LBL - Hayward Scenarios - SERA

March 24, 2025

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Quiz

- Assume a Hayward M 7± earthquake occurs March 24 2025 (today) at 4 pm, breaking the fault from San Pablo to Fremont (the north and south segments)

- Question 1. Will there be a sustained power outage (> 5 minute duration) at Davis / Citrus Hall (here)?

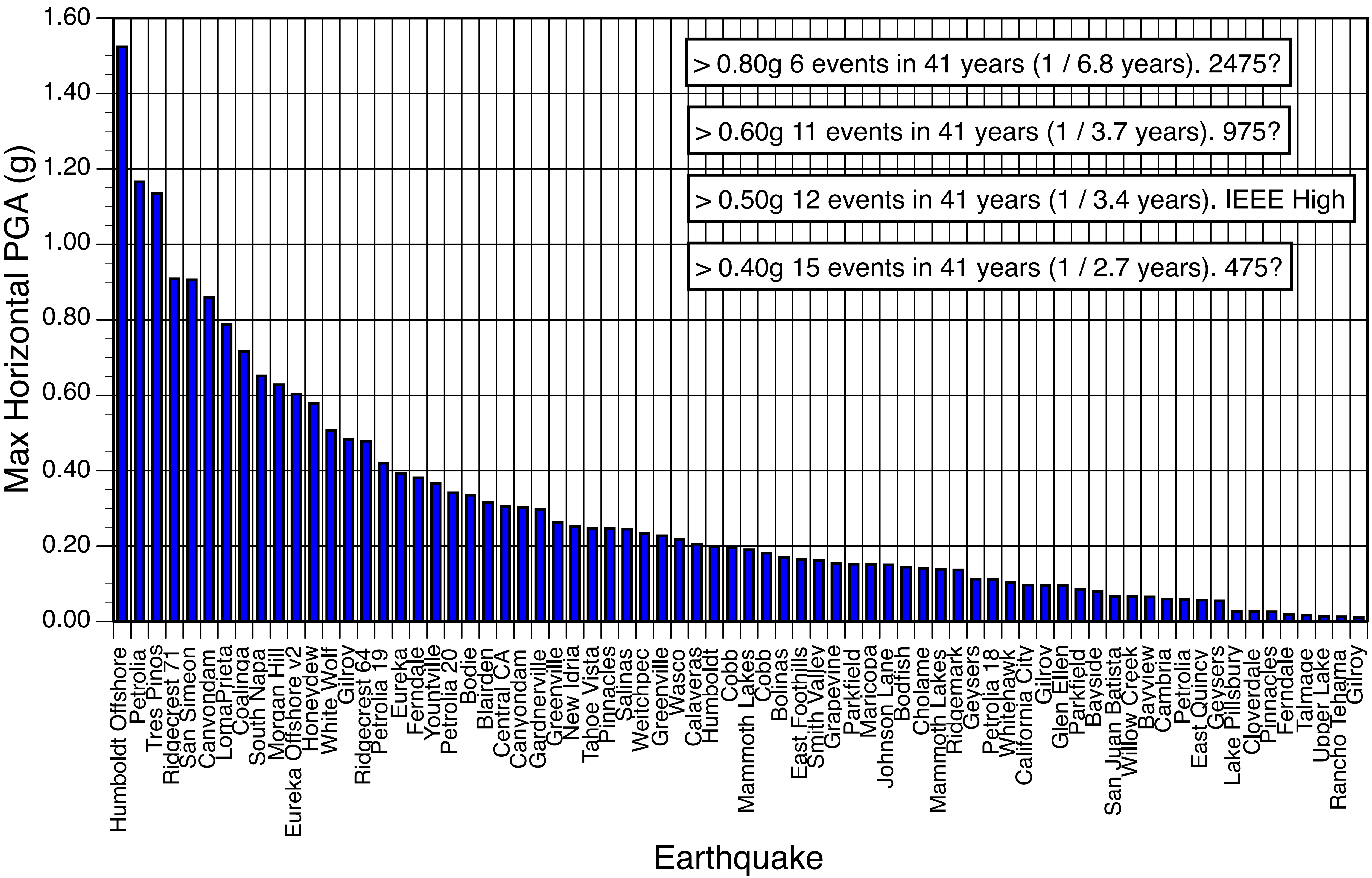
- Question 2. If "yes", what will the duration of the outage be? Minutes? Hours, Days? Weeks?

- Question 3. Why?

	Yes	No
Will there be an outage?		

	None or < 5 min	5 mins to 1 hour	1 hour to 4 hours	4 hours to 12 hours	12 hours to 1 day	1 day to 2 days	2 -4 days	4 - 7 days	1 - 2 weeks	2 -4 weeks
How Long will the outage last?										

Maximum PGA, Anywhere in Northern California

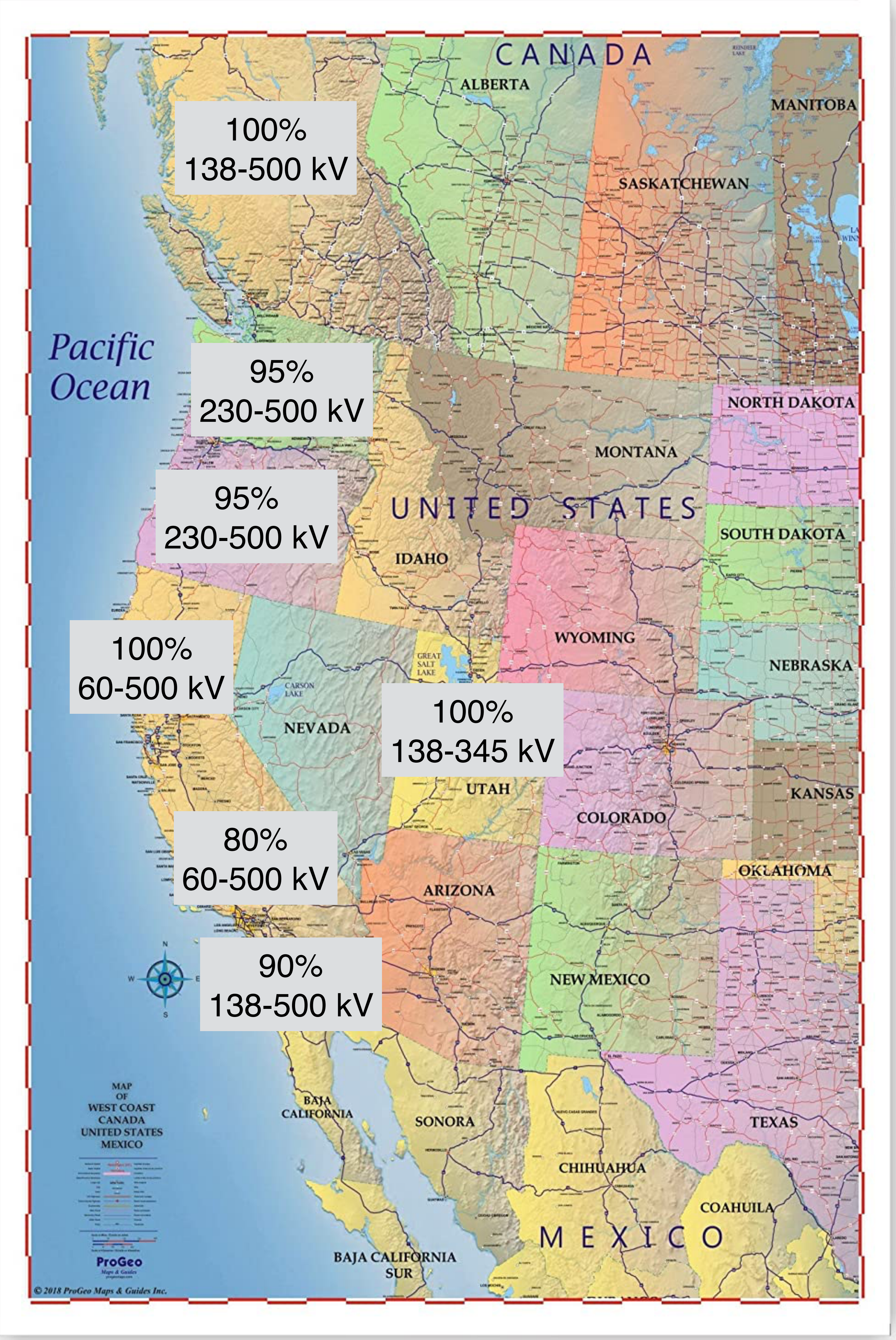


Computed using ShakeMaps (Max H1, H2)

Topics

- BART: Spatial Variation of Ground Motions; Benefit Cost Analysis; $1 Billion Seismic Upgrade Program (2002)
- Power and Gas: Spatial Variation of Ground Motions; Probabilistic Analysis with Spatial Variation of Ground Motions; Comparison to LBL Hayward R1 Motions (2025)
- EBMUD: Fires, Earthquakes?

What is SERA?



SERA MODELS (ELECTRIC)

BC Hydro

Bonneville Power Administration

Pacificorp (Oregon)

PG&E

SCE

SDG&E

Rocky Mountain Power (Utah)

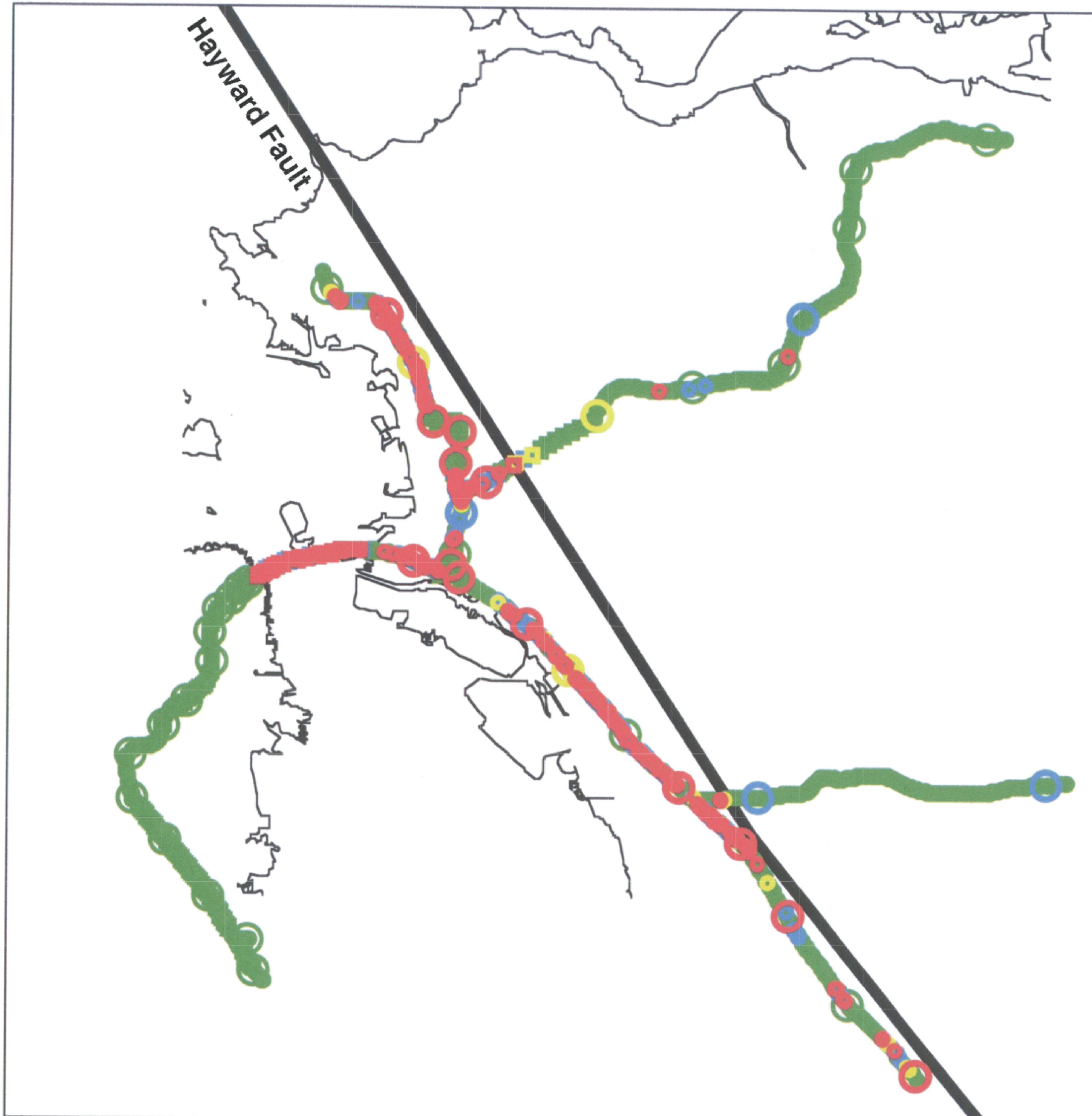
Total. > 3,000 substations. (60 million people)

BART
Seismic Risk Analysis

Prepared by:

G&E Engineering Systems Inc.

SEISMIC RETROFIT
BUILDING A STRONGER SYSTEM



SERA v. 6.0.3.1

Scale. (Feet per inch) = 26865

One Inch

BART Facilities
At-Grade
Aerial
Underground
Passenger Station

SCENARIO EARTHQUAKE:
HAYWARD M - 7.0

Winter Time
Simulation No. 1
13-MAY-02 11:48:38

Damaged, No Function
Damaged, Part Functional
Damaged, Functional
No Damage, Functional

Simulation 1

North

**Figure 6-1.
Status Quo
Alignment Status
Hayward M - 7.0**

Retrofit Alternative	Description	Total Cost ($1,000)
Package 1. Safety Improvements and Transbay Tube	Upgrade aerial guideways, selected passenger stations, selected buildings, the Transbay Tube and select equipment	729,233
Package 2. Operability Improvements from Rockridge to Daly City Yard	All Package 1 retrofits, plus Operability Improvements from Rockridge Station to Daly City Yard, additional upgrade to the Lake Merritt Administration building, plus upgrades to equipment important for operations	827,521
Package 3. Operability Improvements from North Berkeley to Coliseum	All Package 2 retrofits, plus Operability Improvements from MacArthur Station to North Berkeley Station and from the Oakland Wye to Coliseum Station	882,087
Package 4. Operability Improvements to South Hayward	All Package 3 retrofits, plus Operability Improvements from Coliseum Station to South Hayward Station	972,338
Package 5. Full Operability Improvements to Richmond, Fremont, and Concord	All Package 4 retrofits, plus Operability Improvements from South Hayward Station to Fremont Station, North Berkeley Station to Richmond Station, Orinda Station to Pittsburg / Bay Pointe Station	1,118,457

Table 5-1. Retrofit Cost Summary

$ Millions in Direct Damage Losses

	SERA Avg of 5 Atten.models
Long Term Loss – Excluding ground motion uncertainty	$817.8 random spatial variation of motions average of 100 Monte Carlo Simulations
Long Term Loss – Including ground motion uncertainty	$997.1 with spatial variation of motions average of 100 Monte Carlo Simulations

Table 5-1. Comparation Model Results

Conclusion (2002 vintage): High Stress Drop earthquakes increases the losses more than Low Stress Drop earthquakews reduces the losses.

or.... take Median losses, add 20%. The answer is the same (as long as T < 1 second)

The intra-event variability of ground motion within a single simulation of a scenario earthquake is the variability after removing the median residual for the particular simulation. It is due to complexities of the source (e.g. location and size of asperities), wave propagation (effects of complex crustal structure), and site effects (differences in soil properties within a particular soil classification).

The inter-event variability is defined as having a standard deviation τ, and the intra-event variability is defined as having a standard deviation σ. The total variability is:

$$\sigma_{total} = \sqrt{\tau^2 + \sigma^2}$$

This total variability, σ_{total}, is the standard deviation that is given by attenuation relations, such as those mentioned in Section 3.3.1.

The inter-event variability is estimated using the following relations:

$$\frac{\tau}{\sigma_{total}} = \begin{cases} 0.45 & for \;\; T \le 0.2 \\ 0.45 + 0.24\left[\ln(T) + 1.61\right] & for \;\; 0.2 < T < 0.7 \\ 0.75 & for \;\; T \ge 0.7 \end{cases}$$

The intra-event variability is then given by

$$\sigma = \sqrt{\sigma_{total}^2 - \tau^2}$$

For the intra-event variability, there is a second effect on the spatial correlation. The intra-event variability is not independent at each location. Based on the recordings from the 1999 Chi-Chi (Taiwan) earthquake, the spatial correlation of the intra-event variability is approximated by

$$C_{ij} = \frac{1}{\left(1 + a_1 \Delta x_{ij} + a_2 \Delta x_{ij}^3\right)}$$

where Δx_{ij} is the separation distance in km between sites i and j. The values for coefficients a_1 and a_2 are

$$a_1 = 0.0002$$
$$a_2 = 0.12 \quad for \quad T \leq 0.4$$
$$a_2 = 0.12 - 0.038[\ln(T) + 0.916] \quad for \quad T > 0.4$$

To apply this to the ground motion estimation for a particular simulation of a scenario earthquake, the following algorithm is used. First, the correlation matrix C is computed at period intervals from T=0.1 to T=4.0 seconds (37 total, as intervals T=0.1, 0.2, 0.3 and 0.4 are the same). Next, the C matrix is decomposed using Gaussian elimination into a product of upper and lower triangular matrices:

$$C = LU$$

Create a vector ε of normally distributed random numbers with mean 0 and standard deviation σ. The intra-event variability, ξ_I is computed by

$$\vec{\xi} = L\vec{\varepsilon}$$

The direct application of the intra-site correlation model is CPU and Memory Intensive for a model the size of the BART system. Three main computational problems had to be resolved:

> As the matrix C is fully populated, the bulk storage requirement for a model with n sites is (ignoring approximate 50% savings from skyline storage schemes, and using double precision arithmetic): n x n x 37 x 8 bytes. As the BART system includes about 3,100 sites, then the total storage would be: 3,100 x 3,100 x 37 x 8 = 2.8 Gbytes. This amount of "in-core" storage was impractical in 2002; feasible in 2025
>
> The decomposition of the matrix C requires substantial computation time, with the number of computer operations for a fully populated matrix being approximately: n**3 / 3. For the BART system, this would involve about 3100 * 3100 * 3100 * 37 / 3 operations = 367 billion floating point operations. This can involve many hours of computational time on a 1 Tflop... but ~1 second (?) on an Exascale computer

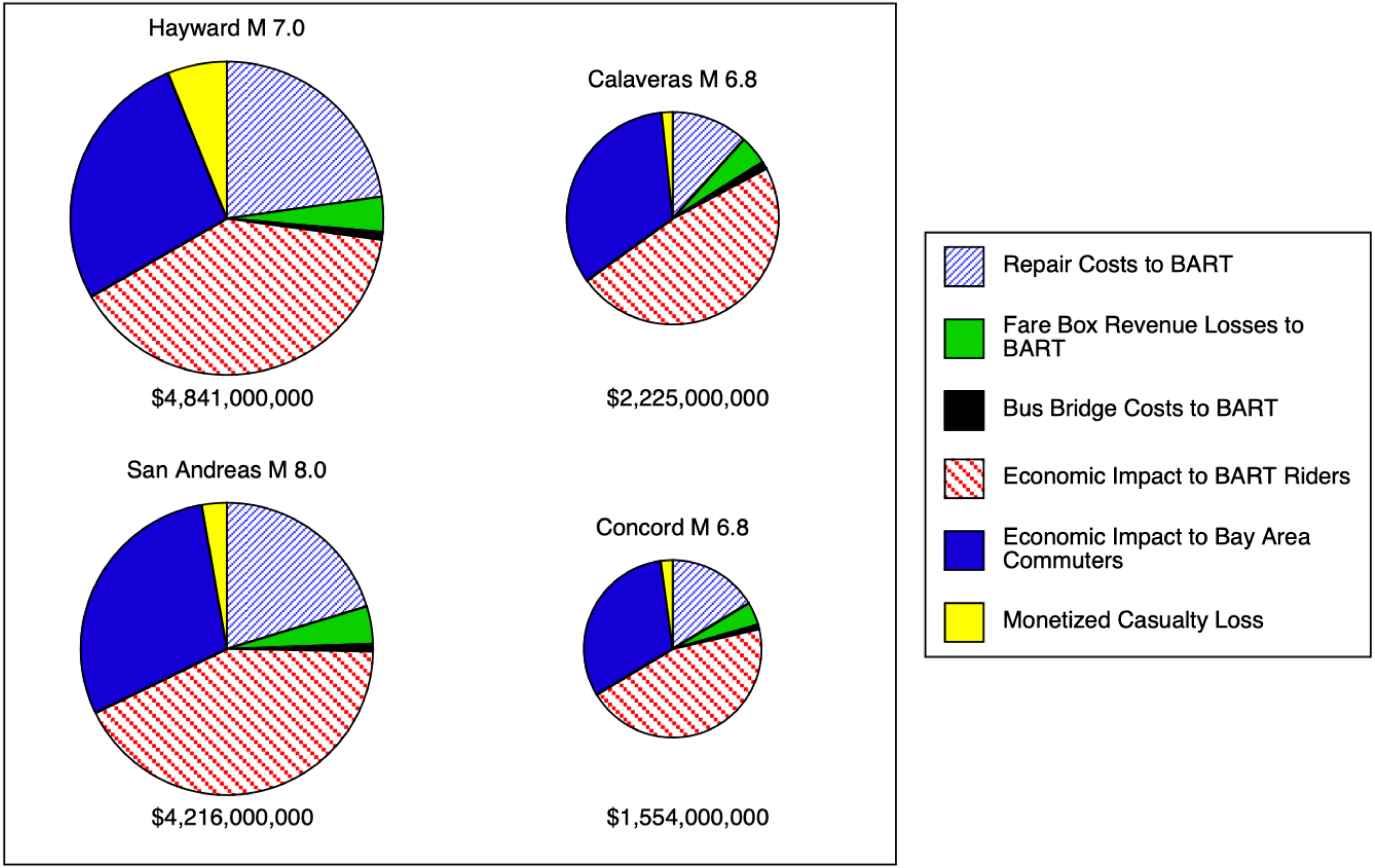


Figure 14-8. Total Economic Impact of Earthquake - BART System - Status Quo

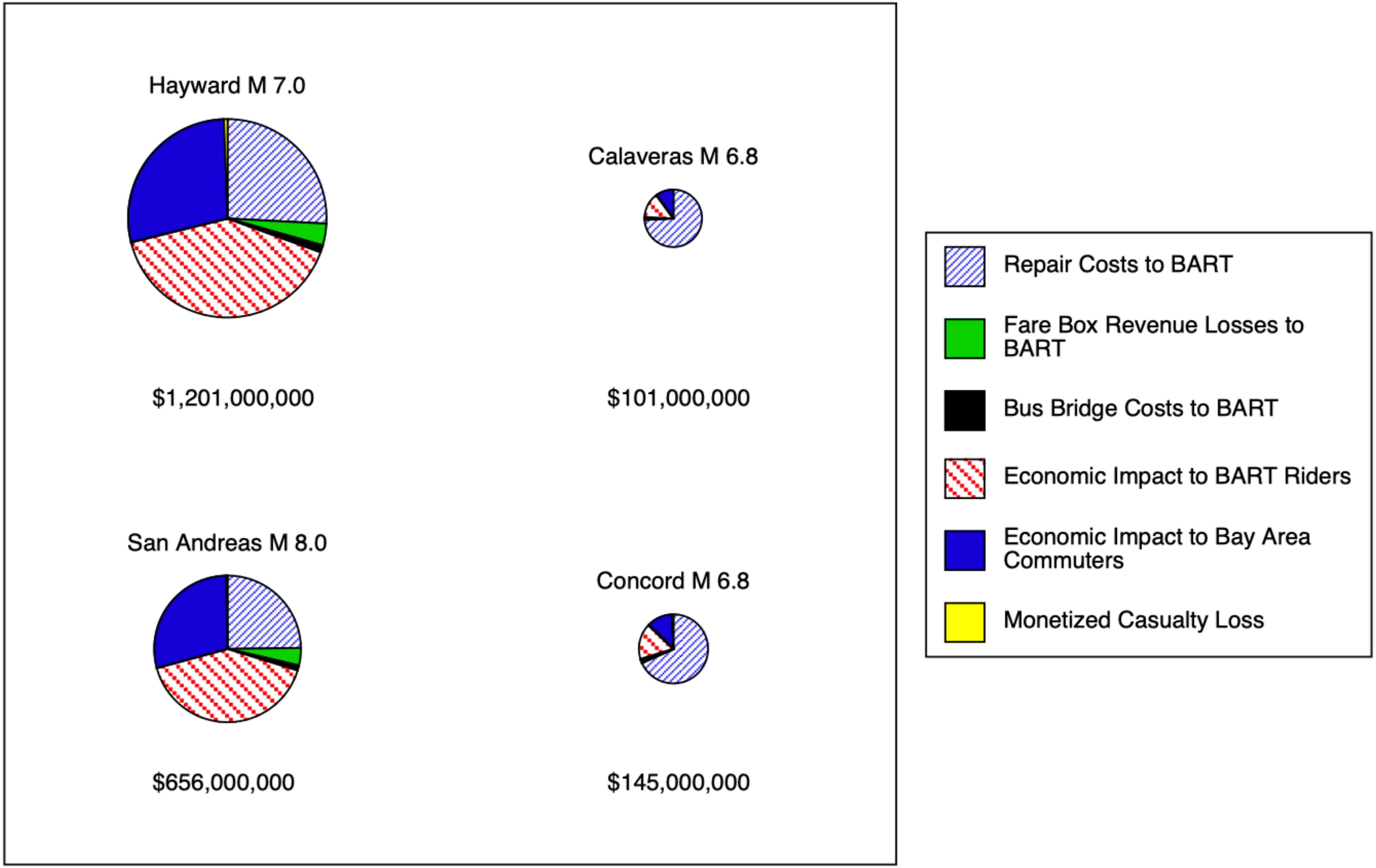


Figure 14-9. Total Economic Impact of Earthquake - BART System - with Package 2

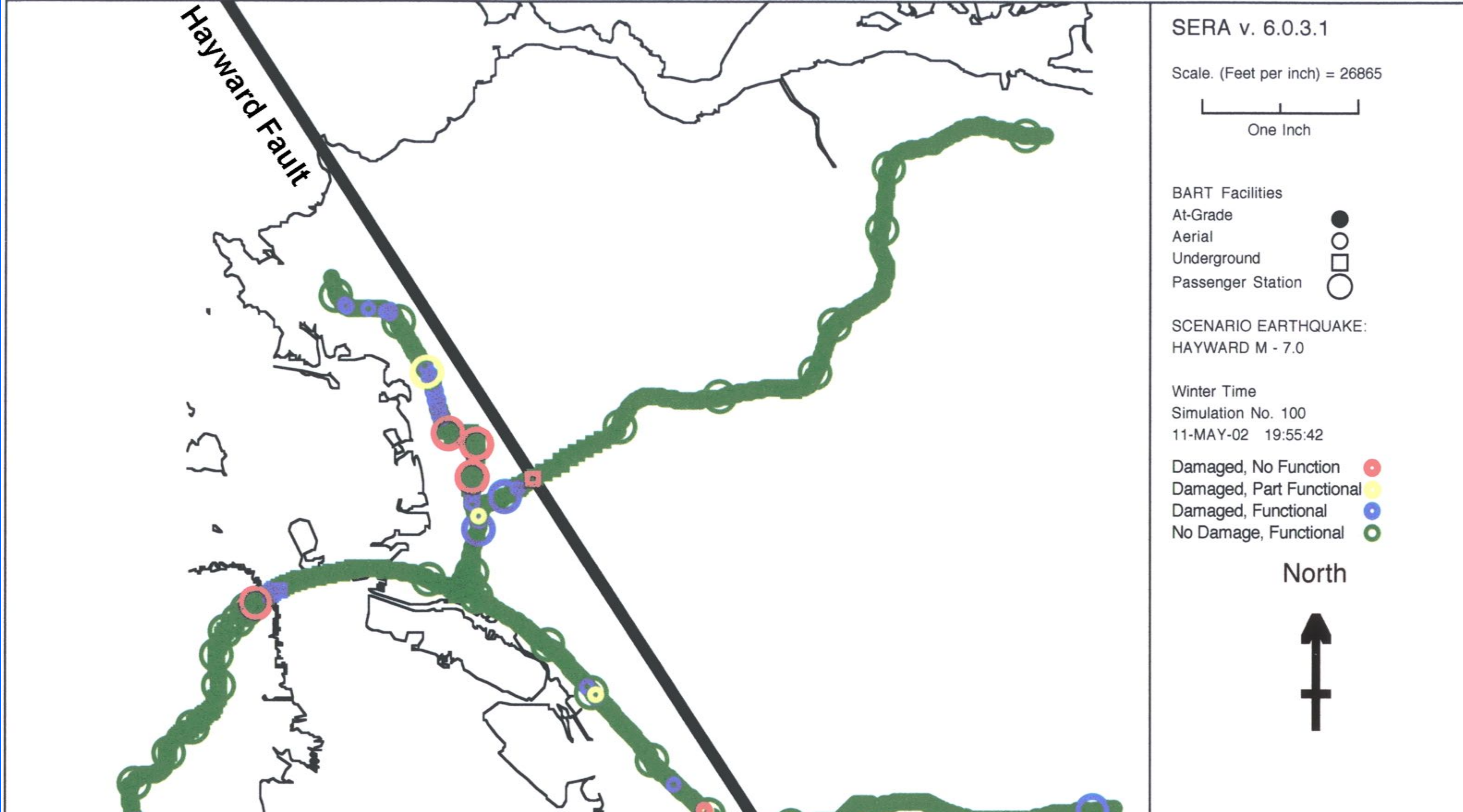


Figure 7-1.
Package 1 Retrofit Alignment Status Hayward M - 7.0

Benefit-Cost Results

BART Condition	Retrofit Cost ($millions)	Annualized Benefits ($millions)	NPV Benefits ($millions)	**BCR**
Status Quo	n/a	n/a	n/a	**n/a**
Life Safety	$594.88	$138.14	$2,338.92	**3.93**
Partial Operability - 1	$737.39	$152.02	$2,573.85	**3.49**
Partial Operability - 2	$863.03	$153.03	$2,591.05	**3.00**
Partial Operability - 3	$1,105.45	$155.20	$2,627.72	**2.38**
Full Operabillity	$1,323.32	$159.53	$2,701.06	**2.04**
Extended Operability	$1,443.32	$163.79	$2,773.13	**1.92**

The EBMUD Water Question

CUSTOMER

pipeline

EBMUD

Wildfire readiness is a year-round job

At EBMUD, our thoughts are with those affected by the Los Angeles area firestorms.

EBMUD partners with fire agencies on prescribed burns.

The devastation highlights the importance of our own emergency preparedness. Breakout blazes can ignite any time of year, and firefighting is particularly challenging where urban development and open spaces meet — as in parts of the East Bay. EBMUD is committed to proactively minimizing wildfire risks, securing vital infrastructure and protecting public safety.

Wind-driven fires the size of those in Southern California would stress any municipal water system, and a coordinated effort would be needed. Thankfully, we are better prepared today because of operational improvements and enhanced coordination implemented after the 1991 Oakland Hills Fire.

WE EMPLOY A MULTI-PRONGED APPROACH INCLUDING:

EMERGENCY RESPONSE

- EBMUD makes water from our local raw water reservoirs like San Pablo Reservoir available for aerial firefighting efforts and works to increase water pressure to aid firefighters.
- We top off local water storage tanks on Red Flag days to maximize water availability for firefighting.

VEGETATION MANAGEMENT

- EBMUD invests $2.5 million each year to reduce fire risk across nearly 29,000 acres of East Bay watershed. EBMUD builds and maintains fuel breaks, removes dead trees, operates grazing programs, and conducts prescribed burns, often in partnership with fire departments.

INFRASTRUCTURE INVESTMENTS

- We have permanent generators at critical facilities and can deploy portable backup generators and pumps to maintain water delivery.
- We perform regular hydrant maintenance and inspection, and invest in reservoirs, pumping plants and pipelines to ensure system reliability.

MUTUAL ASSISTANCE

- We are active in statewide assistance networks to provide help when needed and share best practices for emergency preparedness, response and recovery.

AGENCY COLLABORATION

- EBMUD has drawn on its experience to strengthen regional coordination and hosts annual fire forums to collaborate with key agencies.

LEARN MORE AT *ebmud.com/wildfire-preparedness*

The Bay Area is vulnerable to many types of emergencies. Be ready. Sign up for emergency alerts:
EBMUD Alerts: *ebmud.com/subscriptions* • Alameda County: *ACAlert.org* • Contra Costa County: *CWSAlerts.com/registration*

Corrupt Propaganda ?

What EBMUD Does Not Tell You

- Over the last 2 decades, EBMUD has dramatically reduced Water Storage in the High Fire Risk Areas
- Summit Reservoir: 90% reduction. 37 million gallons -> 3.5 million gallons
- Berryman Reservoir. 15 million gallons -> 2.6 MG
- Piedmont 1, Piedmont 2, Dingee, Swainland: 75% reduction from 30 MG -> 5 MG

EBMUD

- Should EBMUD spend $6 Billion to replace seismically weak water pipes (Cast Iron, Asbestos Cement, etc.)?

The Electric Grid Question

What are we trying to accomplish?

Vancouver, British Columbia, March 4 2025

What are we trying to accomplish?

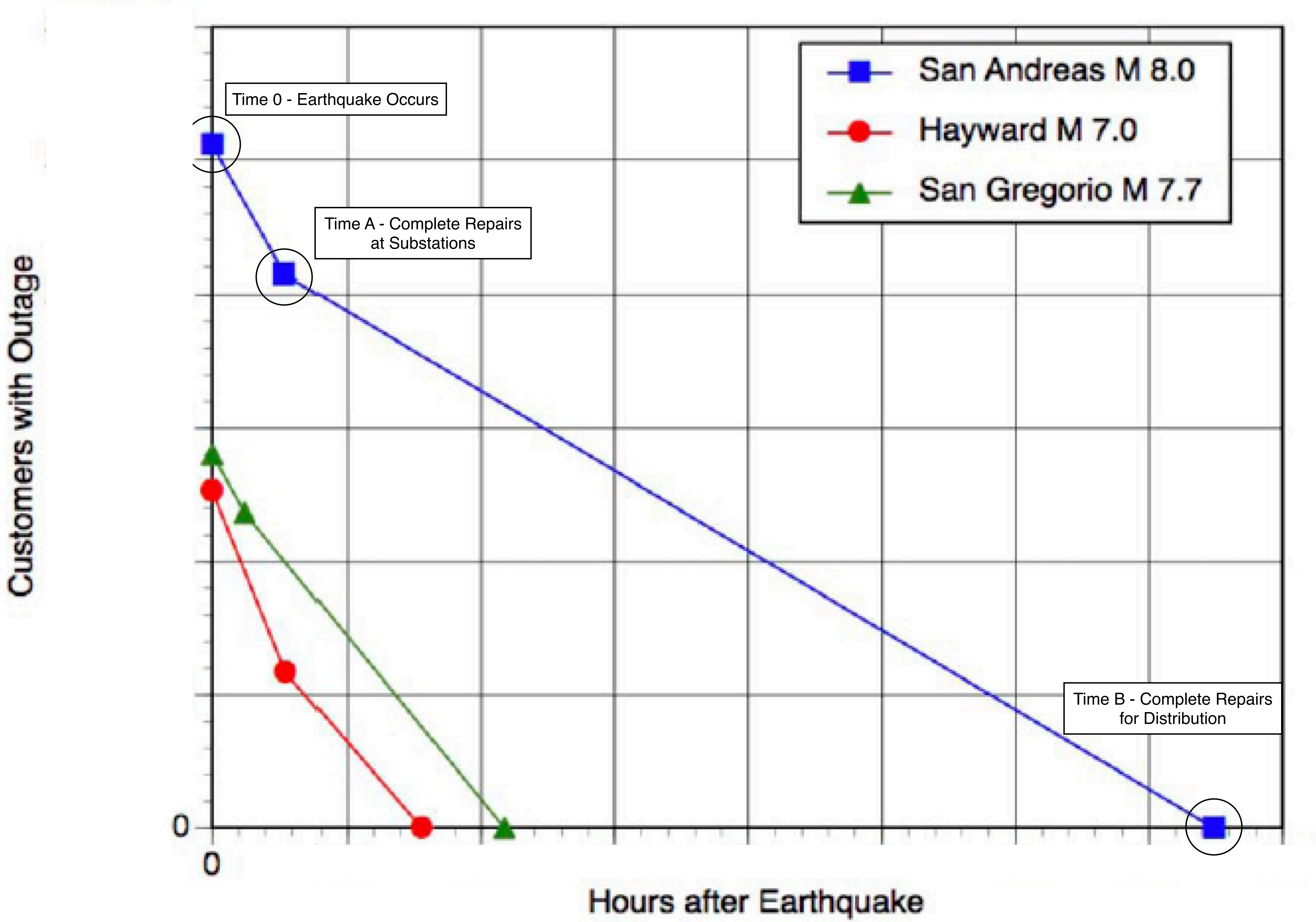
Monroe, Washington, April 24 2024

What are we trying to accomplish?

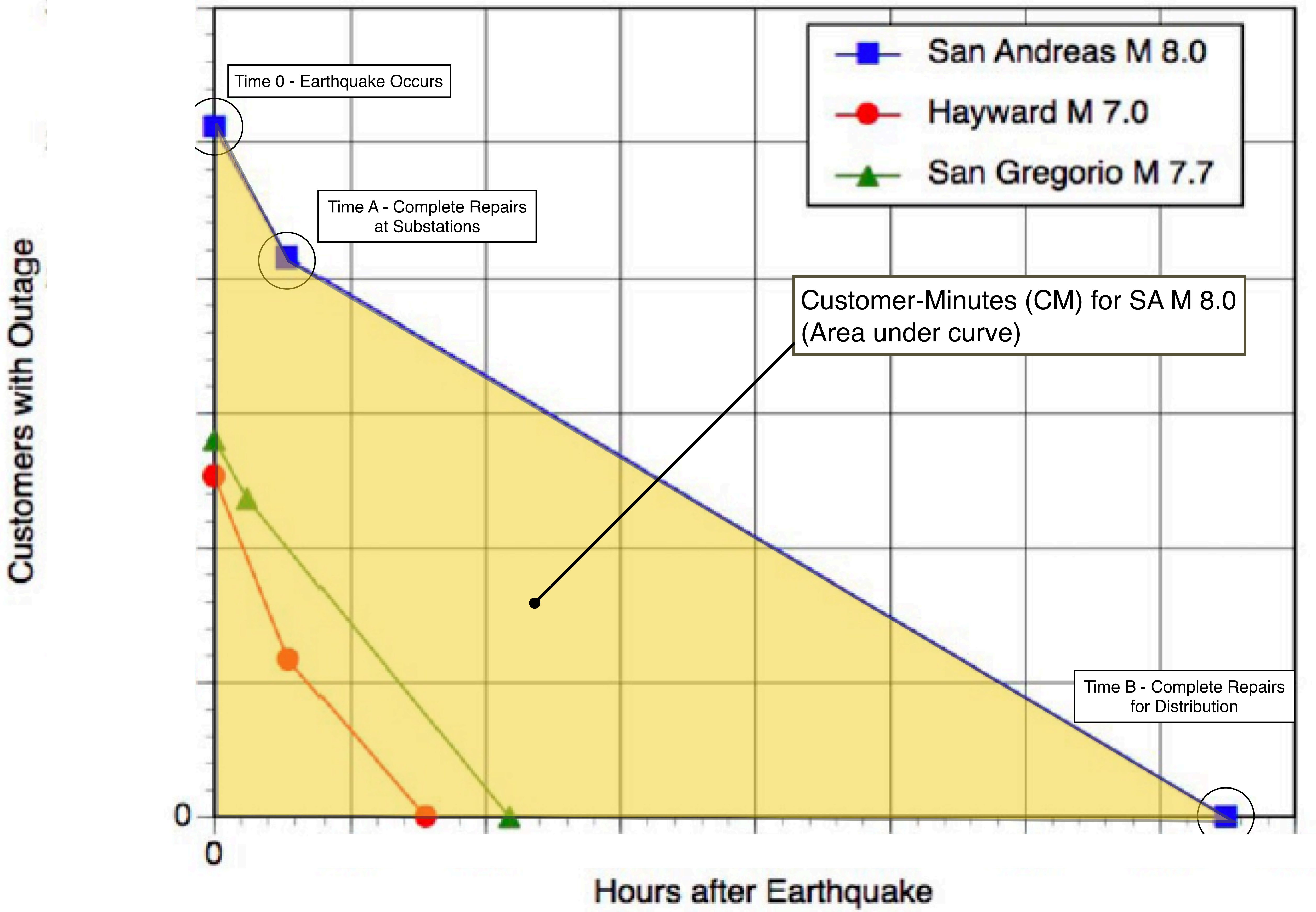
Newport Oregon, May 11 2023

How to Decide?

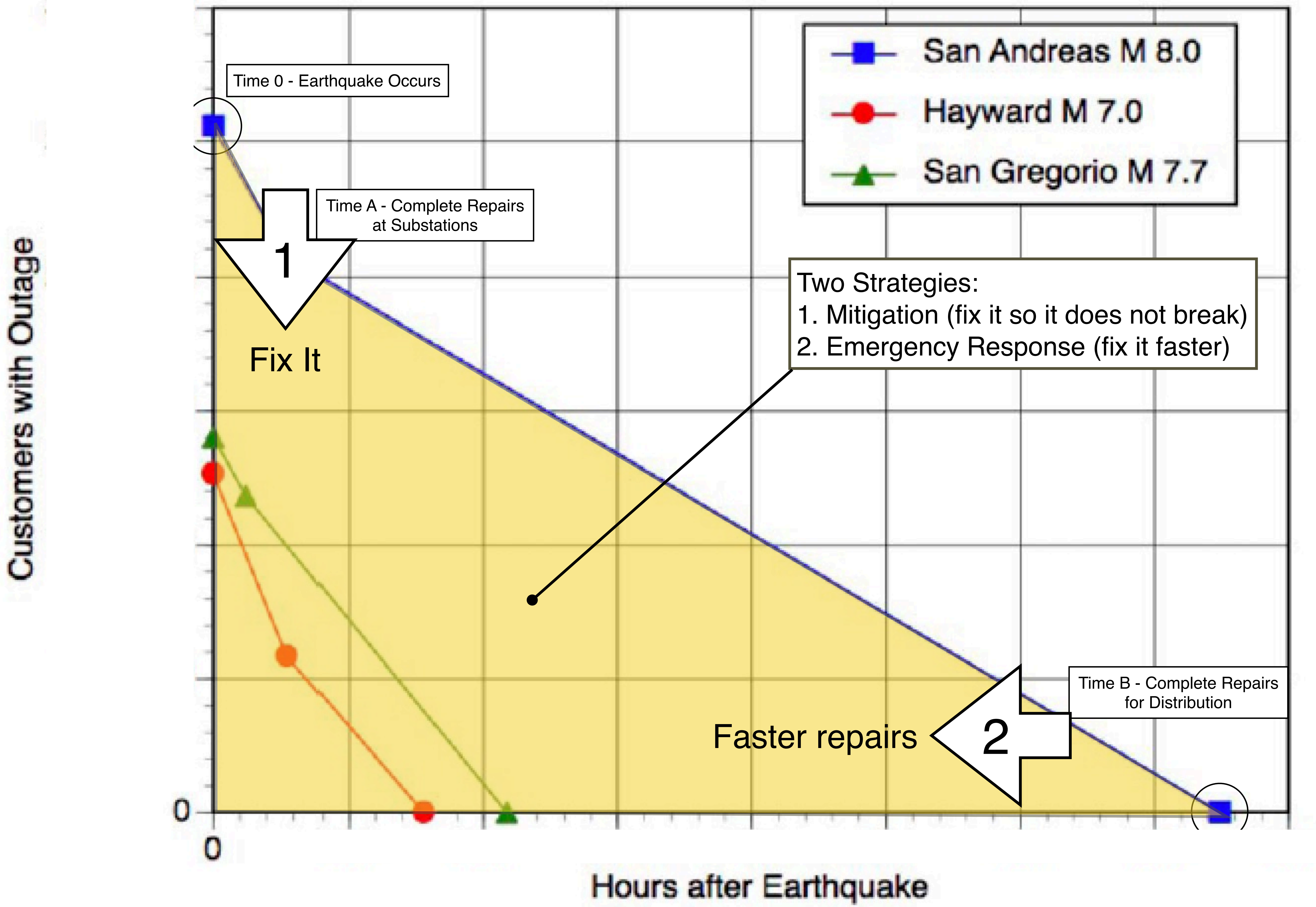
- CM = 100,000 to 1,000,000. A common day. Good enough.
- CM = 4,000,000. Offshore Humboldt M 7.0 Dec 5 2024. Good enough.
- CM = 50,000,000. Big winter storm. Good enough.
- CM = 35,000,000 to 90,000,000. Napa M 6.5 2014, Ferndale M 6.4 2022. Customers were generally satisfied.
- CM = 100,000,000. Customers are edgy.
- CM = 500,000,000. Customers angry. 2002 Wind storm San Gabrial Mountains 2011.
- CM = 1,000,000,000. Customers not happy. Loma Prieta M 6.9 1989.
- CM = 5,000,000,000. Expect lots of complaints from customers and politicians
- CM = 25,000,000,000. Perhaps Governor Newsom Takes Over ... GOLDEN STATE ENERGY??



San Andreas M 8.0
Hayward M 7.0
San Gregorio M 7.7
Time 0 - Earthquake Occurs
Time A - Complete Repairs at Substations
Time B - Complete Repairs for Distribution
Customers with Outage
Hours after Earthquake
0
0



San Andreas M 8.0
Hayward M 7.0
San Gregorio M 7.7
Time 0 - Earthquake Occurs
Time A - Complete Repairs at Substations
Customer-Minutes (CM) for SA M 8.0 (Area under curve)
Time B - Complete Repairs for Distribution
Customers with Outage
0
0
Hours after Earthquake


San Andreas M 8.0
Hayward M 7.0
San Gregorio M 7.7
Time 0 - Earthquake Occurs
Time A - Complete Repairs at Substations
1
Fix It
Two Strategies:
1. Mitigation (fix it so it does not break)
2. Emergency Response (fix it faster)
Time B - Complete Repairs for Distribution
Faster repairs
2
Customers with Outage
0
0
Hours after Earthquake

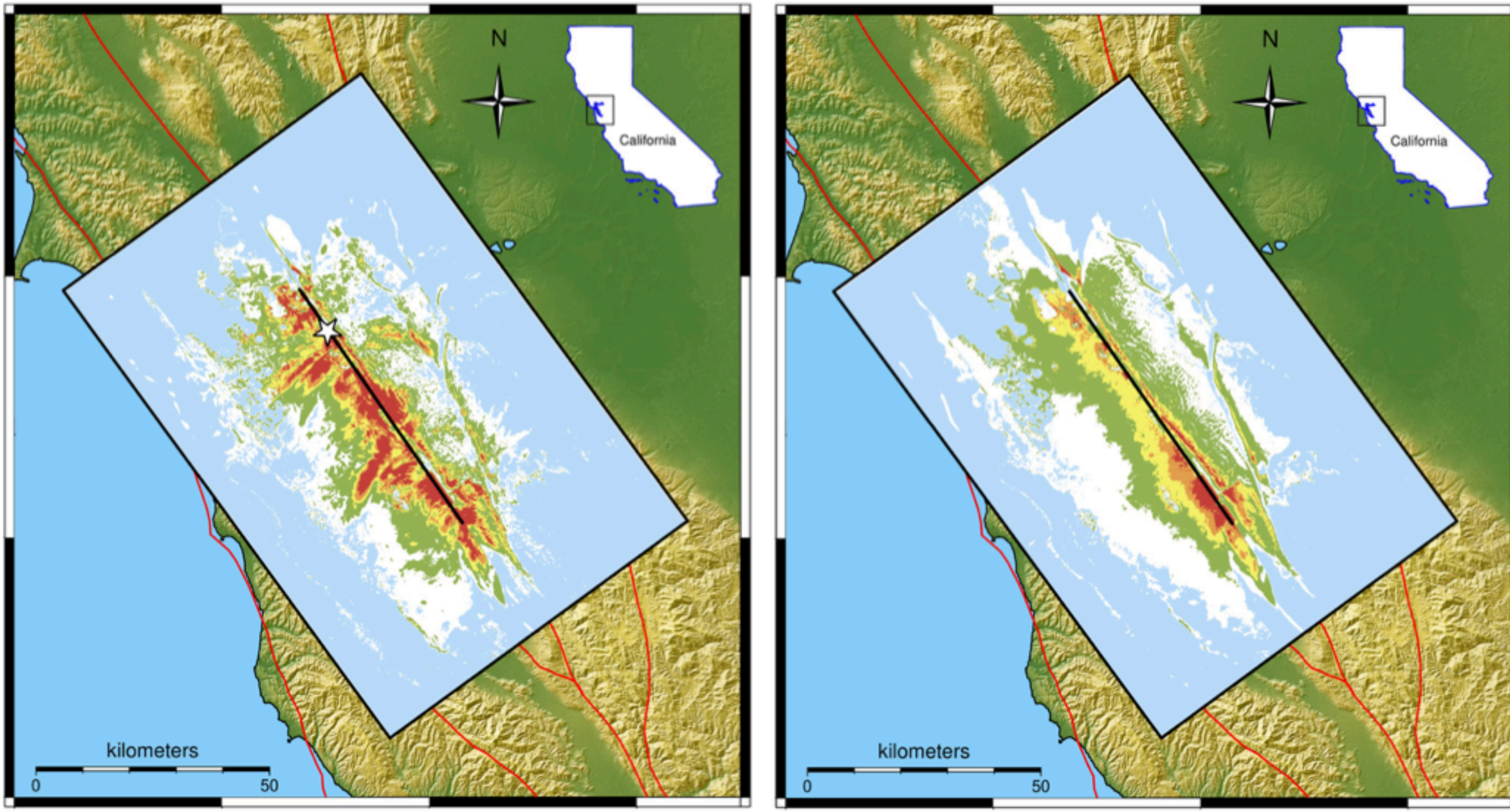
Strategy

- Option 1 (Fix It). Costs $$$. Done as normal design. Get it done over 35 years (equipment replacement cycle), or, in a few cases, get it done immediately.
- Option 2 (Repair Faster). Costs $. Requires big repair crews, parts, coordination. Can the utility muster 10,000 repair crew? or 1,000?
- Benefiåt Cost Ratio. Ideally, the benefits (reduced outage times, less damage, etc.) should outweigh the costs (BCR > 1).
- SERA does a lot of these computations.

What has David McLellan Provided?

Realization R1

Median Motions for all 50 Realizations

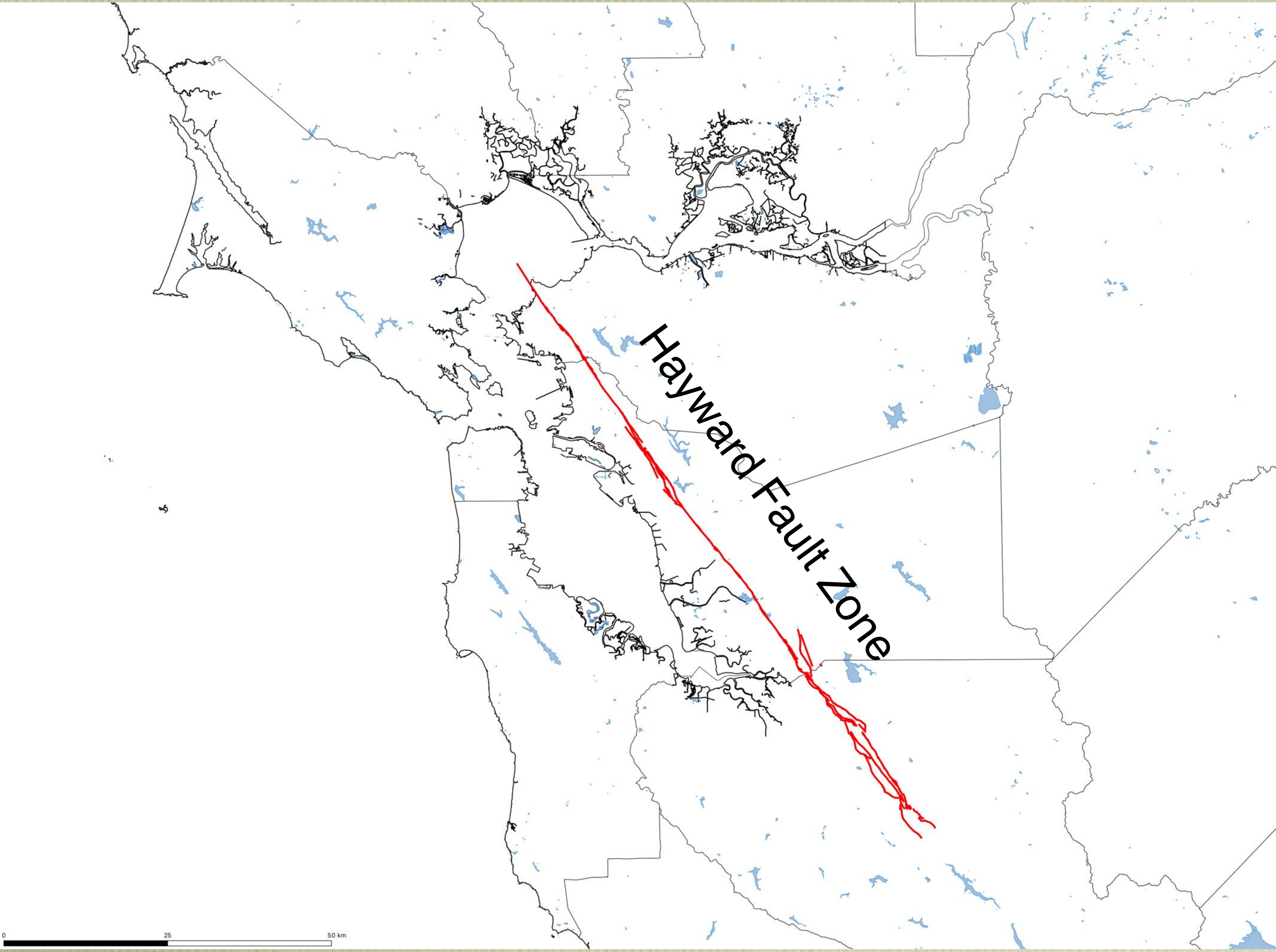


Peak Acceleration (g)

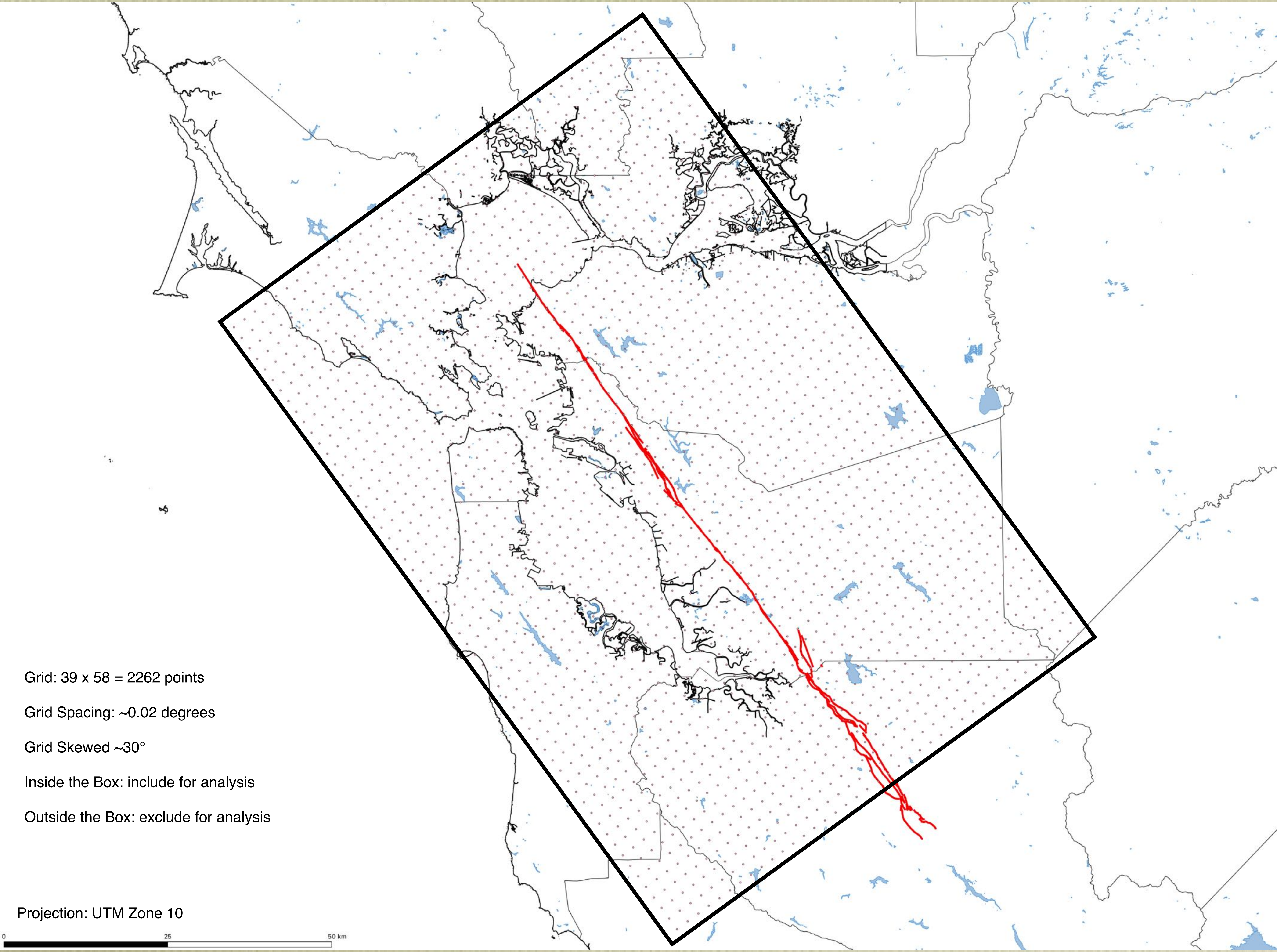
< 0.2 | 0.2 – 0.3 | 0.3 – 0.45 | 0.45 – 0.65 | 0.55 – 0.65 | 0.65 - 1.3

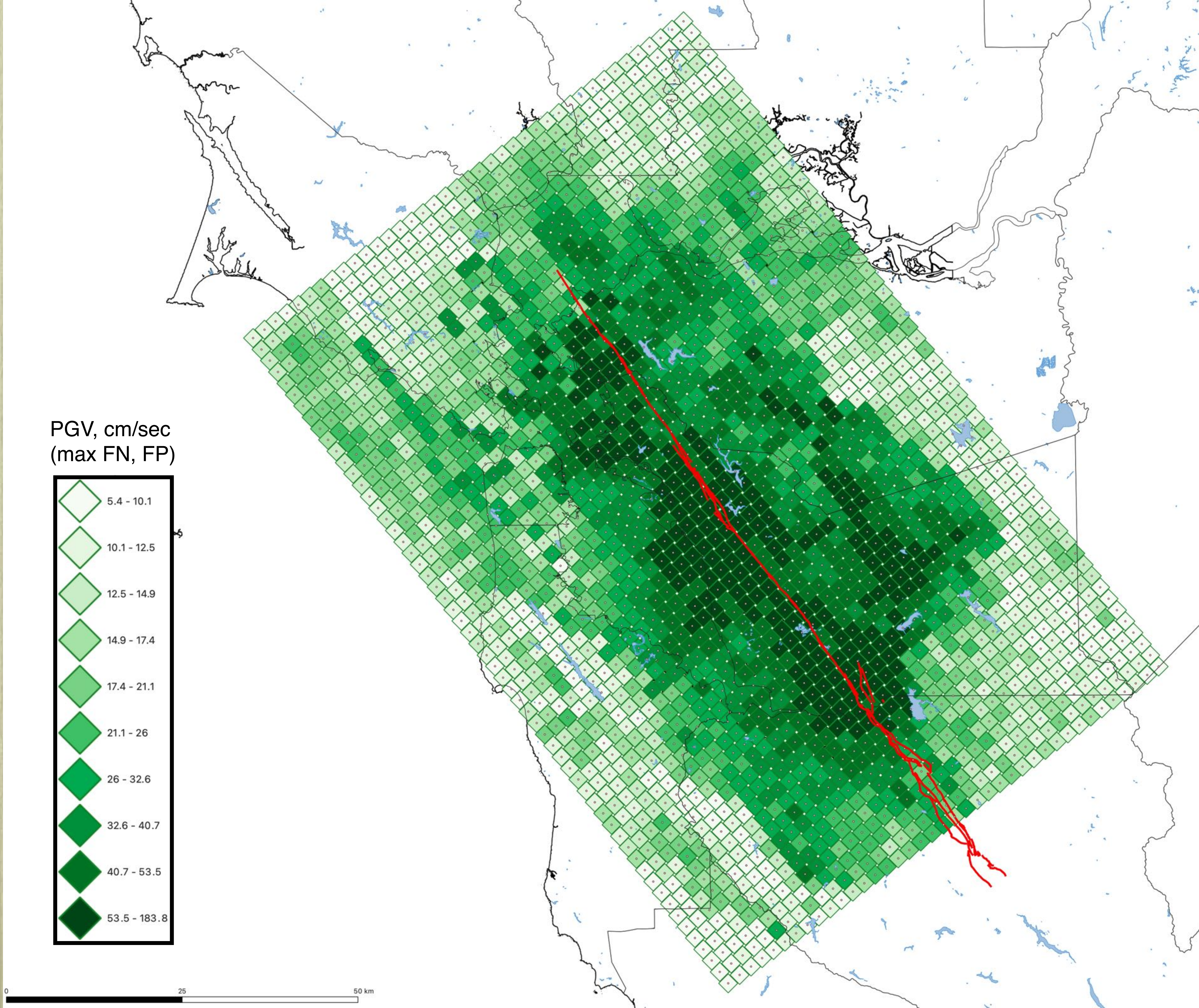
Peak Acceleration (g)

< 0.2 | 0.2 – 0.3 | 0.3 – 0.45 | 0.45 – 0.65 | 0.55 – 0.65 | 0.65 - 1.3



Hayward Fault Zone
0
25
50 km


Grid: 39 x 58 = 2262 points
Grid Spacing: ~0.02 degrees
Grid Skewed ~30°
Inside the Box: include for analysis
Outside the Box: exclude for analysis
Projection: UTM Zone 10
0
25
50 km



PGV, cm/sec
(max FN, FP)
5.4 - 10.1
10.1 - 12.5
12.5 - 14.9
14.9 - 17.4
17.4 - 21.1
21.1 - 26
26 - 32.6
32.6 - 40.7
40.7 - 53.5
53.5 - 183.8
0
25
50 km

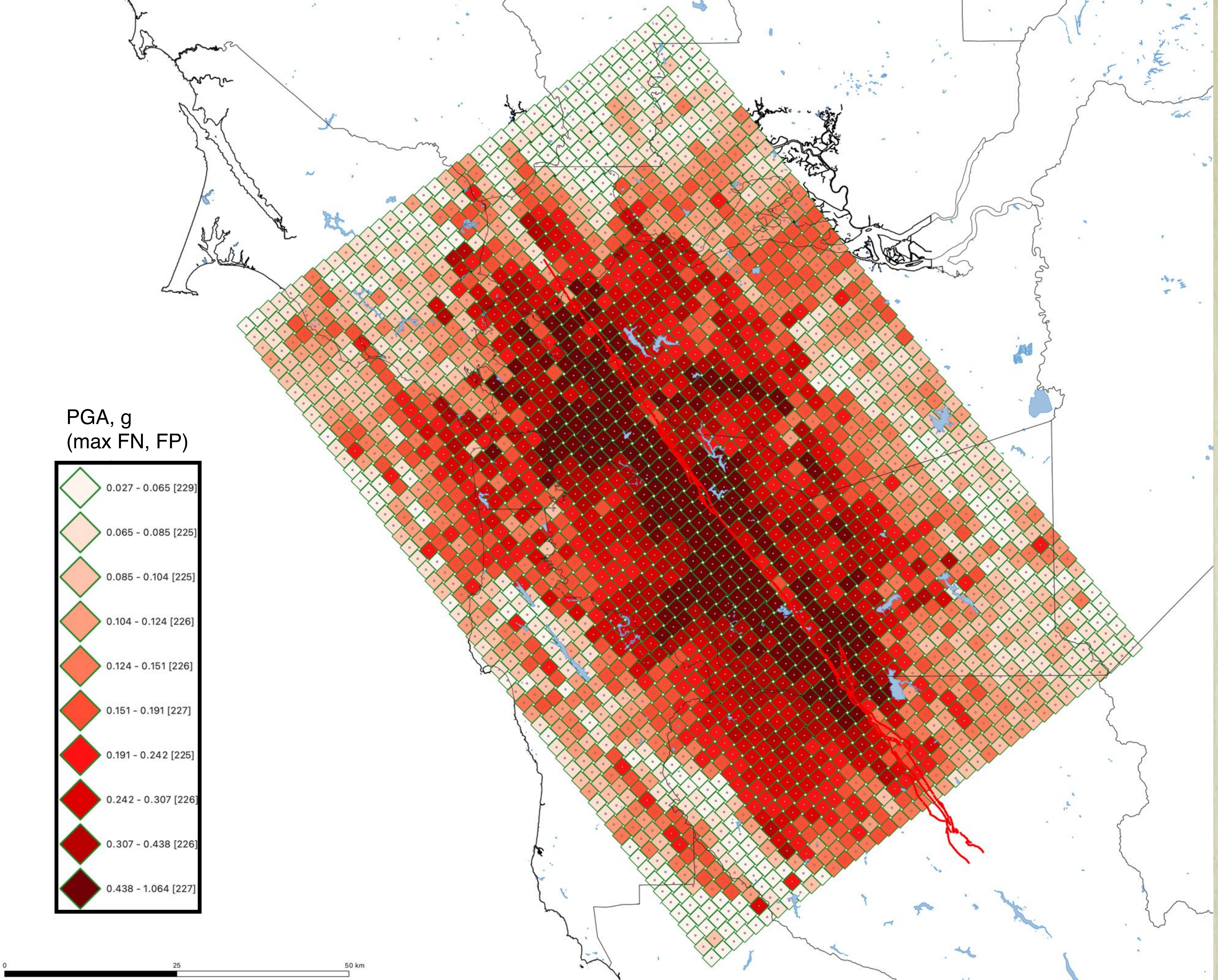

PGA, g
(max FN, FP)
0.027 - 0.065 [229]
0.065 - 0.085 [225]
0.085 - 0.104 [225]
0.104 - 0.124 [226]
0.124 - 0.151 [226]
0.151 - 0.191 [227]
0.191 - 0.242 [225]
0.242 - 0.307 [226]
0.307 - 0.438 [226]
0.438 - 1.064 [227]
0
25
50 km

TABLE 4. SCENARIO: 1. Magnitude Mw = 7.00

File	Record	Latitude	Longitude	PGA (g)	PGV (cm/sec)	SA03 (g)	SA10 (g)	SA30(g)	Vs30(m/s)
1	1	37.9492	-122.8844	0.0615	11.38	0.1418	0.1429	0.0315	501.6
1	2	37.9598	-122.8661	0.0627	10.81	0.2020	0.1133	0.0279	503.2
1	3	37.9705	-122.8477	0.0664	10.70	0.1959	0.1173	0.0346	505.8
1	4	37.9811	-122.8294	0.0679	8.94	0.1520	0.1224	0.0294	507.3
1	5	37.9918	-122.8110	0.0721	10.64	0.1019	0.1643	0.0383	504.8
1	6	38.0024	-122.7927	0.0820	12.62	0.1316	0.2235	0.0227	504.8
1	7	38.0131	-122.7743	0.1257	15.70	0.2184	0.3010	0.0205	363.0
1	8	38.0237	-122.7559	0.0660	6.35	0.1418	0.1122	0.0132	1028.1
1	9	38.0344	-122.7375	0.0773	7.18	0.2194	0.1449	0.0174	1028.1
1	10	38.0450	-122.7191	0.0893	7.59	0.2327	0.1265	0.0193	1028.2
1	11	38.0556	-122.7008	0.0787	6.54	0.1827	0.1276	0.0130	1028.1
1	12	38.0663	-122.6824	0.0691	8.30	0.1480	0.1459	0.0159	1028.2
1	13	38.0769	-122.6640	0.0582	8.75	0.1724	0.0794	0.0113	1028.1
1	14	38.0876	-122.6456	0.0774	8.15	0.1245	0.0867	0.0170	1028.3
1	15	38.0982	-122.6272	0.0641	7.18	0.1071	0.0577	0.0161	1028.1
1	16	38.1088	-122.6087	0.1163	11.48	0.2102	0.2061	0.0147	504.8
1	17	38.1194	-122.5903	0.0583	9.22	0.1194	0.0617	0.0208	734.0
1	18	38.1300	-122.5719	0.0614	10.20	0.1286	0.0503	0.0241	1028.1
1	19	38.1407	-122.5534	0.0980	13.00	0.2490	0.1020	0.0291	504.8
1	20	38.1513	-122.5350	0.1351	15.98	0.2918	0.2071	0.0389	250.0
1	21	38.1619	-122.5166	0.1139	16.61	0.2143	0.1092	0.0537	349.5
1	22	38.1725	-122.4981	0.0528	14.26	0.1357	0.0737	0.0352	784.4
1	23	38.1831	-122.4797	0.0413	11.75	0.0882	0.0572	0.0298	784.4
1	24	38.1937	-122.4612	0.0541	13.24	0.0927	0.0960	0.0570	784.4
1	25	38.2043	-122.4427	0.0626	14.34	0.0874	0.1051	0.0541	784.4
1	26	38.2149	-122.4242	0.0593	16.55	0.1163	0.0981	0.0558	784.4
1	27	38.2254	-122.4058	0.0420	11.21	0.0629	0.0798	0.0464	784.4
1	28	38.2360	-122.3873	0.0492	10.14	0.1133	0.0635	0.0510	784.4
1	29	38.2466	-122.3688	0.0437	8.60	0.0763	0.0763	0.0346	784.4
1	30	38.2572	-122.3503	0.0534	9.21	0.1367	0.0790	0.0278	784.4
1	31	38.2678	-122.3318	0.0565	6.96	0.1214	0.0584	0.0201	784.4
1	32	38.2784	-122.3133	0.0432	7.04	0.0960	0.0619	0.0208	784.4
1	33	38.2889	-122.2948	0.0486	10.45	0.0799	0.1490	0.0618	784.4
1	34	38.2995	-122.2763	0.0486	10.97	0.0757	0.1337	0.0437	784.4
1	35	38.3101	-122.2578	0.0503	8.44	0.1092	0.0866	0.0300	784.4
1	36	38.3206	-122.2393	0.0575	8.01	0.1173	0.1143	0.0217	784.4
1	37	38.3312	-122.2207	0.0397	6.85	0.0810	0.0872	0.0123	784.4
1	38	38.3418	-122.2022	0.0349	7.74	0.1020	0.0635	0.0346	784.4
1	39	38.3523	-122.1836	0.0633	7.16	0.1571	0.0824	0.0486	614.2
1	40	37.9346	-122.8710	0.0757	13.67	0.1551	0.2551	0.0452	500.4

TABLE 4. SCENARIO: 1. Magnitude Mw = 7.00

File	Record	Latitude	Longitude	PGA (g)	PGV (cm/sec)	SA03 (g)	SA10 (g)	SA30(g)	Vs30(m/s)
1	2223	37.5323	-121.4414	0.0756	9.86	0.1714	0.1592	0.0160	979.0
1	2224	37.1188	-122.1252	0.0564	8.00	0.1071	0.1357	0.0214	402.1
1	2225	37.1294	-122.1070	0.0514	8.42	0.1459	0.1276	0.0215	504.8
1	2226	37.1399	-122.0887	0.0593	7.02	0.1714	0.1204	0.0233	574.9
1	2227	37.1505	-122.0705	0.0580	8.05	0.1235	0.0911	0.0219	575.1
1	2228	37.1610	-122.0522	0.0493	8.38	0.1102	0.1005	0.0143	575.2
1	2229	37.1715	-122.0339	0.0592	11.47	0.0821	0.1143	0.0270	575.5
1	2230	37.1821	-122.0157	0.0682	13.15	0.1531	0.1510	0.0453	504.9
1	2231	37.1926	-121.9974	0.0465	9.55	0.1112	0.0895	0.0271	1112.1
1	2232	37.2031	-121.9791	0.0539	8.59	0.1102	0.0671	0.0143	1112.1
1	2233	37.2137	-121.9608	0.0978	10.39	0.2888	0.0852	0.0215	250.0
1	2234	37.2242	-121.9425	0.0320	7.78	0.0607	0.0585	0.0208	822.6
1	2235	37.2347	-121.9242	0.1333	14.85	0.3827	0.1327	0.0261	310.9
1	2236	37.2452	-121.9059	0.1532	16.39	0.6092	0.1245	0.0271	310.9
1	2237	37.2557	-121.8876	0.1494	22.94	0.4510	0.2684	0.0226	250.0
1	2238	37.2662	-121.8693	0.1478	21.96	0.4776	0.2571	0.0283	250.0
1	2239	37.2767	-121.8510	0.1657	16.83	0.5459	0.1633	0.0384	461.1
1	2240	37.2873	-121.8327	0.1546	20.26	0.4969	0.2612	0.0727	250.0
1	2241	37.2978	-121.8143	0.1276	23.43	0.1796	0.2704	0.1163	250.0
1	2242	37.3083	-121.7960	0.1303	22.15	0.3102	0.1806	0.0788	784.4
1	2243	37.3187	-121.7777	0.1441	30.39	0.2255	0.3796	0.0561	784.4
1	2244	37.3292	-121.7593	0.0888	16.92	0.2480	0.1837	0.0591	784.4
1	2245	37.3397	-121.7410	0.1196	27.07	0.2306	0.1827	0.0749	784.4
1	2246	37.3502	-121.7226	0.0832	14.23	0.2194	0.1143	0.0232	784.4
1	2247	37.3607	-121.7043	0.0902	16.24	0.2347	0.1520	0.0305	979.0
1	2248	37.3712	-121.6859	0.1030	15.07	0.3235	0.1003	0.0245	978.9
1	2249	37.3817	-121.6676	0.1473	19.33	0.6051	0.1255	0.0259	978.9
1	2250	37.3921	-121.6492	0.0995	12.57	0.3286	0.1286	0.0341	979.0
1	2251	37.4026	-121.6308	0.1050	12.35	0.3020	0.1561	0.0261	979.0
1	2252	37.4131	-121.6124	0.1134	15.50	0.3163	0.1173	0.0340	979.0
1	2253	37.4235	-121.5940	0.0859	14.47	0.2429	0.1592	0.0397	979.0
1	2254	37.4340	-121.5757	0.1133	11.22	0.4490	0.1276	0.0348	978.9
1	2255	37.4445	-121.5573	0.0924	11.58	0.2122	0.1276	0.0188	978.9
1	2256	37.4549	-121.5388	0.0906	15.48	0.1796	0.1541	0.0258	979.1
1	2257	37.4654	-121.5204	0.0778	9.45	0.1449	0.1102	0.0458	979.0
1	2258	37.4758	-121.5020	0.0753	12.80	0.2673	0.1357	0.0187	979.0
1	2259	37.4863	-121.4836	0.0854	9.83	0.2959	0.1388	0.0154	979.0
1	2260	37.4967	-121.4652	0.0659	10.23	0.1388	0.1071	0.0402	979.0
1	2261	37.5072	-121.4468	0.0798	9.63	0.2031	0.1510	0.0218	978.9
1	2262	37.5176	-121.4283	0.0598	7.82	0.2020	0.1194	0.0262	978.8

LBL R1 Motion

Min and Max

```
SCENARIO =    1. pgaMin =      0.0272. pgaMax =      1.0639. Average PGA =      0.2086   g
SCENARIO =    1. pgvMin =      5.3850. pgvMax =    183.7935. Average PGV =     27.6668   cm/sec
SCENARIO =    1. sa03Min=      0.0413. sa03Max=      2.6429. Average SA03=      0.4952   g, 5%
SCENARIO =    1. sa10Min=      0.0447. sa10Max=      2.3571. Average SA10=      0.3145   g, 5%
SCENARIO =    1. sa30Min=      0.0103. sa30Max=      0.3163. Average SA30=      0.0641   g, 5%
SCENARIO =    1. Vs30Min=    250.0000. Vs30Max=   1204.0000. Average Vs30=    619.9235   m/sec
SCENARIO =    1. numPGA =        2262. numPGV =        2262. numSA03      =        2262. numSA10 =
SCENARIO =    1. latMin =     37.1188. latMax =     38.3523. longMin =  -122.8844. longMax =  -121.4283
```

TABLE 5. Min Max over 1 input scenarios

File No.	pgaMin g	pgaMax g	pgaAvg g	pgvMin cm/sec	pgvMax cm/sec	pgvAvg cm/sec	S03Min g	S03Max g	S03Avg g	S10Min g	S10Max g	S10Avg g	S30Min g	S30Max g	S30Avg g
1	0.0272	1.0639	0.2086	5.39	183.79	27.67	0.0413	2.6429	0.4952	0.0447	2.3571	0.3145	0.0103	0.3163	0.0641

TABLE 5. Min Max over 1 input scen

File No.	pgaMin g	pgaMax g	pgaAvg g
1	0.0272	1.0639	$\boxed{0.2086}$

SERA Suite of 95 Motions

- 14 Causative Faults
- 3 to 9 simulations of each event
- For each event, assign a Return Period
- For each event, compute the ground motions at a grid (delta = 0.005 degrees) using NGA 2013 GMPE models.
- Vary the sigmas (inter-event intra- event) at each grid point (with spatial correlation)
- The sum of 95 scenarios recovers the USGS 2018 National Seismic Hazard Map, for periods from 10 years to 10,000 years. BEAUTIFUL !!!!! Captures Monte Carlo, Benefit-Cost, Scenario, National Codes (2475, etc.), Intra- and Inter-event variability... PLUS.... 100% tied to empirical instrumental variations....

LBL Models vs SERA models

- LBL: 50 realizations of Hayward event, geophysical model with spatial correlations
- SERA: 95 realizations of 14 events, GMPE model with spatial correlations, and with Return Periods that recover the USGS 2018 National Hazard Model

LBL vs SERA models

- LBL: Compute time = 11 hours per realization on EXA-SCALE computer. (1,000,000 Teraflops)
- SERA: Compute time = 5 seconds per realization on a Steve Jobs SUPER-COMPUTER (40 Teraflops)

What are we Trying to Achieve? (2025 Questions)

- EBMUD Water: Should EBMUD spend $1 Billion to replace 300 miles of especially vulnerable water pipes?
- BART Trains: Should BART spend another $600 million to retrofit the Berkeley Hills Tunnel?
- PG&E Electric: Should PG&E spend $10 Billion to underground overhead electric distribution wires?
- PG&E Gas: Should PG&E spend $1 Billion per year to replace 1970s vintage MDPE pipes?

LBL R1 Motion

TABLE 5. Min Max over 1 input scenarios

File No.	pgaMin g	pgaMax g	pgaAvg g	pgvMin cm/sec	pgvMax cm/sec	pgvAvg cm/sec	S03Min g	S03Max g	S03Avg g	S10Min g	S10Max g	S10Avg g	S30Min g	S30Max g	S30Avg g
1	0.0272	1.0639	0.2086	5.39	183.79	27.67	0.0413	2.6429	0.4952	0.0447	2.3571	0.3145	0.0103	0.3163	0.0641

SERA Suite of 95 Motions (partial list)

TABLE 5. Min Max over 95 input scenarios

File No.	pgaMin g	pgaMax g	pgaAvg g	pgvMin cm/sec	pgvMax cm/sec	pgvAvg cm/sec	S03Min g	S03Max g	S03Avg g	S10Min g	S10Max g	S10Avg g	S30Min g	S30Max g	S30Avg g
1	0.0430	1.6617	0.2532	6.61	237.94	40.43	0.1065	3.9733	0.7192	0.0529	2.6126	0.4121	0.0155	0.8817	0.1329
2	0.0265	1.4736	0.2270	2.44	218.86	35.98	0.0556	3.5236	0.6407	0.0212	1.8862	0.3658	0.0048	0.6366	0.1179
3	0.0208	1.0962	0.1754	3.25	201.33	27.95	0.0592	3.4993	0.4968	0.0300	2.3009	0.2844	0.0081	0.7766	0.0917
4	0.0618	1.7399	0.2933	6.27	291.77	46.84	0.1431	5.0712	0.8300	0.0545	3.3345	0.4756	0.0123	1.1254	0.1537
5	0.0455	3.0261	0.2871	6.93	401.56	45.29	0.1158	6.4651	0.8034	0.0575	3.2125	0.4558	0.0136	0.9637	0.1465
6	0.0400	1.9634	0.2830	4.15	294.51	45.39	0.0947	4.7415	0.8078	0.0361	2.8400	0.4652	0.0081	0.9585	0.1505
7	0.0368	1.6378	0.2535	4.84	329.86	41.15	0.0889	5.7332	0.7269	0.0421	3.7698	0.4203	0.0095	1.2723	0.1363
8	0.0425	1.4984	0.2461	5.71	296.07	39.92	0.1117	5.1460	0.7080	0.0496	3.3836	0.4094	0.0112	1.1420	0.1326
9	0.0325	0.5457	0.1373	3.37	102.87	22.31	0.0769	1.7880	0.3940	0.0293	1.1757	0.2281	0.0066	0.3968	0.0741
10	0.0179	0.9969	0.1572	2.17	133.58	22.86	0.0476	2.5021	0.4488	0.0205	1.4664	0.2601	0.0046	0.4949	0.0847
11	0.0245	2.0894	0.1978	2.08	279.98	28.67	0.0515	5.0459	0.5608	0.0196	2.5073	0.3231	0.0044	0.8094	0.1050
12	0.0087	0.8516	0.1161	0.74	104.63	16.84	0.0183	1.9709	0.3314	0.0070	1.1551	0.1923	0.0016	0.3898	0.0628
13	0.0183	1.7944	0.2040	1.55	238.19	29.63	0.0384	4.2927	0.5772	0.0146	2.1330	0.3321	0.0033	0.6399	0.1078
14	0.0085	1.3425	0.1129	1.05	179.90	16.21	0.0231	3.2422	0.3202	0.0099	1.7146	0.1847	0.0022	0.5787	0.0600
15	0.0153	0.8077	0.0837	1.35	108.23	12.23	0.0333	1.9506	0.2401	0.0127	0.9824	0.1397	0.0029	0.3316	0.0456
16	0.0079	0.5783	0.0745	1.02	77.49	10.94	0.0196	1.5788	0.2139	0.0096	0.9253	0.1246	0.0022	0.3123	0.0407
17	0.0046	0.4710	0.0501	0.39	63.12	7.48	0.0096	1.1375	0.1457	0.0037	0.5652	0.0856	0.0008	0.1892	0.0281
18	0.0488	1.3320	0.3189	5.39	216.00	53.10	0.1179	3.7543	0.9286	0.0469	2.4686	0.5437	0.0106	0.8331	0.1774
19	0.0442	1.2007	0.2758	4.37	188.39	45.39	0.0996	3.2744	0.7947	0.0380	2.1530	0.4619	0.0085	0.7266	0.1503
20	0.0305	0.9799	0.2062	3.41	132.86	34.53	0.0777	2.2044	0.6019	0.0296	1.4495	0.3537	0.0067	0.4892	0.1158
21	0.0473	0.9458	0.2372	5.29	154.26	38.70	0.1207	2.6811	0.6775	0.0460	1.7629	0.3924	0.0103	0.5950	0.1277
22	0.0199	0.8378	0.1732	1.83	161.48	28.79	0.0418	2.8067	0.5034	0.0159	1.8455	0.2950	0.0036	0.6228	0.0964
23	0.0362	0.8203	0.2380	3.33	131.81	39.27	0.0760	2.2909	0.6898	0.0290	1.5064	0.4028	0.0065	0.5084	0.1314
24	0.0427	1.1351	0.2559	5.90	204.95	42.40	0.1346	3.5623	0.7401	0.0513	2.3423	0.4318	0.0115	0.7905	0.1409
25	0.0572	1.6878	0.3593	5.26	253.18	59.55	0.1200	4.1874	1.0425	0.0457	2.6603	0.6095	0.0103	0.8978	0.1989
26	0.0674	1.4604	0.3570	7.27	253.76	58.32	0.1659	4.4105	1.0236	0.0632	2.9001	0.5938	0.0142	0.9788	0.1933
27	0.0119	0.7234	0.1360	1.06	92.37	20.08	0.0263	1.7034	0.3914	0.0100	1.0680	0.2281	0.0023	0.3604	0.0745
28	0.0119	0.8340	0.1526	1.18	111.75	22.51	0.0287	2.0140	0.4380	0.0111	1.0830	0.2547	0.0025	0.3655	0.0831
29	0.0112	0.9434	0.1428	1.11	132.25	21.27	0.0275	2.3632	0.4137	0.0105	1.3995	0.2421	0.0024	0.4723	0.0792
30	0.0114	1.0884	0.1382	0.97	145.85	20.30	0.0240	2.6285	0.3969	0.0091	1.3170	0.2312	0.0021	0.4445	0.0755

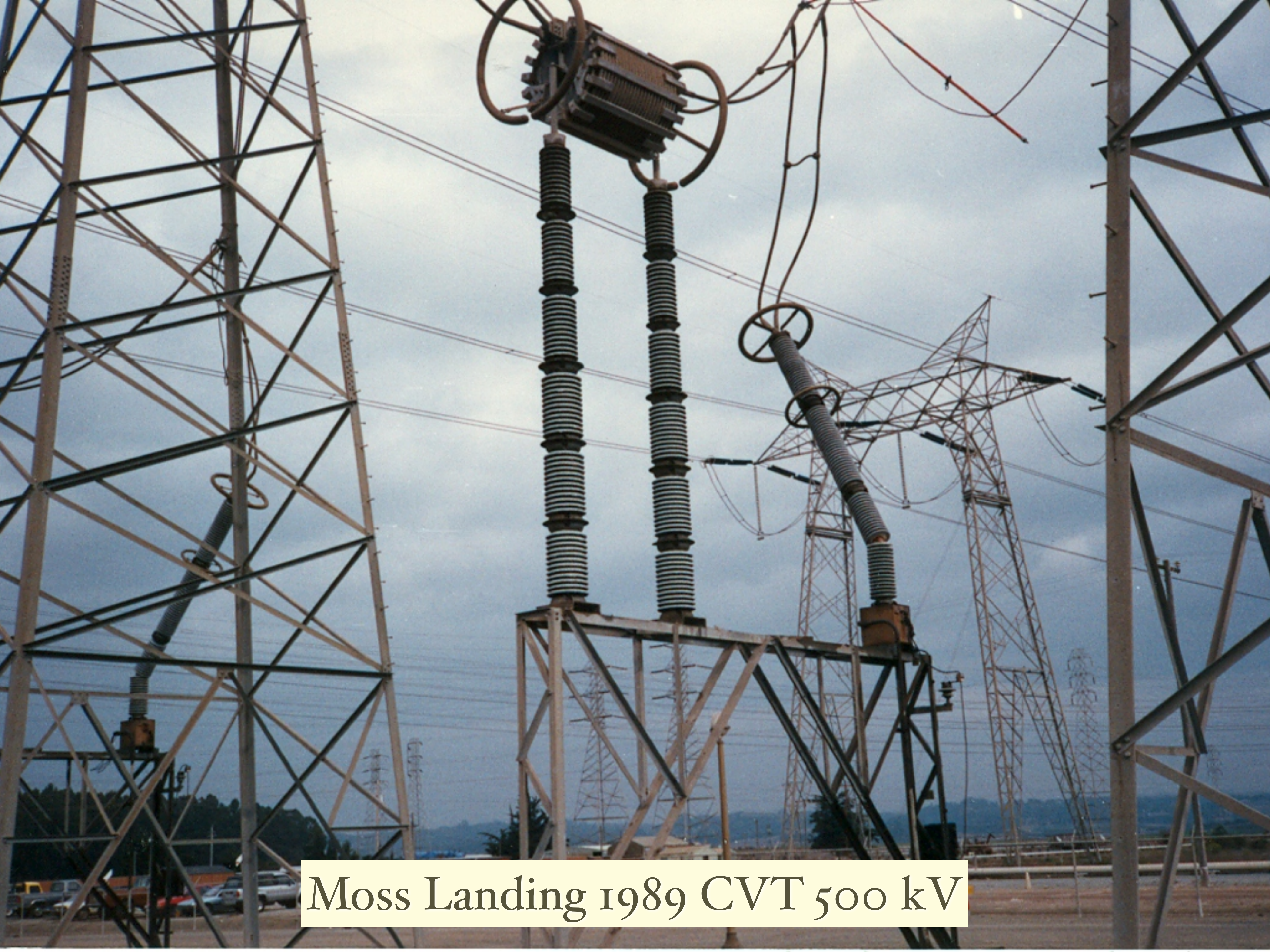
Substation That Serves My House

Simulation	PGA	Fault
SERA 18	0.5651	Hayward
SERA 19	0.5370	Hayward
SERA 20	0.3335	Hayward
SERA 21	0.2725	Hayward
SERA 22	0.4693	Hayward
SERA 23	0.2644	Hayward
SERA 24	0.4437	Hayward
SERA 25	1.0511	Hayward
SERA 26	0.6946	Hayward
LBL R1	0.2169	Hayward

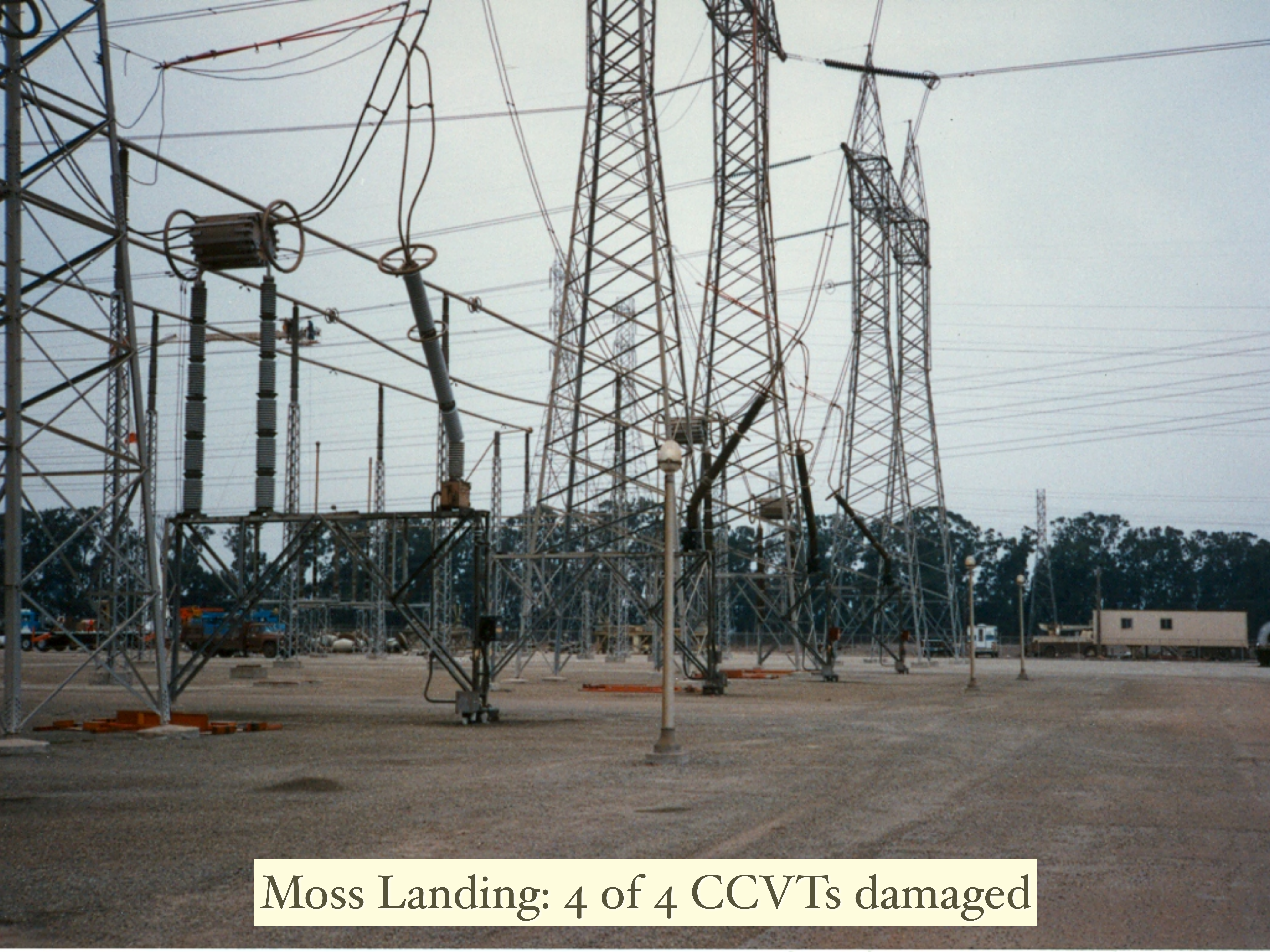
Westinghouse 500 kV CBs being installed at Vincent Substation (c. 1968).

Moss Landing Following Loma Prieta Earthquake

500 kV Circuit Breaker Damage



Moss Landing 1989 CVT 500 kV


Moss Landing: 4 of 4 CCVTs damaged

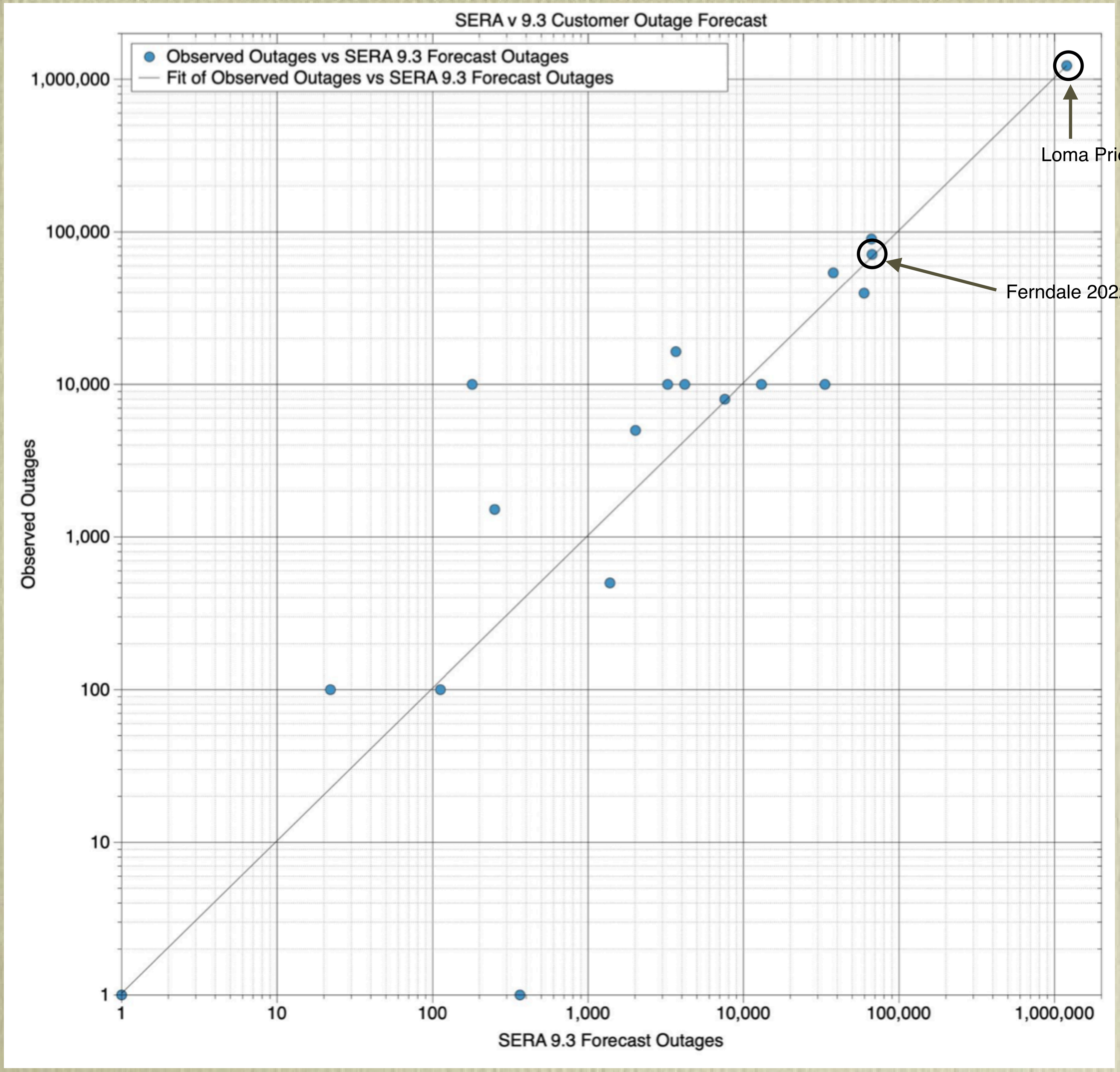
The Elephant in the Room

Low Voltage Feeders

Distribution Outages

- Today (2025), perhaps the single largest contributor to EQ-related outges in modern electric systems

SERA v 9.3.1.3 Capability



Questions?