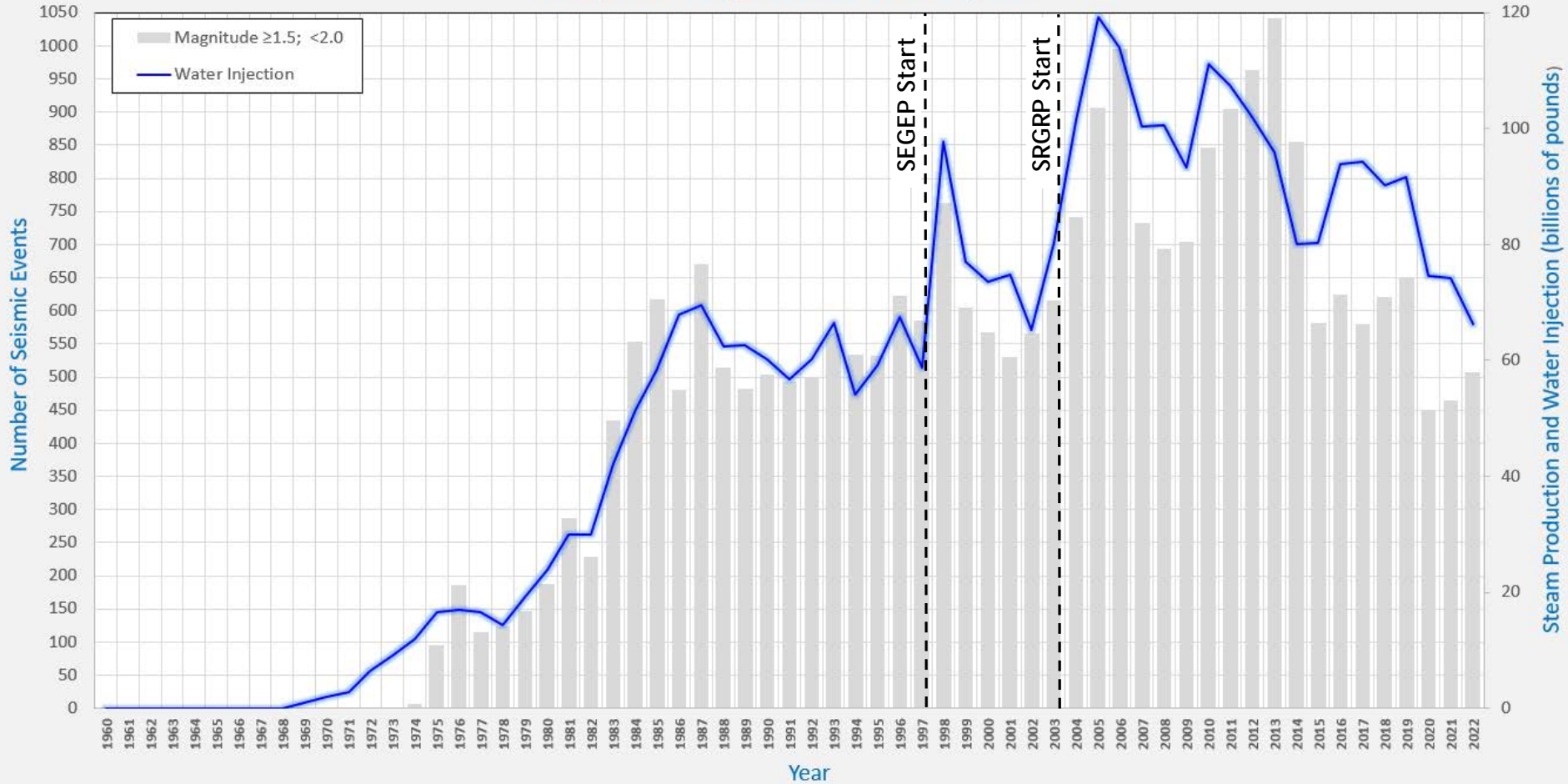
# Yearly Field-wide Steam Production, Water Injection and Seismicity

The Geysers Fieldwide Water Injection, Steam Production And Induced Seismicity  
January 1960 Through December 2022 - Projected \*



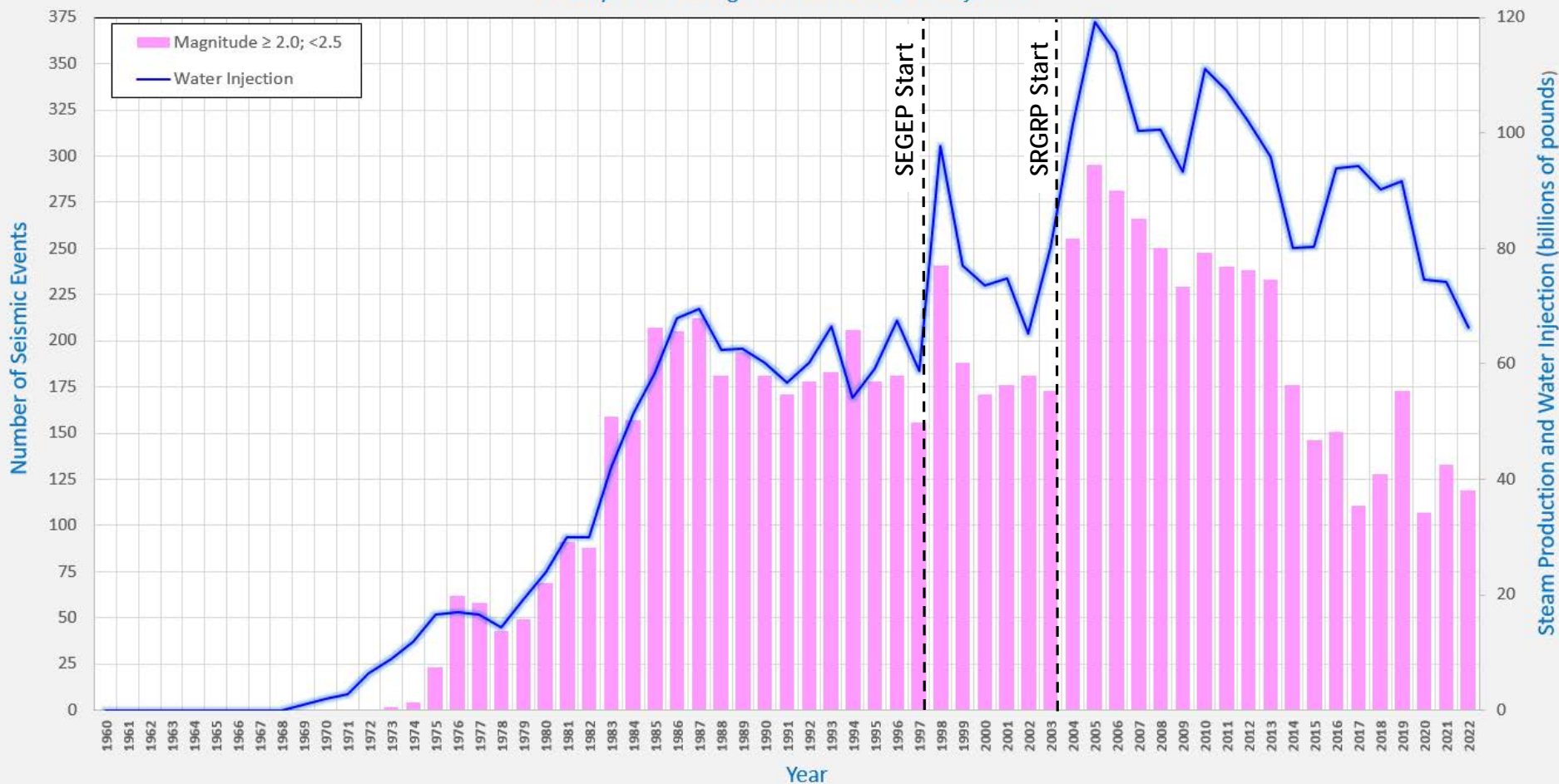
# Yearly Field-wide Water Injection and Seismicity Magnitude $\geq 1.5$ and $< 2.0$

The Geysers Fieldwide Water Injection And Induced Seismicity Magnitude  $\geq 1.5$  and  $< 2.0$   
 January 1960 Through December 2022 - Projected\*



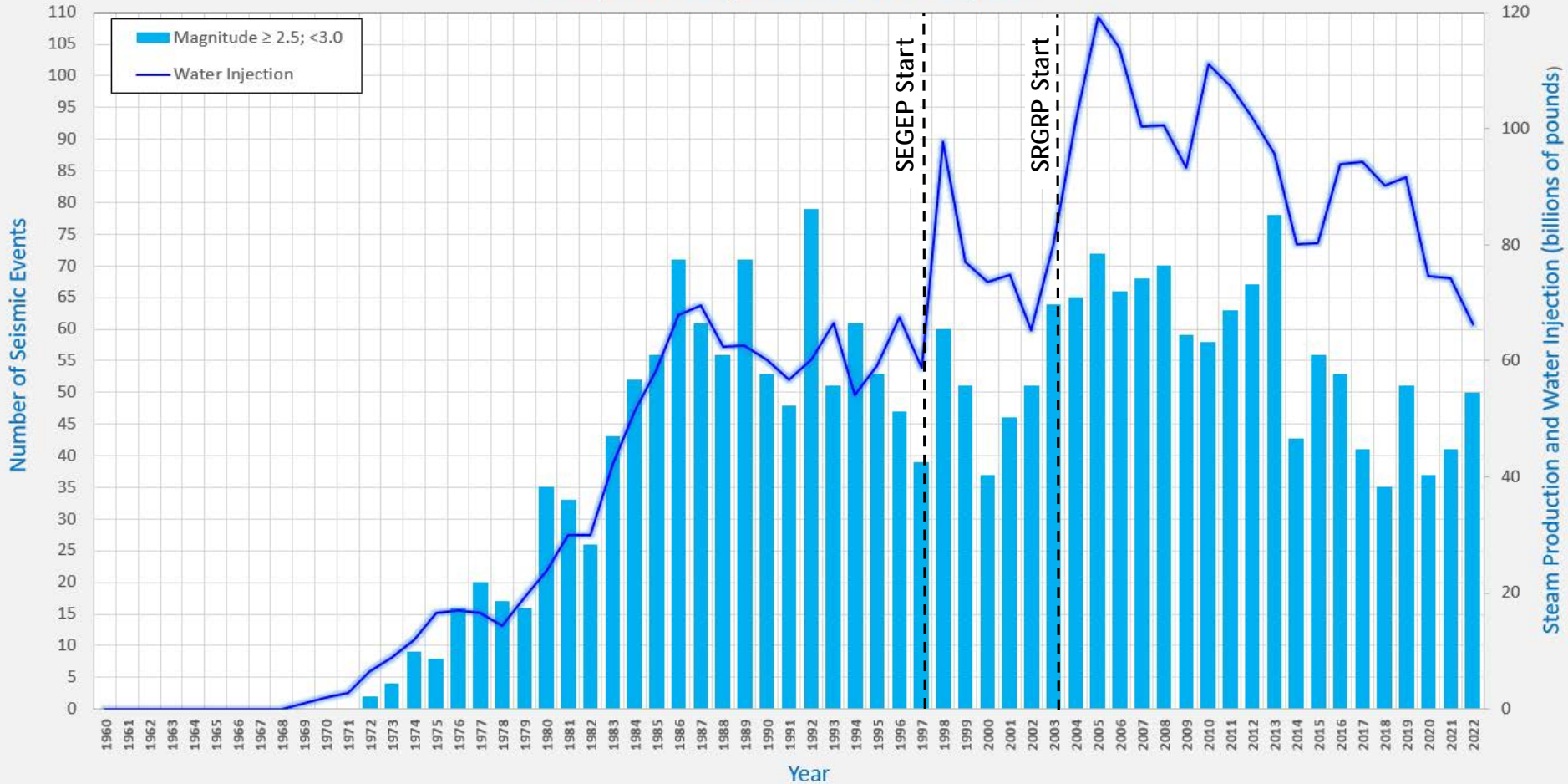
# Yearly Field-wide Water Injection and Seismicity Magnitude $\geq 2.0$ and $< 2.5$

The Geysers Fieldwide Water Injection And Induced Seismicity Magnitude  $\geq 2.0$  and  $< 2.5$   
January 1960 Through December 2022 - Projected\*

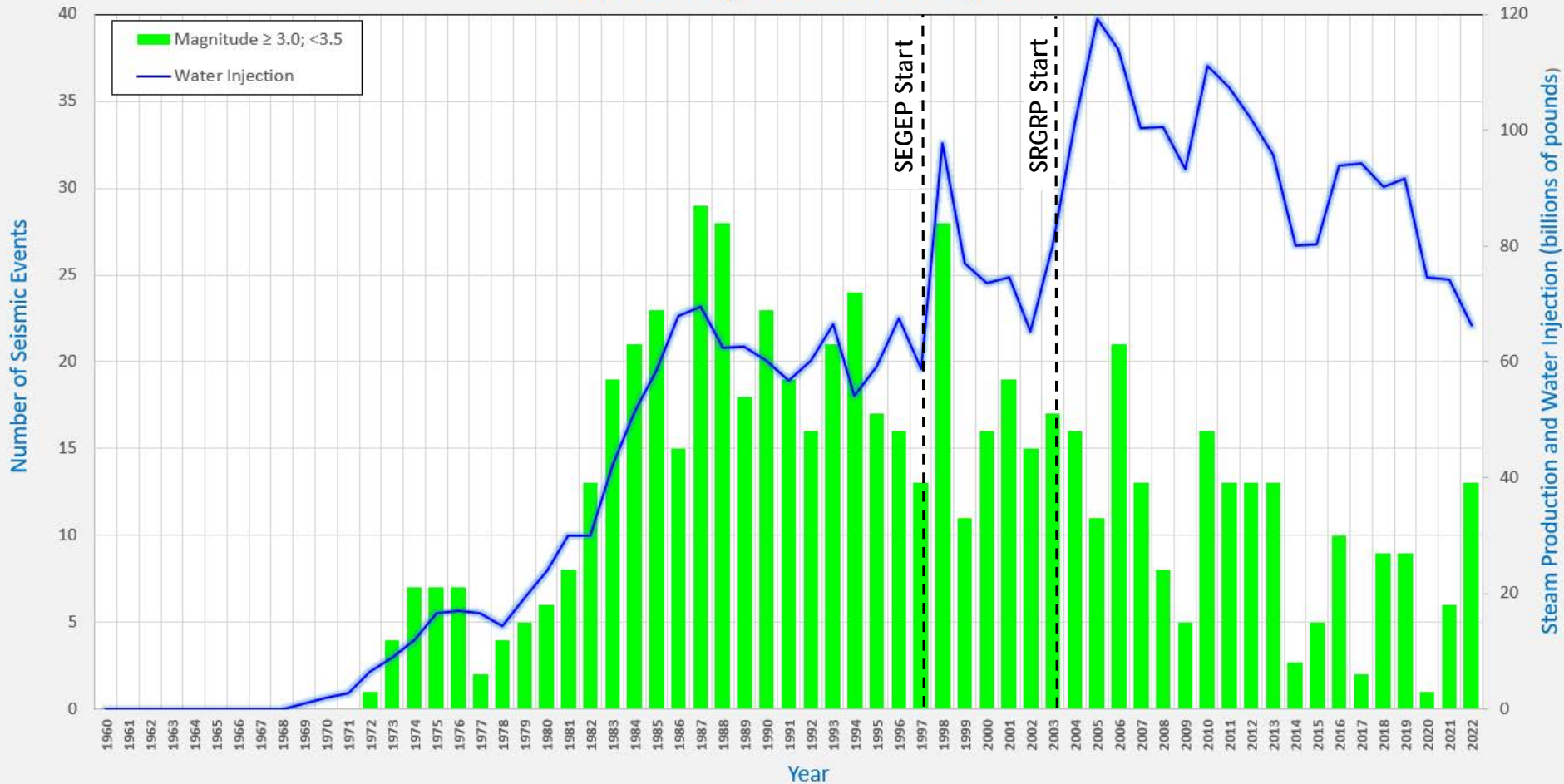


# Yearly Field-wide Water Injection and Seismicity Magnitude $\geq 2.5$ and $< 3.0$

The Geysers Fieldwide Water Injection And Induced Seismicity Magnitude  $\geq 2.5$  and  $< 3.0$   
January 1960 Through December 2022 - Projected\*

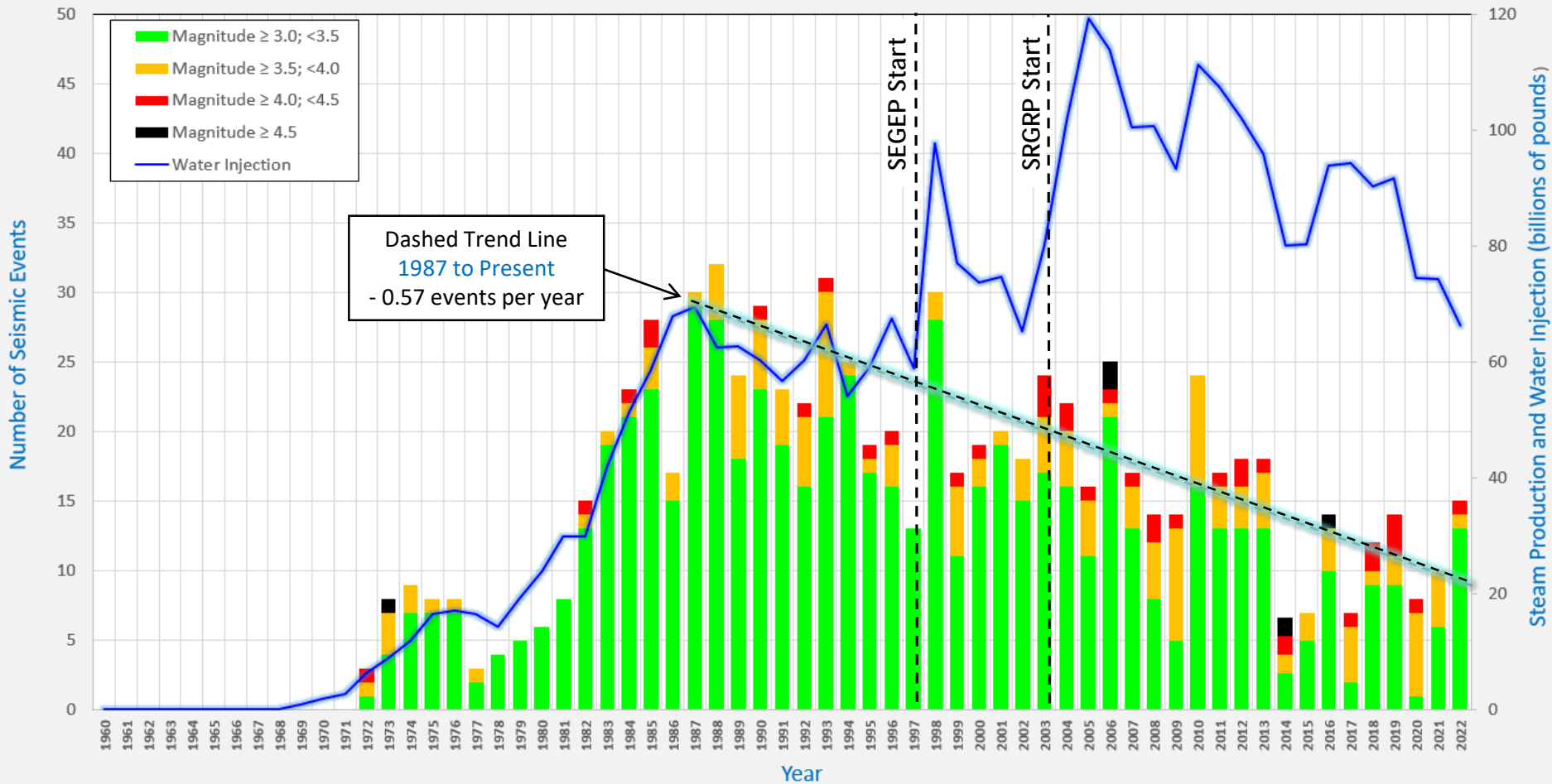


The Geysers Fieldwide Water Injection And Induced Seismicity Magnitude  $\geq 3.0$  and  $< 3.5$   
 January 1960 Through December 2022 - Projected\*



# Yearly Field-wide Water Injection and All Seismicity Magnitude $\geq 3.0$

The Geysers Fieldwide Water Injection And Induced Seismicity Magnitude  $\geq 3.0$   
 January 1960 Through December 2022 - Projected\*



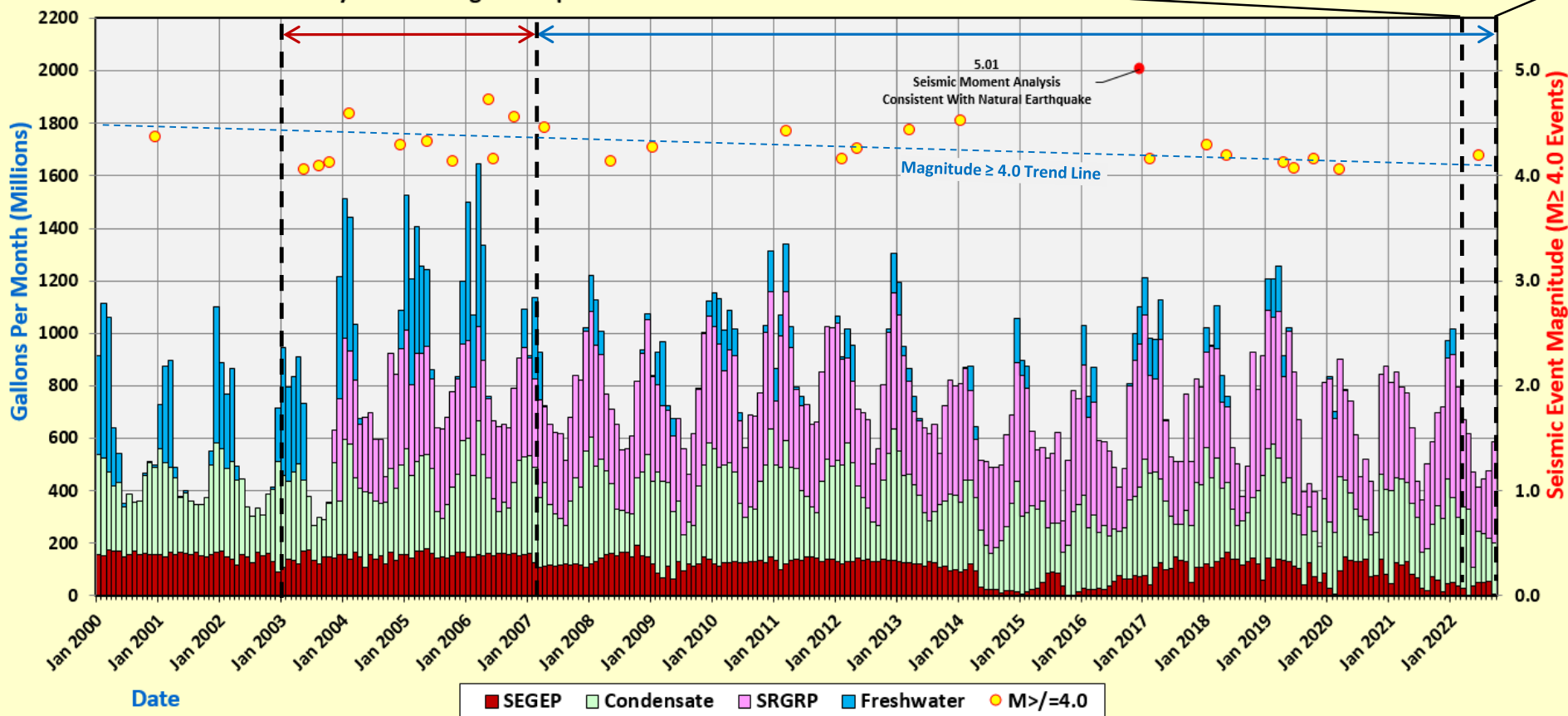
# Monthly Field-wide Water Injection By Water Source And Magnitude $\geq 4.0$ Seismicity

The Average Number of Magnitude  $\geq 4.0$  Events Since January 2007 is 1.08 Per Year

Time Period	Magnitude $\geq 4.0$ Seismic Events
January 2003 through December 2006	2.50 per year
January 2007 through September 2022	1.08 per year

Water Supply for Six Month Reporting Period				
Water Injection By Source (Gallons)				
Month	SEGEP	SRGRP	Condensate	Fresh Water
April	0	287,860,000	328,854,298	0
May	37,062,000	362,520,000	71,527,513	0
June	50,282,000	164,410,000	197,813,024	0
July	50,635,000	207,770,000	185,240,944	0
August	53,592,000	258,510,000	165,822,579	0
September	8,443,000	384,940,000	193,314,516	0

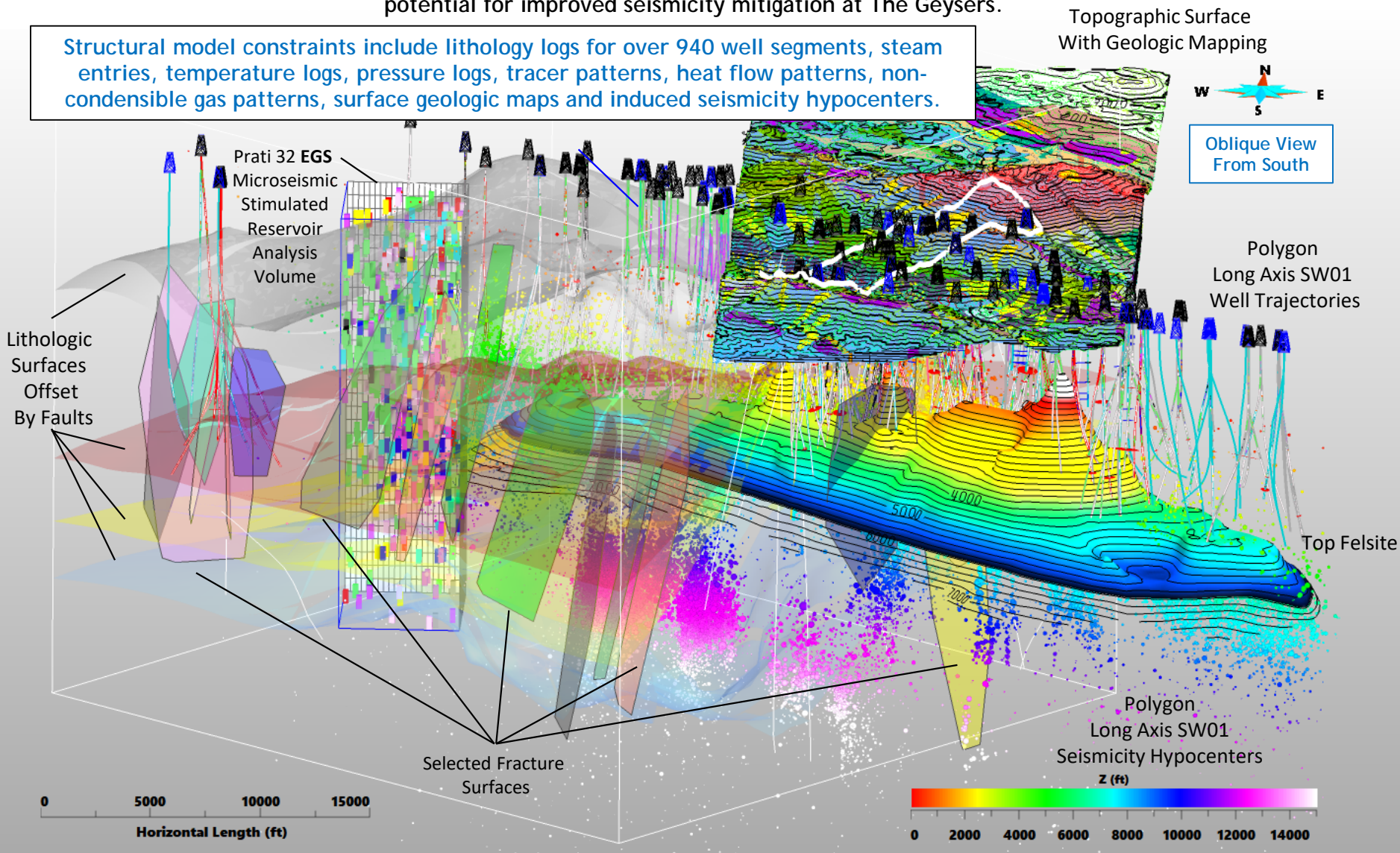
The Geysers  
 Calpine Fieldwide Water Injection Sources  
 Magnitude  $\geq 4.0$  Seismicity  
 01 January 2000 through 30 September 2022



# The Geysers Fieldwide 3D Structural Model

A refined understanding of The Geysers' fluid flow paths, fluid boundaries, reservoir heterogeneity and reservoir compartmentalization *assists* with well planning / targeting, real-time drilling analysis, reservoir management and provides the potential for improved seismicity mitigation at The Geysers.

Structural model constraints include lithology logs for over 940 well segments, steam entries, temperature logs, pressure logs, tracer patterns, heat flow patterns, non-condensable gas patterns, surface geologic maps and induced seismicity hypocenters.





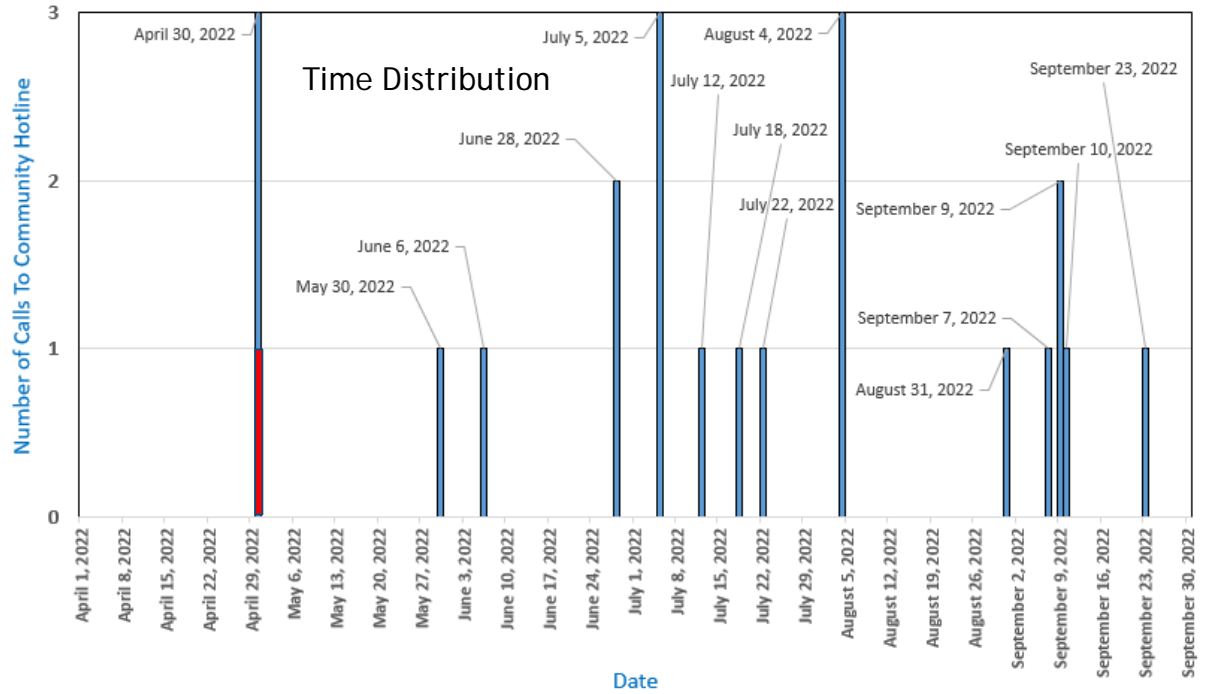
# Community Hotline Discussion

## 22 Calls to the Community Hotline For Reporting Period

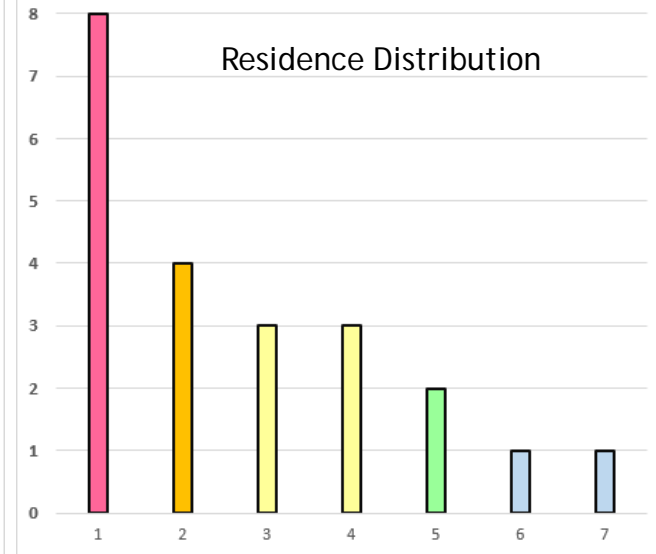
- Anderson Springs: 21 Calls **Blue Bar Portions**
- Cobb: 1 Call **Red Bar Portion**



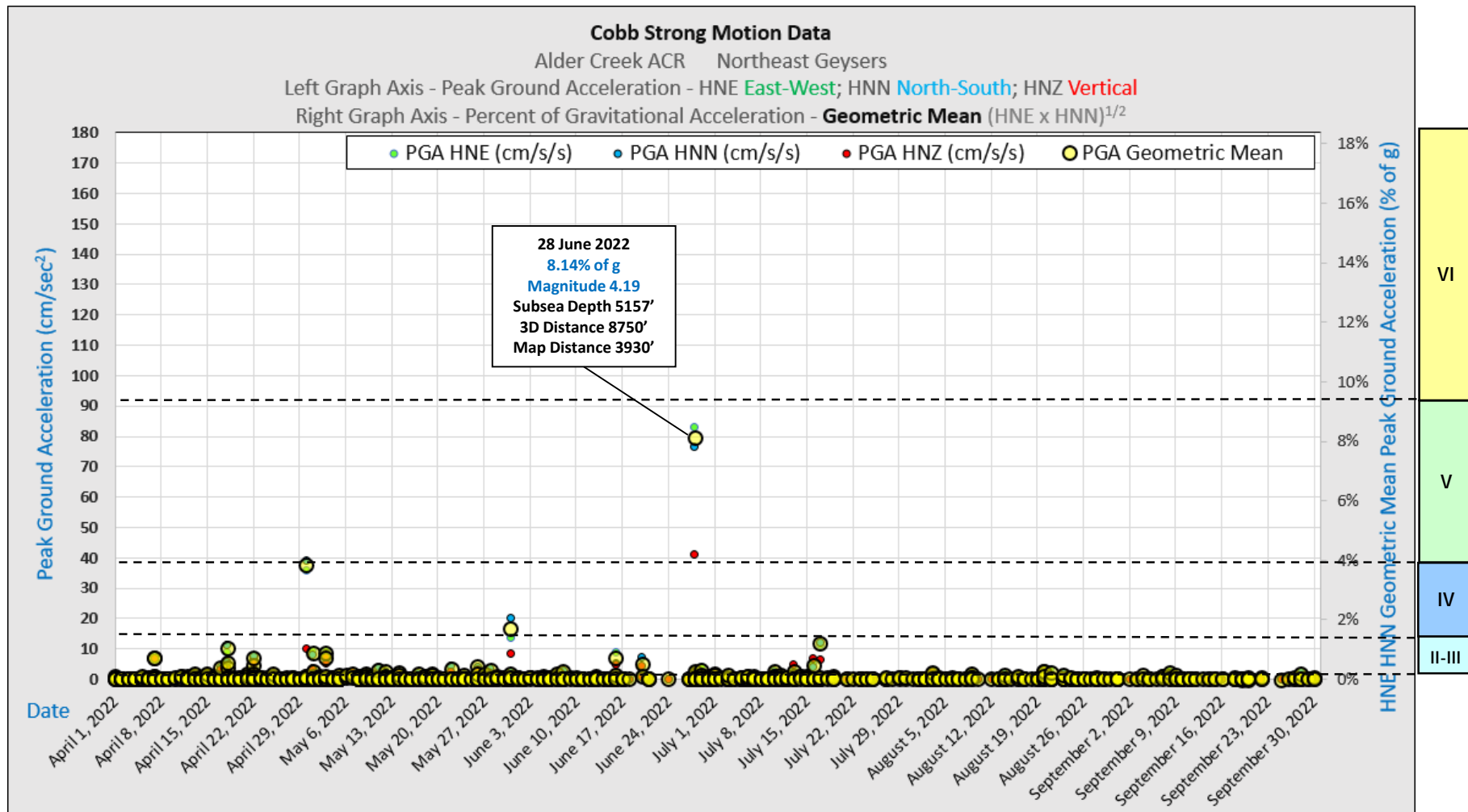
Community Hotline - Twenty-Two Calls - 01 April 2022 To 30 September 2022



Calls From Seven Residences  
Maximum Of Eight Calls From Single Residence

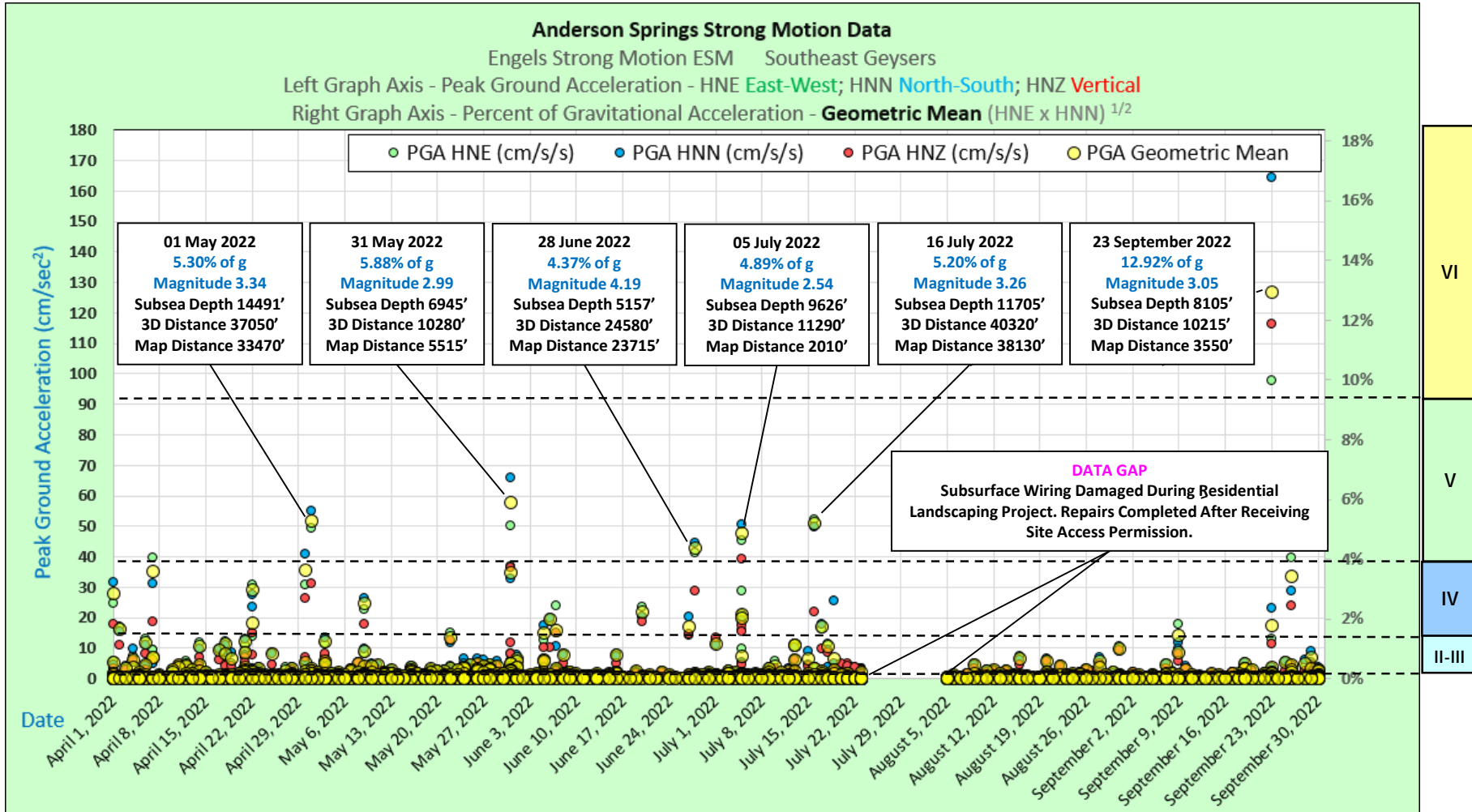


# Cobb Area: Strong Motion Determinations At Alder Creek Strong Motion Station



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

# Anderson Springs Area: Strong Motion Determinations At Engels Strong Motion Station



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



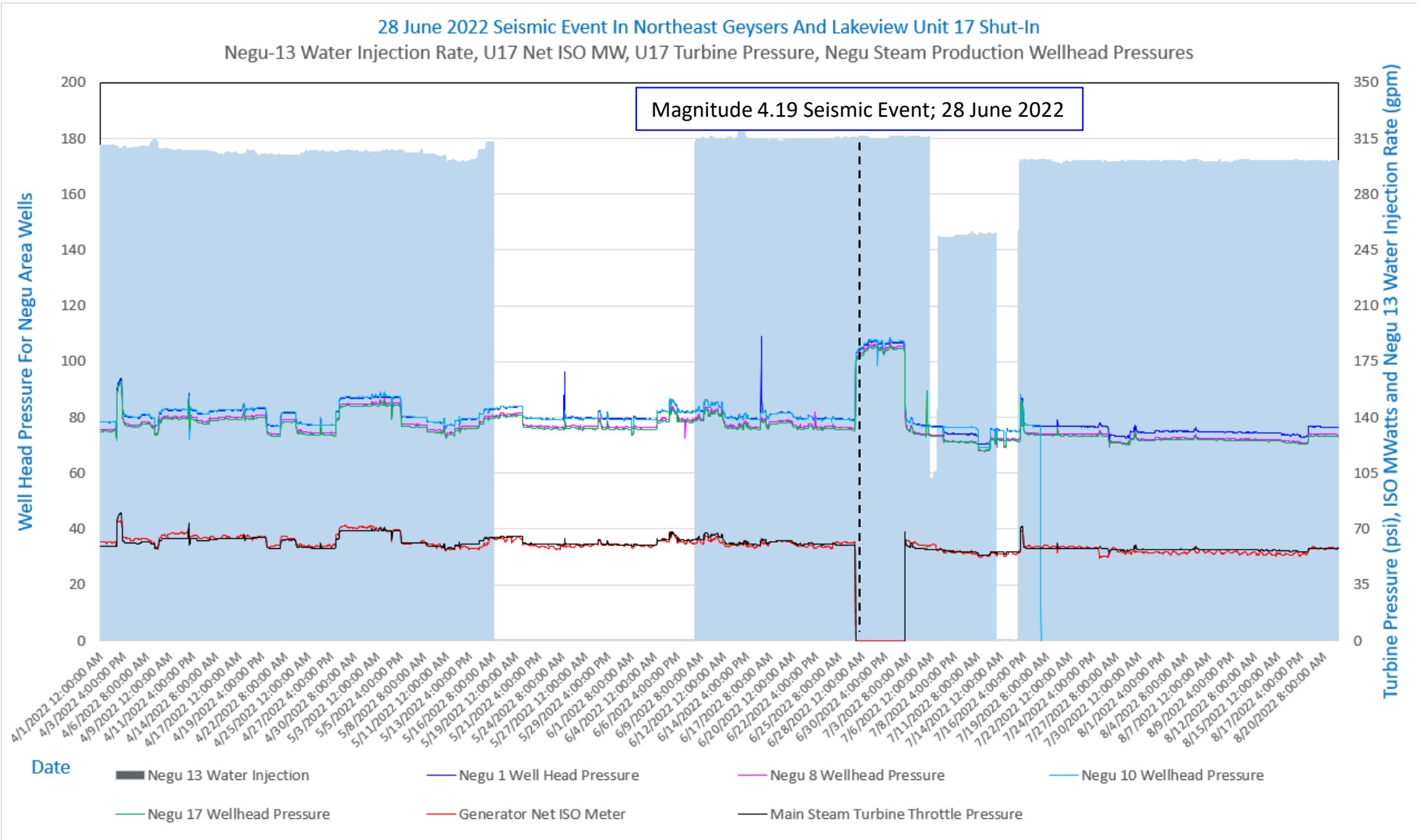
# 28 June 2022 Magnitude 4.19 Seismic Event Analysis

Negu-13 Water Injection Limited To 325 Gallons Per Minute To Assist With Calpine Seismicity Mitigation Efforts (Left Axis)

Negu-13 Reduced To 0 Gallons Per Minute During SRGRP Outage, Introducing Some Variability To Steam Reservoir.

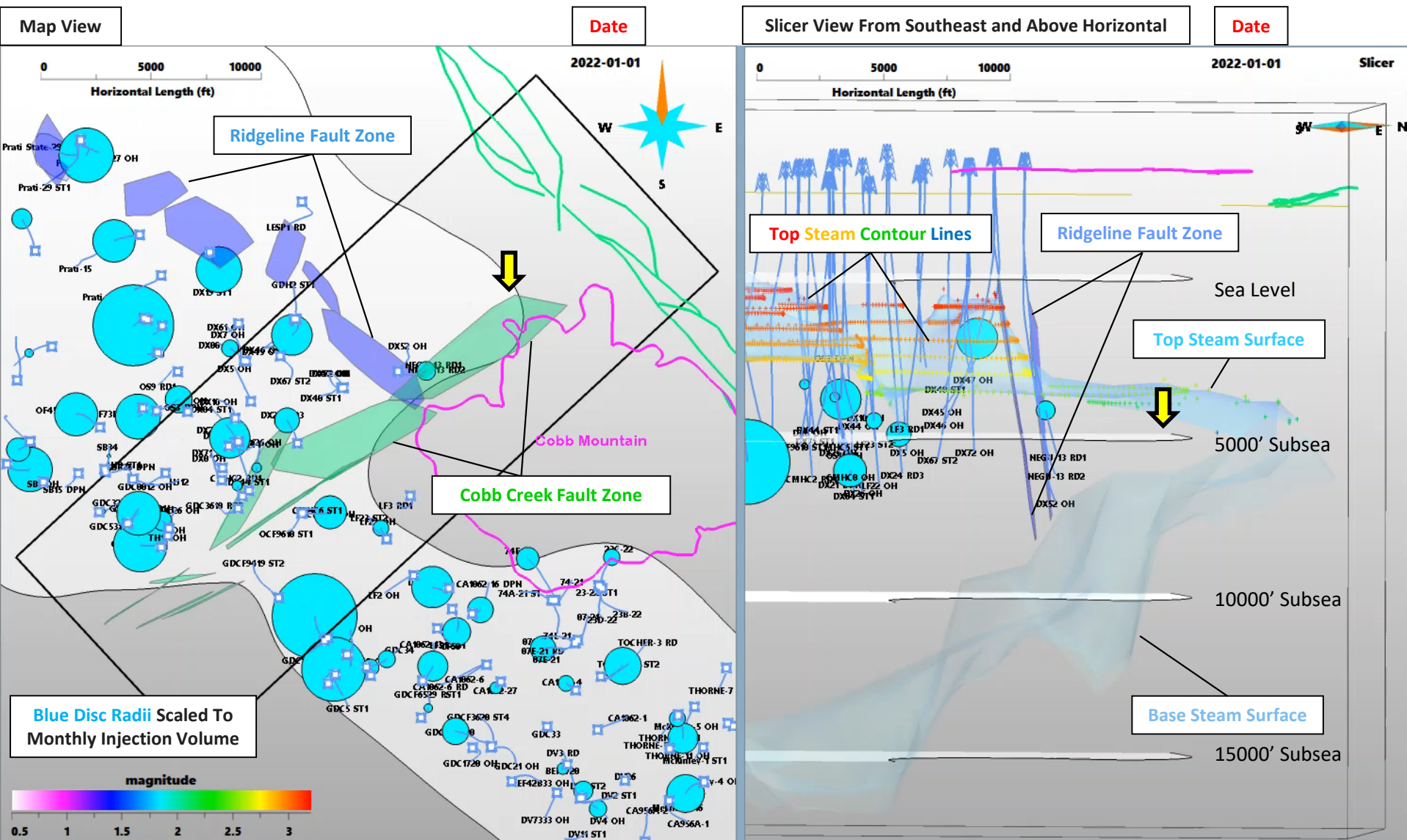
Lakeview Unit 17 Power Plant was taken offline for a PG&E line outage on 27 June 2022 (Megawatts and Turbine Pressure To Zero)

This Increased Negu 1 & 10 Wellhead Pressures, Introducing Additional Variability To Steam Reservoir.



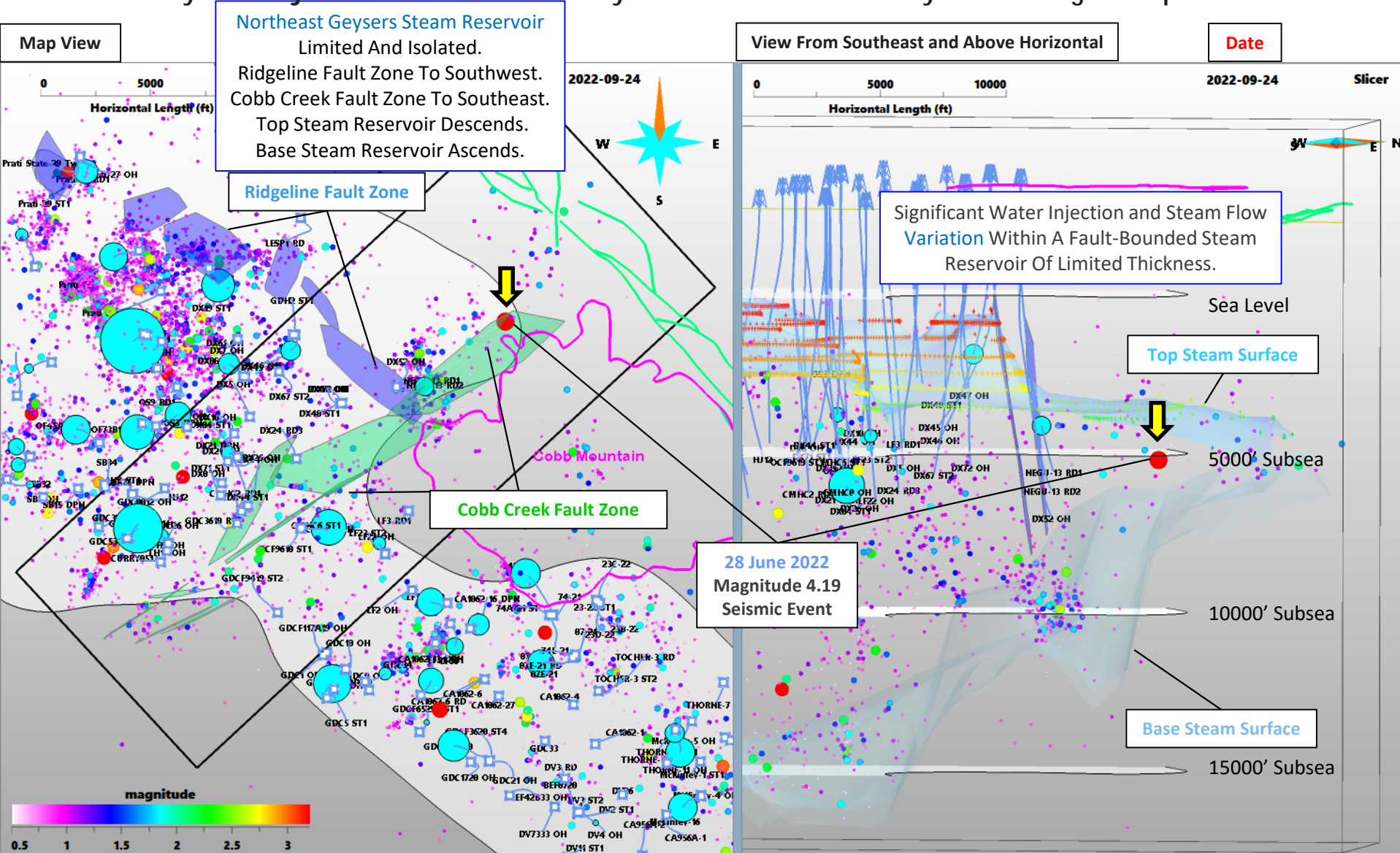
# 28 June 2022 Magnitude 4.19 Seismic Event Analysis

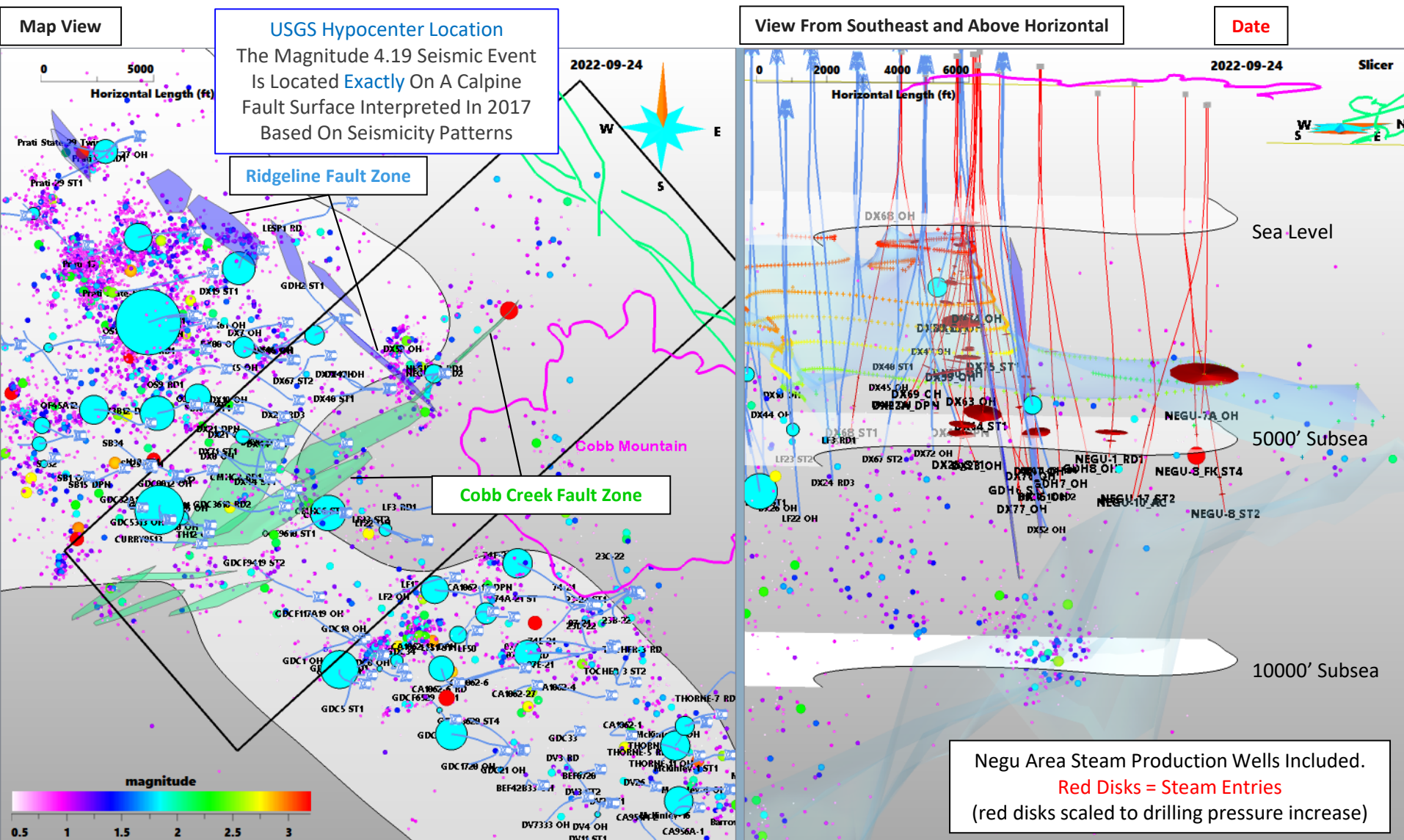
## VIDEO: Weekly Water Injection and Induced Seismicity Animation From 01 January 2022 Through 24 September 2002



# 28 June 2022 Magnitude 4.19 Seismic Event Analysis

## IMAGE: Weekly Water Injection and Induced Seismicity Animation From 01 January 2022 Through 24 September 2002





# IMAGE: Water Injection and Induced Seismicity From 01 January 2022 Through 24 September 2022 Vicinity of 28 June 2022 Magnitude 4.19 Seismic Event

