Ground-Motion Attenuation for the South Napa Earthquake in the Sacramento-San Joaquin Delta, California

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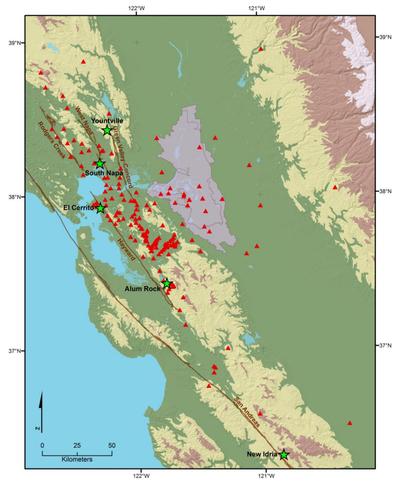
Background

The Sacramento-San Joaquin Delta is located in the California Central Valley to the east of the San Francisco Bay Area (region highlighted in purple on map). In addition to supplying about two-thirds of the state's drinking water, the Delta encompasses critical infrastructure and agricultural, recreational, and environmental resources. It is important to understand the seismic hazard of the Delta. This hazard is dominated by ground motion from earthquakes on the major strike-slip faults of the East Bay: the Calaveras, Hayward-Rodgers Creek, Concord-Green Valley and San Andreas fault systems. Each of these fault systems contributes similar hazard to the Delta. The Hayward-Rodgers Creek fault is considered the most likely fault to produce a large earthquake in the near-future. Although the Northern Calaveras and the Concord-Green Valley faults are less recurrent, earthquakes on these faults will shake the Delta more strongly.

Overview

The M6.0 South Napa earthquake that occurred on August 24, 2014, was recorded by an extensive network of accelerographs. Baltay and Boatwright (2015) compiled and analyzed strong motion records obtained at 134 stations within 50 km and 292 stations within 100 km from the earthquake. They found that peak ground acceleration (PGA) and velocity (PGV) fall off significantly faster with distance than the NGA-West2 ground motion prediction equations published in Bozorgnia et al. (2014). This study focuses on ground motion attenuation within the Sacramento/San Joaquin Delta, situated approximately 50-75 km ESE of the earthquake. We include records from stations operated by the California State Department of Resources (DWR) and the USGS Tri-Valley Urban Array, but consider only the subset of 77 stations at azimuths from 60° to 150° out to a distance of 200 km from the earthquake. The attenuation observed within this data set agrees with Baltay and Boatwright's (2015) conclusion that the Boore and Atkinson (2008) ground motion prediction equations over-predict both PGA and PGV at distances greater than 15 km. We use the ground motion recordings from a set of smaller earthquakes that have occurred in the Bay Area from 2007 to 2015 to check these results, and obtain similar attenuation for these events.



The five events included in this study are indicated by the green stars. Red triangles show locations of *all* stations used, with no distinction between event subsets. The purple region indicates the legal boundary of the Delta.

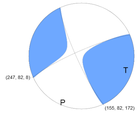
Data

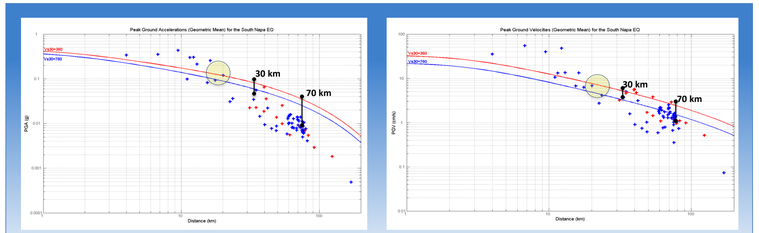
- Both broadband and strong motion data were used
- Bandpass-filtered from 10s – 25Hz and instrument corrected
- PGA and PGV values were calculated using the geometric mean of the horizontal components
- Data were collected from permanent regional networks as well as from temporary seismic deployments
- For each event, a subset of available records were selected based on azimuth and epicentral distance

Results

2014 August 24 South Napa Mw 6.0 Earthquake

Depth: 11.1 km *Station subset: 77 stations, 60° to 150°, ≤ 200 km*





Boore-Atkinson regression lines are plotted using two different Vs30 values, 360 m/s (red, NEHRP boundary for CD site class) and 760 m/s (blue, NEHRP boundary for BC site class). Most Delta sites are classified as CD. PGA and PGV values from Delta stations are plotted in red.

PGA vs Boore-Atkinson GMPE

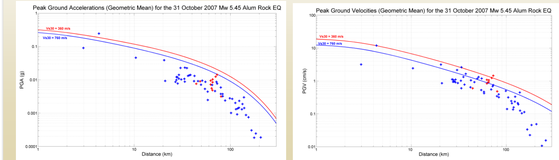
- Fits PGA at ~15km
- Over-predicts by factor of 2 at 30 km
- Over-predicts by factor of 4 at 70 km

PGV vs Boore-Atkinson GMPE

- Fits PGV at ~20km
- Over-predicts by factor of 1.4 at 30 km
- Over-predicts by factor of 2.5 at 70 km

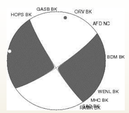
2007 October 31 Alum Rock Mw 5.45 Earthquake

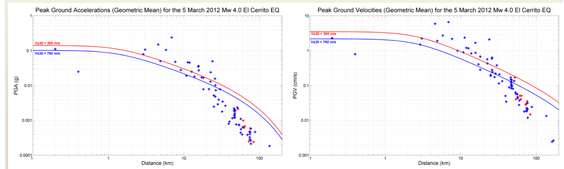
Depth: 9.2 km
Station Subset:
71 stations, 322° to 68°, ≤ 300 km



2012 March 05 El Cerrito Mw 4.0 Earthquake

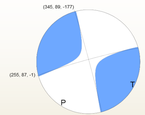
Depth: 8.1 km
Station Subset:
84 stations, 5° to 142°, ≤ 325km

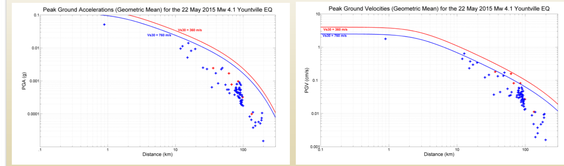




2015 May 22 Yountville Mw 4.1 Earthquake

Depth: 12.8 km
Station Subset:
81 stations, 24° to 162°, ≤ 200 km





Conclusions

The Boore-Atkinson Ground Motion Prediction Equations over-predict PGA by a factor of 4, and PGV by a factor of 2.5, at 70 km, the approximate distance from the South Napa earthquake to the Sacramento-San Joaquin Delta. This over-prediction appears to be derived from the GMPE's underestimate of the anelastic attenuation in the northern Bay Area. We note that the anelastic attenuation in the Boore-Atkinson (and other NGA-West2) relations is fit to the PEER-NGA-West2 data set, which incorporates recordings from all of California.

If the attenuation in the northern Bay Area is significantly stronger than the average attenuation for California, then using a path-specific or regional attenuation to predict ground shaking in the Delta from large earthquakes on a range of nearby and distant faults will significantly reduce the hazard to the Delta levees. The Green Valley, Rodgers Creek, Calaveras, Hayward, and San Andreas faults are the most recurrent fault segments in the probabilistic seismic hazard model.

References

Baltay, A. S. and J. Boatwright (2015), Ground-motion observations of the 2014 South Napa Earthquake, *Seism. Res. Lett.*, 86(2A), doi: 10.1785/0220140232.

Boore, D. M. and G. M. Atkinson (2008). Ground-motion prediction equations for the average horizontal component of PGA, PGV, and 5%-damped PSA at spectral periods between 0.01 s and 10.0 s, *Earthquake Spectra* 24, 99-138.

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Acknowledgements

Broadband and strong-motion waveforms were retrieved from the Northern California Earthquake Data Center (NCEDC) and the IRIS Data Management Center (DMC). For stations where raw waveforms were not available, we used PGA and PGV values determined by the Center for Engineering Strong Motion Data (CESMD). Data from the Tri-Valley Seismic Array were provided by Alena Leeds and Steve Hartzell of USGS Golden. Jim Agnew of the California Department of Water Resources (DWR) provided strong-motion records from 8 DWR stations operating within or near the Delta.