



America's Premier Competitive Power Company
... Creating Power for a Sustainable Future

Seismic Monitoring Advisory Committee Meeting

01 April 2023 to 30 September 2023 Reporting Period

Calpine Geothermal Visitor Center

Thursday 16 November 2023

Craig Hartline
Senior Geophysicist
Geysers Power Company, LLC



Seismic Monitoring Advisory Committee Meeting

Presentation Agenda

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

- Sonoma County Daily High Precipitation Period
- 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 and Station State-Of-Health Analysis](#)
- Fieldwide Induced Seismicity Analysis
 - [Induced Seismicity Analysis](#)
 - [Water Injection and Induced Seismicity Animation](#)
- Strong Motion Data Analysis
 - [Peak Ground Acceleration vs. Hypocentral Distance](#)
- Community Hotline
 - [Seismic Events of Concern And Call Distribution](#)
- Seismicity Ranking For All Active Water Injection Wells
 - [Criteria For Minimization Of Water Injection Rate Variability](#)
 - [Area Of Influence; Energy Release; B-Values](#)
 - [Seismic Event Examples: Directly Related To Water Injection Variability](#)
- Regional Seismicity Relationships
- Seismic Monitoring Research
- 3D Structural Model Building
 - [Goals](#)

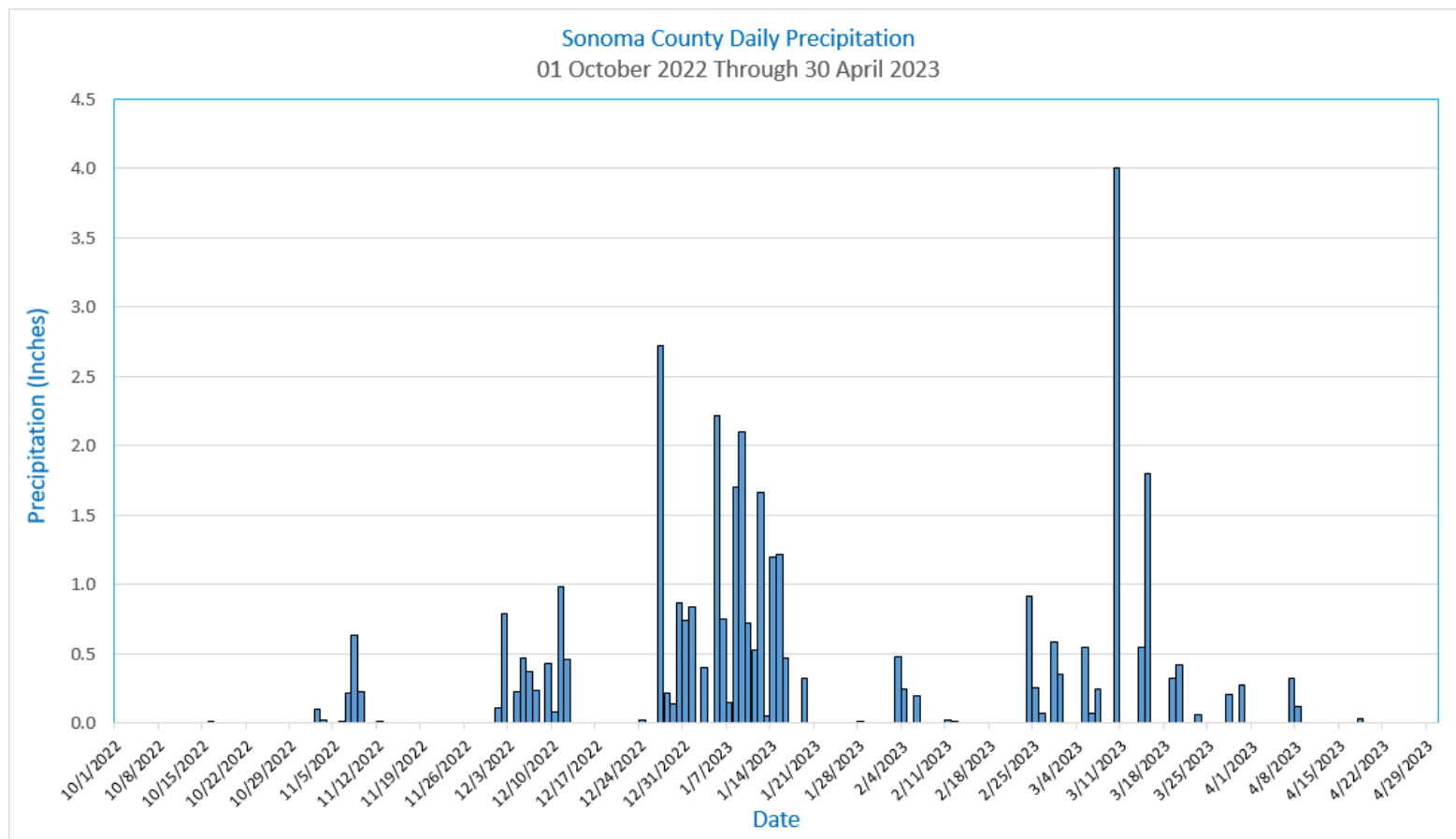
Sonoma County Daily Precipitation

For High Precipitation Period 01 October 2022 Through 30 April 2023

The “atmospheric river” events of late 2022 and early 2023 brought extreme weather conditions to California, including winter storms, travel restrictions, periods of extreme precipitation, flooding and record snow pack accumulations.

The extreme (and highly variable) precipitation rates also resulted in extreme (and highly variable) water injection rates.

Throughout 2023, shorter-term and longer-term stress release has resulted in elevated induced seismicity as the steam reservoir gradually returns to conditions that are more nearly “steady-state”.



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

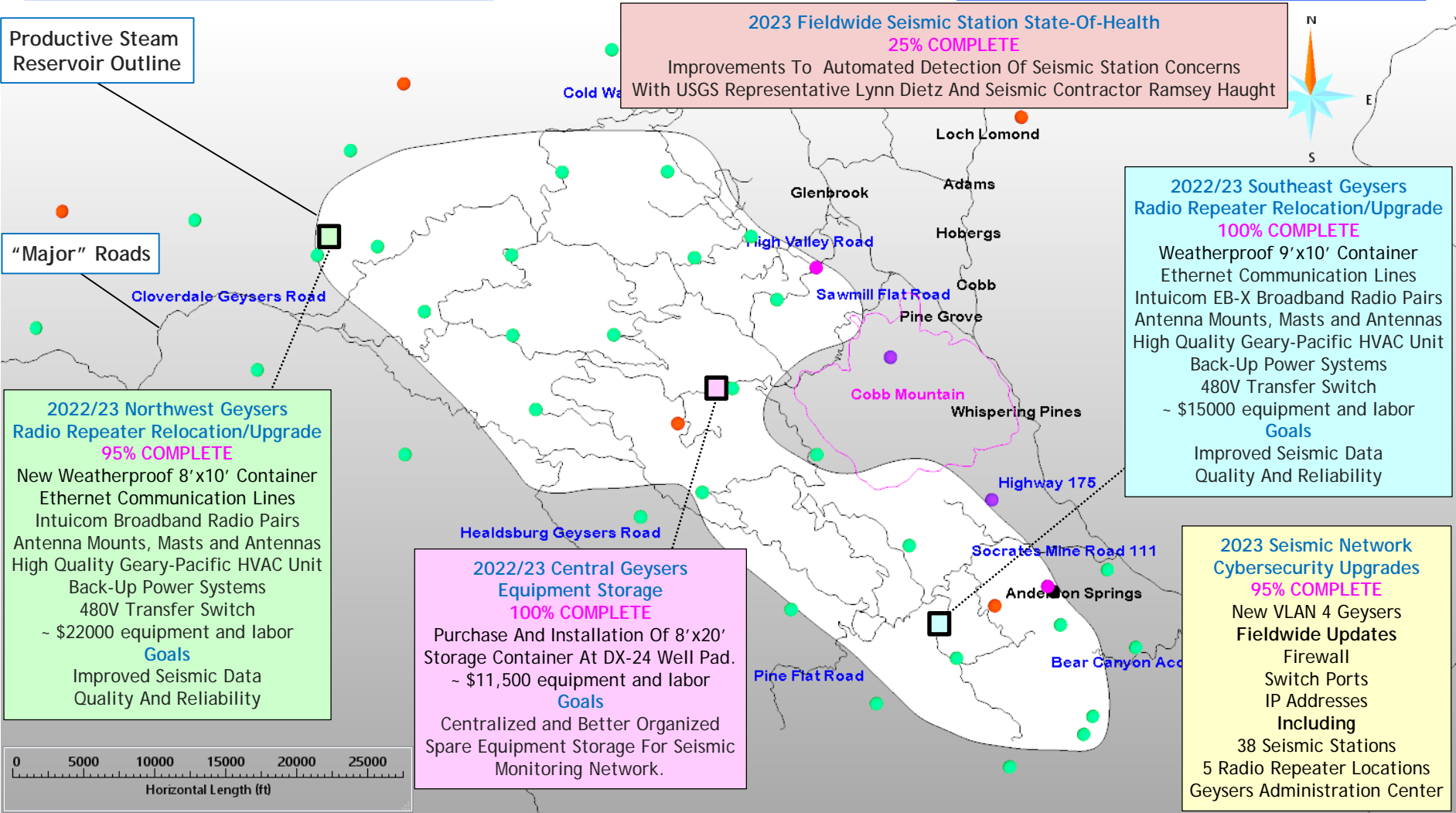
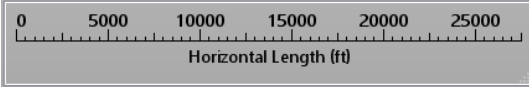
2023 Fieldwide Seismic Station State-Of-Health
25% COMPLETE
Improvements To Automated Detection Of Seismic Station Concerns
With USGS Representative Lynn Dietz And Seismic Contractor Ramsey Haught

2022/23 Southeast Geysers Radio Repeater Relocation/Upgrade
100% COMPLETE
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

2022/23 Northwest Geysers Radio Repeater Relocation/Upgrade
95% 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

2022/23 Central Geysers Equipment Storage
100% COMPLETE
Purchase And Installation Of 8'x20' Storage Container At DX-24 Well Pad.
~ \$11,500 equipment and labor
Goals
Centralized and Better Organized Spare Equipment Storage For Seismic Monitoring Network.

2023 Seismic Network Cybersecurity Upgrades
95% COMPLETE
New VLAN 4 Geysers Fieldwide Updates
Firewall
Switch Ports
IP Addresses
Including
38 Seismic Stations
5 Radio Repeater Locations
Geysers Administration Center

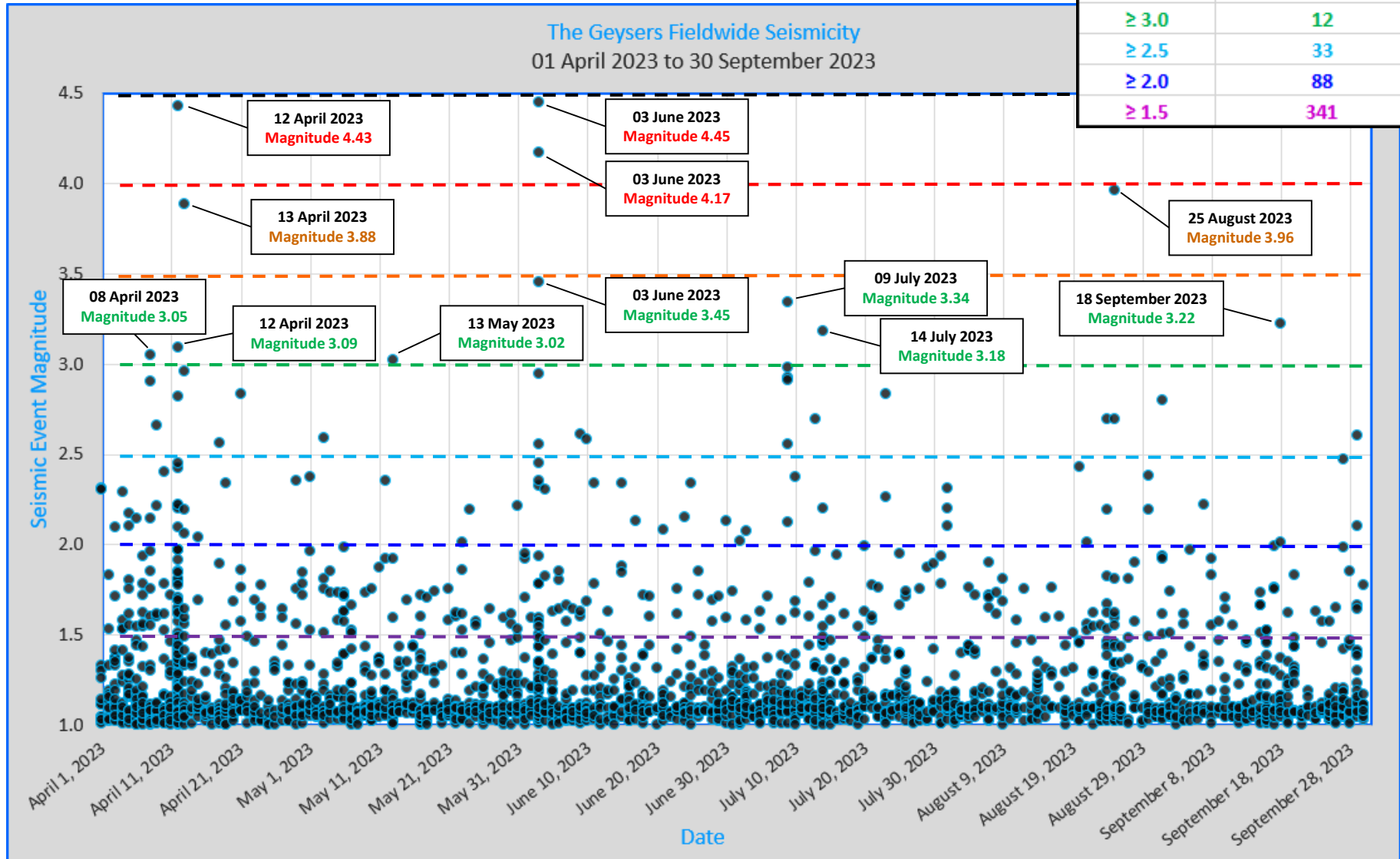


* The closely-spaced LBNL seismic monitoring stations allow accurate energy and hypocenter determination of Geysers' seismic events to approximately magnitude 0.8

Field-wide Seismicity Analysis From 01 April 2023 To 30 September 2023

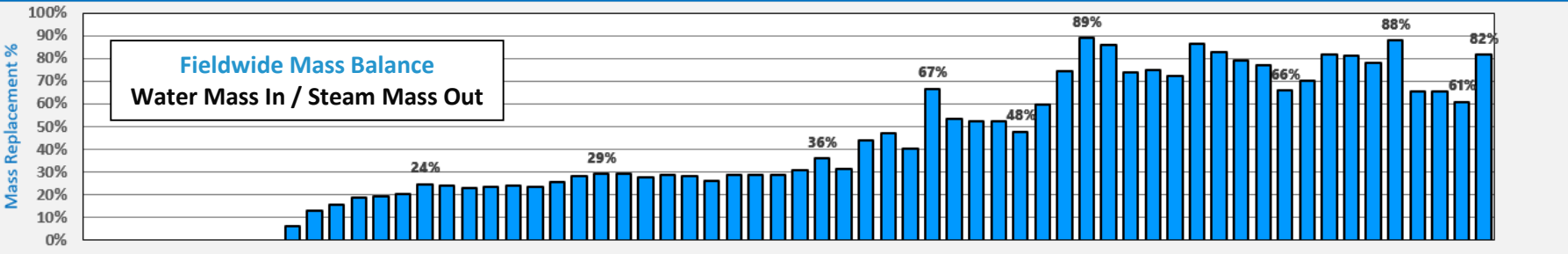
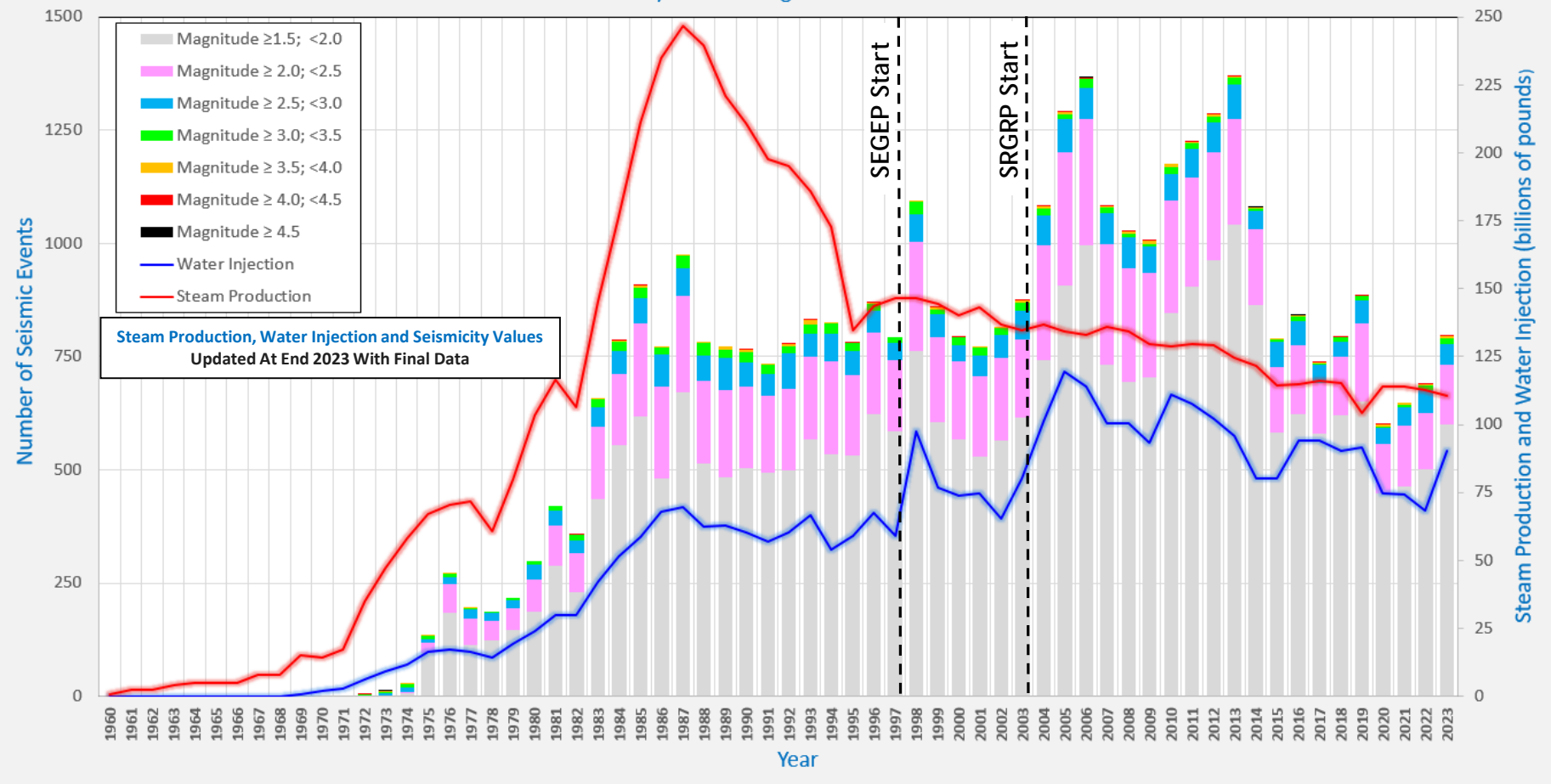
Waveform data, metadata, or data products for this study were accessed through the Northern California Earthquake Data Center (NCEDC), doi:10.7932/NCEDC

Magnitude	Number Of Events
≥ 4.5	0
≥ 4.0	3
≥ 3.5	5
≥ 3.0	12
≥ 2.5	33
≥ 2.0	88
≥ 1.5	341



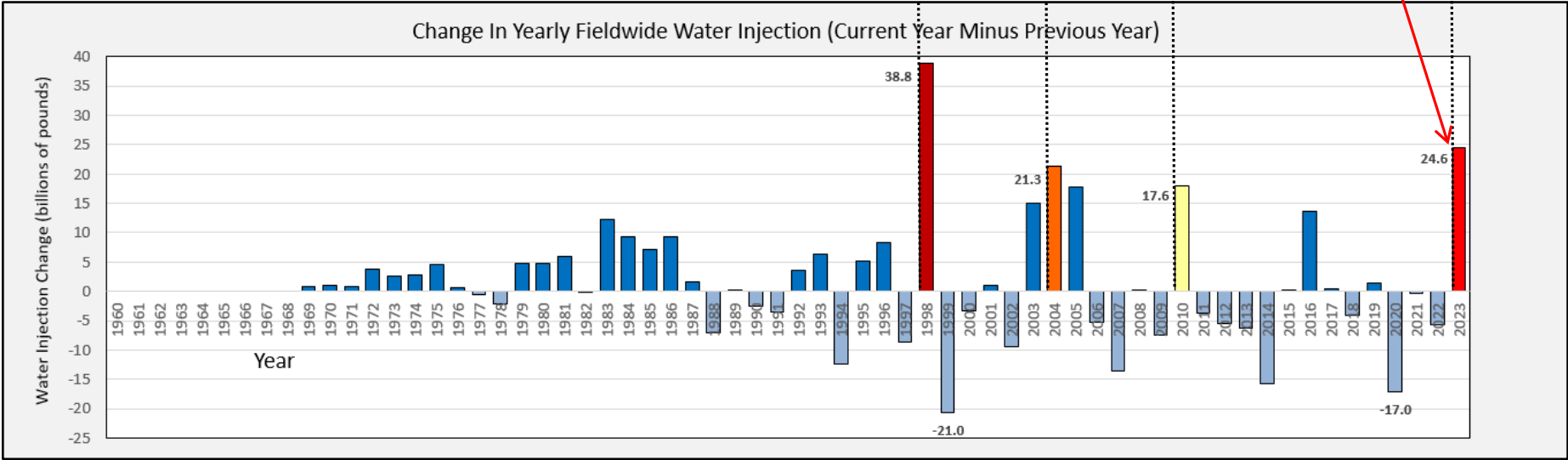
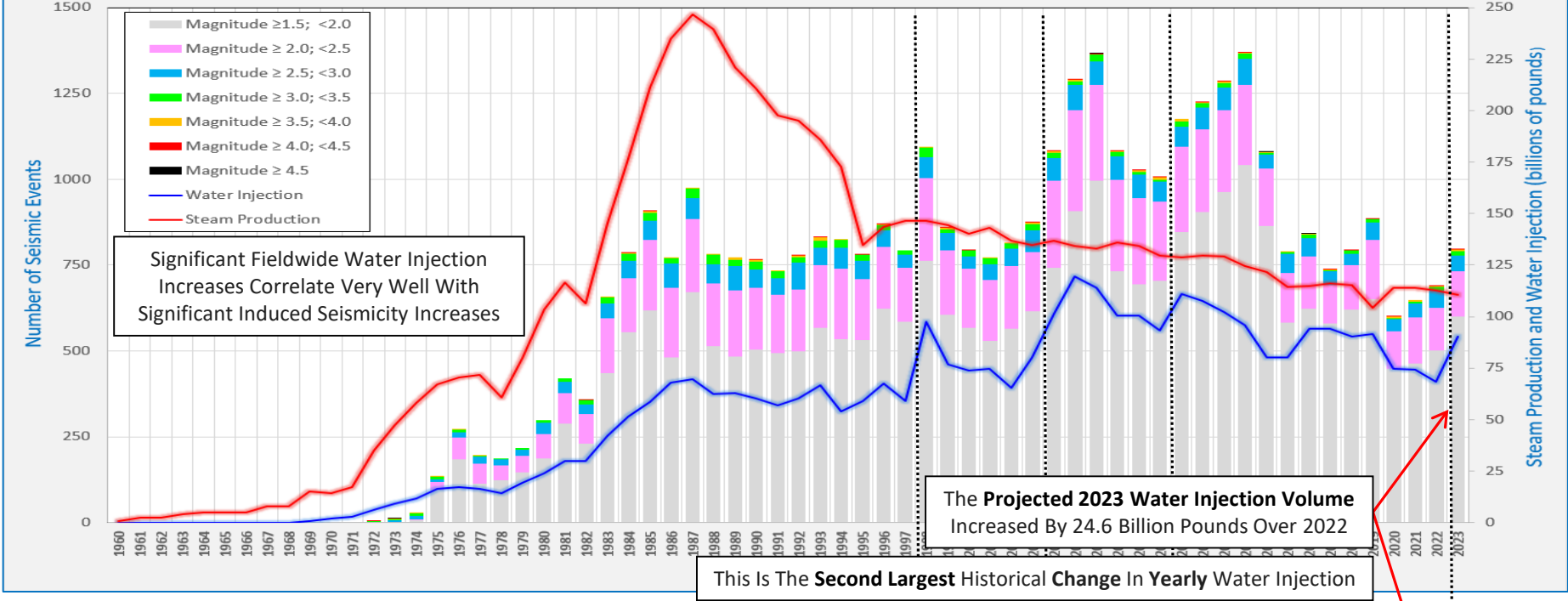
Yearly Field-wide Steam Production, Water Injection and Seismicity

The Geysers Fieldwide Water Injection, Steam Production And Induced Seismicity
January 1960 Through December 2023



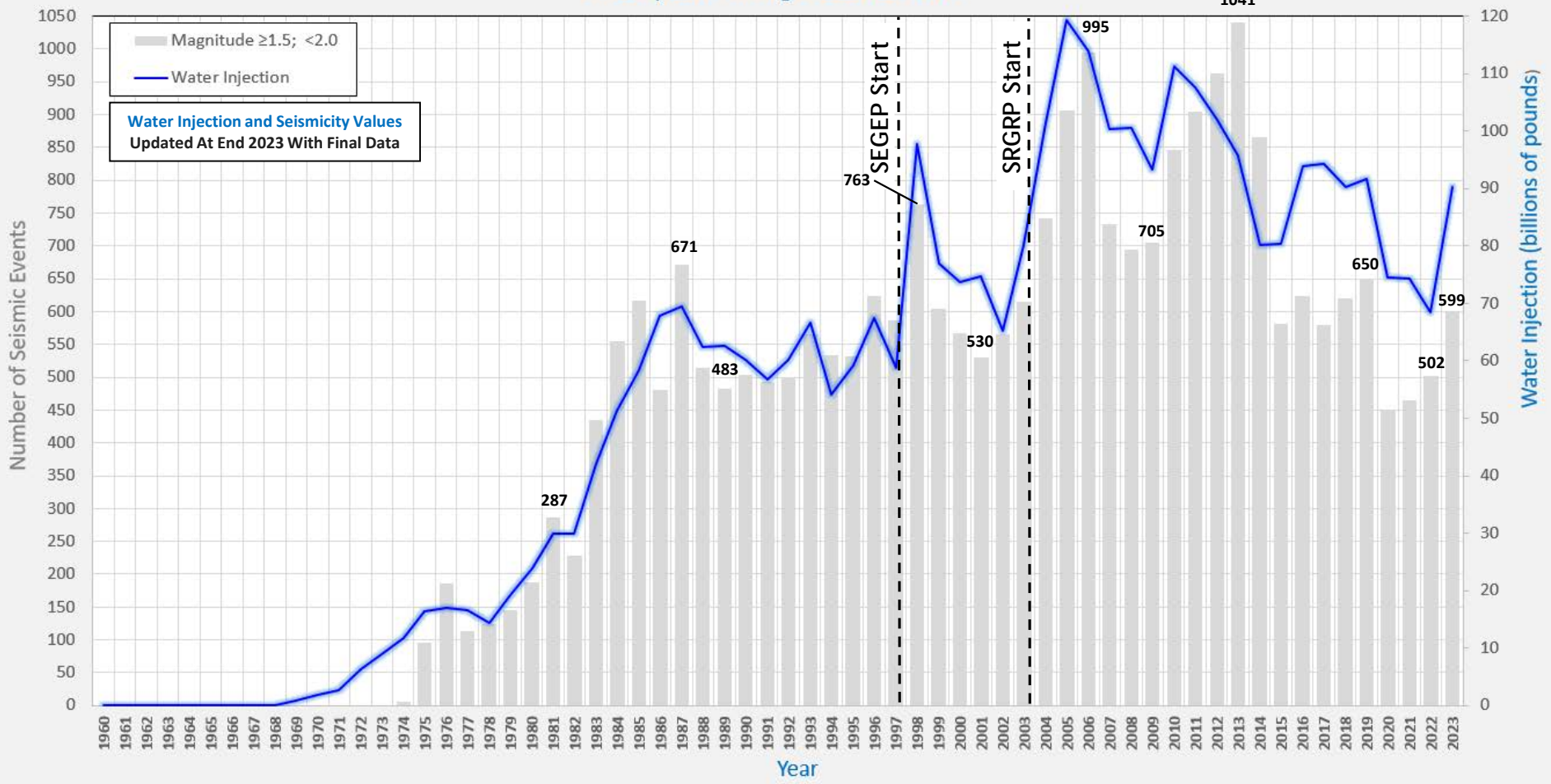
Yearly Field-wide Water Injection, Induced Seismicity And Change In Yearly Fieldwide Water Injection

The Geysers Fieldwide Water Injection, Steam Production And Induced Seismicity
January 1960 Through December 2023



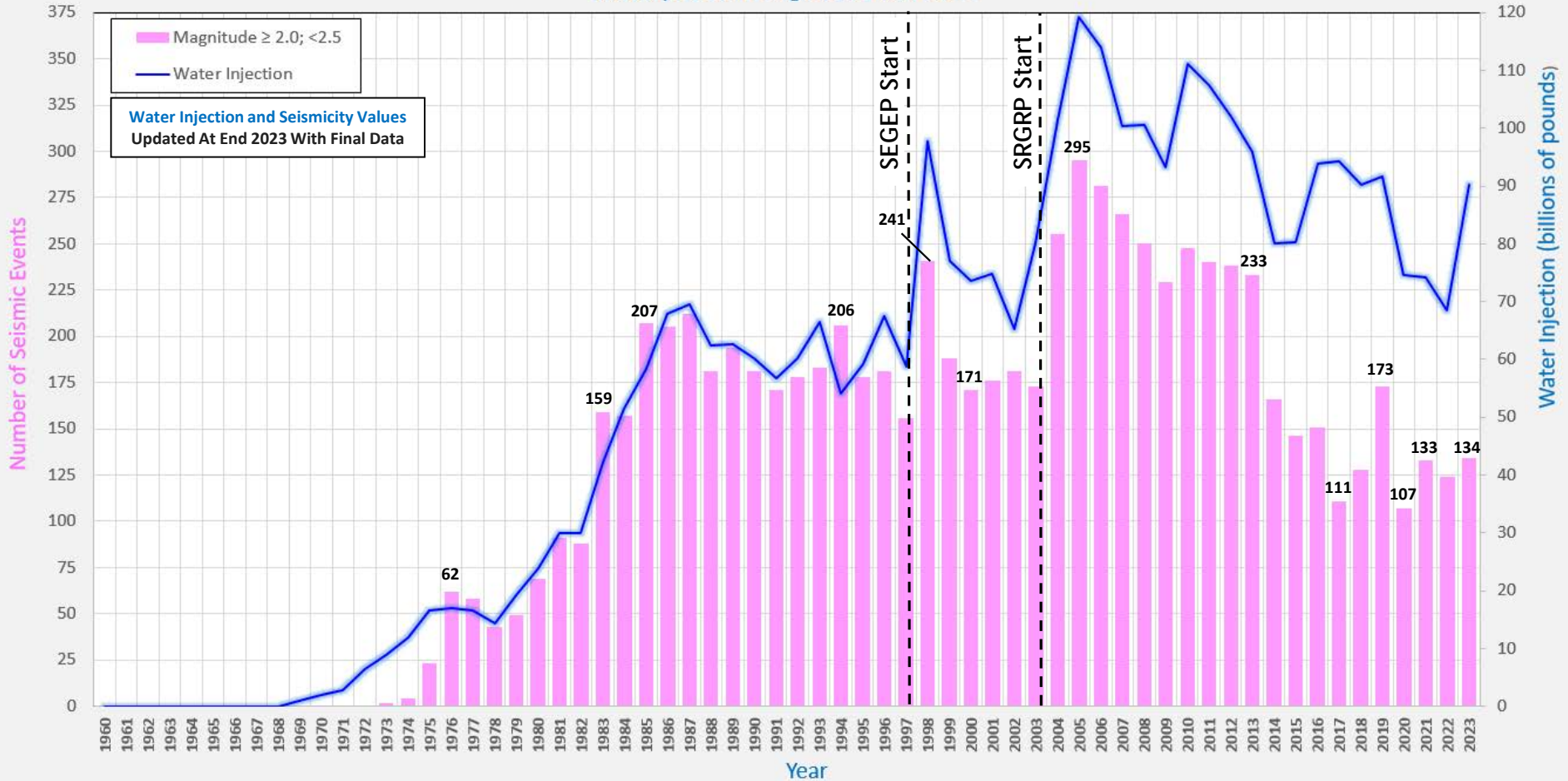
Yearly Field-wide Water Injection and Seismicity Magnitude ≥ 1.5 and < 2.0

The Geysers Fieldwide Water Injection And Induced Seismicity Magnitude ≥ 1.5 and < 2.0
 January 1960 Through December 2023



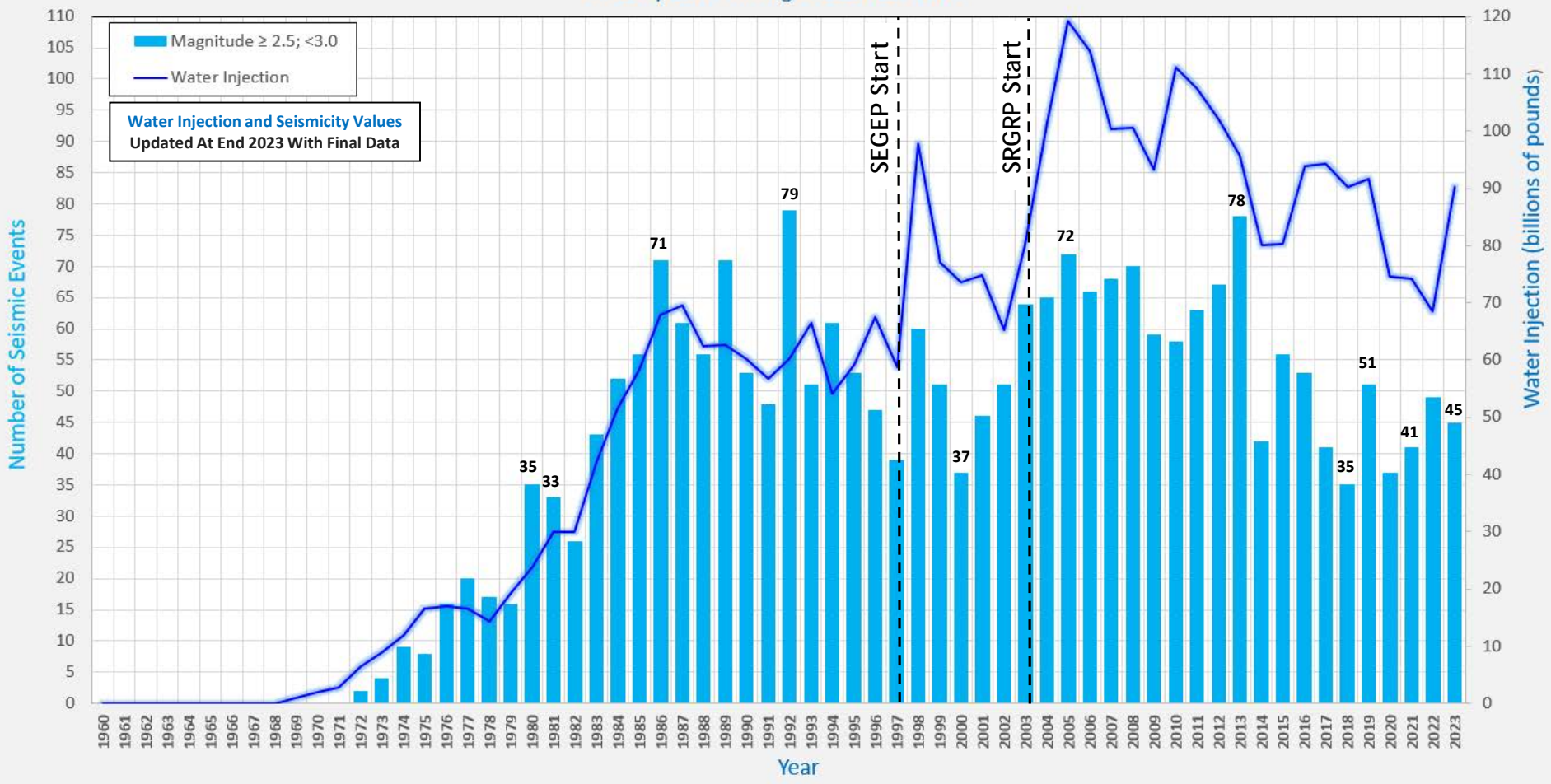
Yearly Field-wide Water Injection and Seismicity Magnitude ≥ 2.0 and < 2.5

The Geysers Fieldwide Water Injection And Induced Seismicity Magnitude ≥ 2.0 and < 2.5
 January 1960 Through December 2023



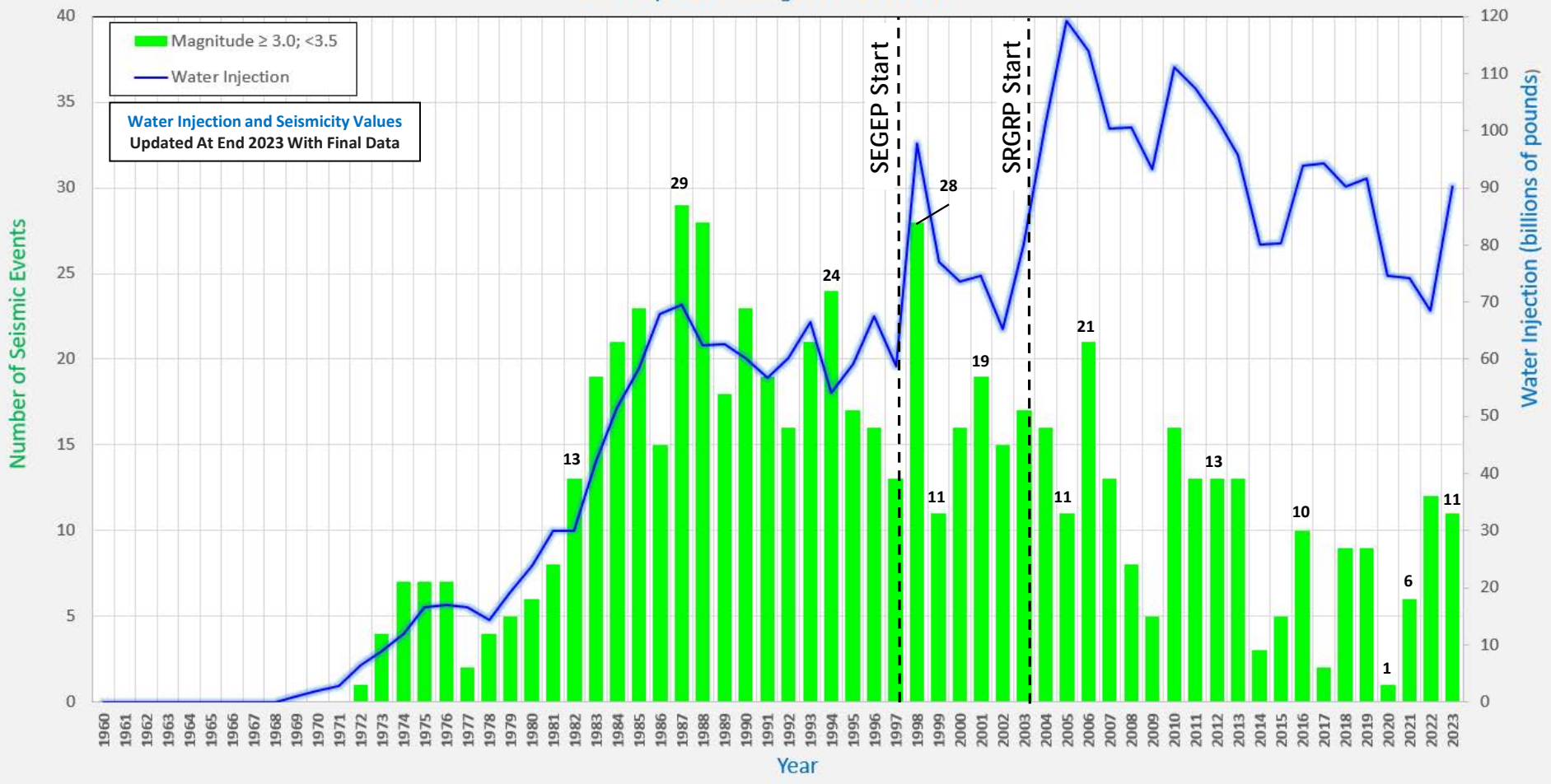
Yearly Field-wide Water Injection and Seismicity Magnitude ≥ 2.5 and < 3.0

The Geysers Fieldwide Water Injection And Induced Seismicity Magnitude ≥ 2.5 and < 3.0
 January 1960 Through December 2023



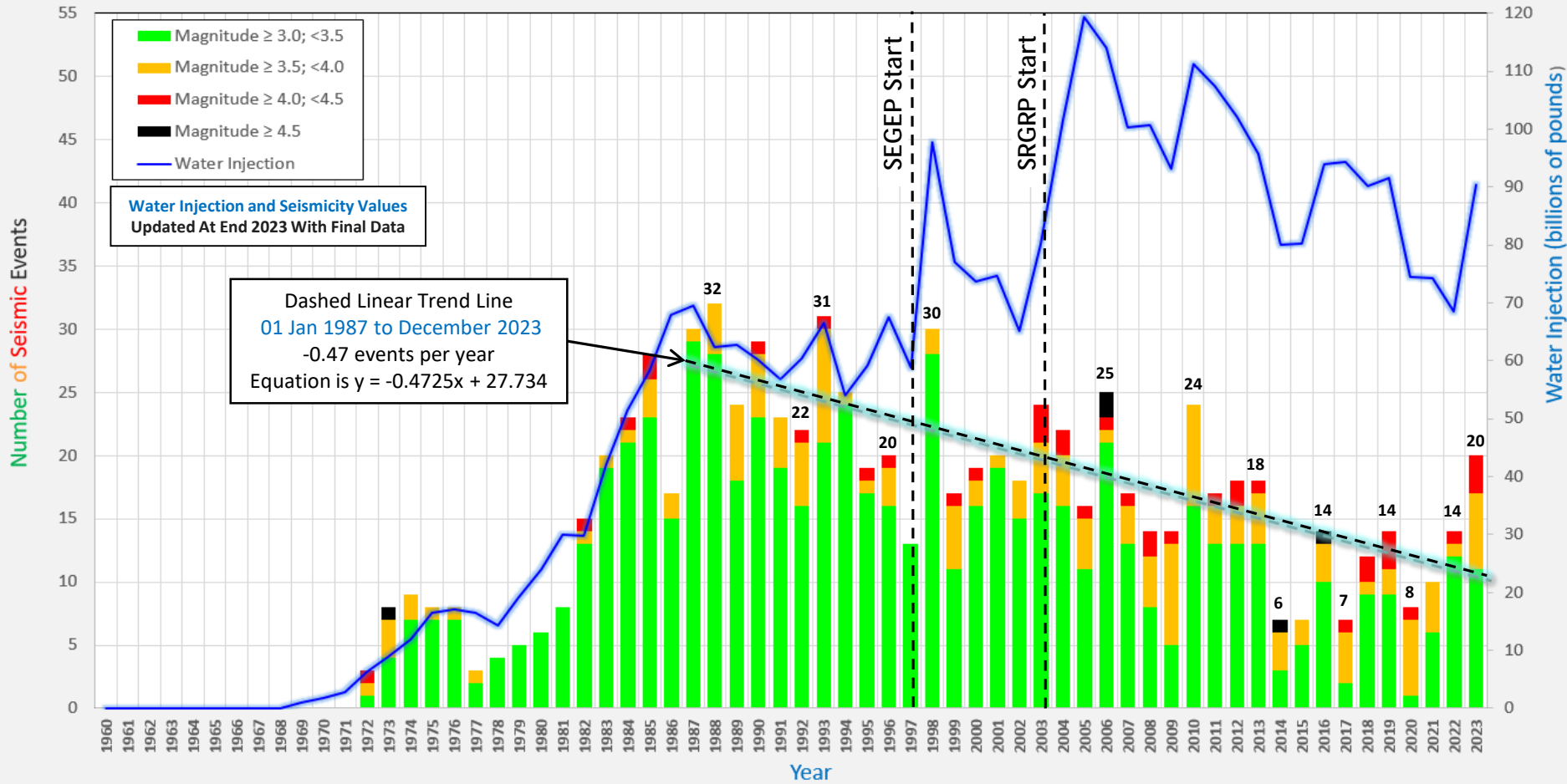
Yearly Field-wide Water Injection and Seismicity Magnitude ≥ 3.0 and < 3.5

The Geysers Fieldwide Water Injection And Induced Seismicity Magnitude ≥ 3.0 and < 3.5
 January 1960 Through December 2023



Yearly Field-wide Water Injection and Seismicity Magnitude ≥3.0

The Geysers Fieldwide Water Injection And Induced Seismicity Magnitude ≥3.0
January 1960 Through December 2023



VIDEO: Field-wide Seismicity Animation At A Daily Interval - Color Scaled By Magnitude

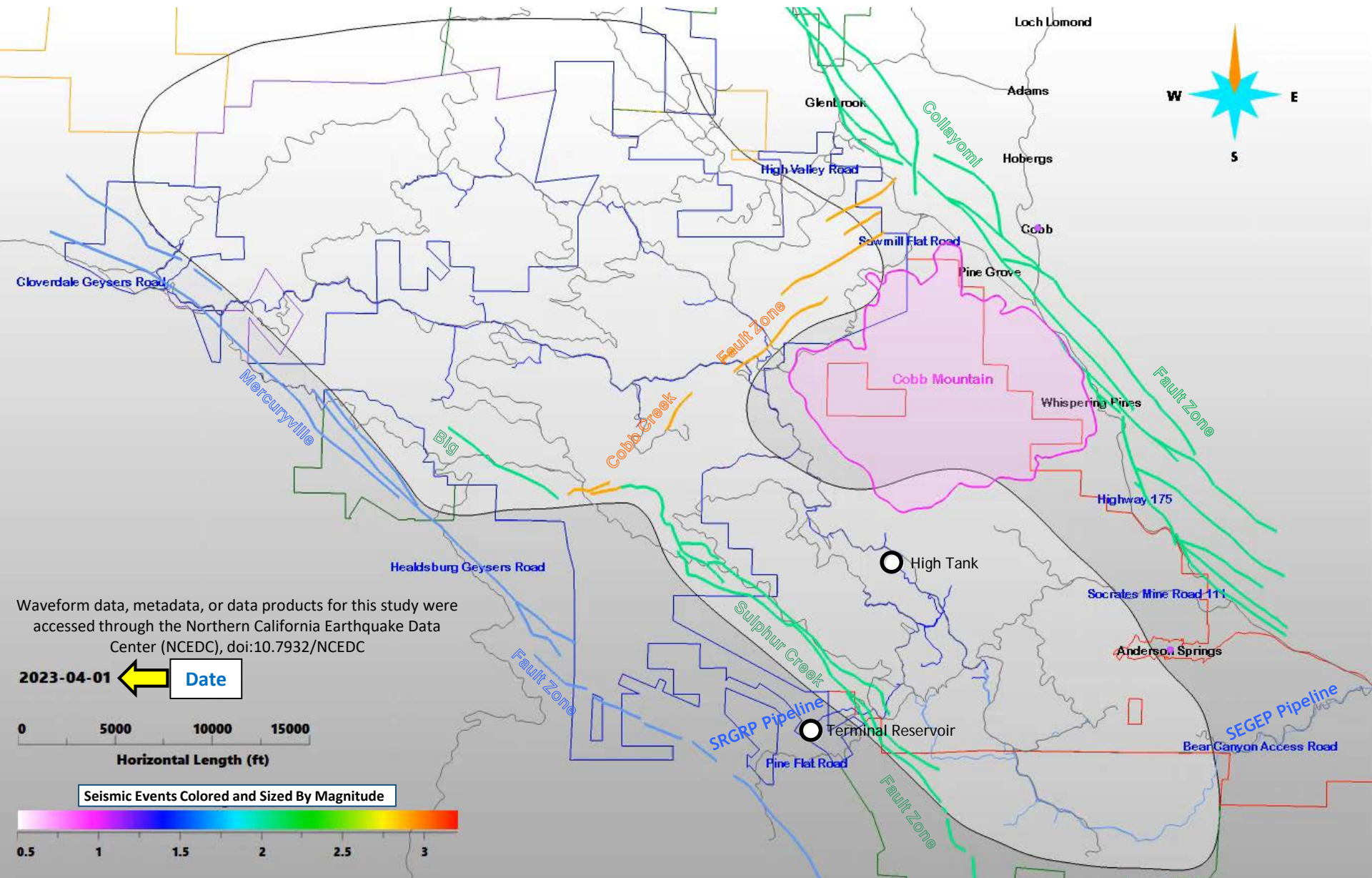


IMAGE: Field-wide Seismicity Animation At A Daily Interval - Color Scaled By Magnitude

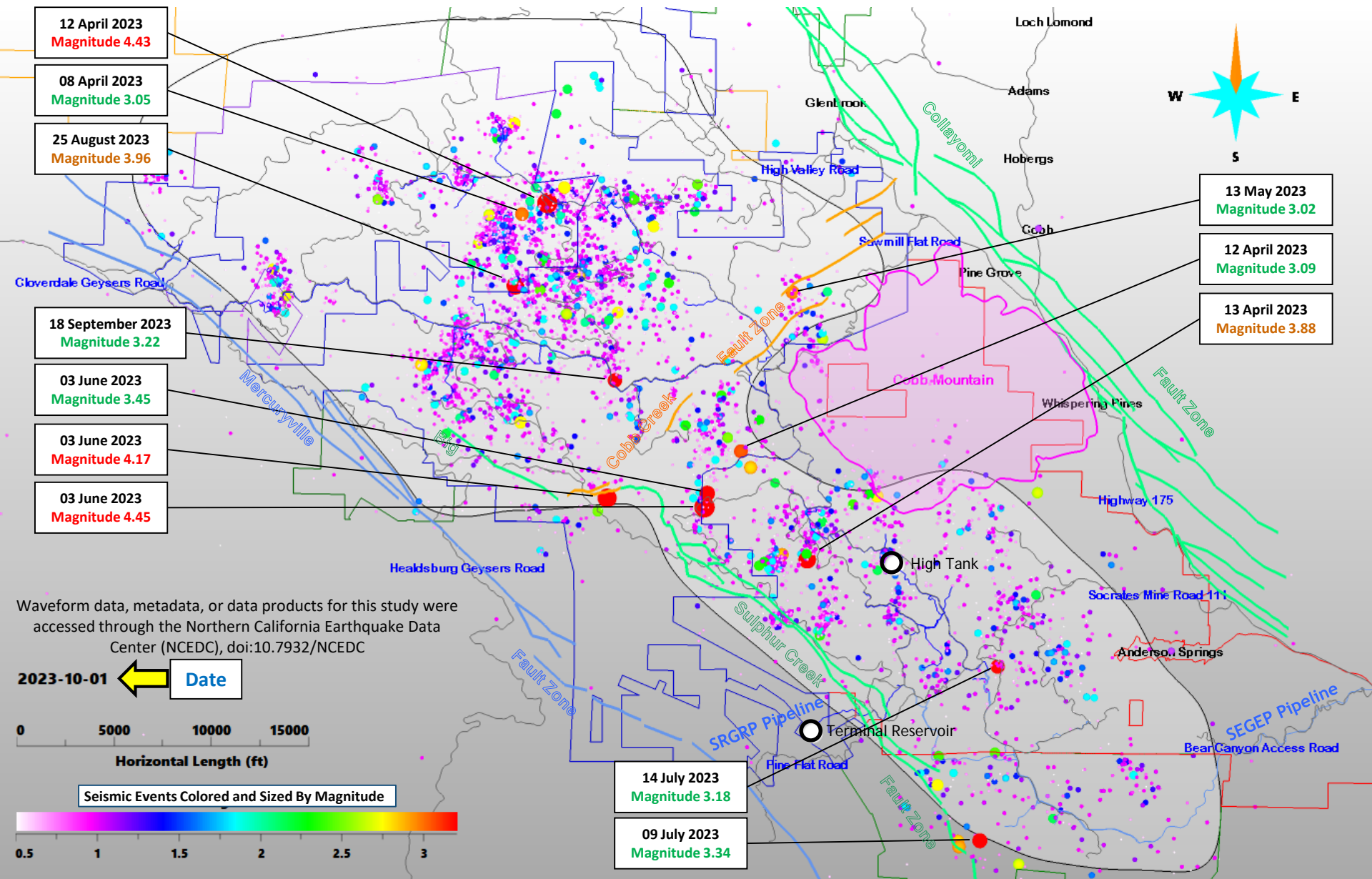
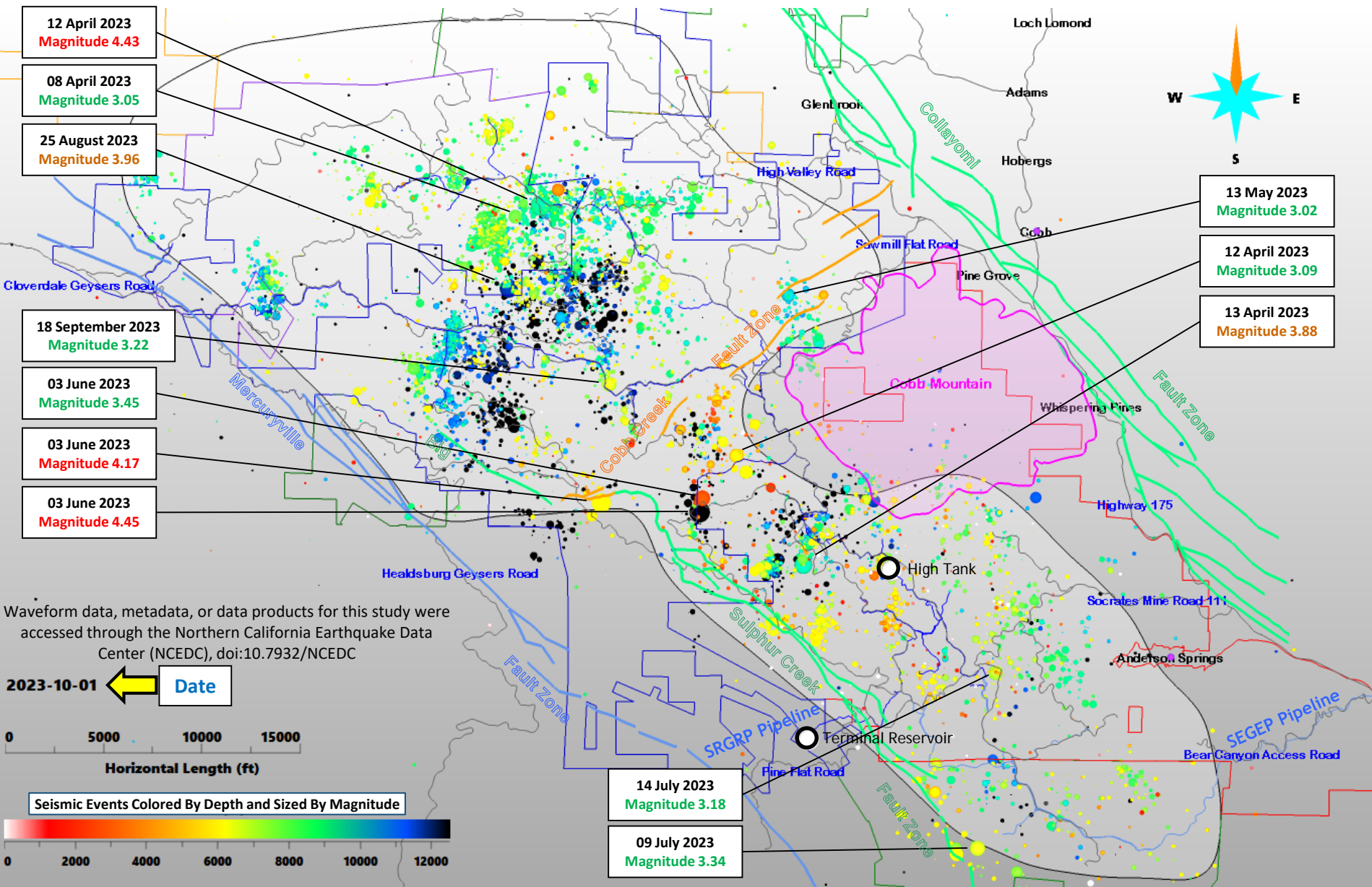
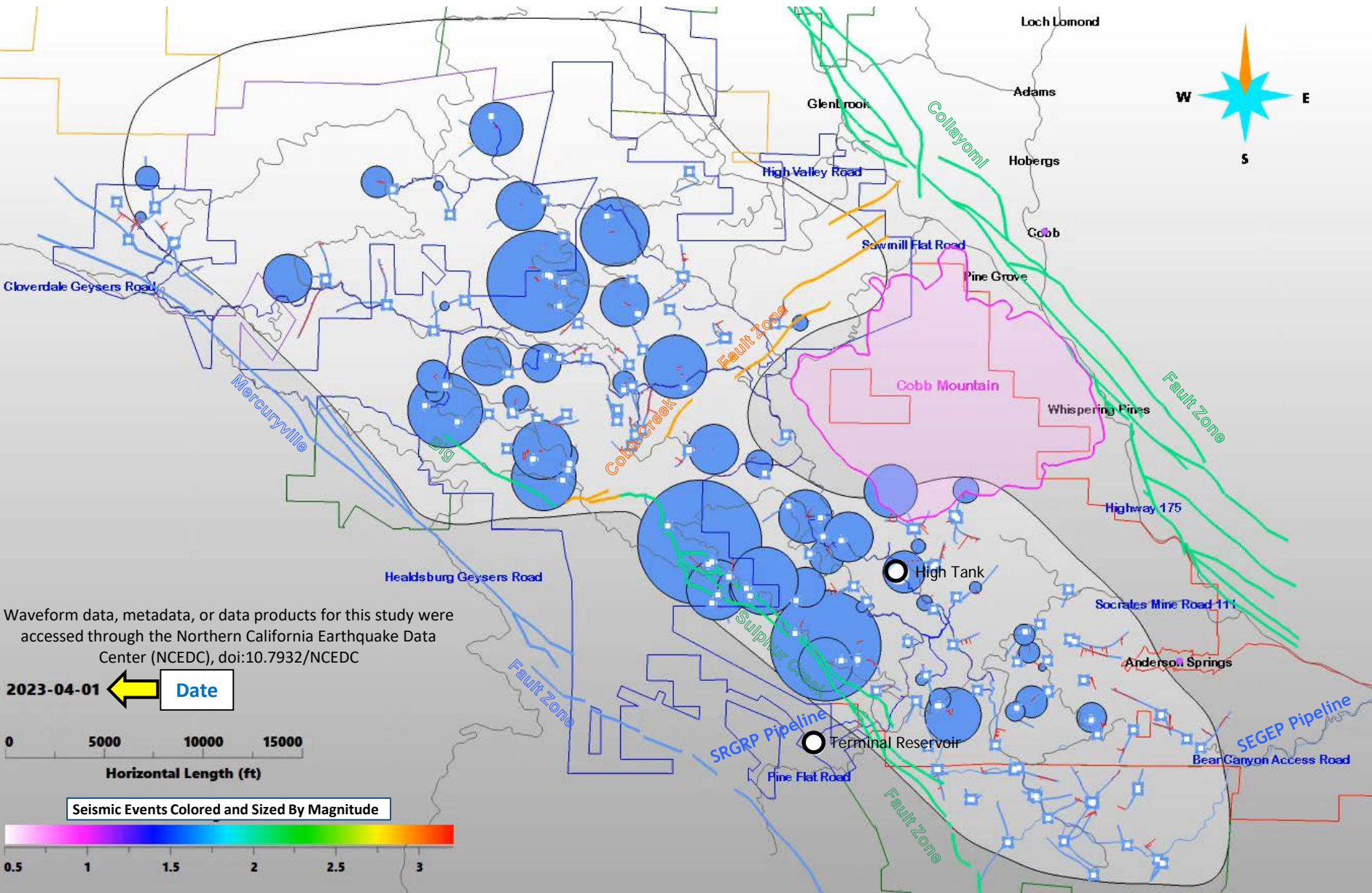


IMAGE: Field-wide Seismicity Animation At A Daily Interval - Color Scaled By Depth



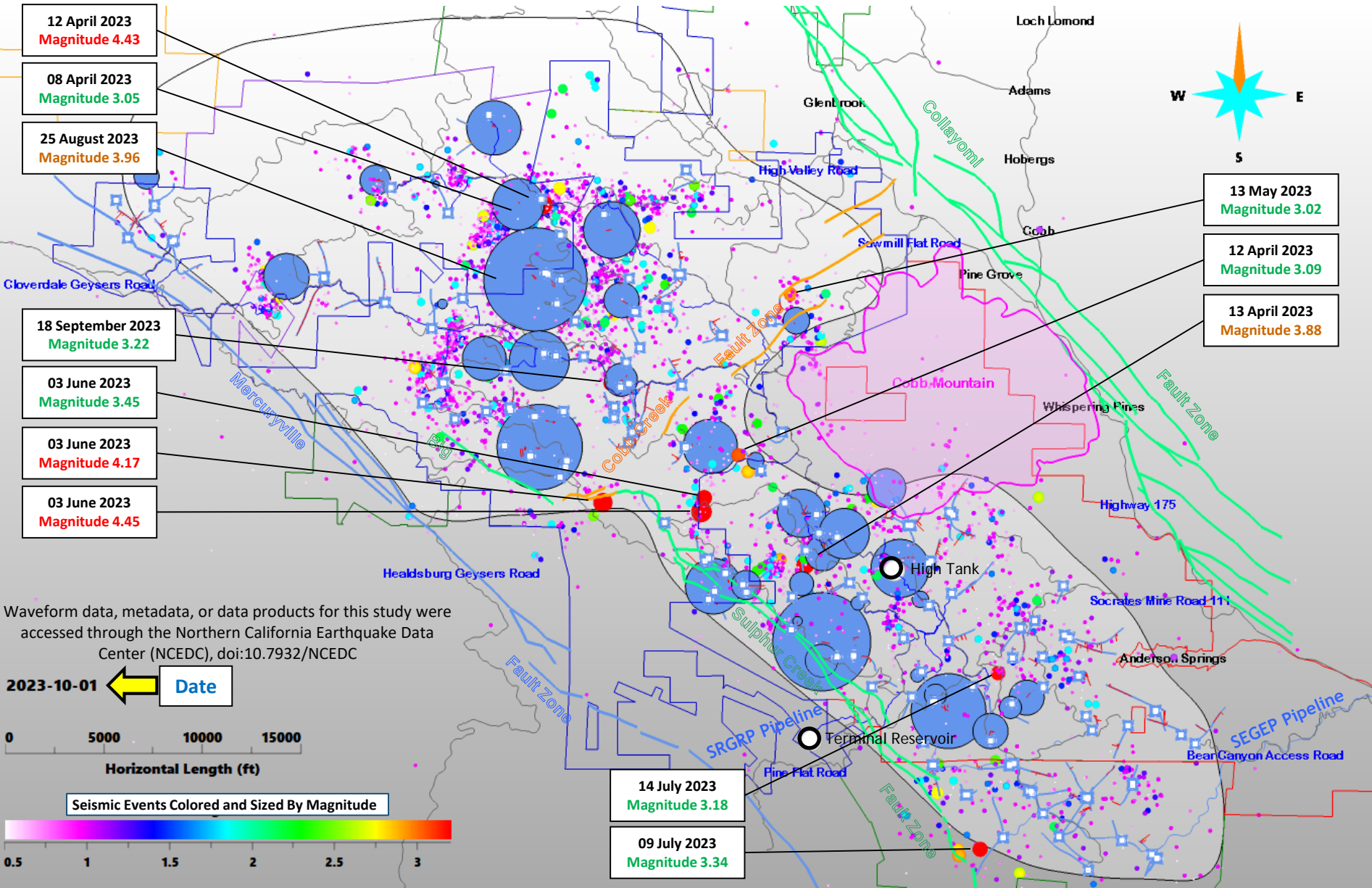
VIDEO: Field-wide Seismicity Animation At A Daily Interval - Color Scaled By Magnitude



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IMAGE: Field-wide Seismicity Animation At A Daily Interval - Color Scaled By Magnitude



VIDEO: Water Injection And Induced Seismicity Daily Animation From 01 April 2023 Through 30 September 2023

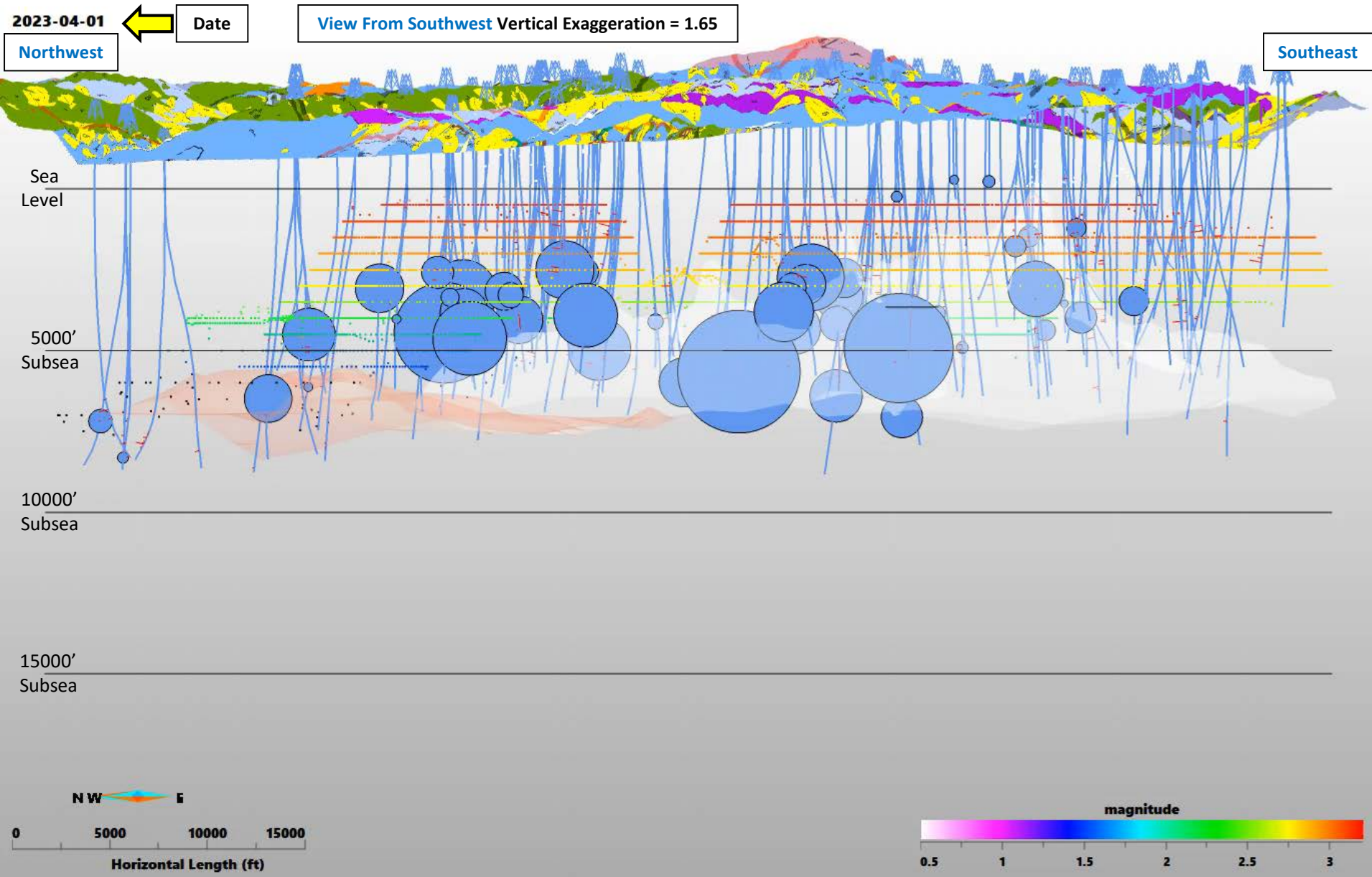
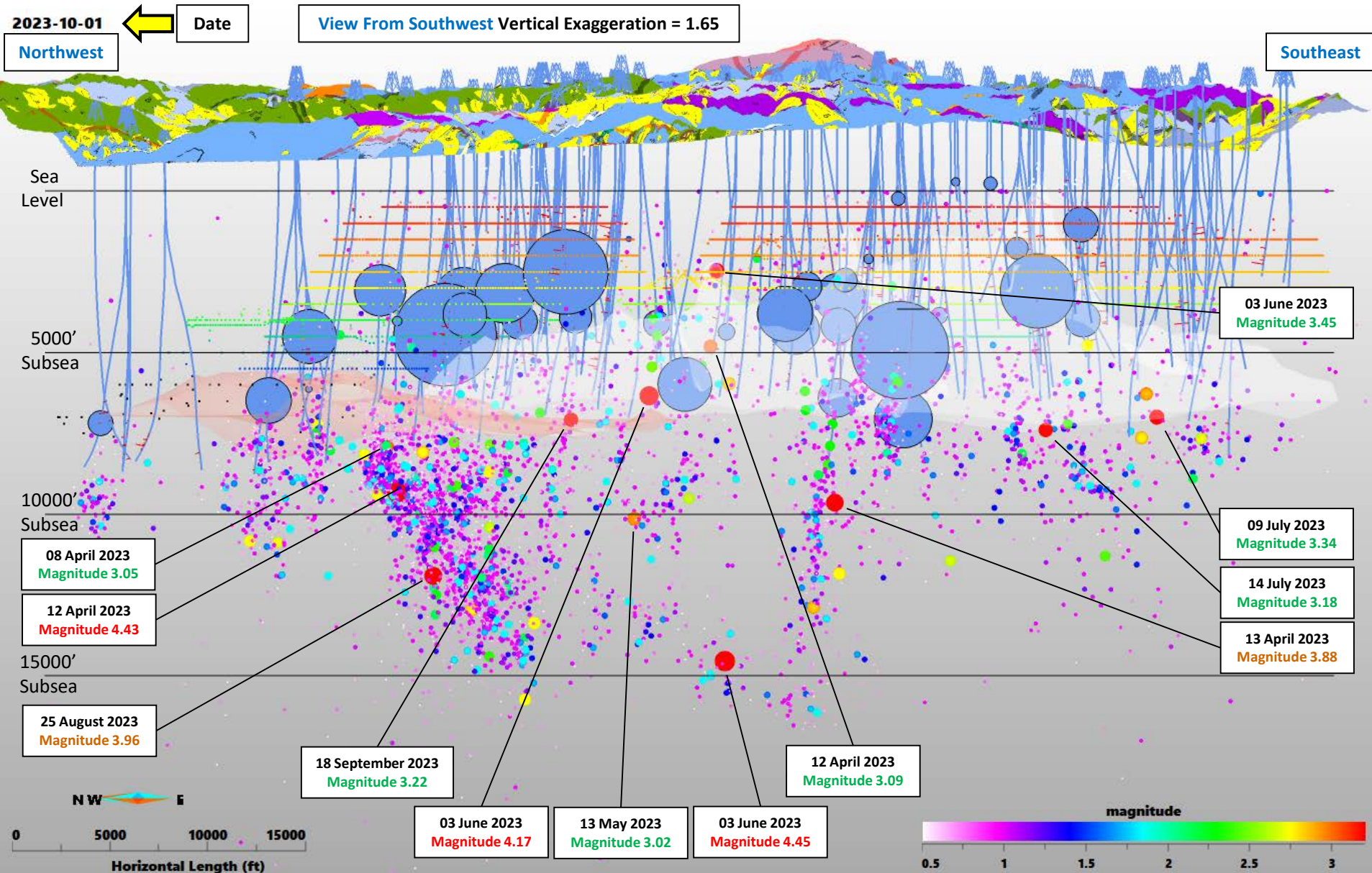


IMAGE: Water Injection And Induced Seismicity From 01 April 2023 Through 30 September 2023



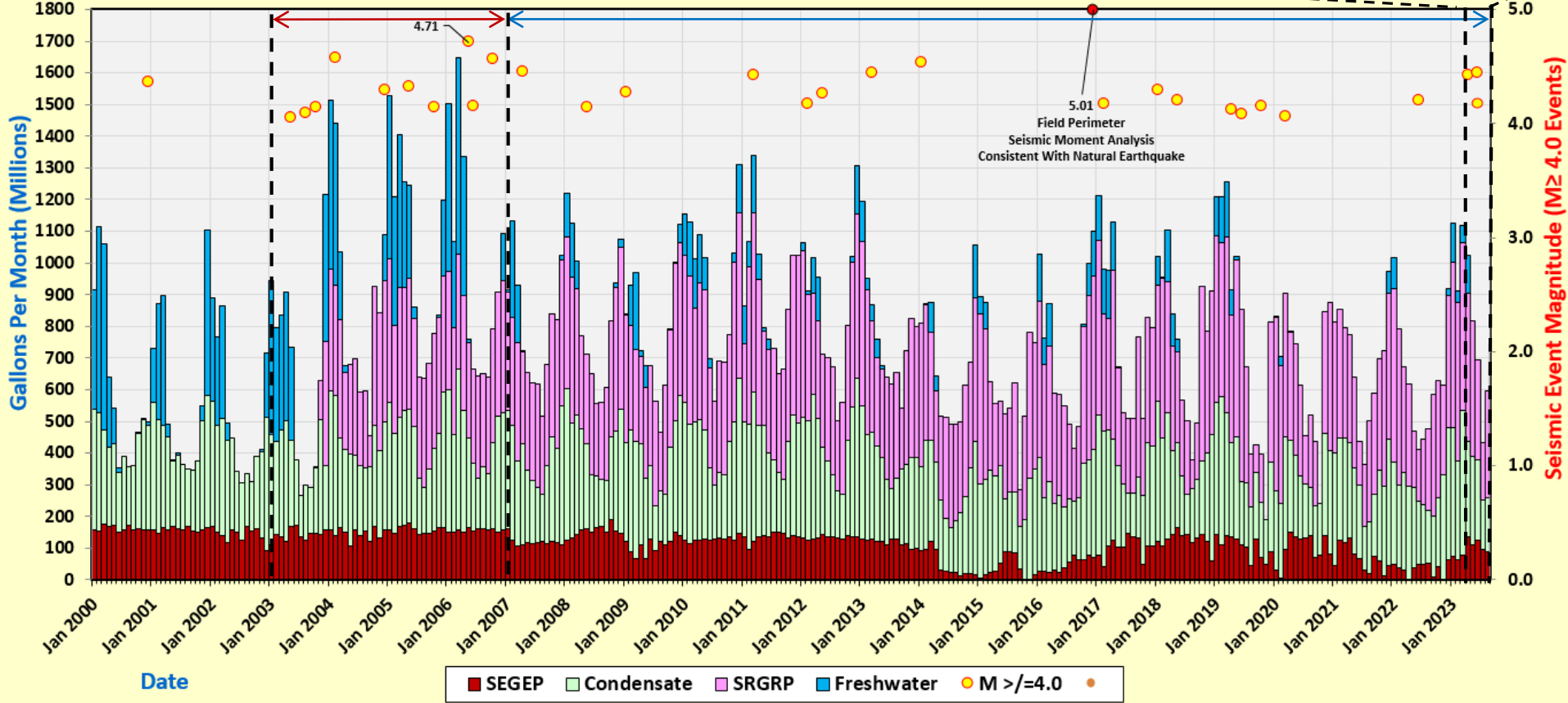
Monthly Field-wide Water Injection By Water Source And Magnitude ≥ 4.0 Seismicity

The Average Number of Magnitude ≥ 4.0 Events Since January 2007 is 1.20 Per Year

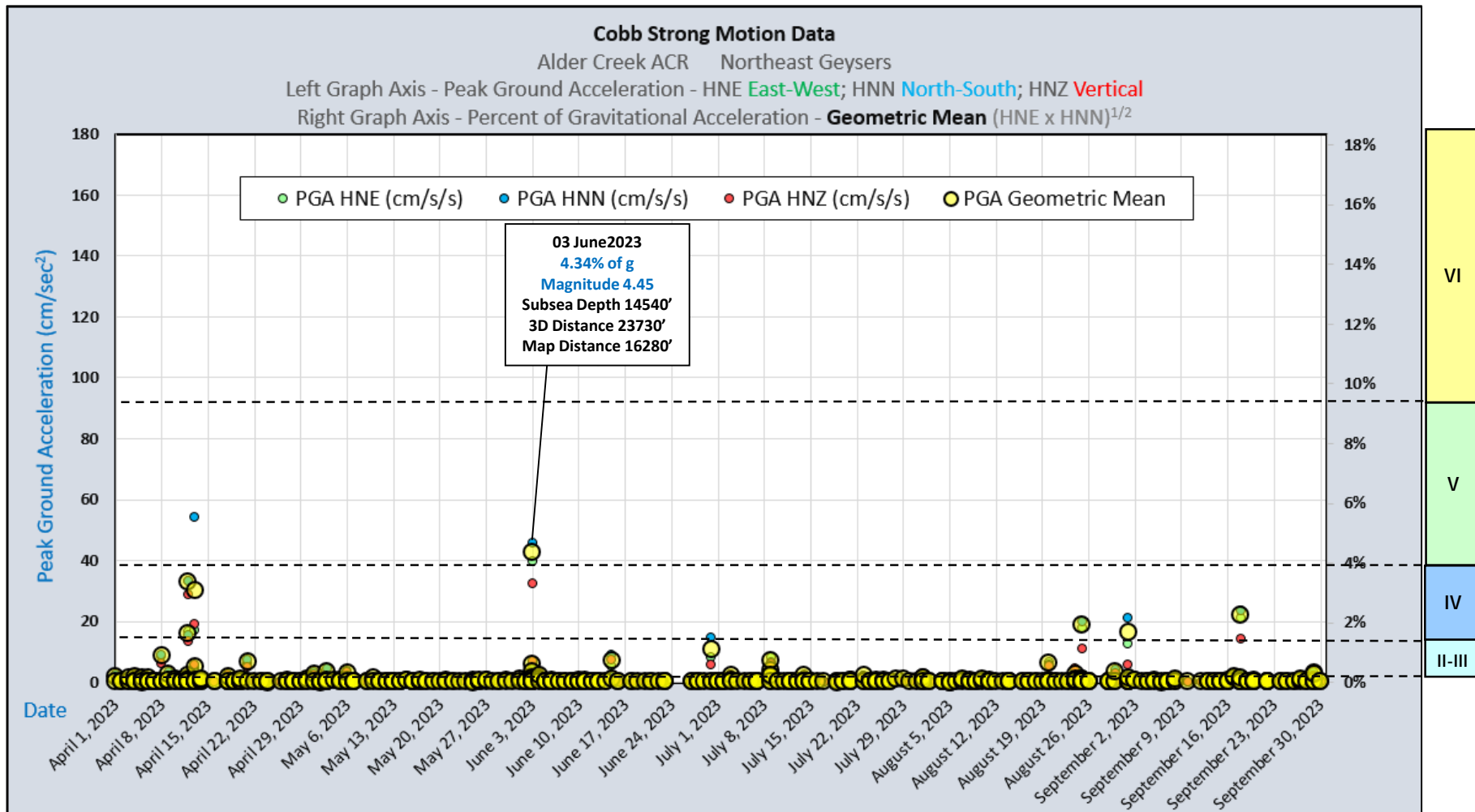
Time Period	Magnitude ≥ 4.0 Seismic Events
January 2003 through December 2006	2.50 per year
January 2007 through September 2023	1.20 per year

Water Supply for Six Month Reporting Period 01 April 2023 To 30 September 2023				
Water Injection By Source (Gallons)				
Month	SEGEP	SRGRP	Condensate	Fresh Water
April	135,912,000	466,740,000	301,937,504	118,506,250
May	109,944,000	429,060,000	280,118,695	0
June	125,215,000	316,990,000	252,939,470	0
July	97,582,000	179,670,000	154,397,031	0
August	88,989,000	336,300,000	170,749,800	0
September	90,226,000	385,320,000	264,171,608	0

The Geysers
Calpine Fieldwide Water Injection Sources
Magnitude ≥ 4.0 Seismicity
01 January 2000 to 30 September 2023



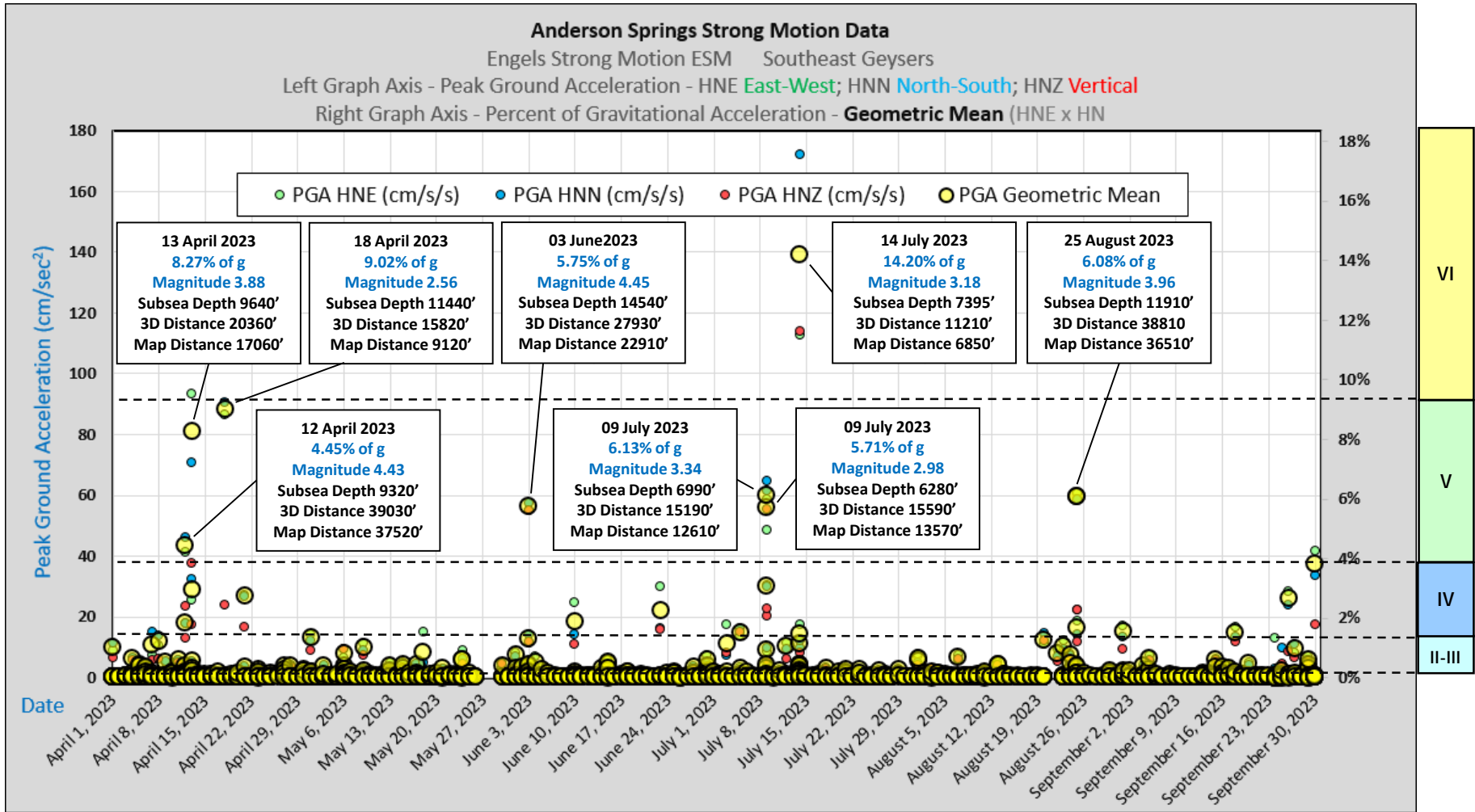
Cobb Area: Strong Motion Determinations At Alder Creek Strong Motion Station



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

45 Calls To Community Hotline; All From Anderson Springs



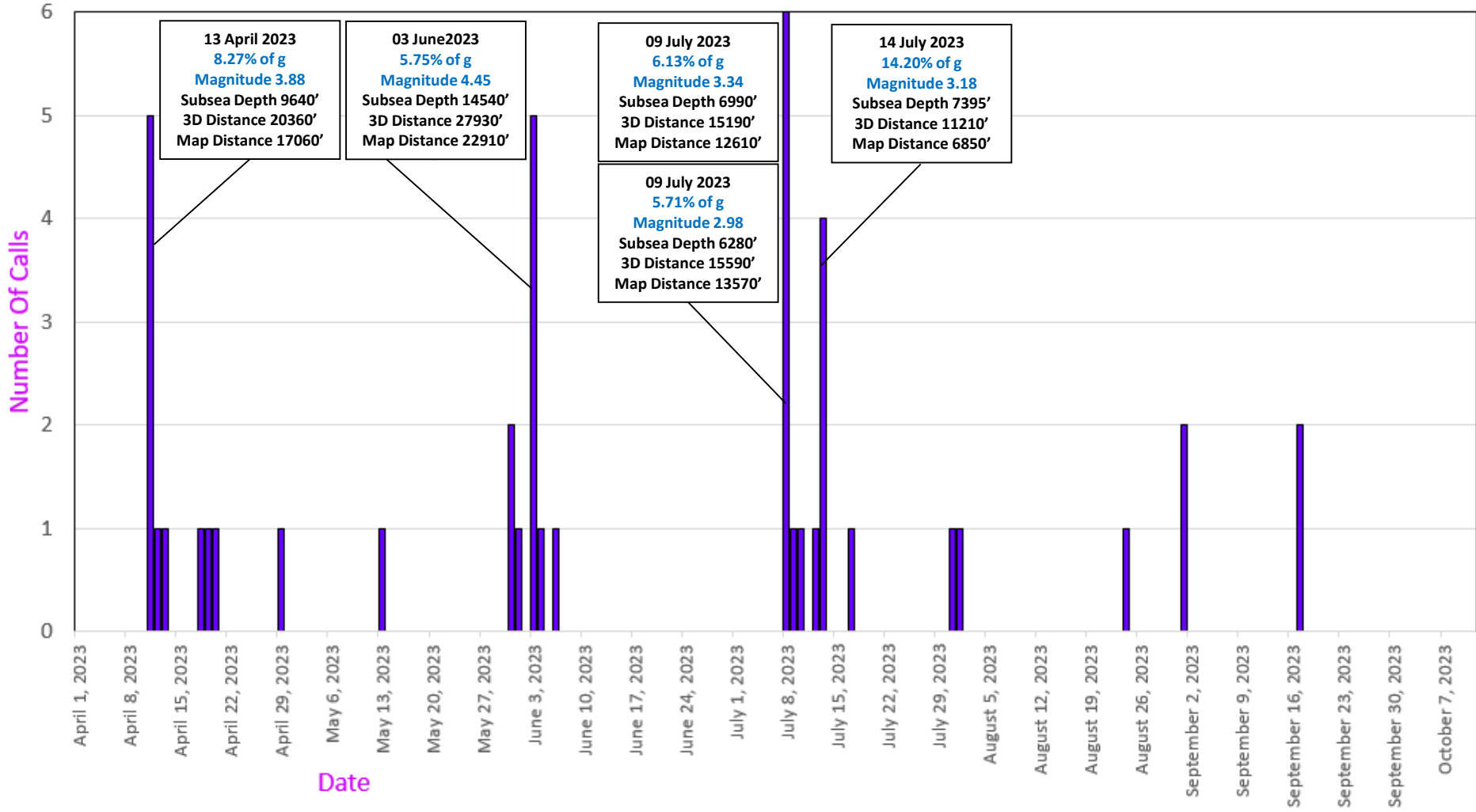
Perceived Shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Damage	None	None	None	Very Light	Light	Moderate	Mod/Heavy	Heavy	Very Heavy
Peak Acceleration (% of g)	< 0.17	0.17 - 1.4	1.4 - 3.9	3.9 - 9.2	9.2 - 18.0	18.0 - 34.0	34.0 - 65.0	65.0 - 124.0	> 124.0
Peak Velocity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



Community Hotline Calls

45 Calls To Community Hotline; All From Anderson Springs

01 April 2023 - 30 September 2023 Community Hotline Call Distribution



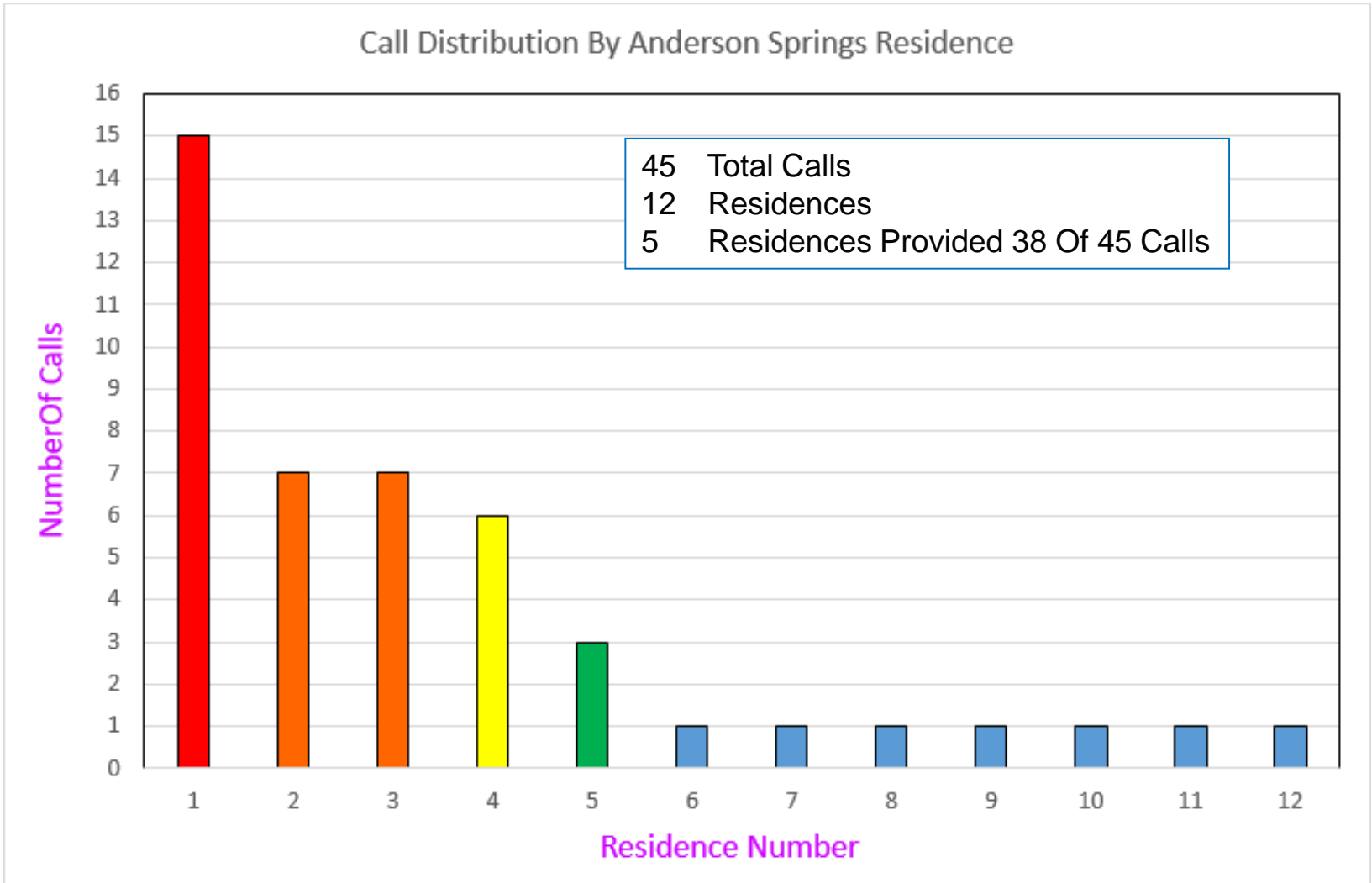
13 April 2023
8.27% of g
Magnitude 3.88
Subsea Depth 9640'
3D Distance 20360'
Map Distance 17060'

03 June 2023
5.75% of g
Magnitude 4.45
Subsea Depth 14540'
3D Distance 27930'
Map Distance 22910'

09 July 2023
6.13% of g
Magnitude 3.34
Subsea Depth 6990'
3D Distance 15190'
Map Distance 12610'

14 July 2023
14.20% of g
Magnitude 3.18
Subsea Depth 7395'
3D Distance 11210'
Map Distance 6850'

09 July 2023
5.71% of g
Magnitude 2.98
Subsea Depth 6280'
3D Distance 15590'
Map Distance 13570'



Calpine IC&E Technicians have been testing the automation of injection well rate determinations with the following goals:

- (1) Effective level control through **small flow modifications to multiple injection wells instead of large flow modifications to few wells.**
- (2) Temporary water surpluses and deficits balanced out **without the need to make large modifications to injection well flows.**

This fieldwide water well management goal is perfectly aligned with Calpine seismicity mitigation efforts.

Completed seismic mitigation ranking with the criteria below to assist with minimization of individual water well volume/rate variability:

Average Water Injection Rate

Measured Values

Variability Of Water Injection Rate

Median Absolute Deviation

Average Distance Of Data Values From Median

Distance From Other Water Injection Wells

Measured Centers Of Injection Separation

Distance From Communities

Anderson Springs and Cobb Most Sensitive Communities

Scalar Applied To Anderson Springs Due To Known Site Amplification Issues

Energy Release Within Well Ellipse

$\text{Log}_{10}(\text{energy}) = 11.8 + 1.5(\text{magnitude})$

Largest Seismic Event(s) Within Well Ellipse

Number of Events ≥ 2.65

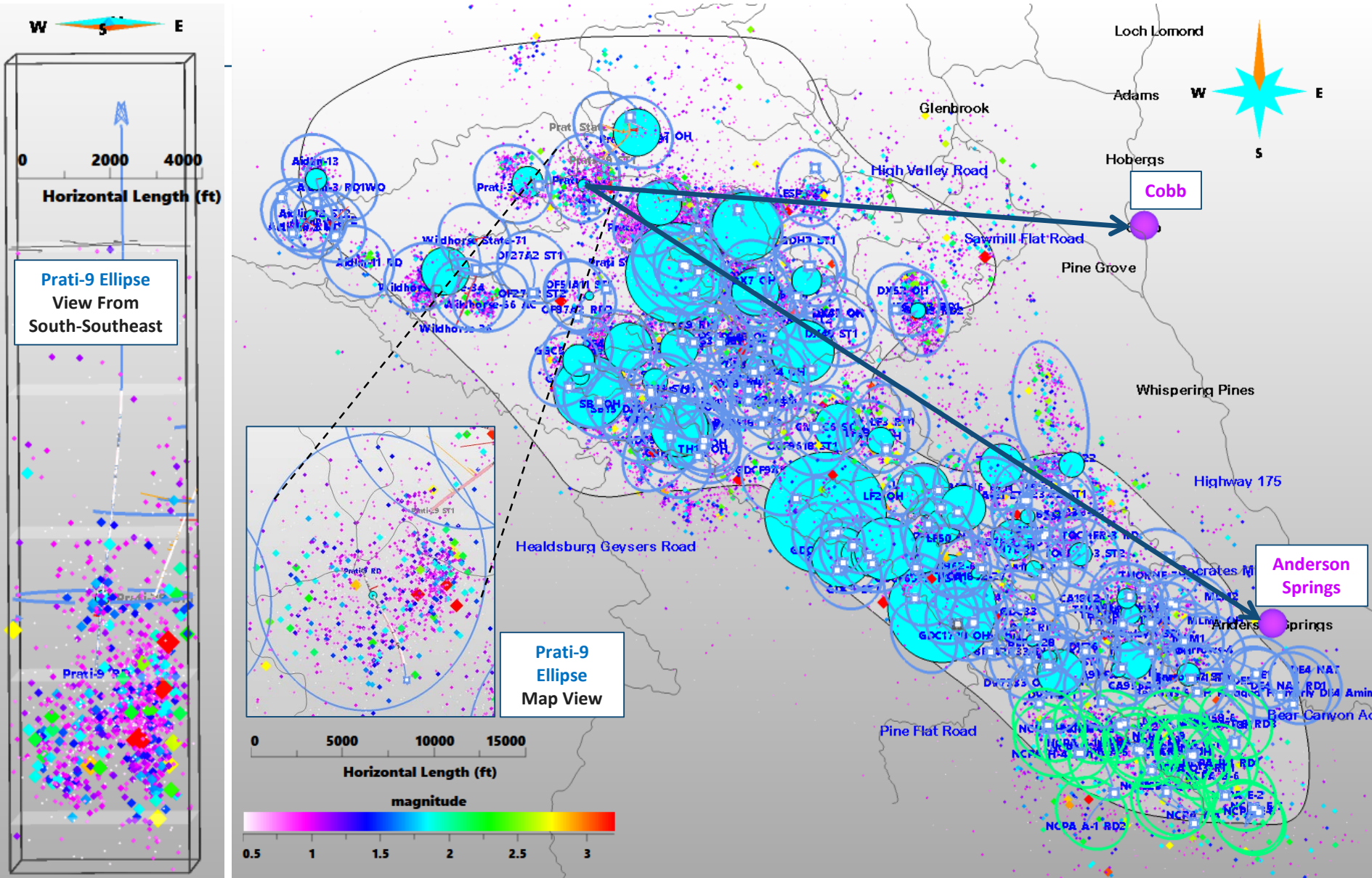
B-Values (Magnitude vs. Frequency) Within Ellipse

B-Values Based On Gutenberg-Richter Relationship

Spatial and Temporal Changes In B-Values

Analysis Of Individual Wells: Water Injection and Induced Seismicity Relationships

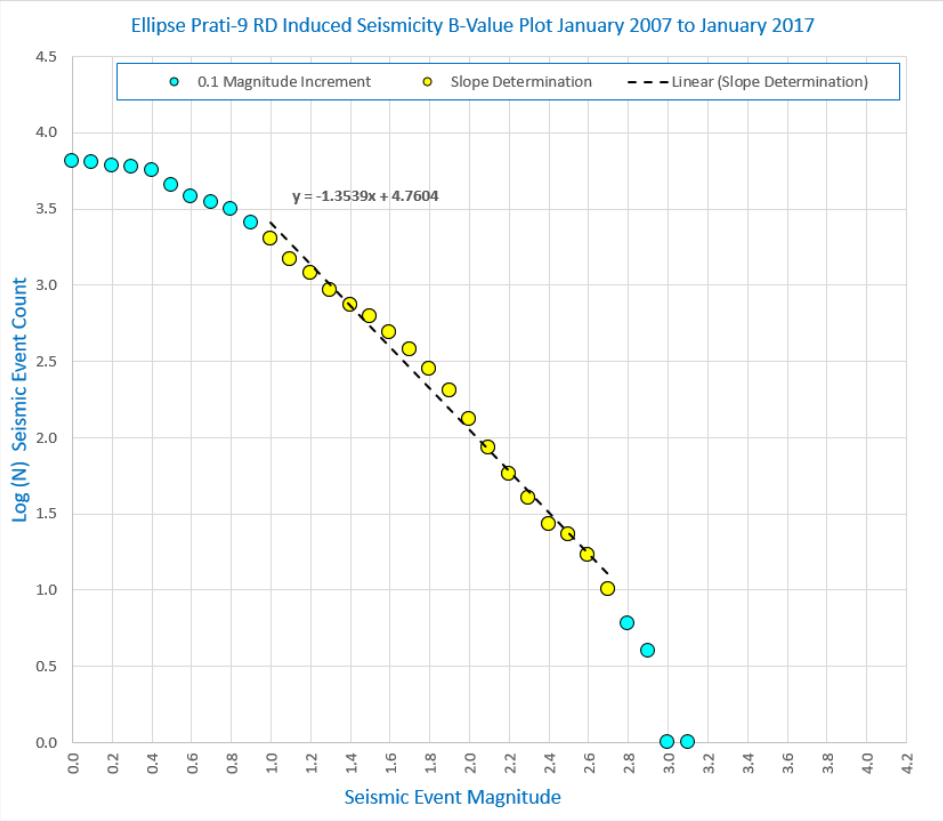
Primary Area Of Influence for All Historical Individual Water Injection Wells Determined



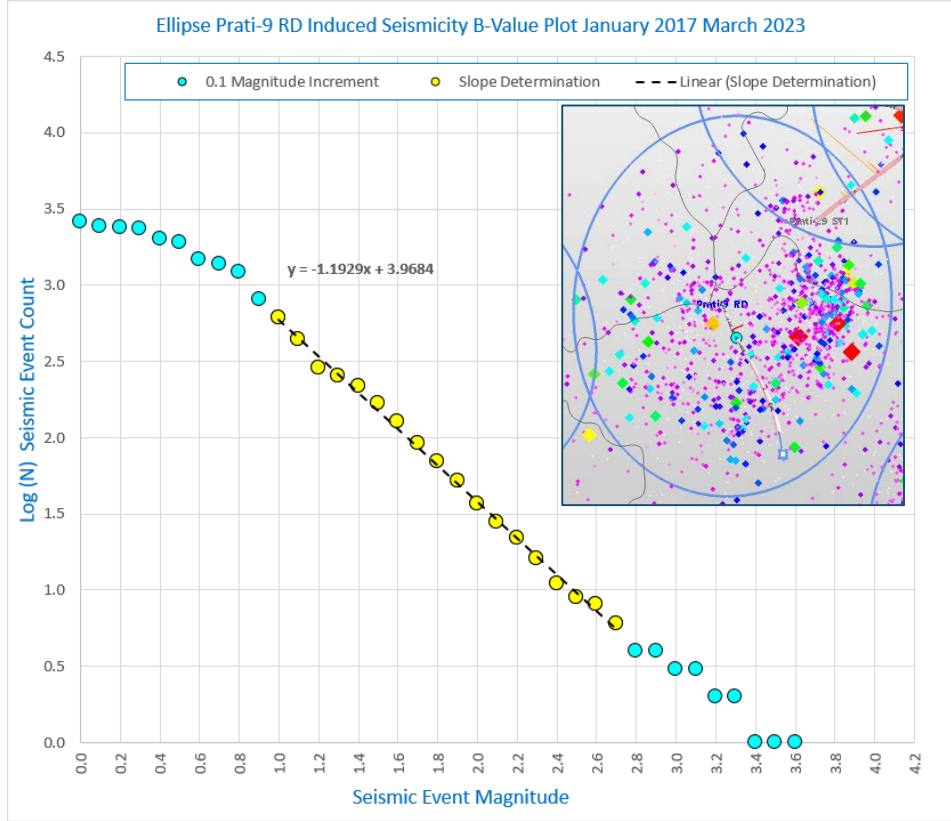
Induced Seismicity Mitigation

Prati-9 B-Value Analysis Over Limited Time Intervals

January 2007 to January 2017



January 2017 to March 2023

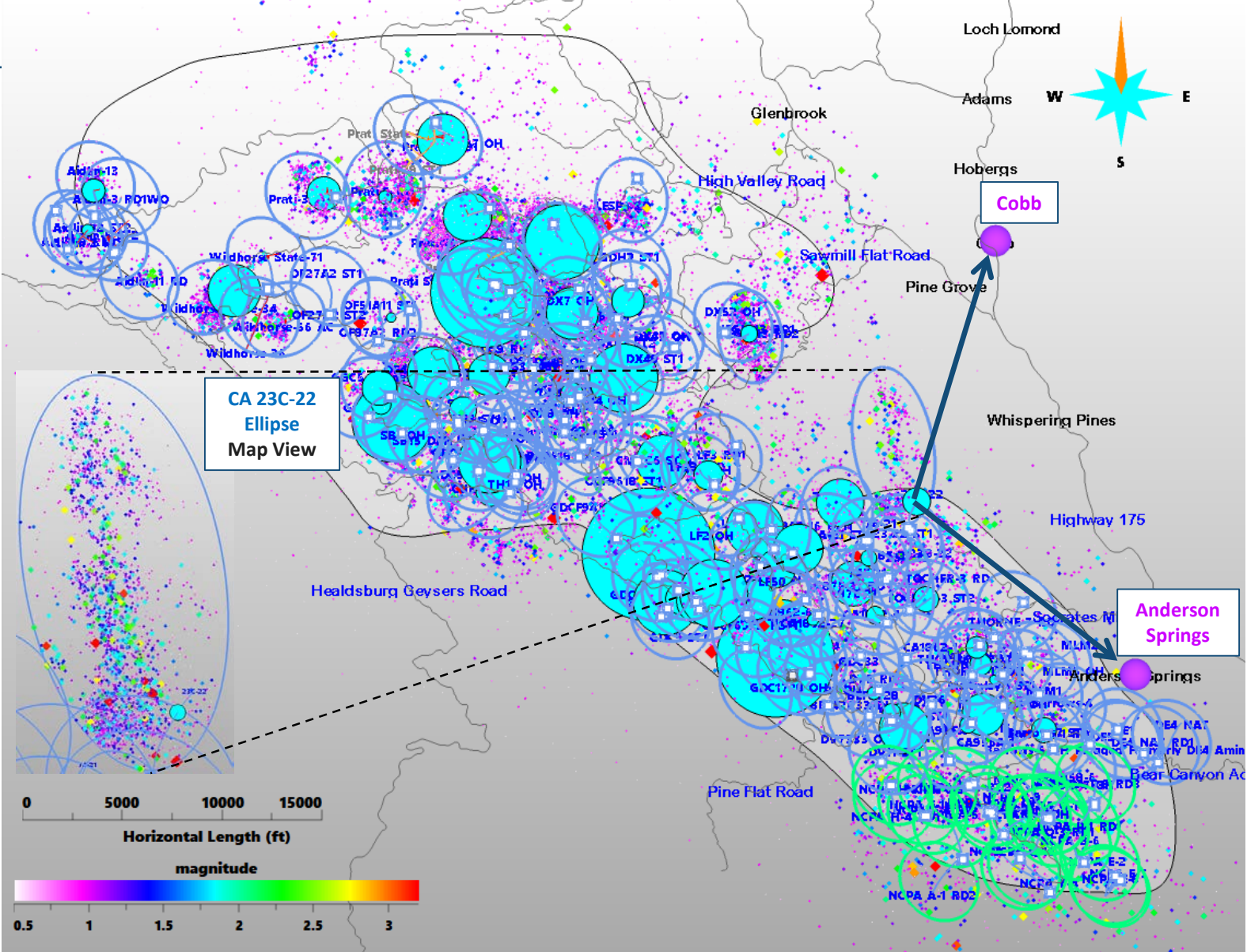
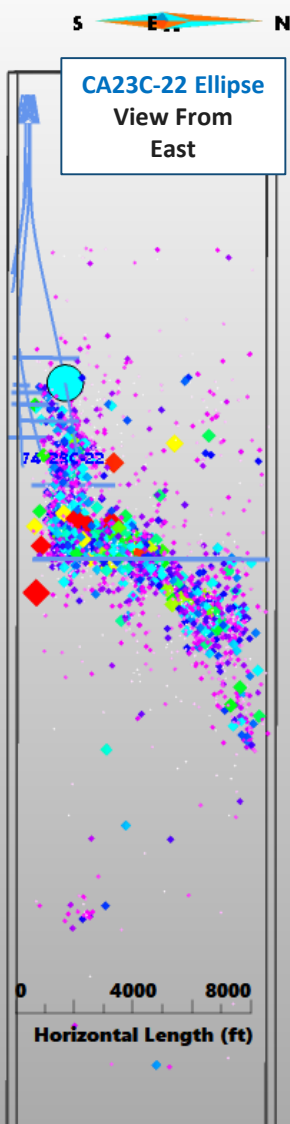


A higher slope or "B-Value" indicates that a reservoir zone tends to produce more low magnitude seismicity

Since 2017, Prati-9 water injection has shifted towards lower B-Values, increasing the probability of a larger seismic event. This fact, along with changing seismicity progression, suggest that water injection has shifted to a different reservoir zone

Analysis Of Individual Wells: Water Injection and Induced Seismicity Relationships

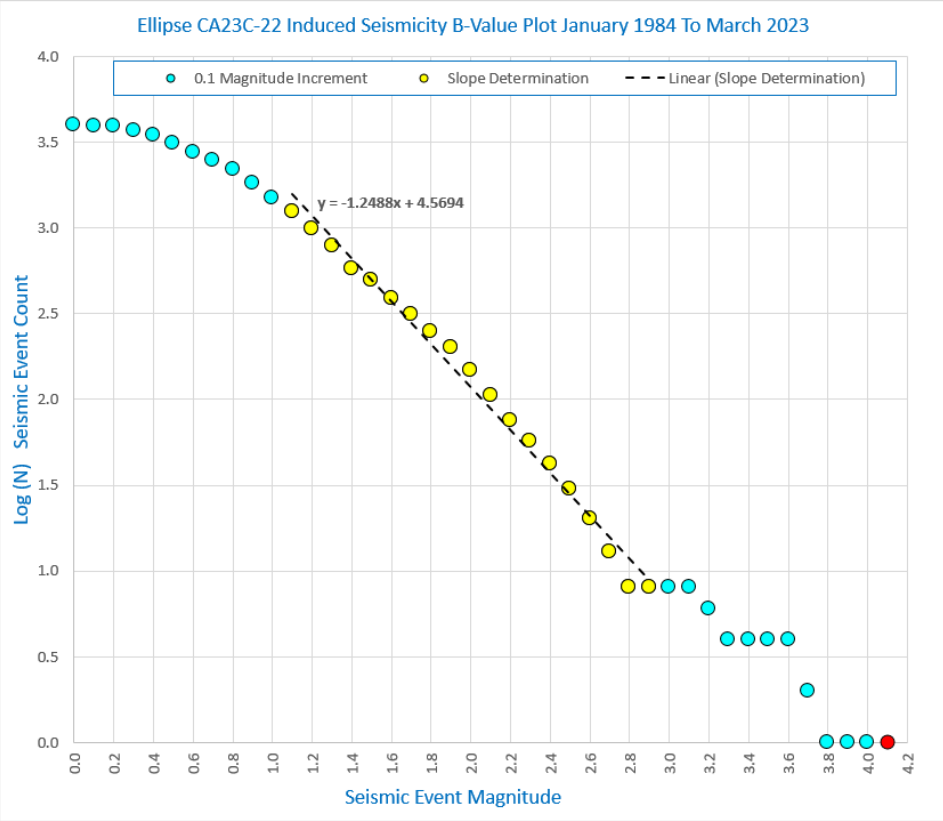
Primary Area Of Influence for All Historical Individual Water Injection Wells Determined



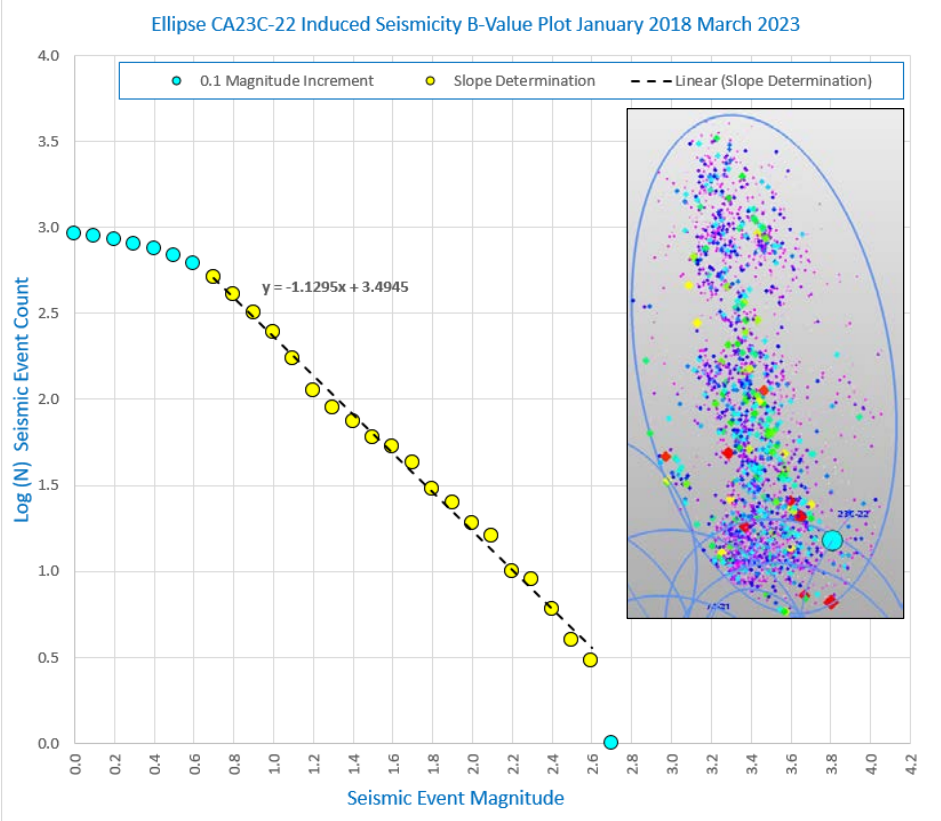
Induced Seismicity Mitigation

CA 23C-22 B-Value Analysis Over Limited Time Intervals

January 2007 to January 2017



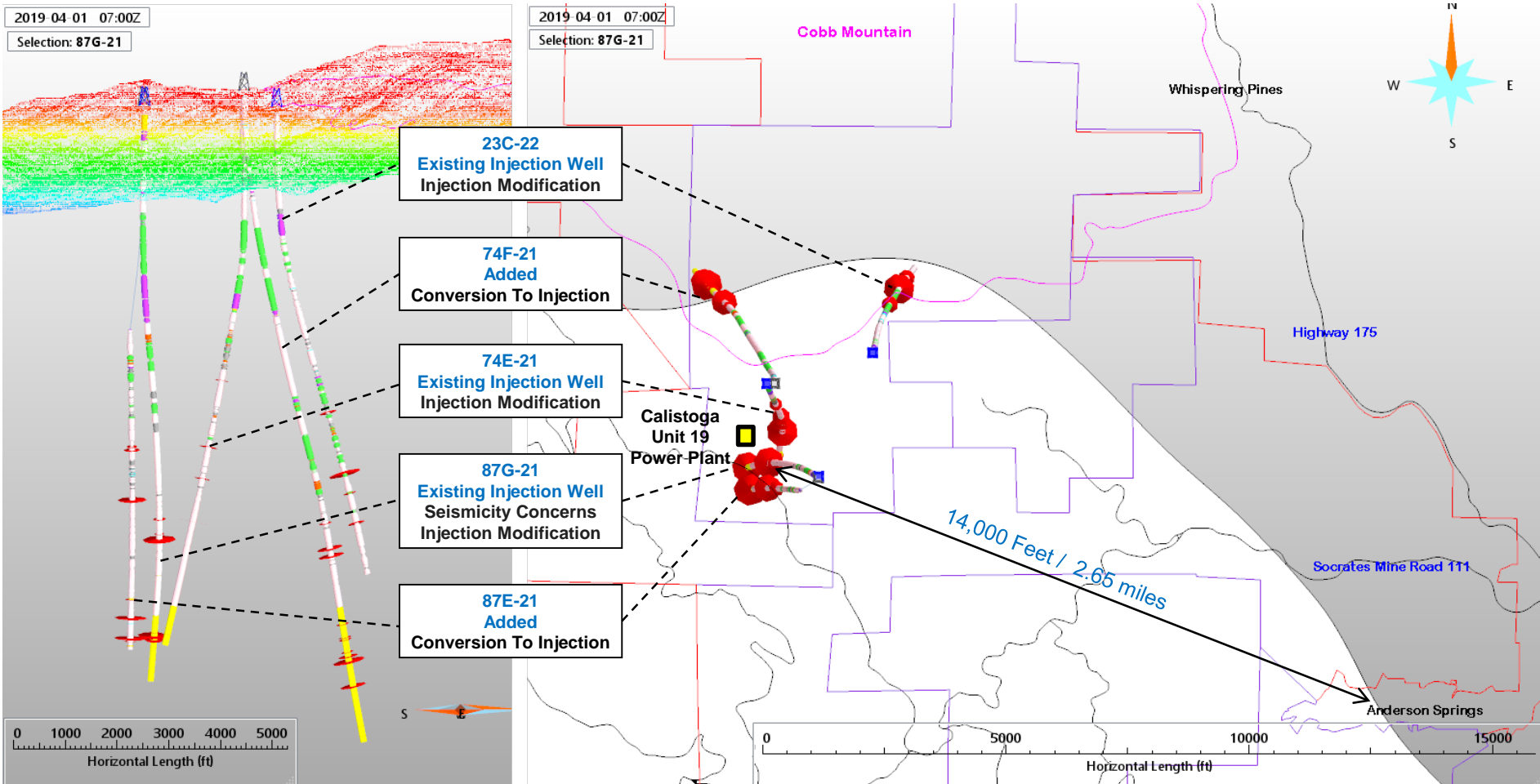
January 2018 to March 2023



Although CA 23C-22 has shifted toward **slightly** higher B-Values, no seismic events > magnitude 2.7 since 01 January 2018. A program completed in 2019 to allow better distribution of Calistoga Unit 19 water injection appears successful. See summary on next slide.

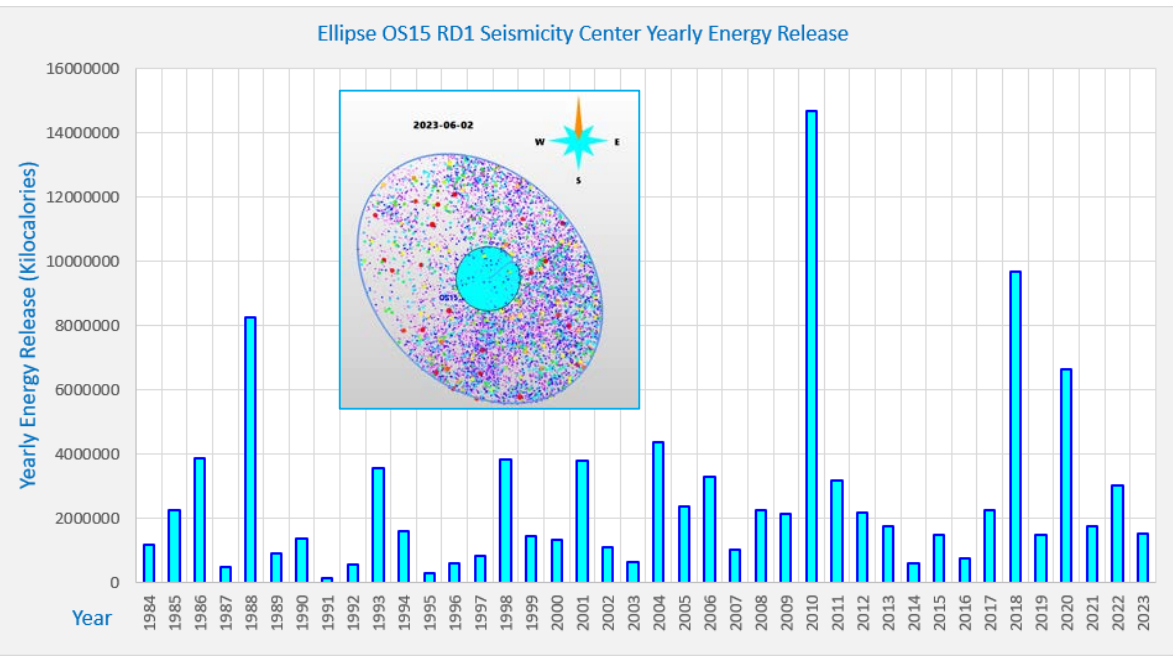
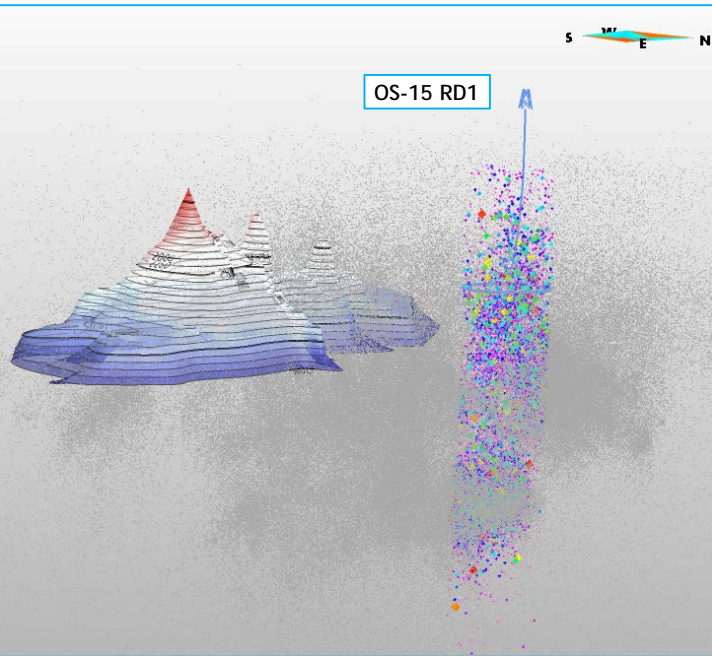
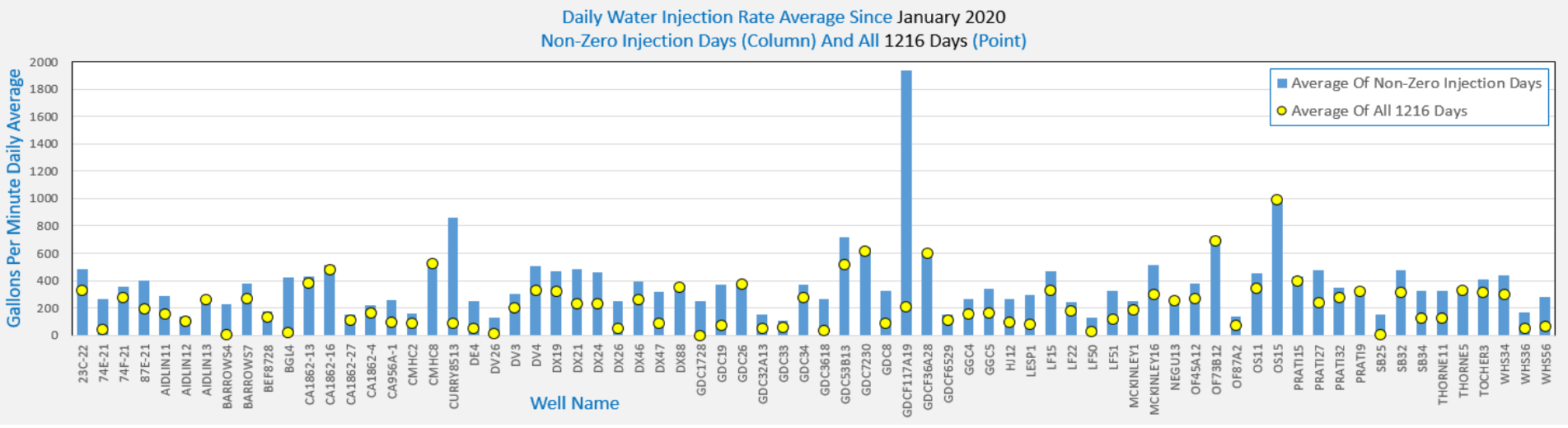
Calistoga Power Plant Area

- 74F-21 October 2019 Conversion of Steam Production Well to Injection
- 87E-21 November 2019 Conversion of Steam Production Well to Injection
- 23C-22 Early 2020 Modification to Existing Water Injection
- 74E-21 Early 2020 Modification to Existing Water Injection
- 87G-21 Early 2020 Modification to Existing Water Injection



Induced Seismicity Mitigation

Water Injection Well Ranking: Injection Rate/Variability And Seismic Energy Release

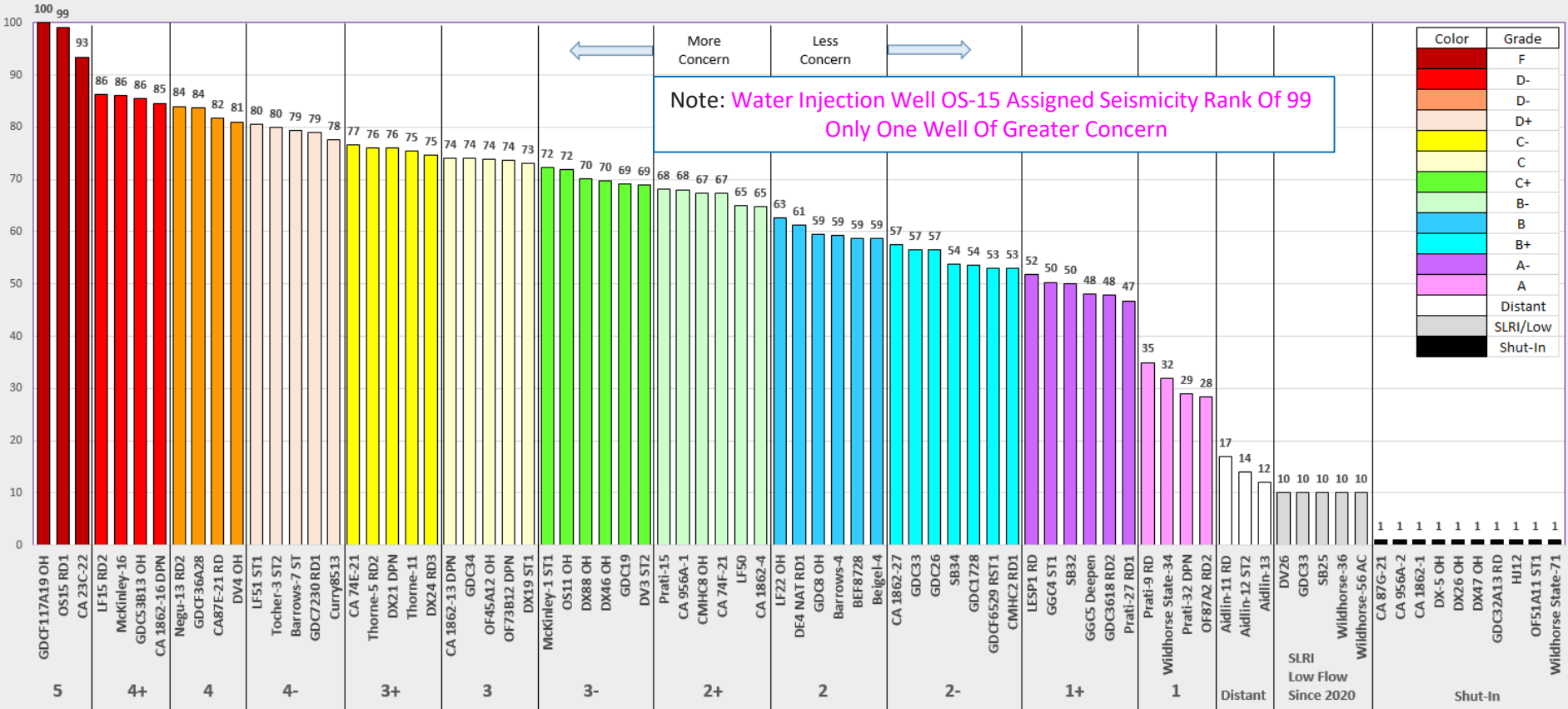


Induced Seismicity Mitigation

09 August 2023 Completion Of Water Injection Well Ranking Utilizing:

- Distance From Communities
- Average Water Injection Rate
- Variability Of Water Injection Rate
- Largest Seismic Event(s) Within Well Ellipse
- Energy Release Within Well Ellipse
- B-Values (Magnitude vs. Frequency) Within Ellipse (*reviewed; not individually ranked*)
- **Weighted Summation of These Individual Ranking Criteria Shown Below**

Seismicity Ranking For Water Injection Wells Based On:
 (1) Community/Well Separation Distances (2) Since 2020 Water Injection Rates/Variability; (3) Well Area Time-Scaled Seismic Energy Release



Note: Water Injection Well OS-15 Assigned Seismicity Rank Of 99
 Only One Well Of Greater Concern

Color	Grade
Red	F
Dark Red	D-
Orange	D-
Light Orange	D+
Yellow	C-
Light Yellow	C
Light Green	C+
Green	B-
Light Blue	B
Blue	B+
Purple	A-
Pink	A
White	Distant
Grey	SLRI/Low
Black	Shut-In



Induced Seismicity Mitigation

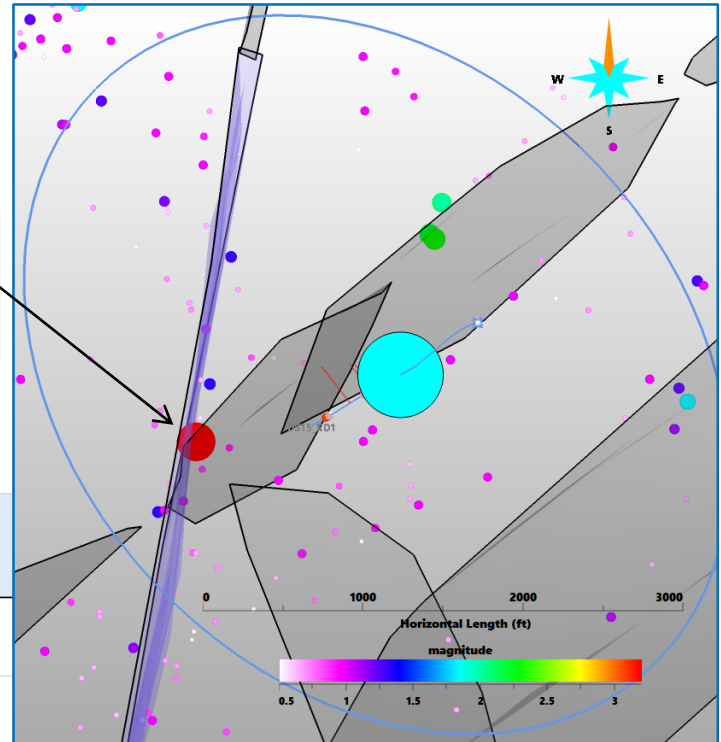
09 August 2023

Completed Ranking Of Water Injection Well
 Water Injection Well OS-15 Assigned Seismicity Rank Of 99
 Only One Well Ranked With Greater Concern

25 August 2023 16 Days Later

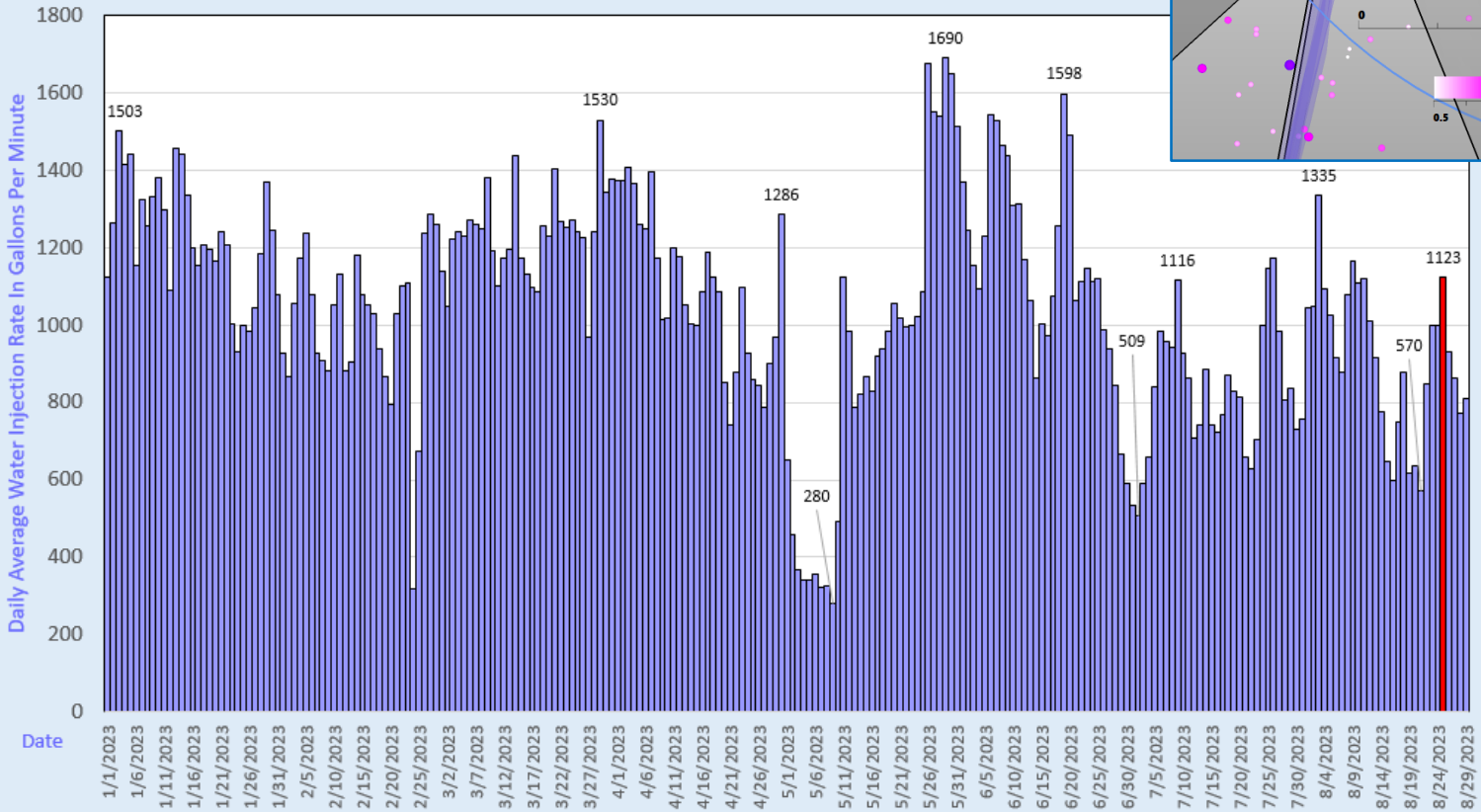
Magnitude 3.98 Seismic Event
 Within 1330' Of OS-15 Injection Center
 Aligned With 3D Model Fault Surface Created 2018; Slightly Refined 2022
 Continuing Large And Variable Rates Of Injection
 Responsible For Community Hotline Response And CBS News Report

25 August 2023
Magnitude 3.98
 1330' From OS-15 Injection Center
 Aligned With N9°E 3D Model Fault Surface



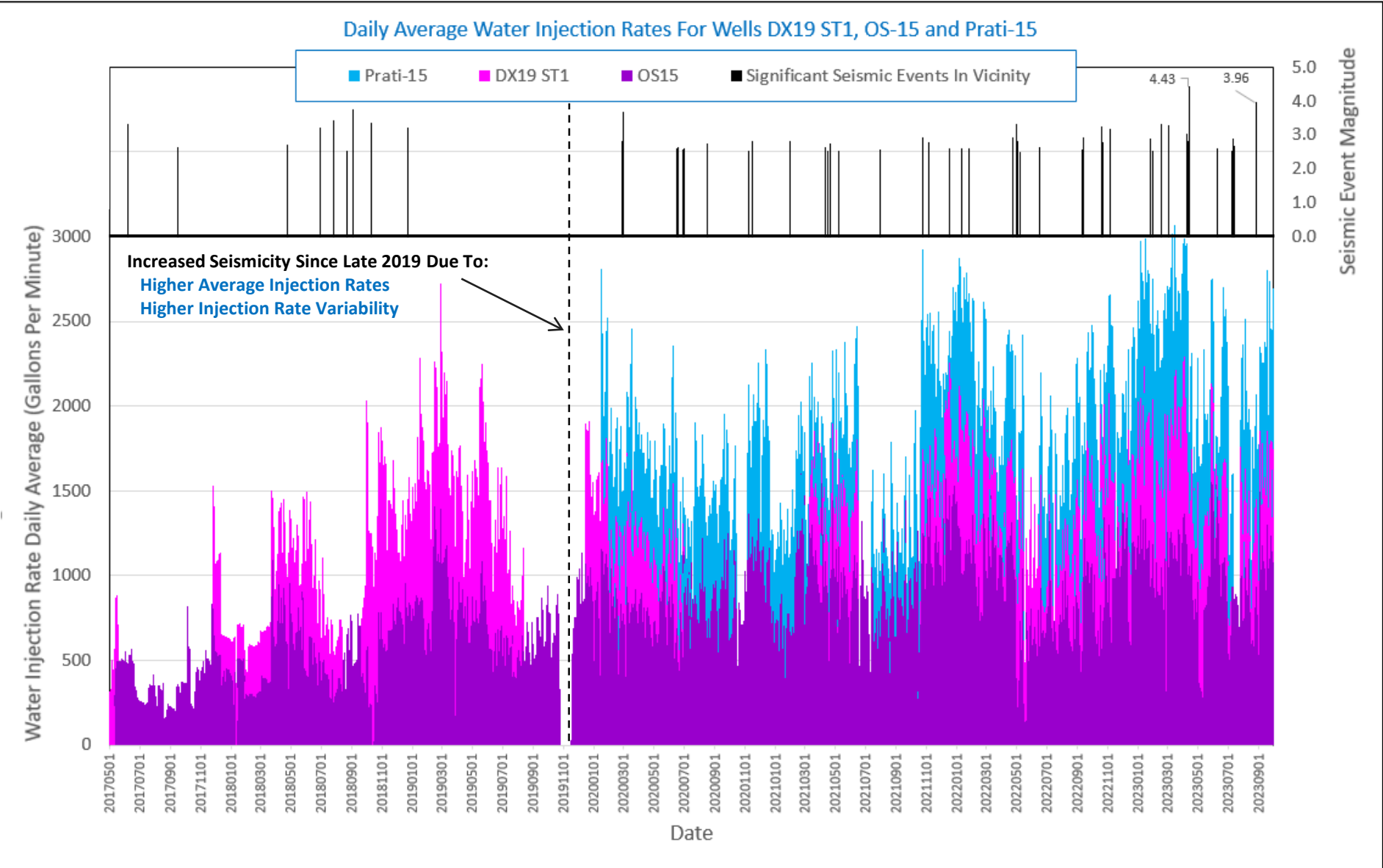
OS-15 Water Injection Well Daily Average Injection Rate

GY.GY.ER_99_INJ_OS15_FR_AI



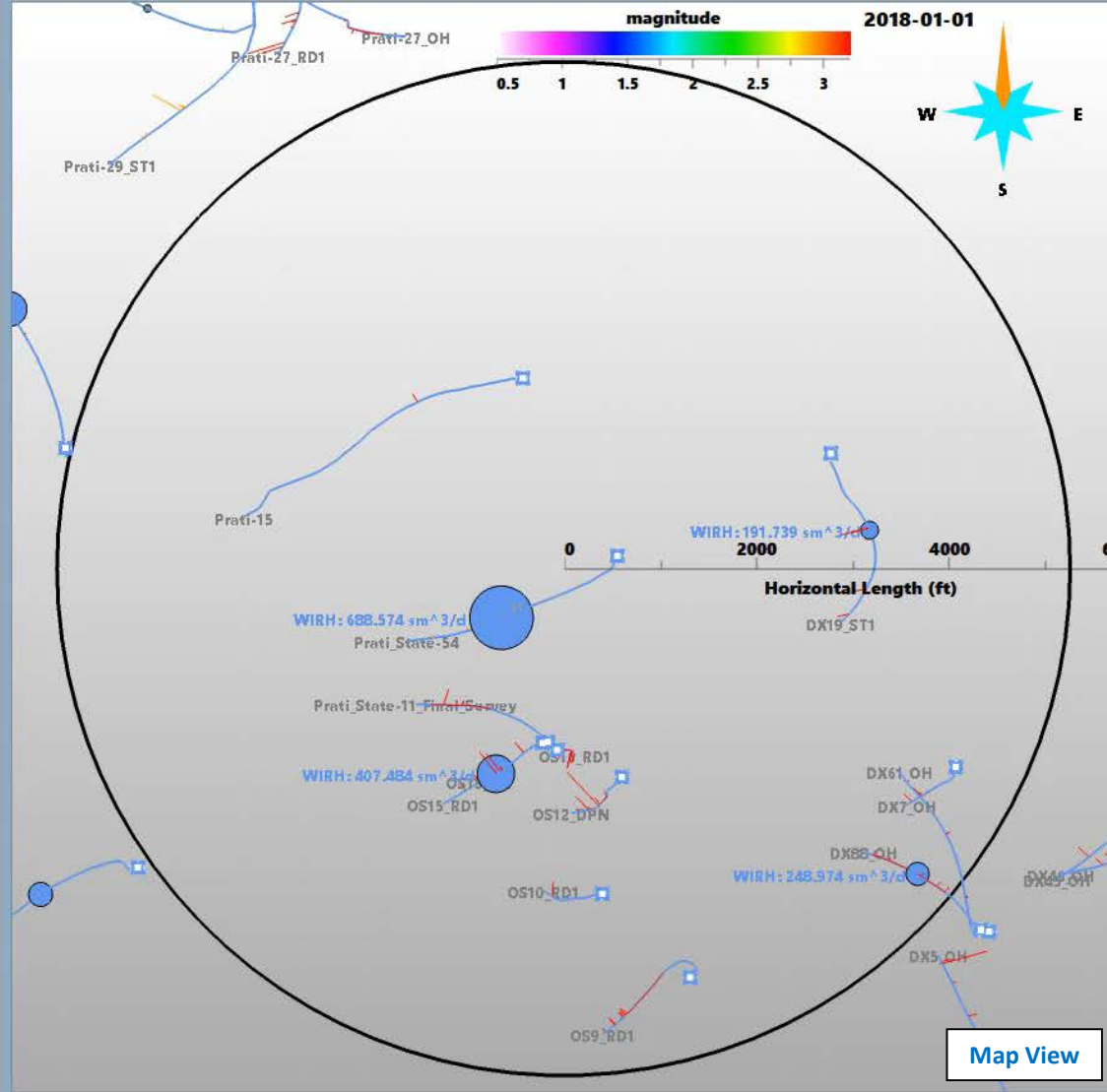
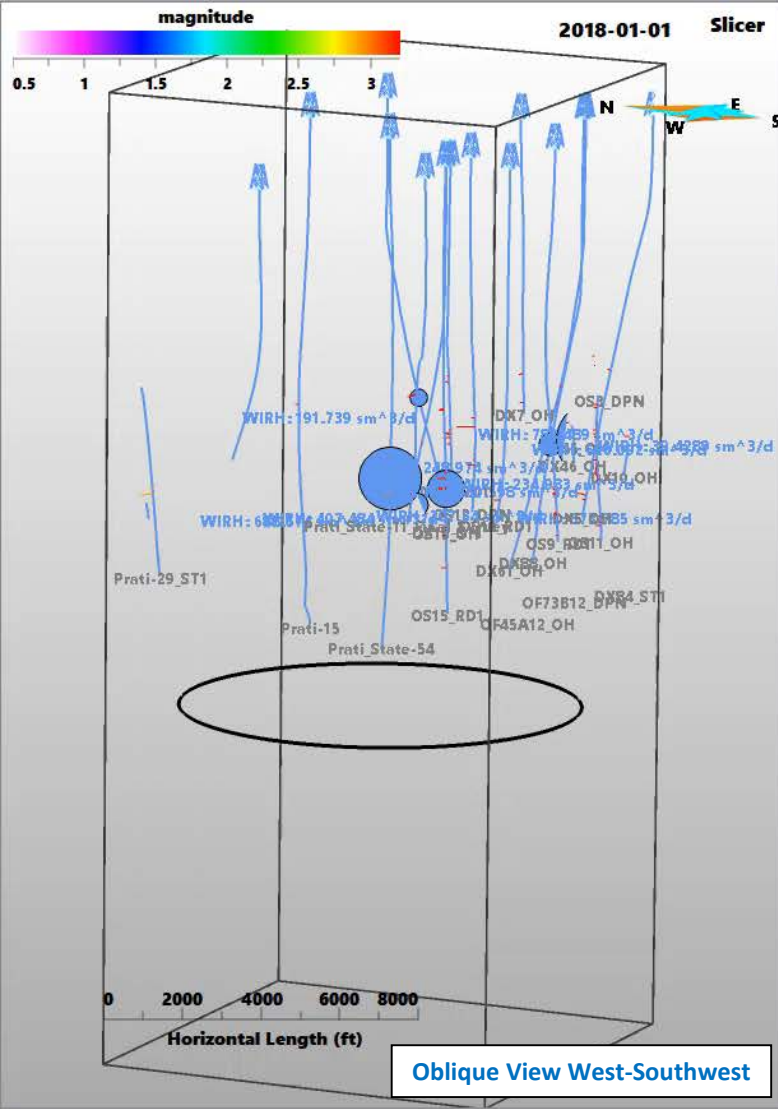
Relationship Between Water Injection Variability And Induced Seismicity

Daily Average Water Injection Rates For Wells DX19 ST1, OS-15 and Prati-15 And Seismicity \geq Magnitude 2.5 In Vicinity



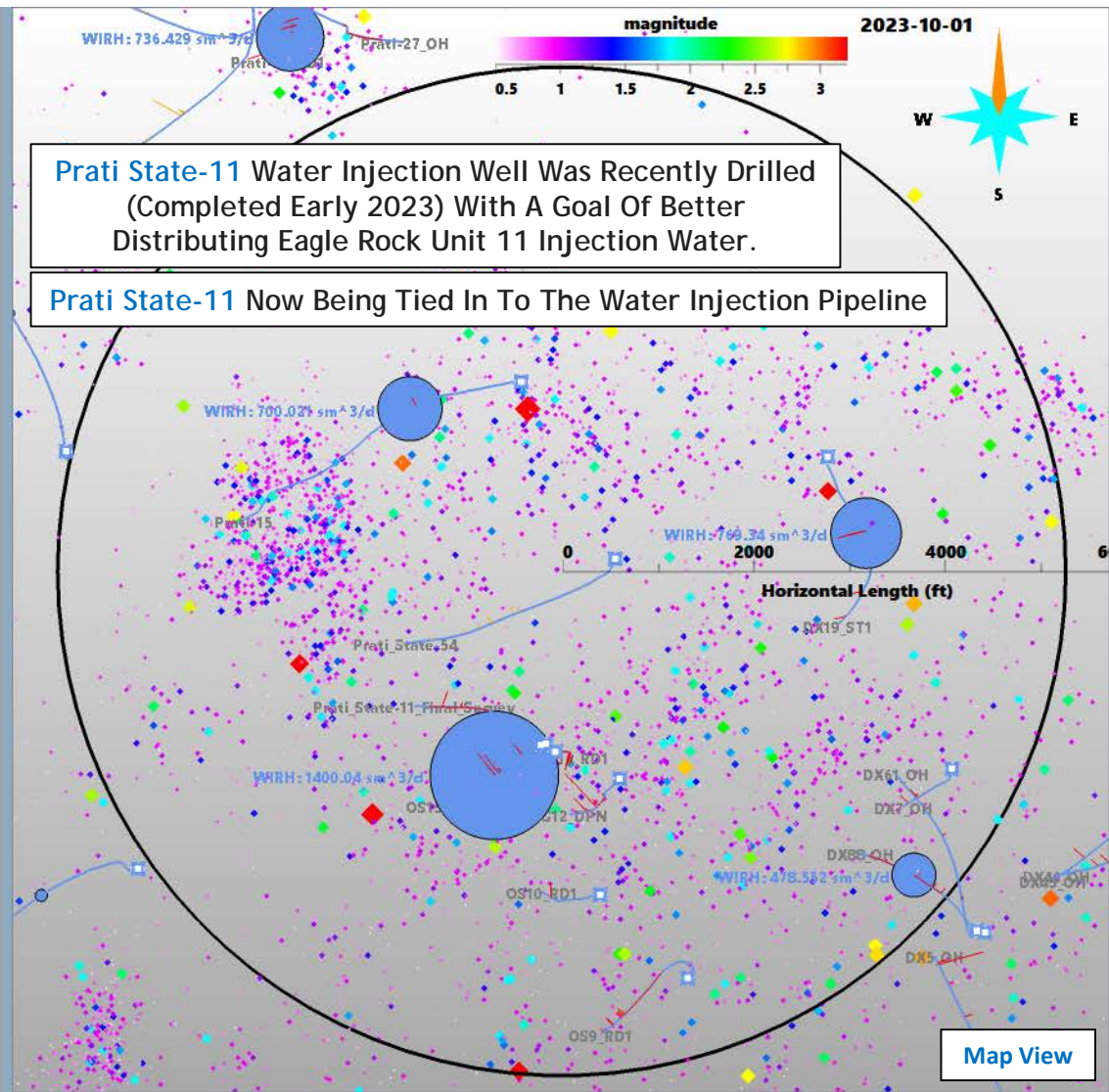
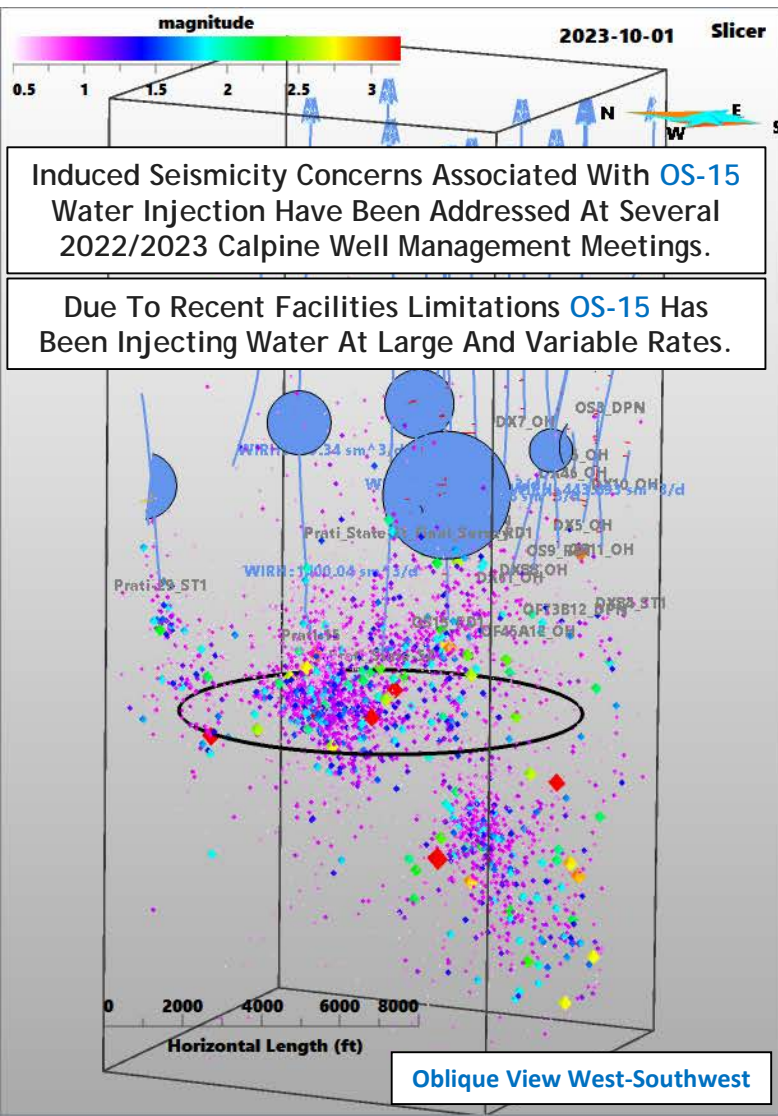
Relationship Between Water Injection Variability And Induced Seismicity

Video: Daily Average Water Injection Rates For Wells DX19 ST1, OS-15 and Prati-15 Proportional To Blue Disks
 Vicinity Induced Seismicity Shown For A One Year Interval Prior To Date Shown Indicated



Relationship Between Water Injection Variability And Induced Seismicity

Video: Daily Average Water Injection Rates For Wells DX19 ST1, OS-15 and Prati-15 Proportional To Blue Disks
 Vicinity Induced Seismicity Shown For A One Year Interval Prior To Date Shown Indicated



From: Kenneth McNamara <Kenneth.McNamaraJr@calpine.com>

Sent: Sunday, September 17, 2023 11:03 PM

To: Geysers Injection Team <GeysersInjectionTeam@calpine.com>

Subject: Santa Rosa flow down to 11.1 MGD from 15.1 MGD @ 22:10 hours or 10:20 pm due to SRGRP losing a string of pumps

From: USGS ENS <ens@ens.usgs.gov>

Sent: Sunday, September 17, 2023 11:25 PM

To: Craig Hartline <Craig.Hartline@calpine.com>

Subject: 2023-09-18 06:20:52 UPDATED: (Magnitude 3.5) Northern California 38.8 -122.8 (642d9)

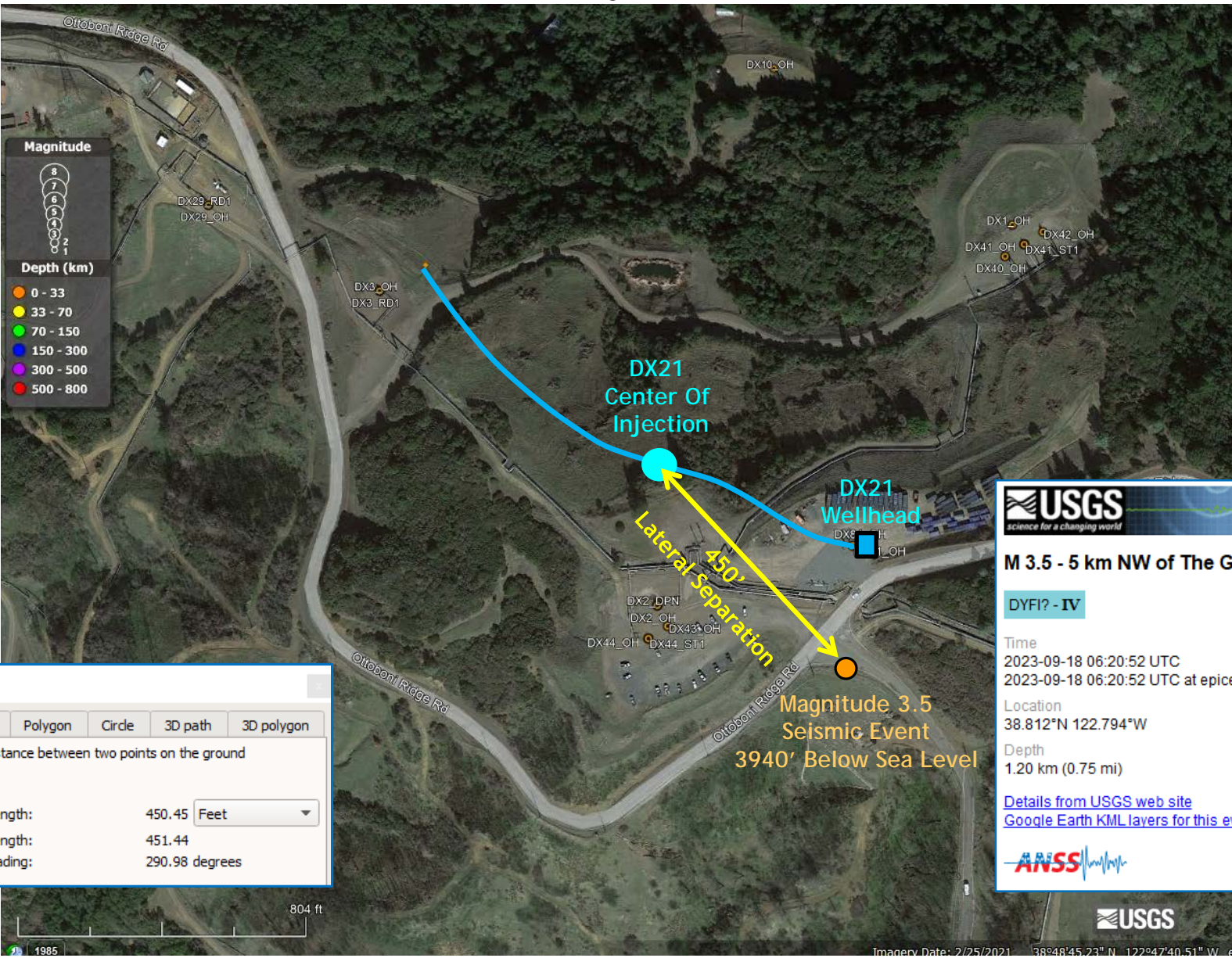
M3.5 Earthquake - Northern California

Preliminary Report

Magnitude	3.5
Date-Time	Universal Time (UTC): 18 Sep 2023 06:20:53 Time near the Epicenter (1): 17 Sep 2023 23:20:53 Time in your area (1): 17 Sep 2023 21:20:53
Location	38.812N 122.794W
Depth	1 km
Distances	6.2 km (3.9 mi) W of Cobb, California 21.8 km (13.5 mi) SW of Clearlake, California 23.3 km (14.4 mi) NNE of Healdsburg, California 29.4 km (18.2 mi) N of Windsor, California 115.9 km (71.8 mi) WNW of Sacramento, California
Location Uncertainty	Horizontal: 0.1 km; Vertical 0.2 km
Parameters	Nph = 69; Dmin = 0.4 km; Rmss = 0.08 seconds; Gp = 32° Version = 2
Event ID	nc 73938186 ***This event supersedes event EW1695018050.

Relationship Between Water Injection Variability And Induced Seismicity

Magnitude 3.5 Seismic Event 450' Southeast Of The DX-21 Water Injection Center



Magnitude

Depth (km)

- 0 - 33
- 33 - 70
- 70 - 150
- 150 - 300
- 300 - 500
- 500 - 800

USGS
science for a changing world

M 3.5 - 5 km NW of The Geysers, CA

DYFI? - IV

Time
2023-09-18 06:20:52 UTC
2023-09-18 06:20:52 UTC at epicenter

Location
38.812°N 122.794°W

Depth
1.20 km (0.75 mi)

[Details from USGS web site](#)
[Google Earth KML layers for this event](#)

ANSS

Ruler

Line Path Polygon Circle 3D path 3D polygon

Measure the distance between two points on the ground

Map Length: 450.45 Feet

Ground Length: 451.44

Heading: 290.98 degrees

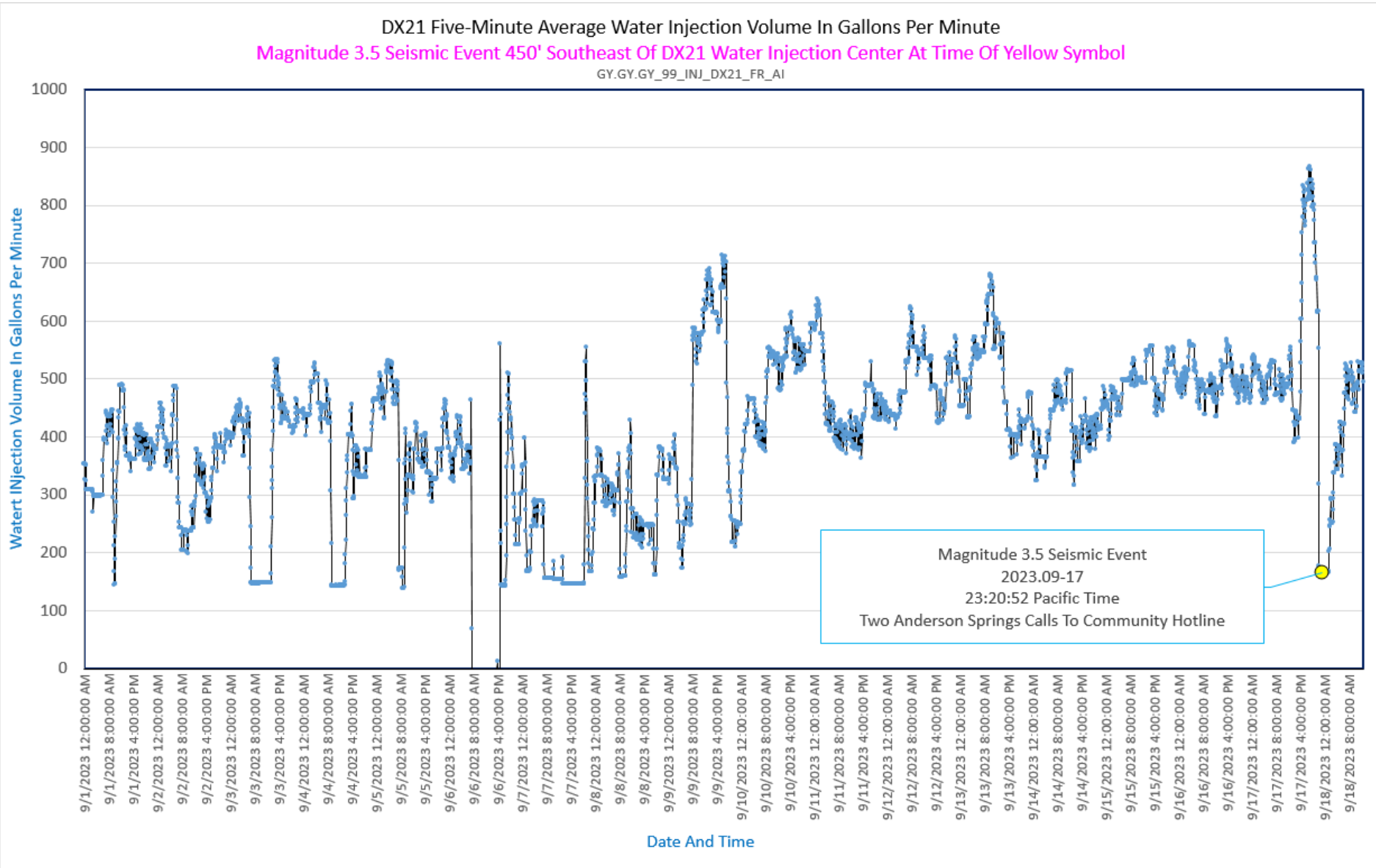
804 ft

1985

Imagery Date: 2/25/2021 38°48'45.23" N 122°47'40.51" W

Excellent Example Of The Relationship Between Water Injection Variability And Induced Seismicity

Magnitude 3.5 Seismic Event 450' Southeast Of The DX-21 Water Injection Center



Additional Seismic Monitoring and Research

California Energy Commission Electric Program Investment Charge (EPIC) Program EPC-16-021

Accepted Proposal

High-Resolution Micro-Earthquake Imaging of Flow Paths Using a Dense Seismic Network and Fast-Turnaround, Automated Processing

Additional funding for joint MT/Seismic Inversion approved by the California Energy Commission in March 2020

Program Goal

Development of advanced, low-cost, microseismic imaging for high-resolution spatial and temporal images of subsurface fluid flow, flow barriers and heterogeneity in producing geothermal fields. The project will focus on microseismicity imaging challenges that are unique to geothermal reservoirs.

Improved 3D and time-lapse subsurface resolution is anticipated to assist with seismicity mitigation efforts at The Geysers.

Applicant

Lawrence Berkeley National Laboratory

Project Partners

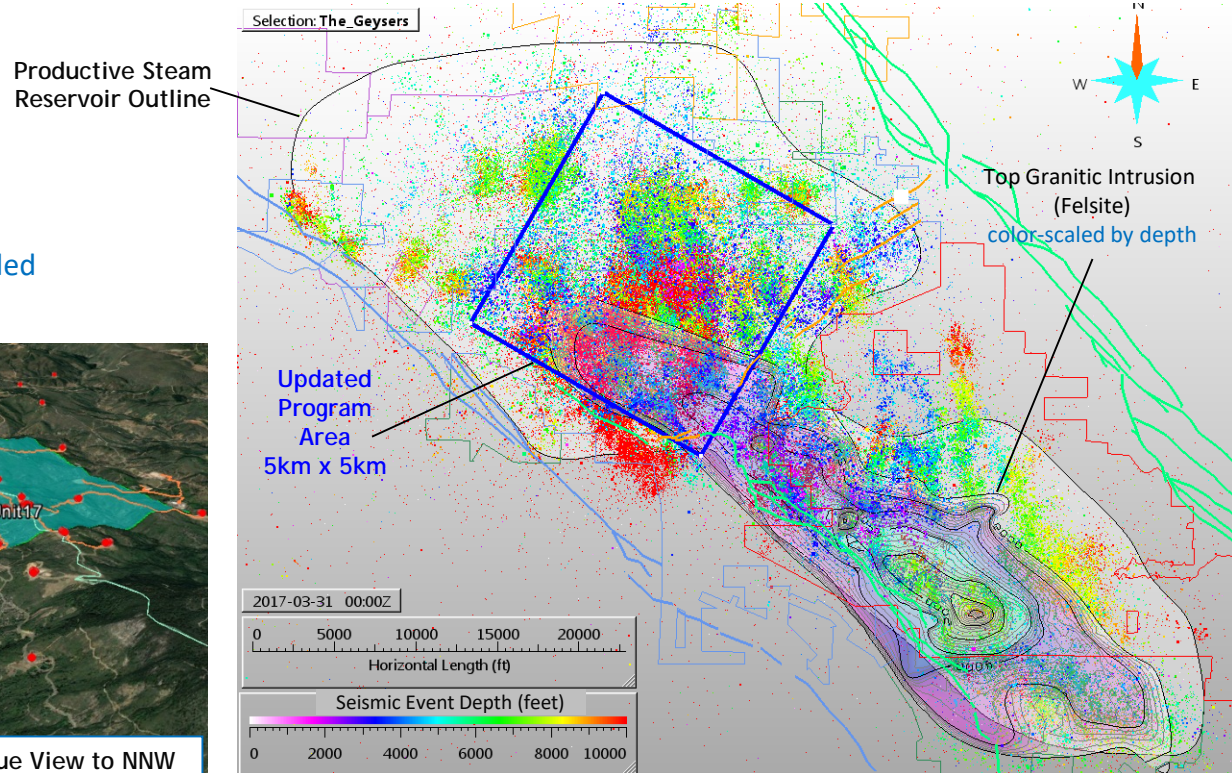
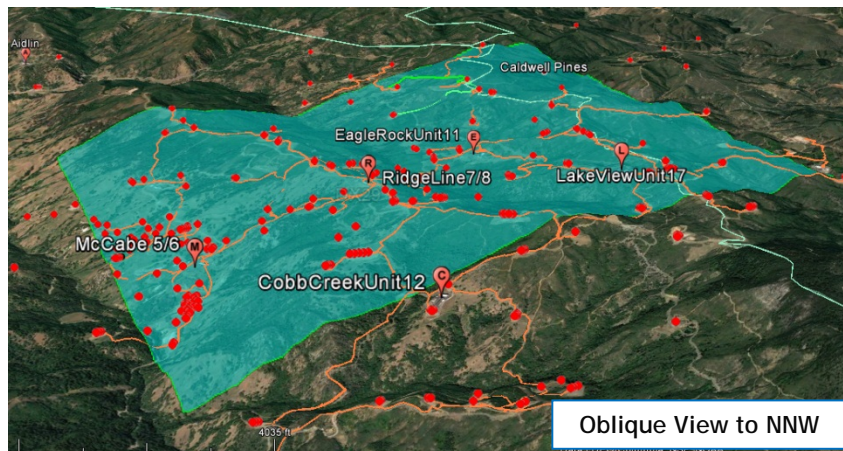
Geysers Power Company, LLC

Array Information Technology

Jarpe Data Solutions

California Energy Commission Funds Recommended

\$1,672,639



Additional Seismic Monitoring and Research

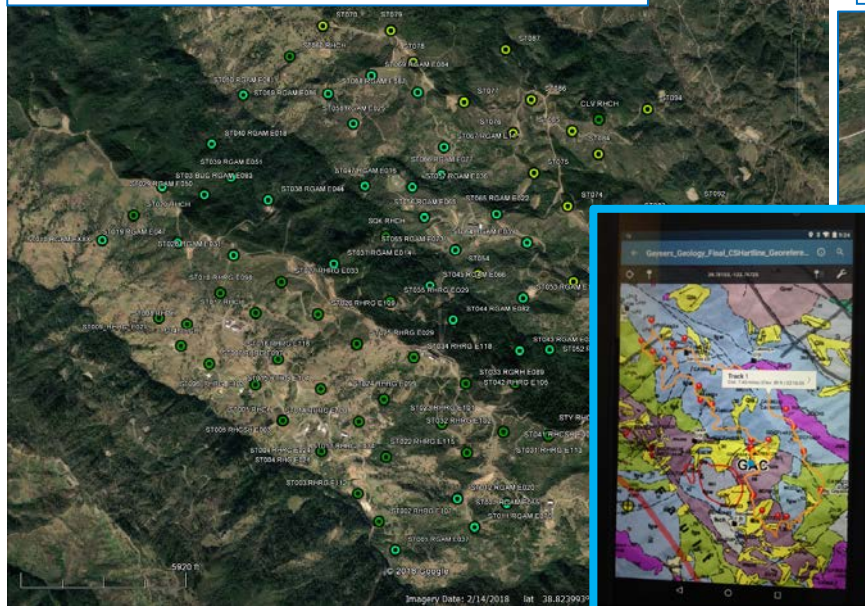
California Energy Commission Electric Program Investment Charge (EPIC) Program EPC-16-021

Geysers Power Company, LLC has provided:

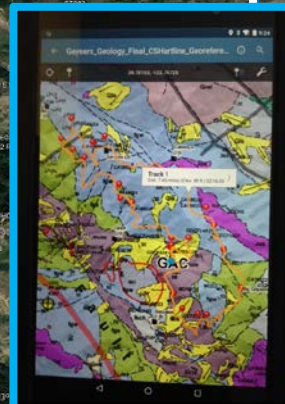
- The field location for this program.
- Technical support with survey design planning.
- On-site assessments including GPS surveying with updated equipment and techniques.
- Assistance to LBNL Contractor Ramsey Haught during 17 seismic sensor test installations.
- Coordination and updating of GPS surveys/maps data recovery at 2-3 month intervals.

Green Labeled Points

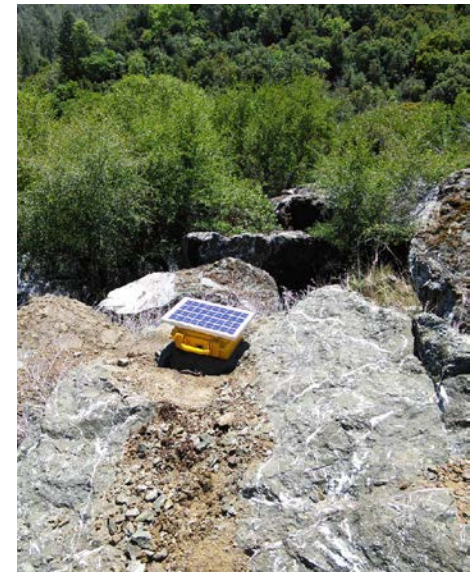
Actual Installation Locations for 93 Sensor Station Installation Program. Not a uniform grid pattern due to extreme topography and access concerns.



Surveying of 23 Test Sensor Station Locations and Access Routes Completed By Calpine With Samsung Nexus 7 Tablet and Paired Garmin GLO Device.



Generation Three Sensor Station

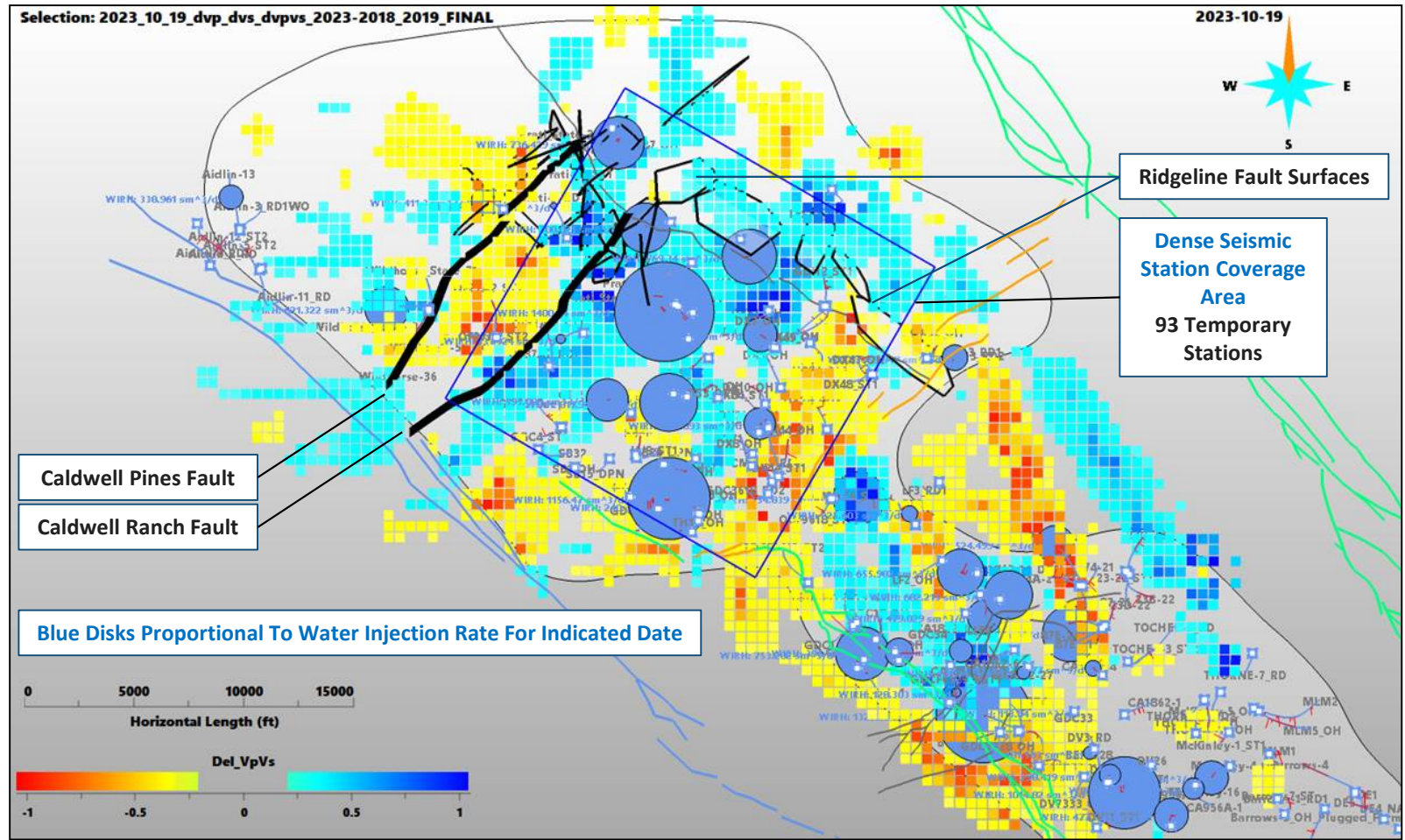


Sensor Installation on Rock Outcrop



Map View

Differential Vp/Vs Velocity Volume For 2023 10.19 vs. 2019 .01.01
Depth Slice 5000' To 6000' Subsea; Delta Vp/Vs Scale From -1.0 To 1.0
Higher Vp/Vs Values Are Indicative Of Fluid Replacement Of Steam By Water



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.

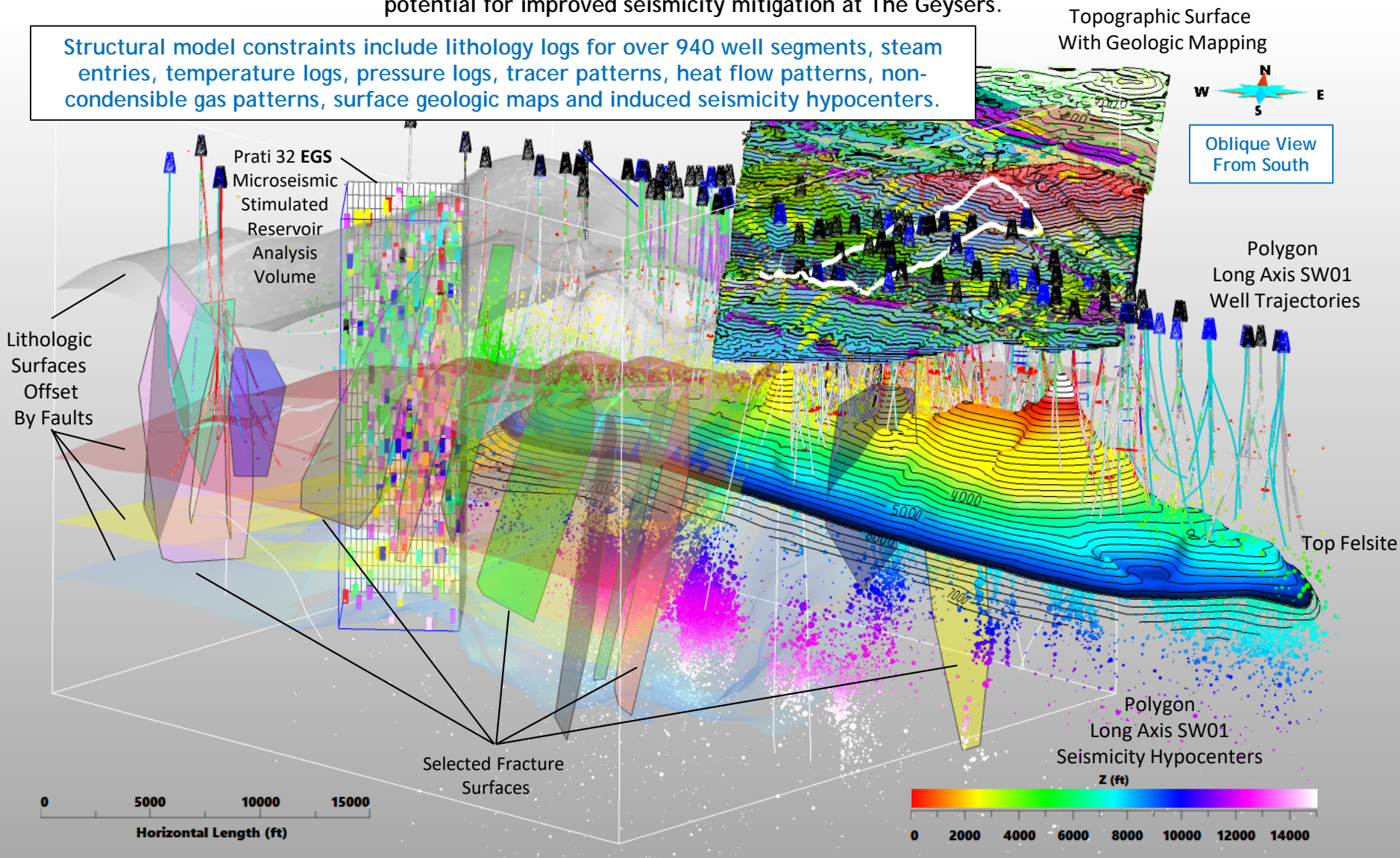




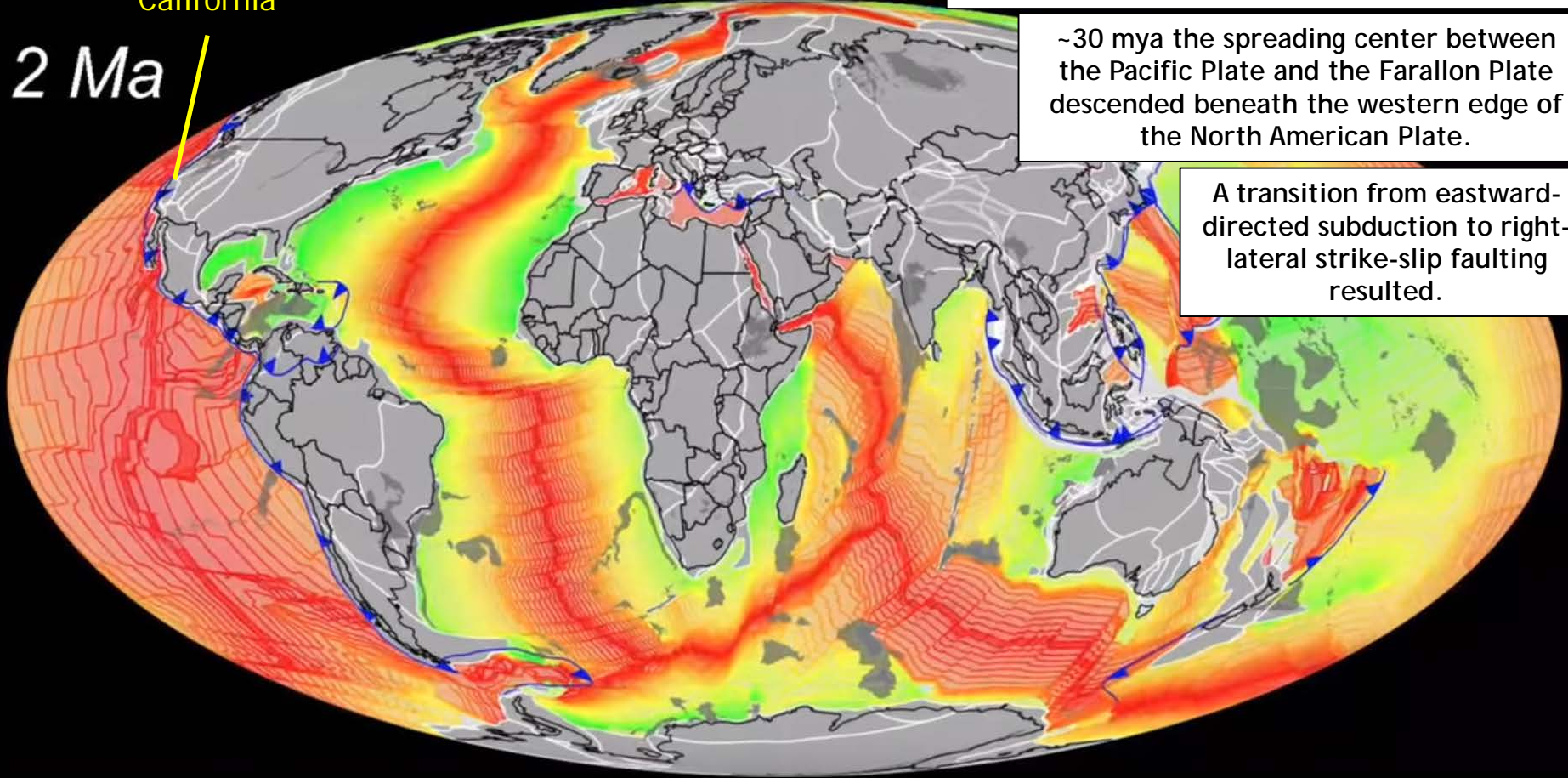
Plate Tectonic Evolution from Pangea to Modern Continental Configuration

200 Million Years Ago to Present x 10

Plate Tectonics by C.R. Scotese

California

2 Ma



The Geysers Geothermal Field exists within a complex assemblage of late Mesozoic Franciscan rocks (200 to 80 mya) representing the ancient Farallon plate subduction complex.

~30 mya the spreading center between the Pacific Plate and the Farallon Plate descended beneath the western edge of the North American Plate.

A transition from eastward-directed subduction to right-lateral strike-slip faulting resulted.

▶ ⏪ 🔊 4:19 / 4:19

Scroll for details

HD 🏠

From: Scotese, C.R., and Elling, R.P., 2017.

Plate Tectonic Evolution during the last 1.5 Billion Years: The Movie.

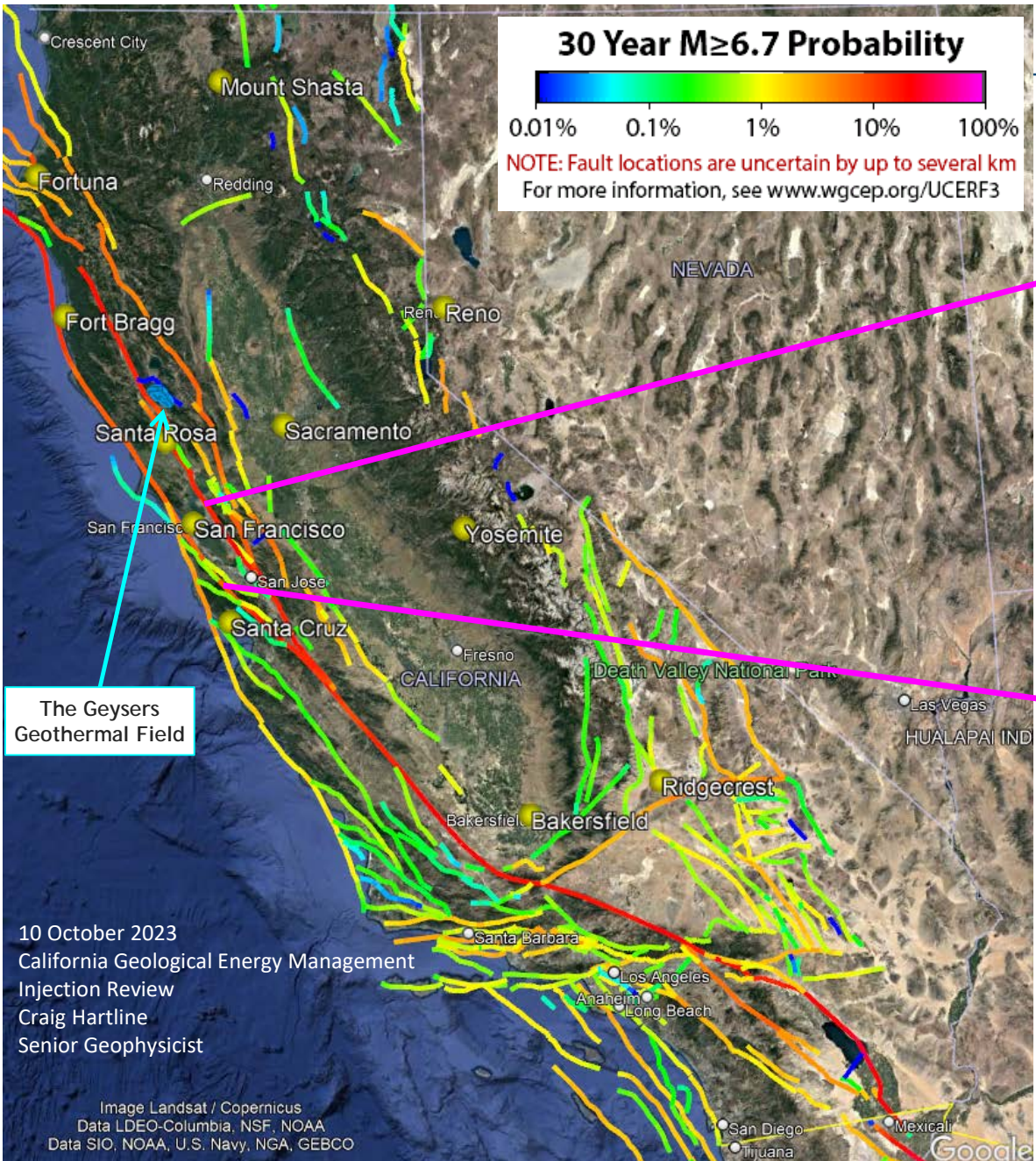
Plate Tectonics at 50, William Smith Meeting, October 3-5, 2017,

The Geological Society, Burlington House, London, p. 16-17.



United States Geological Survey Earthquake Probability Data

UCERF3 / Uniform California Earthquake Rupture Forecast Version 3



Hayward (No) 2011 CFM, Subsection 6

Mag	30 Year Participation Prob (%)			Ratios	
	Mean ¹	p _{2.5} ¹	p _{97.5} ¹	Gain ²	U3/U2 ³
M≥6.7	13.46	7.38	20.36	1.61	1.23
M≥7.0	11.39	5.99	17.86	1.61	2.14
M≥7.5	3.59	0.41	7.74	1.59	93.99
M≥8.0	0.02	< 0.01	0.17	1.74	-

1. Mean and percentiles across all UCERF3 logic tree branches
2. Mean time dependent probability gain (to time independent UCERF3)
3. Mean UCERF3/UCERF2 probability, averaged over parent fault section

San Andreas (Peninsula) 2011 CFM, Subsection 3

Mag	30 Year Participation Prob (%)			Ratios	
	Mean ¹	p _{2.5} ¹	p _{97.5} ¹	Gain ²	U3/U2 ³
M≥6.7	6.79	0.19	17.32	0.68	0.85
M≥7.0	6.76	0.18	17.29	0.68	0.86
M≥7.5	5.86	0.13	14.76	0.67	1.11
M≥8.0	2.38	0.01	9.31	0.92	1.38

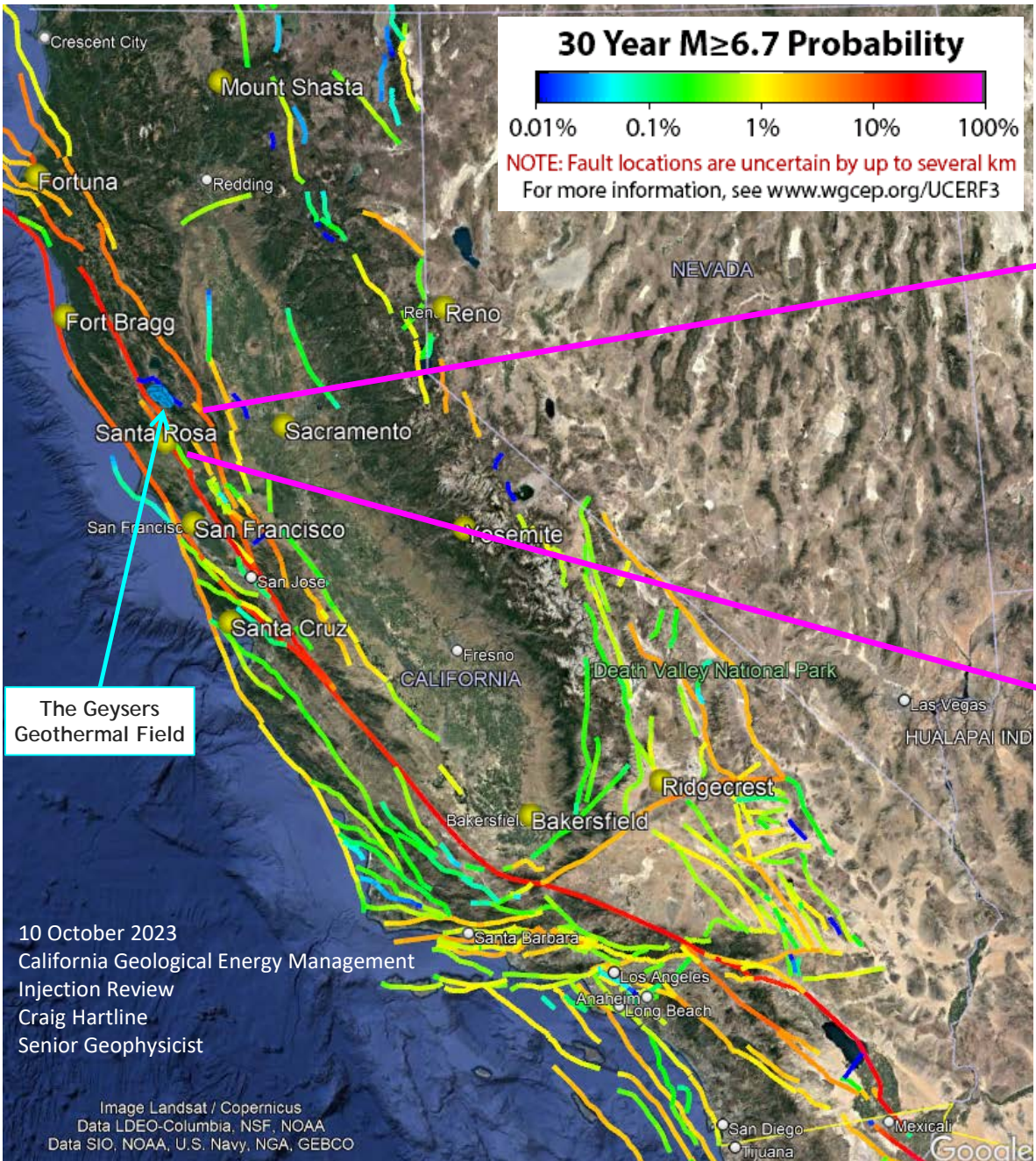
1. Mean and percentiles across all UCERF3 logic tree branches
2. Mean time dependent probability gain (to time independent UCERF3)
3. Mean UCERF3/UCERF2 probability, averaged over parent fault section

10 October 2023
 California Geological Energy Management
 Injection Review
 Craig Hartline
 Senior Geophysicist

Image Landsat / Copernicus
 Data LDEO-Columbia, NSF, NOAA
 Data SIO, NOAA, U.S. Navy, NGA, GEBCO



United States Geological Survey Earthquake Probability Data UCERF3 / Uniform California Earthquake Rupture Forecast Version 3



Bartlett Springs 2011 CFM, Subsection 0

Mag	30 Year Participation Prob (%)			Ratios	
	Mean ¹	P _{2.5} ¹	P _{97.5} ¹	Gain ²	U3/U2 ³
M≥6.7	5.41	2.81	10.18	1.26	0.99
M≥7.0	4.95	2.67	9.32	1.26	1.11
M≥7.5	3.33	1.19	7.06	1.26	56.26
M≥8.0	< 0.01	-	< 0.01	1.16	-

1. Mean and percentiles across all UCERF3 logic tree branches
2. Mean time dependent probability gain (to time independent UCERF3)
3. Mean UCERF3/UCERF2 probability, averaged over parent fault section

Rodgers Creek - Healdsburg 2011 CFM, Subsection 5

Mag	30 Year Participation Prob (%)			Ratios	
	Mean ¹	P _{2.5} ¹	P _{97.5} ¹	Gain ²	U3/U2 ³
M≥6.7	12.68	7.16	18.47	1.57	0.71
M≥7.0	10.35	4.95	15.89	1.59	1.09
M≥7.5	3.35	0.22	7.60	1.59	91.67
M≥8.0	< 0.01	< 0.01	0.05	1.74	-

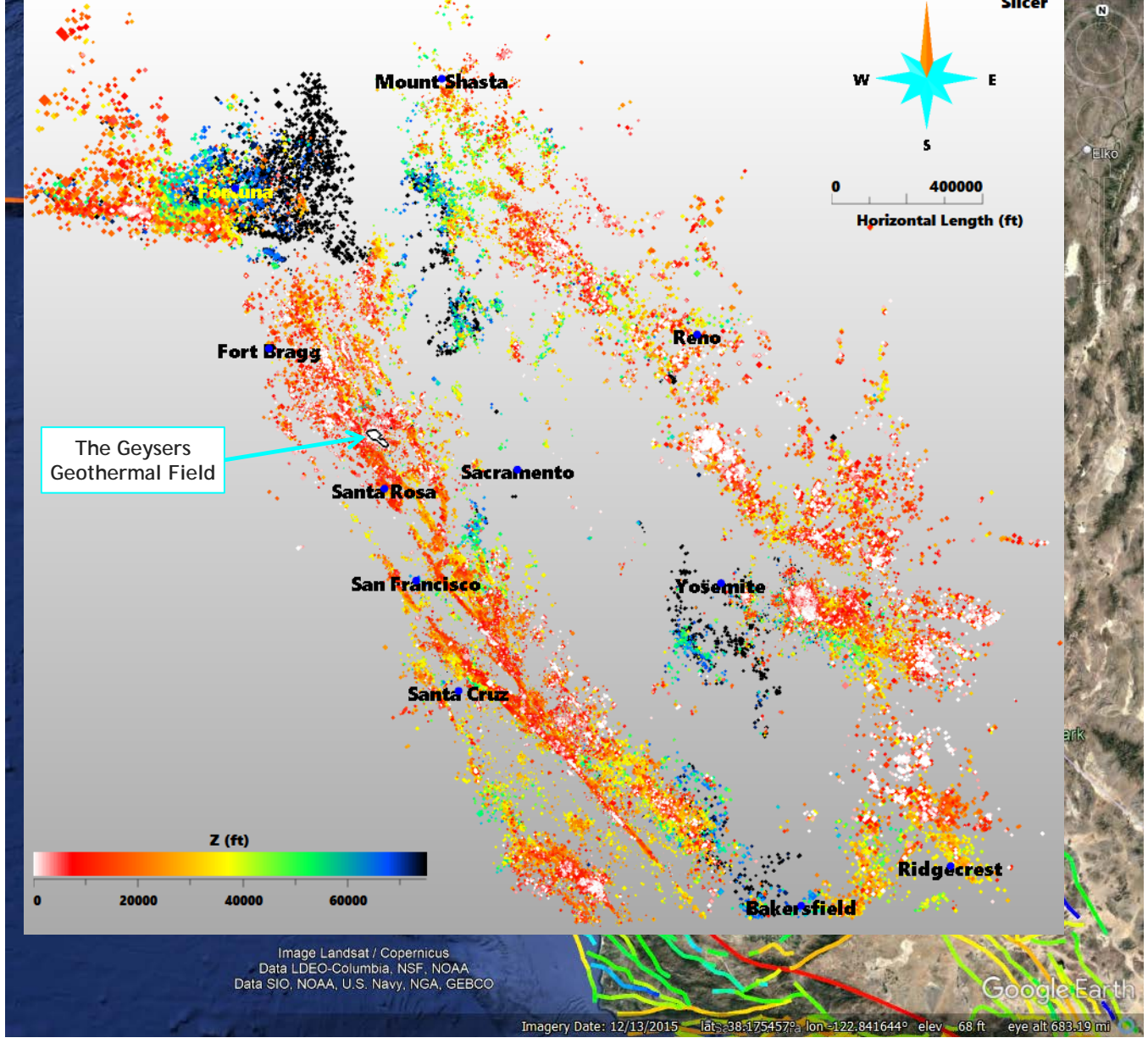
1. Mean and percentiles across all UCERF3 logic tree branches
2. Mean time dependent probability gain (to time independent UCERF3)
3. Mean UCERF3/UCERF2 probability, averaged over parent fault section

10 October 2023
California Geological Energy Management
Injection Review
Craig Hartline
Senior Geophysicist

Image Landsat / Copernicus
Data LDEO-Columbia, NSF, NOAA
Data SIO, NOAA, U.S. Navy, NGA, GEBCO



UCERF3 / Uniform California Earthquake Rupture Forecast Version 3 Overlain With 1984-2023 Northern California Earthquake Data Catalog

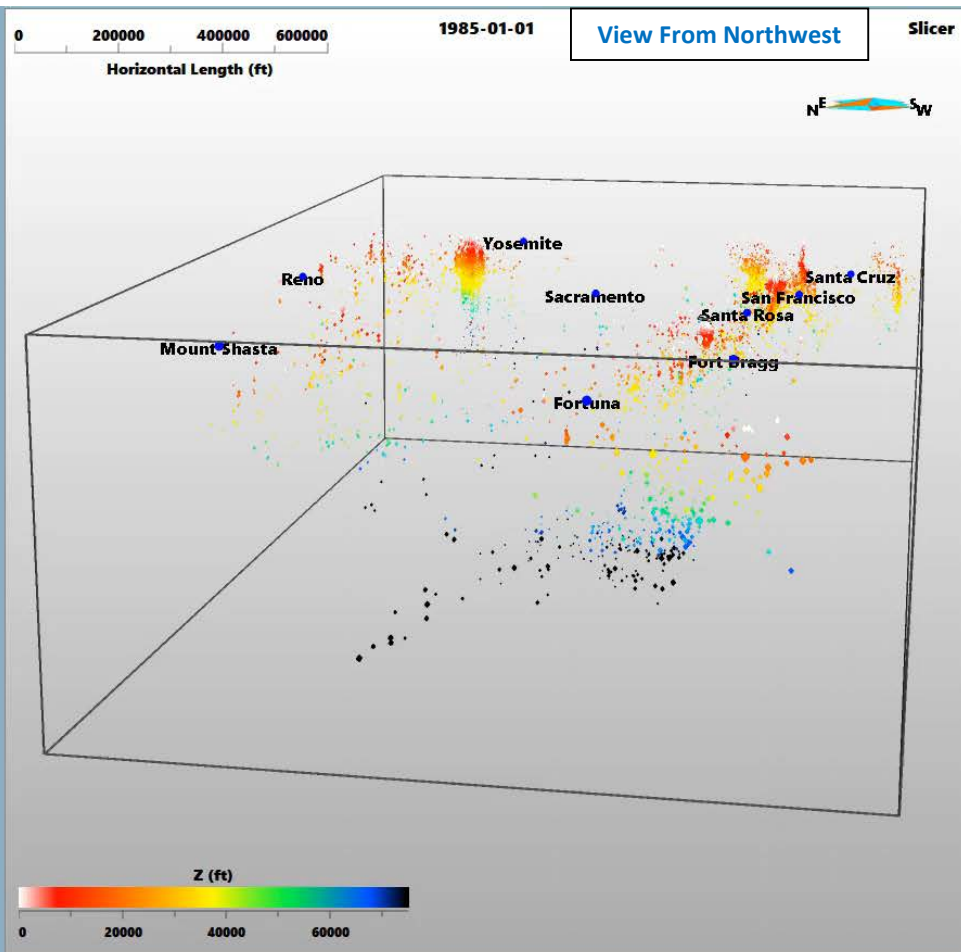
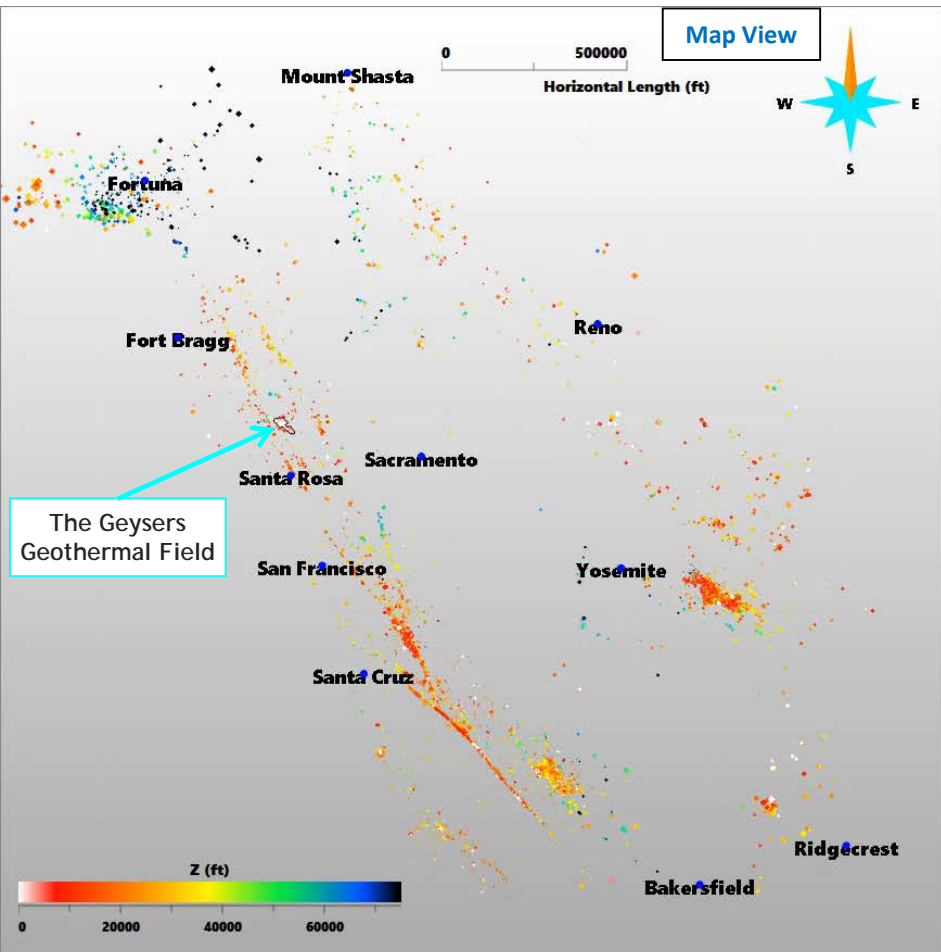


NCEDC Seismicity Data
 Double-Difference Catalog
 1984-Present

 Latitude Range
 42.0°
 34.5°

 Longitude Range
 -126.0° -117.8°

United States Geological Survey Earthquake Northern California Earthquake Data Catalog 1984-2023 Seismicity VIDEO Animation At Six Month Interval; Five Most Recent Years Displayed



United States Geological Survey Earthquake Northern California Earthquake Data Catalog 1984-2023 Seismicity With Slicer Cross Sectional VIDEO Animation At Right

