StEER STRUCTURAL EXTREME EVENTS RECONNAISSANCE	**EVENT BRIEFING**		
	Event:	20 December 2021, Petrolia, Mw 6.2 Earthquake	
	Region:	California, USA	
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Key Lessons

- ❏ There are a large number of ground motion recording stations in the vicinity of the epicenter of this earthquake. Such ground motion stations in California are very important for characterizing seismic hazards and ultimately for reducing the impacts of earthquakes to increase the resilience of communities.
- ❏ There are two instrumented bridges in the earthquake area. Use of data from these structures and others are important for identifying the dynamic characteristics of different structures, developing and updating numerical models, and decision making immediately following an earthquake. Therefore, the number of instrumented structures should be increased.
- ❏ A ground motion recording station in Ferndale, CA recorded a peak ground acceleration (PGA) of 28.7% g, which led to minor nonstructural damage. Depending on the quality of construction, this level of ground shaking can also lead to minor to moderate structural damage. Therefore, the preliminary reported shaking levels need to be explored further, along with damage inspection of structures in Ferndale. If these preliminary values are accurate with the observation of no structural damage, it would indicate good seismic performance of structures in this region.
- ❏ California's Office of Emergency Services indicated that 2,500 people were notified about the earthquake in advance of strong shaking through the state's earthquake early warning system, which might have prevented possible injuries.
- ❏ This earthquake is another reminder of the potential of major earthquakes that will continue to take place in the US, particularly the Western US. Along with an earlier flurry of earthquakes off the coast of Oregon, attention should be given to this series of strike-slip earthquakes along the flanks of the Juan de Fuca plate.
- ❏ Had the earthquake originated at a location on the Mendocino triple junction that is closer to populated areas, an earthquake of this magnitude could have had more severe consequences.

Event Description

On December 20, 2021, at approximately 12:10 pm local time, a magnitude 6.2 earthquake, with a depth of 15.2 km, struck 39 km W of Petrolia and 45.3 km SW of Eureka, off the coast of Northern California. The earthquake was felt in a large area as far north as Roseburg, Oregon and as far south as San Francisco (KSBW, 2021). There was no tsunami warning after the earthquake.

The objectives of this event briefing are to: 1) provide details of the 20 December 2021 Mw 6.2 Petrolia Earthquake, 2) summarize damage to structures and community impacts, and 3) list key lessons learned.

Hazard Description

The epicenter of this 6.2 magnitude earthquake was 40.307°N, 124.749°W (Figure 1). The earthquake was followed by several aftershocks ranging between Mw 2.5 and 4.0 (KTLA, 2021).

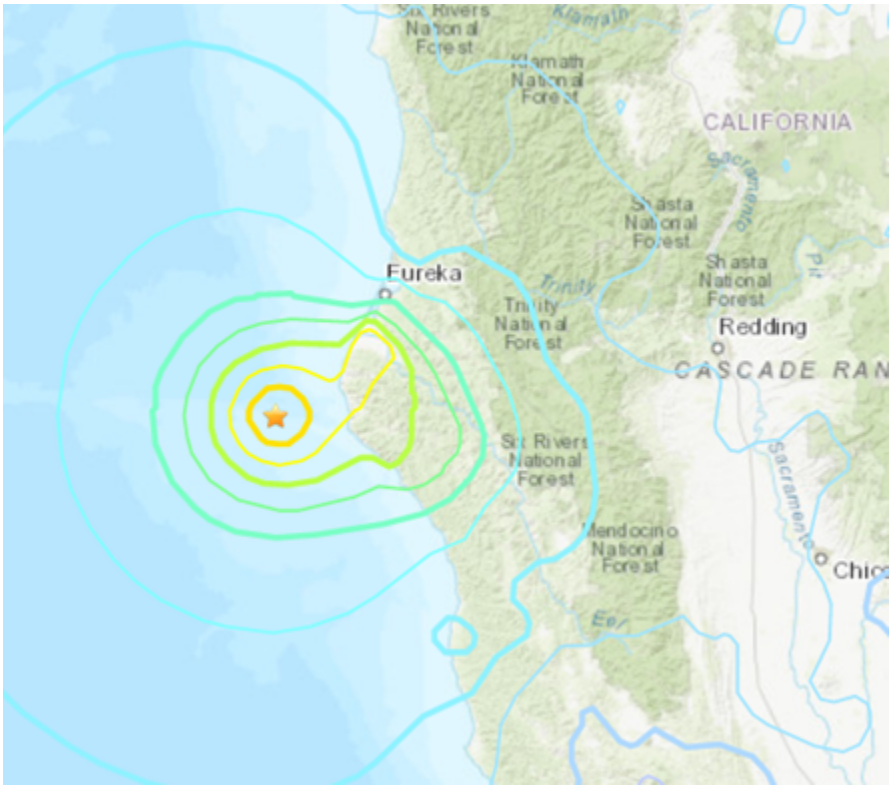

Figure 1. Epicenter and estimate intensity of the Mw 6.2 Petrolia earthquake, USGS (2021)

This earthquake occurred as the result of strike-slip faulting on a transform boundary at a relatively shallow depth of 15.2 km (USGS, 2021). The location and faulting mechanism indicated that the earthquake did not occur on the Cascadia subduction zone nor the San Andreas Fault, both of which can produce large magnitude earthquakes. Rather, the earthquake likely occurred on or near east-west trending Mendocino fracture zone (Figure 2), which is located at the plate boundary

between the Pacific Plate and southern Juan de Fuca Plate (USGS, 2021). At the location of the earthquake, the Juan de Fuca Plate moves southeastward with respect to the Pacific Plate at a rate of 47 mm/yr. As is common for strike-slip fault earthquakes, this earthquake did not generate a tsunami.

Earthquakes are common in the region around the Mendocino triple junction (Figure 2). In the past century, within 250 km of this earthquake, there were 40 earthquakes with Mw 6.0 or larger, including six earthquakes of Mw 7.0 or larger. These prior earthquakes primarily occurred along the Mendocino fracture zone, in the Cascadia subduction zone, or within the Juan de Fuca/Gorda Plate. On June 15, 2005, a Mw 7.2 earthquake occurred northwest of this earthquake within the Juan de Fuca/Gorda Plate on a northeast-striking left-lateral strike slip fault.

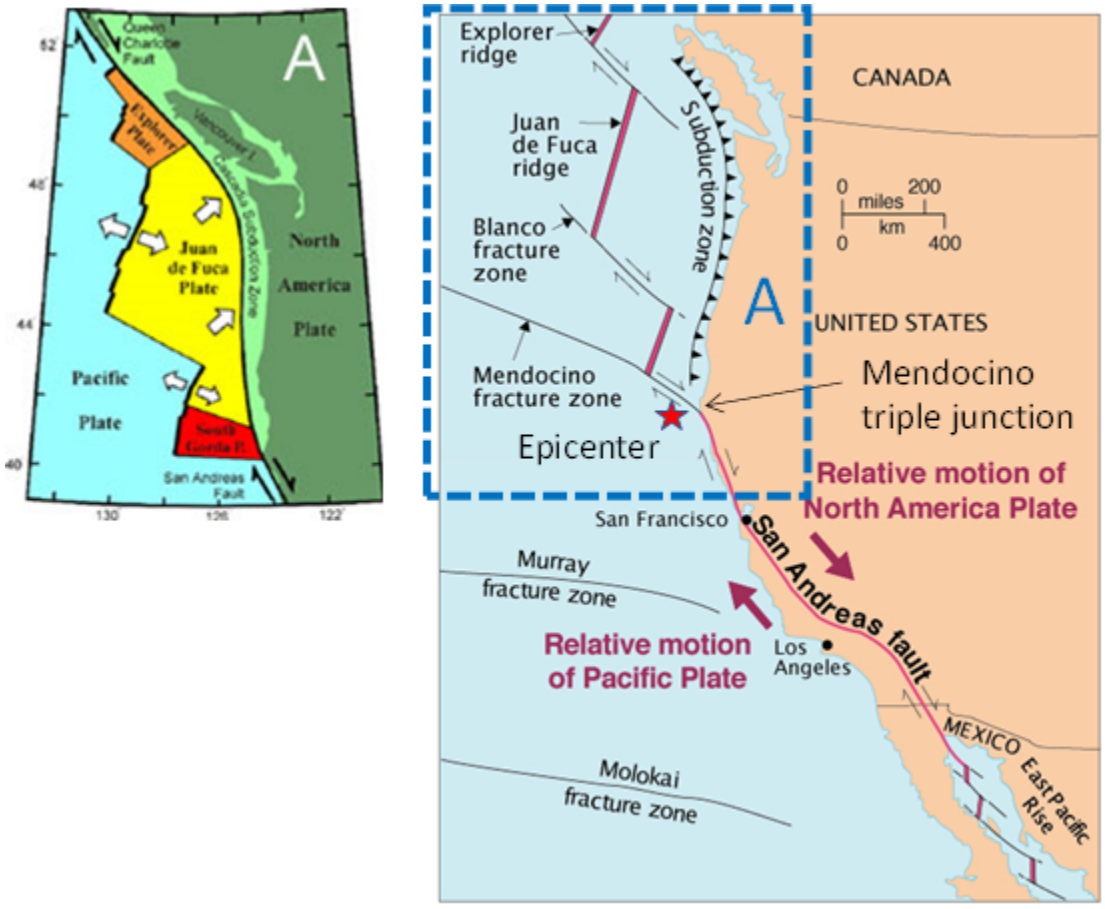

Figure 2. Plate boundaries near the epicenter of the earthquake (left image: Potter (2007), right image: Kious, W.J. and Tilling, R.I. (1996), with modification)

Fortunately, there are a large number of ground motion recording stations in the vicinity of this earthquake's epicenter (marked with triangles in Figure 3). The peak ground shaking recorded at the stations closest to the epicenter are listed in Table 1. Despite the ground motion stations being far

field, peak ground acceleration (PGA) values as large as 32.5% g and Peak Ground Velocity (PGV) values as large as 24.6 cm/sec were recorded, indicating moderate levels of shaking.

Figure 3. Ground motion recording stations (marked with triangles) around the epicenter of the earthquake (USGS, 2021)

It is noted that station 1023 is in downtown Ferndale, where some nonstructural damage was observed (see following section). Depending on the quality of construction, this level of ground shaking (PGA = 28.7% g) can also lead to minor to moderate structural damage. Therefore, the preliminary shaking levels reported in USGS (2021) and Table 1 need to be explored further, along with damage inspection of structures in Ferndale. If these preliminary values are accurate and there is indeed no structural damage, it would indicate good seismic performance of structures in this region.

In addition to the ground motion recording stations, the California Strong Motion Instrumentation Program (CSMIP) has two instrumented bridges (marked with rectangles in Figure 4) in this region. Use of data from these structures and others are important for identifying the dynamic characteristics of different structures as well as for developing and updating numerical models, and for decision making immediately following an earthquake. Therefore, more buildings, bridges, and other structures need to be instrumented in areas with high potential of ground shaking due to earthquakes.

Table 1. Peak values of ground motions closest to the epicenter of the earthquake (USGS, 2021)								
Station Name	**Network**	**Epicentral Distance (km)**	**PGA (%g)**			**PGV (cm/sec)**		
			EW	**NS**	**Vert.**	**EW**	**NS**	**Vert.**
PETL	BDSN	32.65	25.1	14.5	12.7	12.1	6.3	4.2
89101	CSMIP	36.80	26.4	32.5	9.7	9.9	13.3	3.5
KCT	NC	37.18	10.1	16.1	5.1	9.7	9.1	3.5
KCO	NC	38.76	9.5	3.6	6.5	9.1	6.3	2.6
1584	NSMP	41.09	14.9	15.7	5.3	12.6	11.3	3.0
1023	NC	47.45	21.2	28.7	8.5	23.9	24.6	5.0
KMPB	NC	50.98	20.2	24.7	12.7	12.2	13.6	6.2
RBOW	BDSN	50.53	7.9	9.8	6.1	6.6	7.1	1.8
BDSN: Berkeley Digital Seismic Network, CSMIP: California Strong Motion Instrumentation Program, NC: USGS Northern California Network, NSMP: United States National Strong Motion Network								

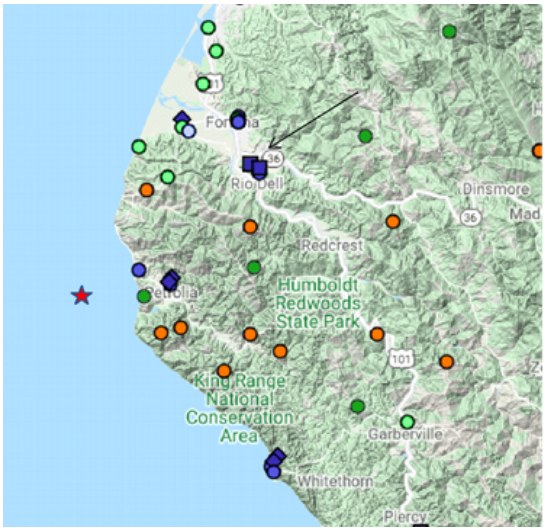

Figure 4. Location of bridges instrumented by CSMIP in the earthquake region (CESMD, 2021)

Damage to Structures

At the time of writing this briefing, there was no visible structural damage observed as the result of this earthquake, but nonstructural damage was reported. Figure 5 shows shattered storefront windows and goods knocked from shelves in a market in Ferndale (SF Chronicle, 2021). Similar shattered windows were observed in a few other businesses (NCJ, 2021). As noted earlier, if the preliminary shaking values listed in Table 1 are correct, this is an indication that structures in this region performed well.

Figure 5. Shattered storefront windows and goods fallen off the shelves in a market in Ferndale (San Francisco Chronicle, 2021)

Other Infrastructure

A few roads were closed due to rockslides. However, there were no other major infrastructure impacts reported disrupting services and access to communities. The Humboldt County Sheriff's office of emergency services did not issue any evacuation orders (KSBW, 2021).

Community Impacts

As indicated earlier, this earthquake was felt over a wide region, which is also demonstrated by the felt responses reported through the USGS “Did you Feel It?” program (Figure 6). Variation of felt intensity with hypo-central distance is plotted in Figure 7, where it is observed that the closest felt response was reported at a hypocentral distance of 36.9 km and there were only four responses from locations with hypocentral distance less than 50 km. Although it was a sizable earthquake with magnitude 6.2 and there were significant levels of shaking, these felt responses are an indication of less severe shaking in populated areas, which helped reduce the potential for structural damage, fatalities, and injuries. This important information obtained from the “Did you Feel It?” responses indicates the significant potential of Citizen Science applications, programs like “Did you Feel It?”,

and social media responses, such as Tweets, to document the consequences of earthquakes. This is especially true in areas with scarce accelerometers and other sensors.

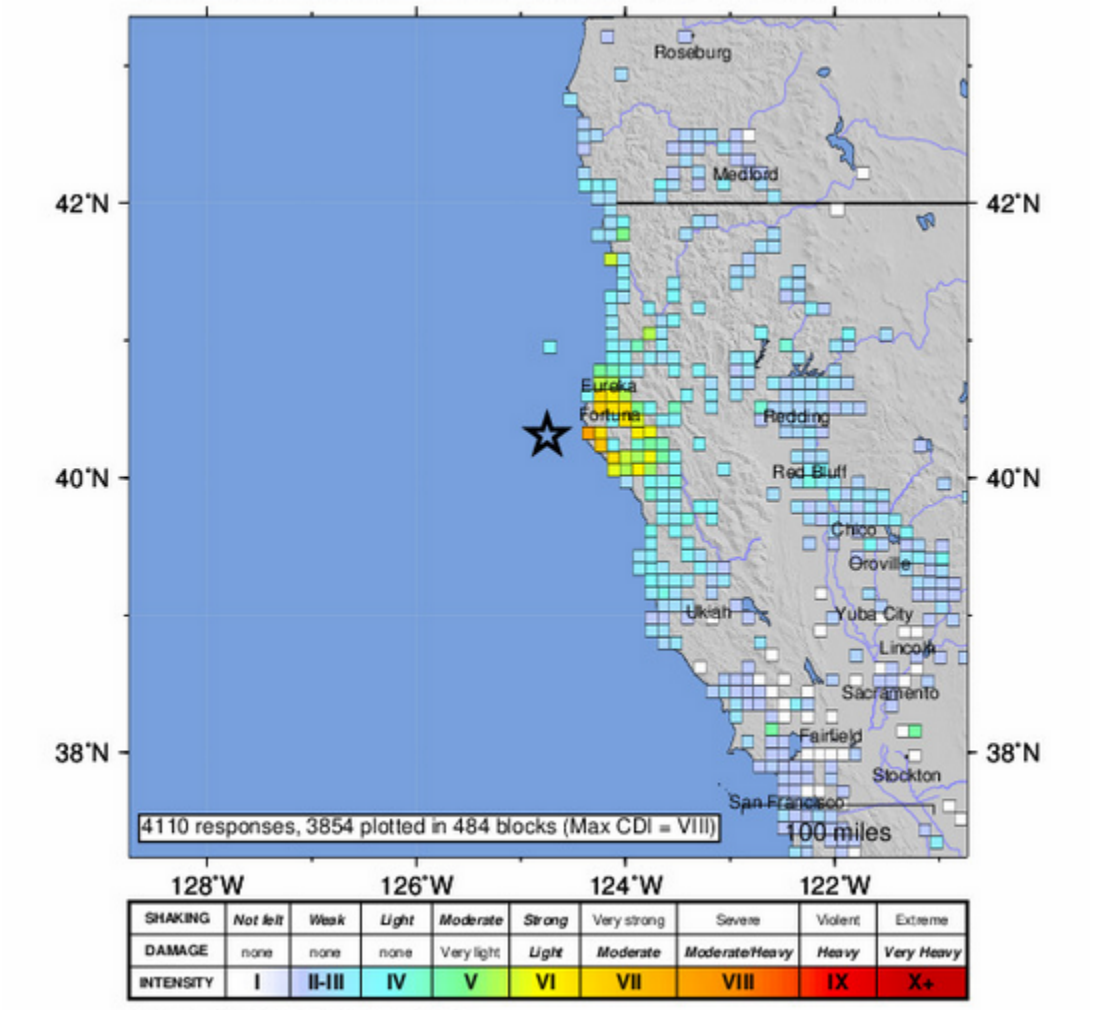

Figure 6. USGS Community Internet Intensity Map of the 2021 Petrolia Earthquake, developed by the USGS "Did you Feel It?" program, indicating the wide area where the earthquake was felt

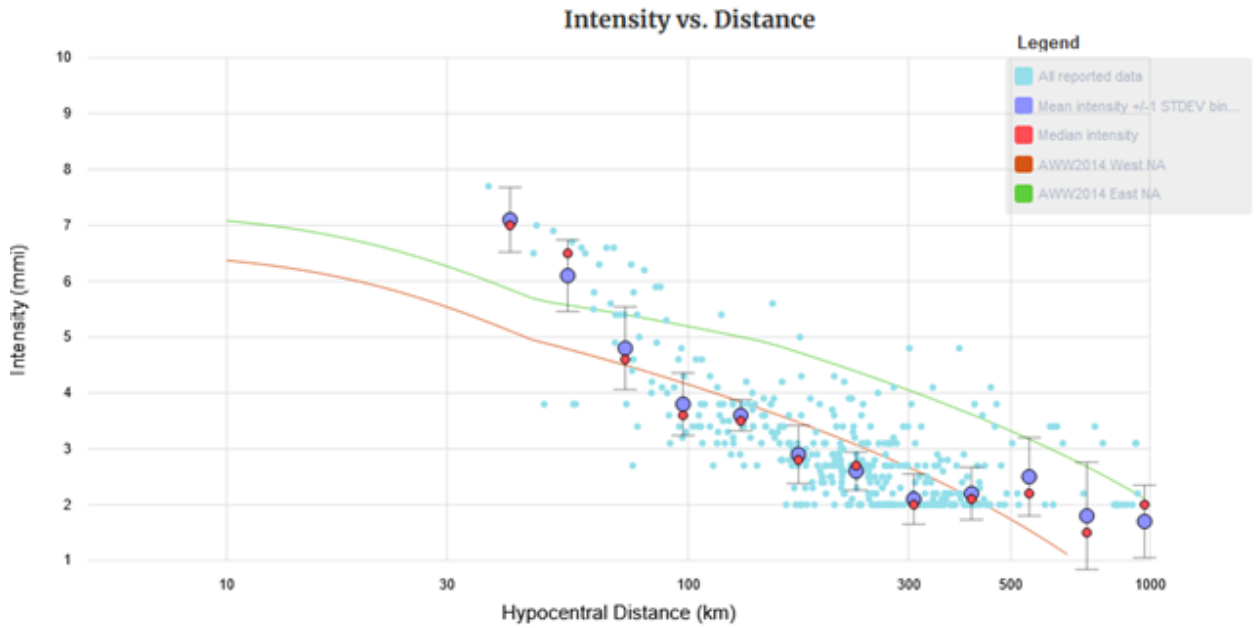

Figure 7. Variation of felt intensity with hypocentral distance from the USGS "Did you Feel It?" responses (USGS, 2021)

California's Office of Emergency Services indicated that 2,500 people were notified about the earthquake in advance of strong shaking through the state's early warning system called MyShake (ABC7, 2021), which might have prevented possible injuries. Regarding the consequences of the earthquake, USGS PAGER tool estimated the number of fatalities to be less than 1, between 1 and 10, and between 10 and 100, with probabilities of 65%, 30%, and 4%, respectively (Figure 8). At the time this briefing was issued, there were no fatalities or injuries in this earthquake, affirming the accuracy of this estimation. Economic loss was expected to be less than $1 million, between $1 million and $10 million, between $10 million and $100 million, and between $100 million and $1,000 million, with probabilities of 45%, 34%, 17%, and 4%, respectively (Figure 8).

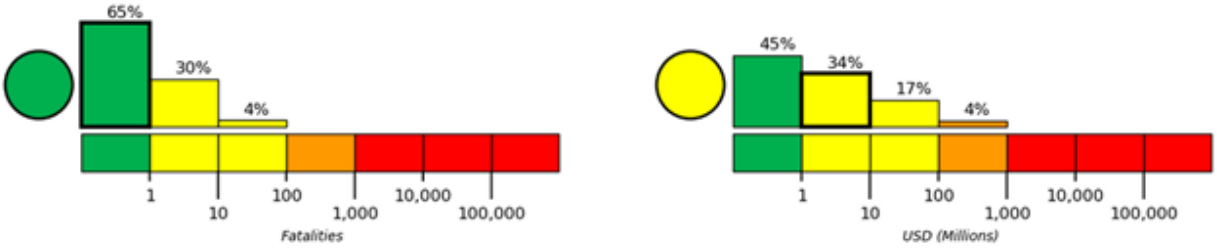

Figure 8. USGS PAGER loss estimates (USGS, 2021)

This earthquake is another reminder of the potential of major earthquakes that will continue to take place in the USA, particularly Western USA. Along with an earlier flurry of earthquakes off the coast of Oregon, attention should be given to these series of strike-slip earthquakes along the flanks of the Juan de Fuca plate. Had the earthquake originated at a location in the Mendocino triple junction that is closer to populated areas, an earthquake of this magnitude could have had more severe consequences.

StEER Response Strategy

At present, StEER has not deemed it necessary to form a Virtual Assessment Structural Team (VAST) or Field Assessment Structural Team (FAST) in response to this event. Rather, StEER's present response takes the form of this Event Briefing, which shares with the community StEER's impressions of the event and implications for natural hazard research and practice. Information provided herein was gathered from various websites, news channels, and USGS. Therefore, this briefing does not include insights from detailed field investigations. StEER will continue to monitor this event and should the damage to structures warrant the formation of a VAST or FAST, StEER will notify the community through its standard channels.

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