Bridge Investigation Team Report for the August 24, 2014 South Napa Earthquake

Introduction: On Sunday, August 24, 2014 at 3:20 AM PDT, a M6.0 earthquake struck south of the city of Napa (38.22° N, 122.31° W), in Napa County, at a depth (hypocenter) of 11 km. This is the third significant earthquake to impact the area over the last 25 years. On October 17, 1989 the M6.9 Loma Prieta earthquake occurred 100 km to the southwest, and damaged several bridges in the region due to amplification of long period motions in the unconsolidated soft sediments. The September 3, 2000 M5.2 Napa Earthquake caused a great deal of damage to waterlines, powerlines, and houses, but little significant damage to bridges. Experience with previous seismic events has shown bridge damage seldom occurs for earthquakes with magnitudes less than 6.0. However, it was unexpected to see such large recorded ground motion during this earthquake, especially by the Carquinez Bridge, 15 miles from the fault rupture. Additional study will be required to understand how such large recordings occurred.

In this report of the bridge investigation team, we will study the performance of the bridges in the area and discuss what it means to current bridge seismic design criteria, to efforts to retrofit and screen bridges, and to current efforts to address seismic hazards such as ground shaking, near fault effects, liquefaction, and lateral spreading.

Tectonics: The South Napa earthquake occurred in a seismically active region within the San Andreas fault system. The San Andreas system contains many right-lateral strike-slip faults that form the boundary between the Pacific plate and North American plates. In Figure 1, the location and extent of the fault rupture is shown in red. The insert shows the location of the epicenter in relation to the San Andreas fault system.

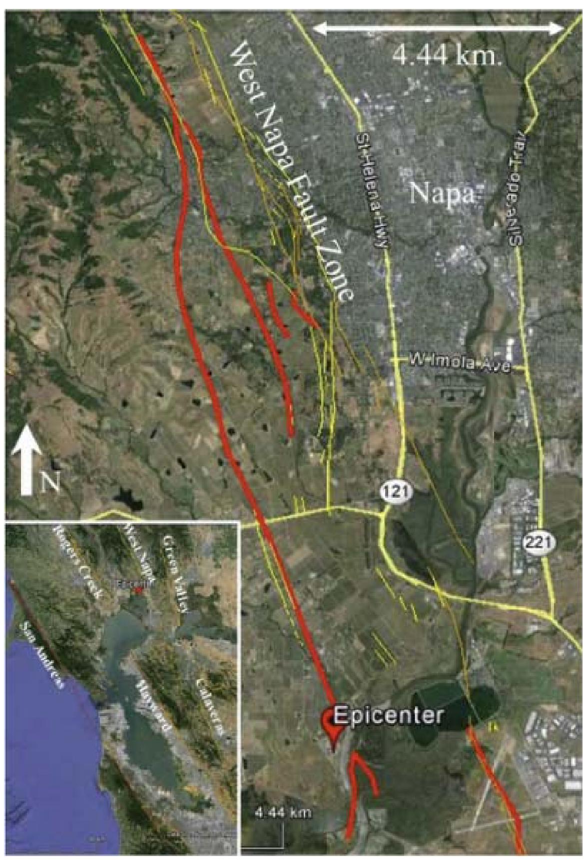


Figure 1. Aerial view showing epicenter of the South Napa earthquake and location of nearby faults.

The northern end of San Pablo Bay is tectonically constrained on the west by the (orange) Hayward-Rogers Creek Fault System and on the east by the (orange) Concord-Green Valley Fault System. The fault with the most recent movement close to the earthquake epicenter is the West Napa Fault. The 2000 M5.2 Napa earthquake was also thought to have been caused by the West Napa Fault but is now thought to have been located three miles to the west of the northern extent of the West Napa fault[1].

The most recent earthquake ruptured 11 km below the ground and caused a surface rupture from the epicenter to the northwest for about six miles along a previously mapped strand of the West Napa Fault: the Browns Valley section. At this point the surface rupture jumped ½ mile to the east and continued on an unmapped strand of the West Napa Fault for several more miles. Ground motion recordings indicate that the fault rupture, propagating to the northwest, released a strong pulse towards the City of Napa.

Figure 2. Fault offset across State Route 121 during the South Napa earthquake.

Performance of State Bridges: There are several reasons why very little bridge damage occurred during the South Napa Earthquake. A magnitude 6.0 earthquake usually doesn't have enough energy to cause significant bridge damage. Also, the most vulnerable bridges had been retrofitted. Out of 412 bridges in Solano, Napa, and Sonoma Counties 54 bridges had been retrofitted and the others were screened in the

[1] USGS Earthquake Hazards Program: http://www.strongmotioncenter.org/NCESMD/data/yountville_03sep2000/eqinfo.htm

1990s and found not to be significantly vulnerable. Figure 3 shows the area that experienced significant ground shaking during the earthquake.

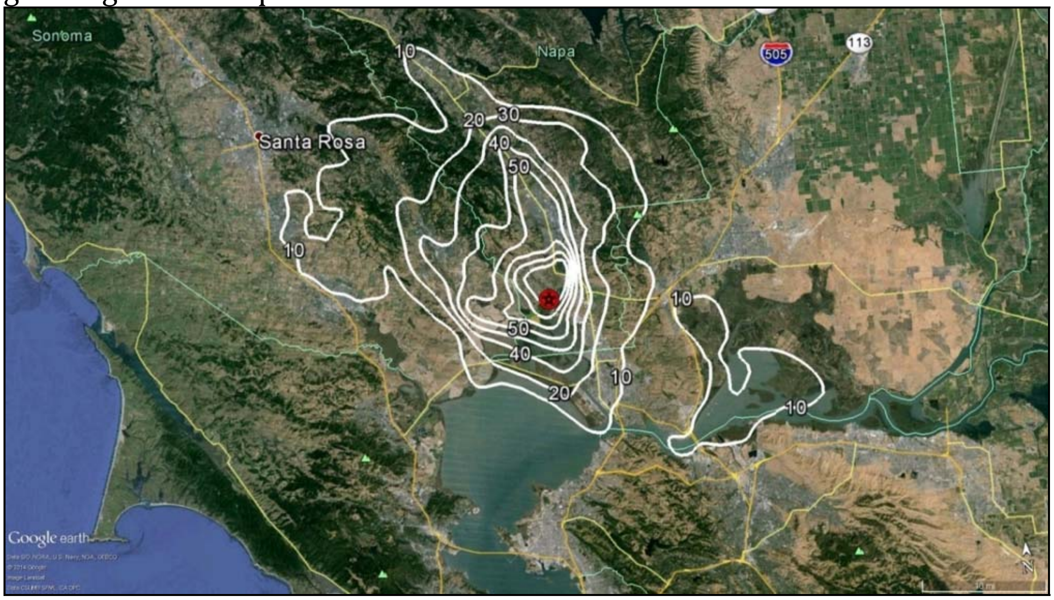
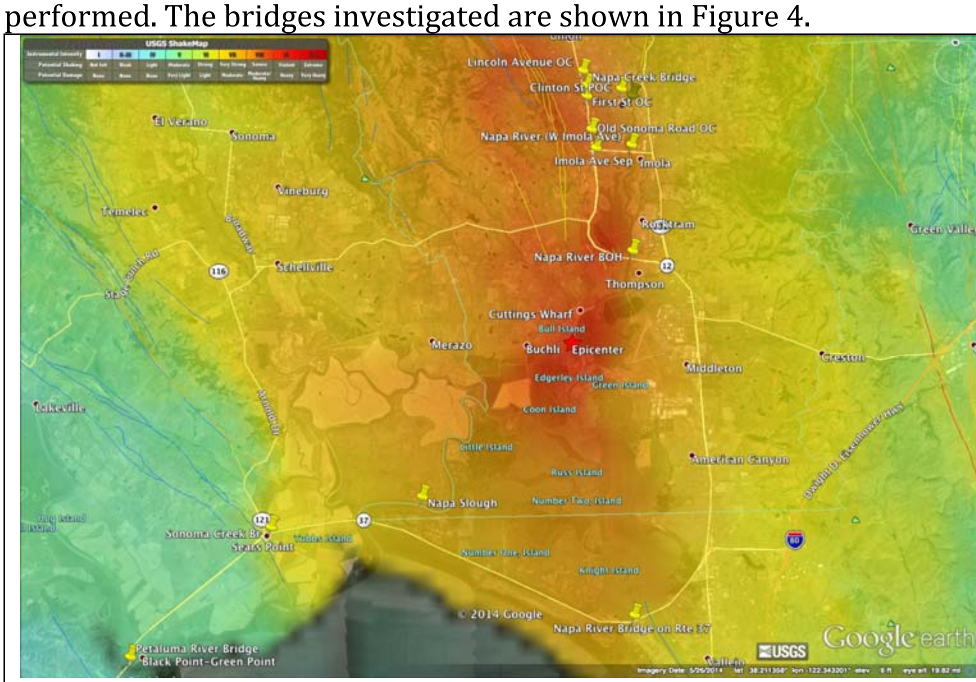


Figure 3. USGS Shake Map Showing One Second Spectral Acceleration for South Napa Earthquake[2].

The earthquake occurred on Sunday at 3:20 AM. Caltrans Structure Construction and Structure Maintenance teams drove into the area after the earthquake and reported that there was only minor bridge damage. The next morning a bridge investigation team consisting of Mark Mahan, Don Lee, Mark Yashinsky, and Ron Bromenschenkel from Caltrans Office of Earthquake Engineering and Robert Zezoff from Caltrans Office of Structures Local Assistance drove to the area to evaluate how the bridges performed. The bridges investigated are shown in Figure 4.



Napa River Br	23 0064
Napa River BOH	21 0049
Napa River (Imola)	21 0108LR
Imola Ave Sep.	21 0086L
Old Sonoma Rd OC	21 0087
First Street OC	21 0088
Lincoln Ave OC	21 0089
Sonoma Creek Br	23 0063
Petaluma River Br	27 0013
Napa Slough Br	21C0117
Greenwood Ave Br	21C0042
Clinton St POC	21C0094
Third St (Napa R) Br	21C0012

Figure 4. Bridges investigated after the South Napa Earthquake.

[2] http://earthquake.usgs.gov/earthquakes/shakemap/nc/shake/72282711/#download

1: Napa River Bridge on Route 37 Br. #23 0064 (38.1203°, -122.2800°)
This is a 33 span precast girder bridge on flexible two column piers and stiff four column piers that was built in 1963. Like many river crossings it starts at ground level and then quickly rises to provide clearance over the river (Figure 5).

Figure 5. Napa River Bridge.

A problem with many older precast girder bridges is that the connections were not well designed for earthquakes. The girders need to be continuous to protect the superstructure and force plastic hinging into ductile columns. The girders on the Napa River Bridge were inadequately developed and many of them pulled on the end diaphragms during the 1989 Loma Prieta earthquake (Figure 6).

Figure 6. Damage to the Napa River Bridge during the 1989 Loma Prieta EQ.

The bridge was repaired after the earthquake and was extensively retrofitted in 1996. The retrofit included bolsters and transverse prestressing to the end diaphragms to increase girder continuity. Additional seat width and pipe seat restrainers were installed at locations with expansion joints. The foundations were retrofit with additional piles and larger pile caps. All of the columns were encased in steel jackets (see Figure 7).

Figure 7. Retrofitted Napa River Bridge with steel column casings and enlarged footings.

A strong motion instrument downhole array[3] was installed at the bridge, which recorded 0.2g acceleration, 19 cm/s velocity, and 2 cm displacement at the ground surface.   The bridge was also instrumented (see Figure 8) with accelerometers between piers 13 and 14 at the crest of the bridge, which recorded 0.53g acceleration and 14.7 cm (about 6 in transverse) of displacement (Figures 9 and 10).

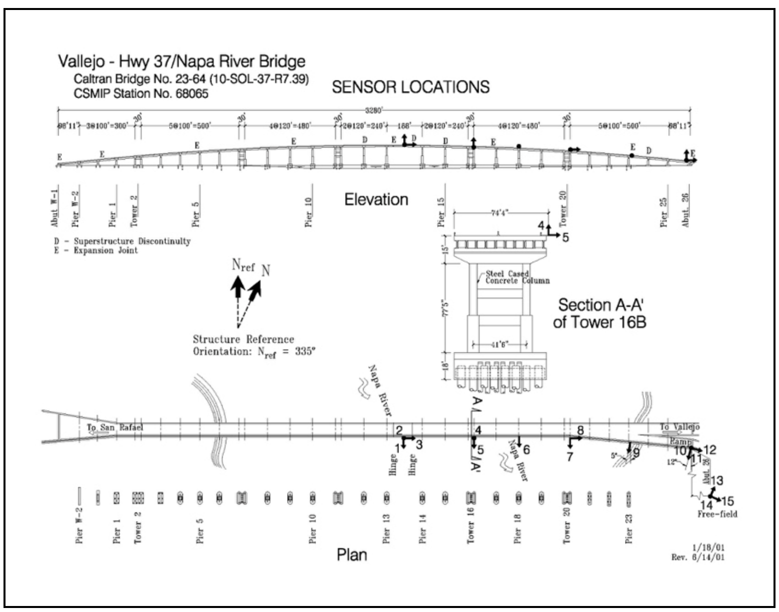


Figure 8. Location of instruments on Napa River Bridge on Route 37.

[3] http://www.strongmotioncenter.org/cgi-bin/CESMD/iqrStationMap.pl?ID=AmericanCanyon_24Aug2014_72282711

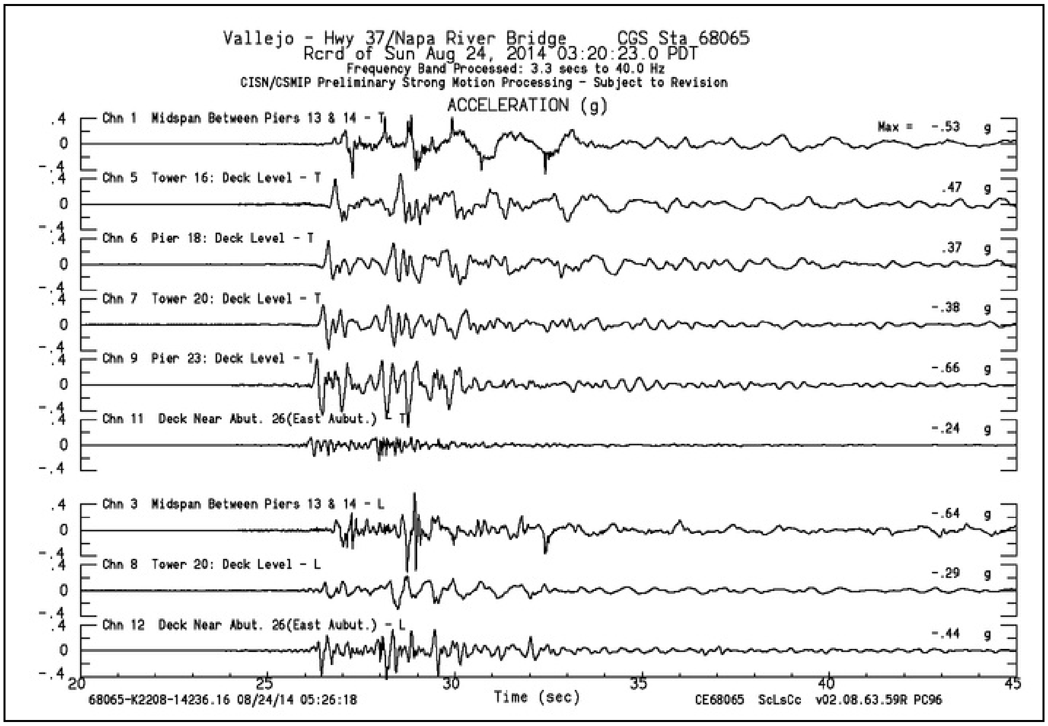


Figure 9. Acceleration records on Napa River Bridge on Route 37.

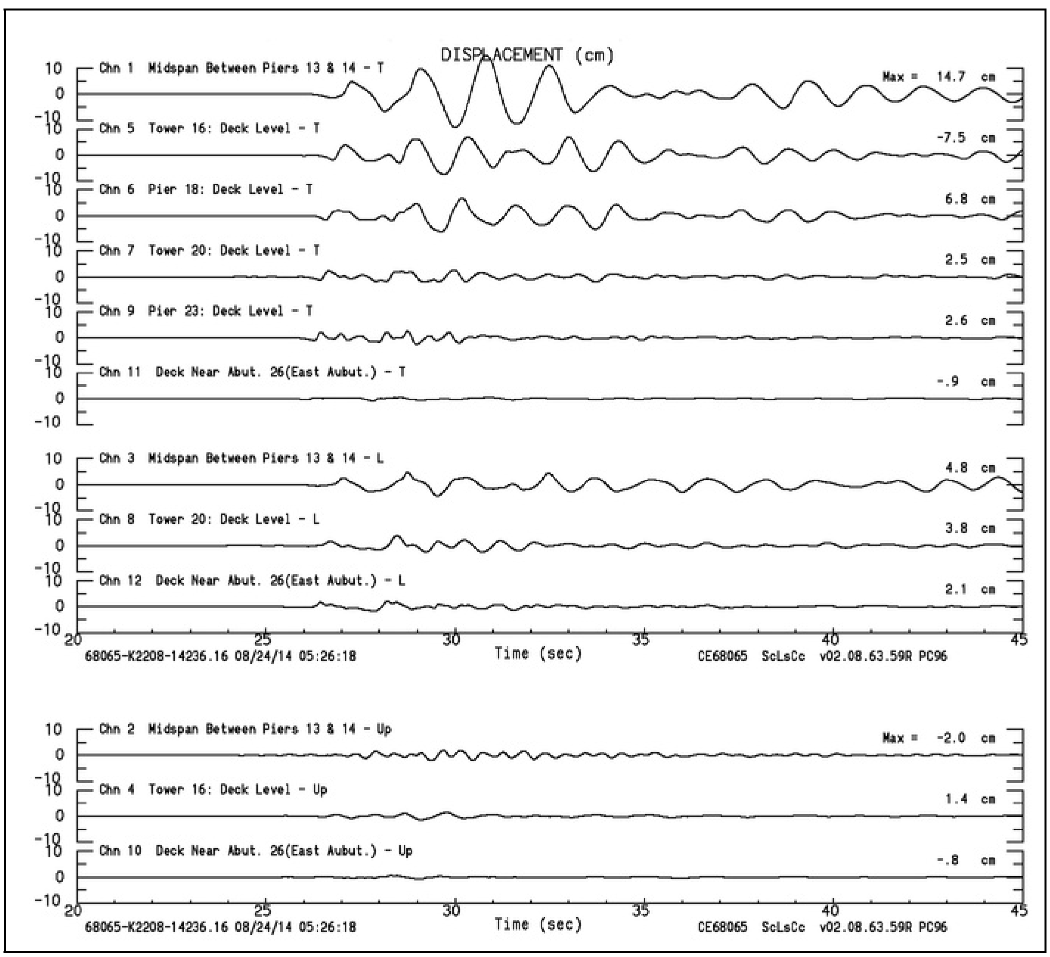


Figure 10. Displacement records on Napa River Bridge on Route 37.

The only damage to the Napa River Bridge was that the expansion joints opened and closed enough to damage a few of the type B joint seals which are to be replaced. The hand railing at the expansion joints opened up enough (Figure 11) to cause the first responders to close the bridge as a precautionary measure. When Caltrans bridge engineers arrived at the bridge, a quick inspection showed them that there was no serious damage and they re-opened it to traffic.

Researchers from the Pacific Earthquake Engineering Research (PEER) Center performed their own reconnaissance on the bridge and observed that Pier 19 seemed to be tilted to the north (right) relative to the other piers (see Figure 12). However, there are no cracks or deformations to indicate that this was related to the earthquake.

Figure 11. Damage to the Napa River Bridge was permanent longitudinal displacement at the expansion joints.

Figure 12. Photo of Pier 19 (2nd pier from right) taken by the PEER Team.

2: Napa River Bridge & Overhead on Rte 29 Br. #21 0049 (38.245°, -122.285°)

This is a 13 span prestressed concrete continuous box girder bridge on single column bents that was built in 1977. It's 2,230 ft long with a 250 ft long span over the Napa River (see Figure 13).

Figure 13. Napa River Bridge and Overhead.

This bridge was built after the 1971 San Fernando Earthquake and consequently it was better designed for earthquakes. The columns had good confinement and the in-span hinges were well designed (see Figure 14). Moreover, the foundations were retrofitted with additional piles in 1994.

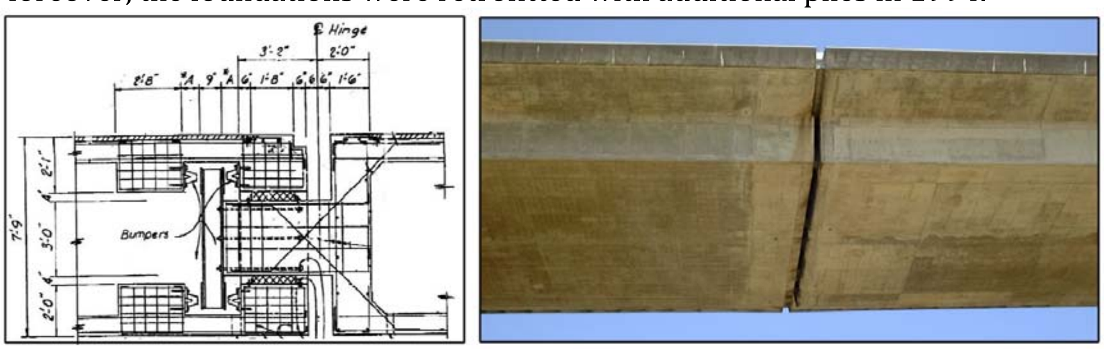


Figure 14. Unusual in-span hinges on the Napa River BOH.

This was the closest bridge to the earthquake epicenter (about 2 miles). Although the bridge wasn't instrumented there was a station nearby at Napa College (red dot) that recorded peak ground motion of 0.375g (Figure 15).

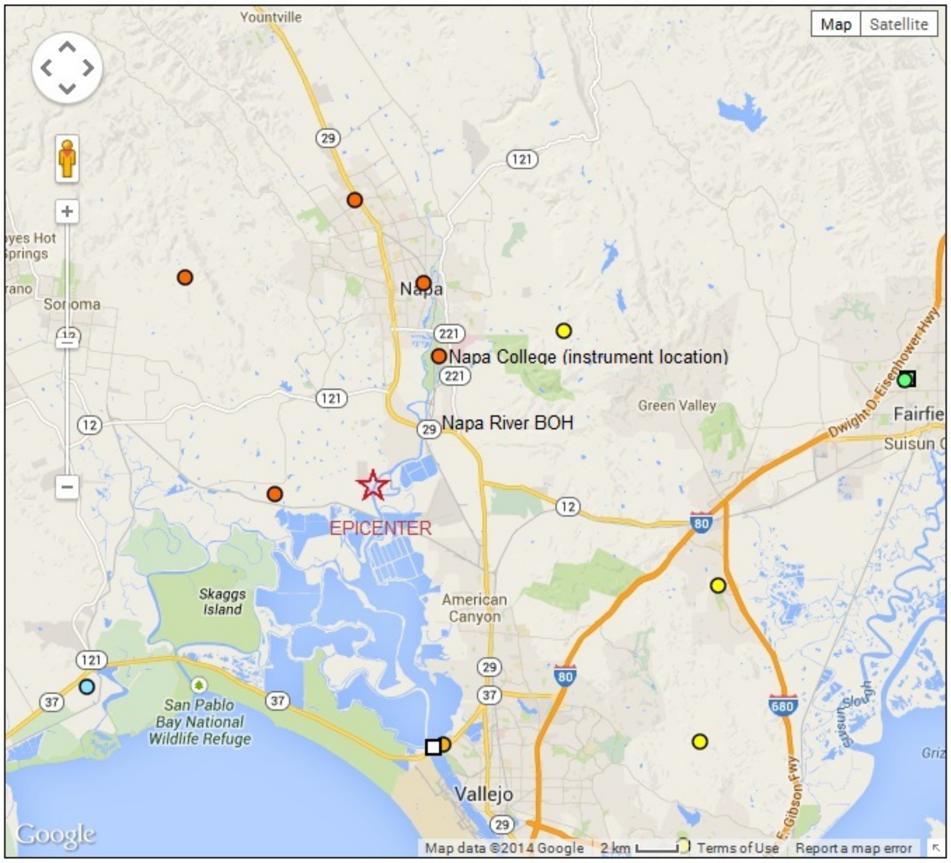


Figure 15. Map showing epicenter, bridge, and instrument locations.

The only damage to the bridge structure during the earthquake was at Abutment 14 on the west side of the river. Where the abutment was in contact with the wingwall it had a concrete spall of six inches by six feet with exposed reinforcement (see Figure 16).

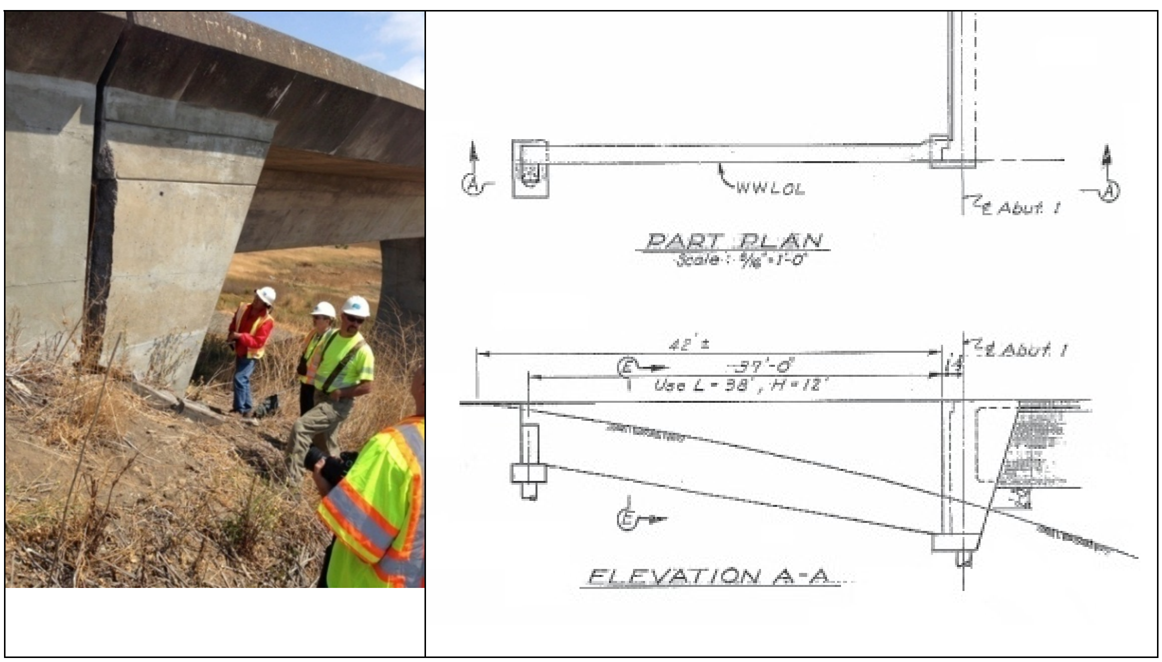


Figure 16. Abutment 14 concrete spall on the Napa River Bridge and Overhead.

3: Napa River (W. Imola Ave) Bridges Br. # 21 0108L/R (38.2814°, -122.2842°)
The next structure we investigated is a pair of bridges that were built in 2007. They are 13 span (2143 ft long) prestressed concrete continuous box girder bridges on single column bents. These nearly new bridges have not been retrofitted.

Figure 17. Napa River (West Imola Avenue) Bridges

When the investigation team first saw the abutments on the West Imola Avenue Bridges they assumed there was soil behind them that was held in place with mechanically stabilized earth (MSE) retaining walls. However, when they looked behind the abutment they saw the approaches were actually slab bridges on standard concrete pile extensions. What they had thought were MSE Walls turned out to be precast curtain walls. Caltrans prefers to have soil behind the abutment to provide stiffness and damping during an earthquake. However, on such a long bridge a stiff abutment plays a much smaller role.

This bridge is also very close to the Napa College station that recorded peak acceleration of 0.375g during the earthquake. The damage that occurred during the earthquake, cracks and spalls of the curtain walls at all the abutments, was the result of the ends of the superstructure banging against the slender curtain walls (Figures 18 and 19). More substantial abutments could have held the superstructure more securely in place. However, it is unlikely that the superstructure could unseat since the approach slab is securely attached to the end of the superstructure. Also, when Caltrans Office of Structures Maintenance and Investigations (OSMI) went inside the superstructure, they found the hinge restrainers had been poorly installed and were damaged at the swage connections or at the tension indicators (Figure 20). Restrainers must be carefully installed, which requires tightening them until the spiral washers close and then backing off to account for the variation in temperature. However, restrainers are a secondary system for earthquake protection and the hinges all had 36 inch seats.

This bridge had the most expensive cost estimate for repair of all the state bridges (See Appendix).

Figure 18 Outside and nnside of an abutment on the Napa River (West Imola Avenue) Bridges.

Figure 19. Close-up of damaged curtain walls on the Napa River (West Imola Ave) Bridge.

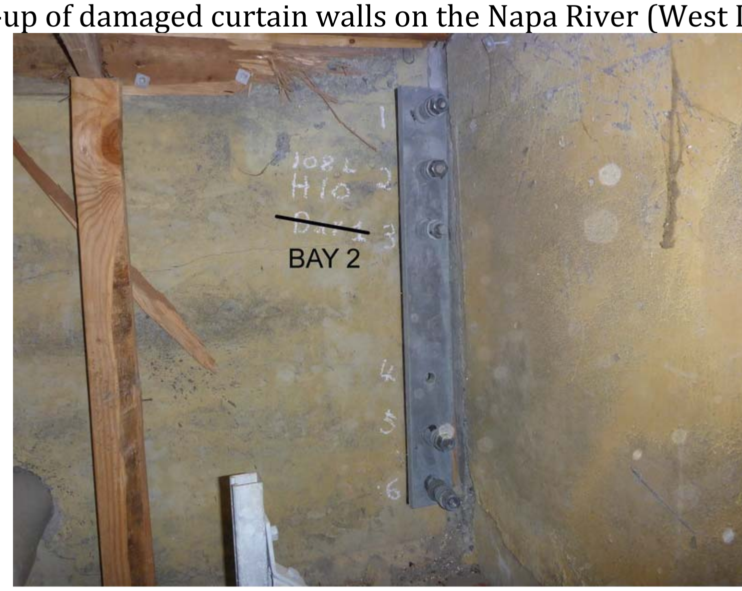


Figure 20. Restrainer damage at Hinge 10, Bay 2 of Napa River (W. Imola Ave) Bridge.

4: Imola Avenue (SR 121) Separation -Br. #21 0086L/R (38.2819°, -122.3000°)

The Imola Avenue Separation is composed of parallel bridges that carry SR 29 over SR 121. They are single span (88 ft long) bridges on strutted abutments (Figure 21). This is not a particularly good seismic detail and explains why the end diaphragm on the left bridge banged against the wingwall and cracked (Figure 22). These bridges are close to the previously studied Napa River (West Imola Avenue) Bridge and saw less than 0.4g peak ground acceleration during the earthquake.

Figure 21. Strutted abutments on Imola Avenue Separation.

Figure 22. Damage to left bridge from banging against wingwall.

5: Old Sonoma Rd OC on SR 29   Br. #21 0087   (38.2819°, -122.3000°)

The next two bridges cross SR 29 near strong motion station N016 (Figure 23). This station recorded peak ground acceleration of 0.611g during the South Napa earthquake. Station N016was further from the epicenter but it recorded larger ground motion because near fault effects increased shaking in the direction of the fault rupture.

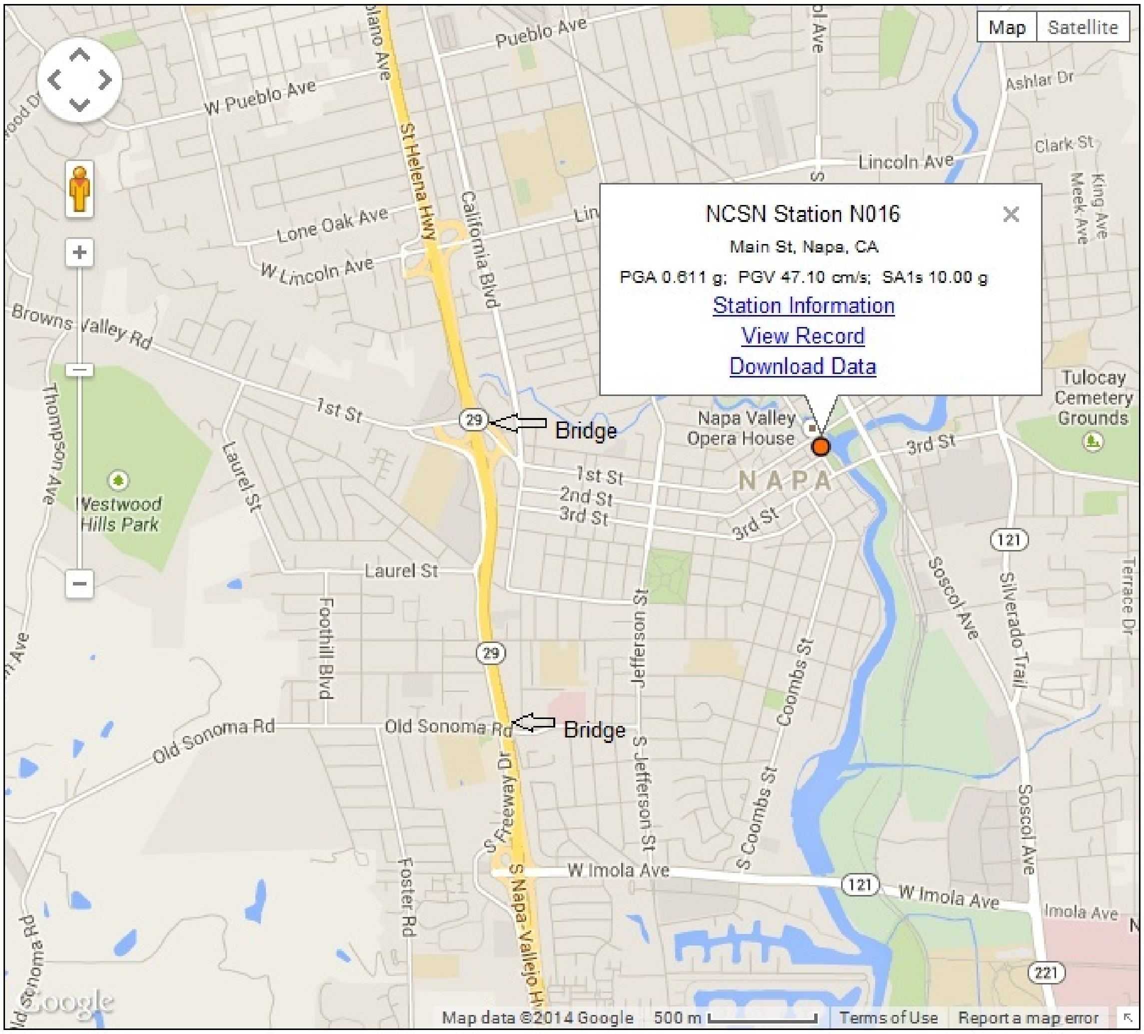


Figure 23. Old Sonoma Rd and First Street Overcrossings near NCSN Station N016

The Old Sonoma Road Overcrossing is a four span 307 ft long precast concrete girder bridge on two column bents built in 1961 across SR 29 in the City of Napa (Figure 24). The bridge was retrofitted with cable restrainers in the 1980s and it had an additional retrofit in the 1990s.

Existing damage such as banging between the railing and the curb and settlement of the bridge approaches was made worse by the South Napa Earthquake (Figure 25).

Figure 24. Photo of Old Sonoma Road Bridge after the South Napa Earthquake.

Figure 25. Earthquake damage (banging between the curb and the barrier) at the Old Sonoma Road Bridge.

6: First Street OC on SR 29   Br. #21 0088   (38.2997°, -122.3025°)

The First Street OC is a 296 ft long (4 span) steel girder bridge on a curve built in 1964 (Figure 26). The bridge was retrofitted with cable restrainers in the 1980s. Earthquake damage included spalling of the deck overhang due to banging of the expansion joint (Figure 27) as well as approach settlement similar to what occurred on the Old Sonoma Road OC.

Figure 26. Photo of First Street Bridge taken after the South Napa Earthquake.

Figure 27. Spalling of the deck overhang at expansion joint (rubble on bent cap).

7: Napa Slough Bridge Br. #21C0117 (38.1601°, -122.3806°)

Although state-owned bridges performed well during the earthquake a few of the locally-owned bridges had serious damage. The Napa Slough Bridge is a 13 span precast girder bridge supported on battered pile extensions that was built in 1966. This bridge is now a privately-owned bridge and closed to public traffic. During the earthquake the piles were damaged as a consequence of the batter (which attracted more load) and because of the large motion that can occur in a slough (see Figures 28 through 30). Although some piles were damaged the earthquake was not of long enough duration to cause serious damage. The #4 hoops at 12 inches prevented excessive buckling of the main reinforcement and the piles continued to support the superstructure.

Figure 28. Tops and bottoms of the pile extensions spalled during the earthquake.

Figure 29. Closer view of damage at top of pile extensions.

Figure 30. Damage at the bottom of pile extensions on Napa Slough Bridge.

This bridge was retrofitted as part of the Local Agency Bridge Retrofit Program in 1994. The retrofit included pedestals, strengthened diaphragms with bolsters, and cable restrainers at the eight expansion joint locations on the bridge (Figure 31 and 32). However, nothing was done to strengthen or increase the ductility of the pile extensions.

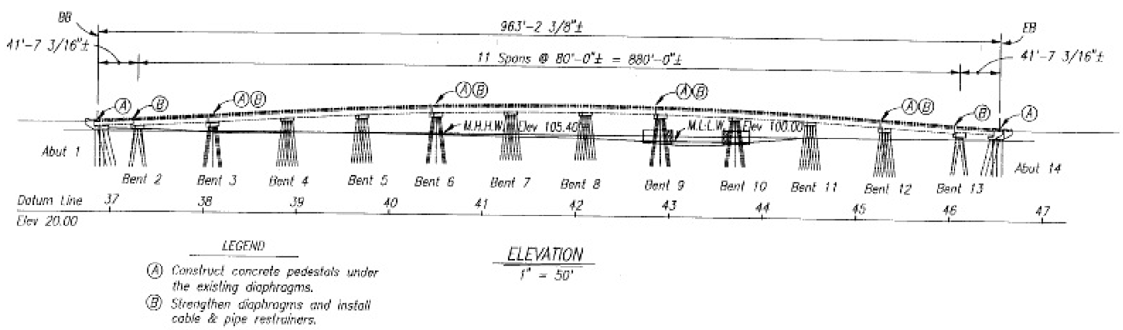


Figure 31. Locations where the bridge was retrofitted to prevent unseating.

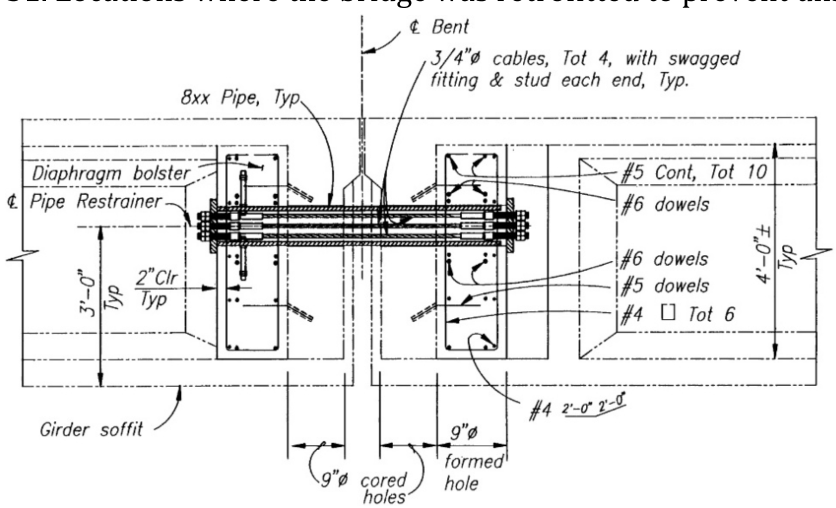


Figure 32. Retrofit at expansion joint location on Napa Slough Bridge.

8: State Route 37 Bridge across Sonoma Creek #23 0063 38.1559°, -122.4082°
The Sonoma Creek Bridge is a twenty-two span precast girder bridge on precast pile extensions. It was seismically retrofitted with CISS Piles supporting the bent cap when it was widened in 1999 (Figure 33). The bridge is two miles from the previously studied Napa Slough Bridge and had a similar substructure and similar soil. The retrofit protected this bridge from serious damage during the earthquake.

Figure 33. Sonoma Creek Bridge with seismically retrofitted substructure.

9: Greenwood Ave Br across Garnet Creek #21C0042 38.5927°, -122.5908°
The Greenwood Avenue Bridge is a single span masonry arch that was built in 1904. It appears that existing damage was exacerbated by the earthquake resulting in the bridge being closed to traffic after the earthquake (Figure 34).

Figure 34. Photos of Greenwood Ave. Br. taken after the earthquake.

OTHER BRIDGES STUDIED:

10: Clinton Street POC across Napa Creek #21C0094 38.3006°, -122.2882°

The Clinton Street Pedestrian Overcrossing is a recently built steel truss bridge. During the earthquake the anchor bolts at the bottom of the truss were broken and the approaches settled so much that the bridge was closed (Figure 35). NCSN Station N016 near the bridge recorded PGA=0.61g

Figure 35. Approach settlement on Clinton Street POC.

11: Route 37/29 Separation #23 0218   38.1377°, -122.2560°

The Route 37/29 Separation is 6-span prestressed concrete continuous box girder bridge that was built in 2005. Damage to interior shear key at abutment and damage to expansion joints (Figure 36). CGS Station 68294 near the bridge recorded PGA=0.47g and 1 sec SA= 0.11g.

Figure 36. Damaged expansion joint at Abutment 7 on Route 37/29 Separation.

12: Third Street (Napa River) Bridge #21C0012 38.2980°, -122.2833°
The Third Street Bridge was recently built to replace an existing arch bridge as part of a flood control project on the Napa River. It is a three span haunched box girder bridge on pier walls. There was evidence of banging between the abutment backwall, the wingwalls, and the barrier rail during the earthquake. There was also evidence of sand boils under the bridge suggesting that the shaking may have been exacerbated by soil liquefaction. NCSN Station N016 near the bridge recorded PGA=0.61g

13: State Route 37 Bridge across Petaluma River #27 0013 38.1559°, -122.4082°
2183 ft long precast girder and steel stringer bridge on flexible and stiff piers
Seismic retrofit with steel casings around link beams (and some columns) in 1994
CGS Station 68778 at bridge PGA = 0.024g, PGV = 1.67 cm/s, 1 sec SA = 0.01g
No Damage

14. Carquinez (I-80) Bridges across Carquinez Strait #23 0015R 38.0625°, -122.2284°
Cantilever 5 span truss bridge built in 1958
Very extensive seismic retrofit in 1997
CGS Station 68206 at bridge PGA = 0.995g, PGV = 22.2 cm/s, 1 sec SA = 0.12g
No Damage. Ongoing studies to understand why such large accelerations occurred.

15. Carquinez (I-80) Bridges across Carquinez Strait #28 0352L 38.0625°, -122.2284°
Suspension Bridge built in 2003 with peer-reviewed state-of-the-practice seismic design. CGS Station 68206 at bridge PGA = 0.995g, PGV = 22.2 cm/s, 1 sec SA = 0.12g
No Damage

16. Mare Island Causeway across the Napa River #23C0248 #38.1109°, -122.2747°
Steel lift bridge with steel girder and concrete trestle approaches. A bascule bridge was built in 1934 and replaced by the lift bridge in 1980. Bridge is near the Vallejo Fire Station (PGA = 0.329g, PGV = 21.11 cm/s, 1 sec SA = 0.18g) and the Napa River Bridge (PGA = 0.198g, PGV = 19.00 cm/s, 1 sec SA = 0.14g) Existing damage to the steel rocker bearings and concrete trestles was exacerbated by the earthquake (Figure 37). There was also concern about the piles and the local agency (City of Vallejo) was going to write a contract for divers to look for damage.

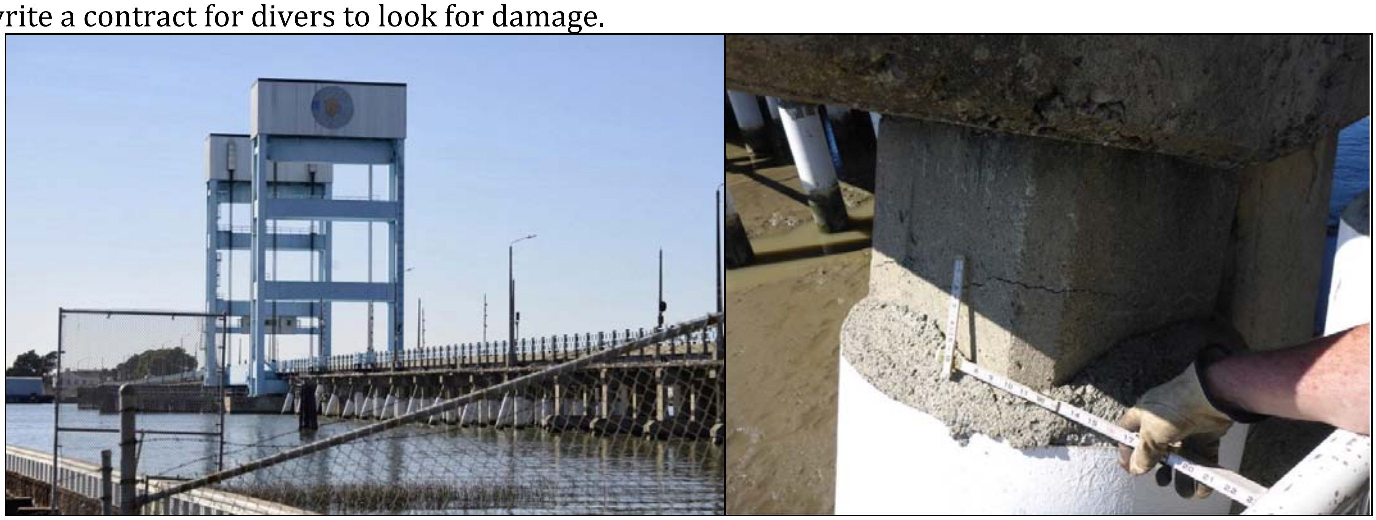


Figure 37. Mare Island Causeway and damage to battered piles of the concrete trestle.

Conclusion: Lack of significant bridge damage is considered a success during earthquakes. However, not much bridge damage is expected from a M6.0 earthquake. In Figure 38 below we can compare ground shaking intensity from the M6.9 Loma Prieta and M6.0 South Napa EQs. We can see the area of high shaking was many times larger during Loma Prieta.

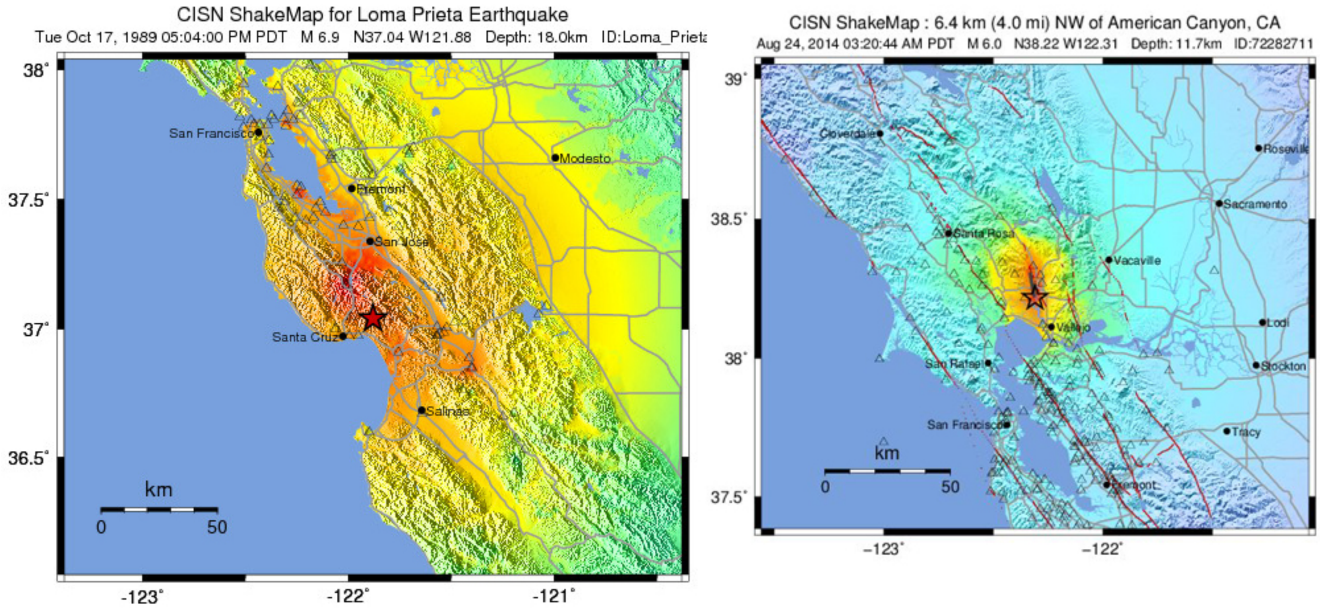


Figure 38. Comparison of M6.9 Loma Prieta and M6.0 Napa EQs.

The large effort to screen the existing bridge inventory and retrofit the most vulnerable bridges contributed to the lack of bridge damage during this earthquake. Still the earthquake poses more questions than it answers. The distribution of strong ground motion and the lack of damage near stations that recorded PGA of 0.6g and even 1.0g requires an explanation. Also, the very large ground shaking records were often right next to very small records. Why was there very strong shaking at the Carquinez Strait so far from the West Napa Fault? If accelerations are not a good indicator of damage maybe alternative instruments should be used. The recordings took a long time to be collected. Caltrans needs to work more closely with the California Geological Survey (CGS) Strong Motion Instrumentation Program (SMIP) to improve the collection of strong motion information to aid in post earthquake evaluation and response. The threshold that turns on strong motion recorders needs to be set at values reflecting the type and importance of the bridge. Raw data should be immediately sent to Caltrans for evaluating bridge performance. Caltrans and the public cannot afford to wait several days while strong motion data is collected by hand from bridge sites.

The seismicity of the Napa Valley/American Canyon needs to be better understood. The faults are poorly defined south of Napa and unknown under San Pablo Bay. Also, what can this earthquake tell us about the large earthquakes we are expecting on the Hayward, Green Valley, Concord, and other large magnitude faults in Northern California?

The geology of the area also needs more study. The area is covered in unconsolidated soft sediments, which amplified long period ground shaking during the 1989 Loma Prieta earthquake. What was their role during the South Napa earthquake? There was little evidence of liquefaction and lateral spreading after the earthquake. Can this earthquake improve our ability to determine when liquefaction and lateral spreading will occur? Of roughly 40 bridges that were studied in the area of strong shaking, 2 bridges (Lincoln Ave OC (21-0089) and Napa Creek (21-0022)) had factors of safety for liquefaction less than 1. The team investigated both bridges. The sidewalks on the Lincoln Ave OC had previously settled and had settled some more during the South Napa earthquake. There was no sign of soil movement at the nearby Napa Creek Bridge. However, the current water table may be low because of the drought. Caltrans is planning to perform drilling at these bridge locations to see if the water table was at a level where liquefaction is expected to occur. If the water table is at that level, then this suggests the calculation for liquefaction may be overly conservative.

Over ten miles of surface faulting was observed during the earthquake. Geologists returning to the same sites over the next few days found the fault offset continued to grow over time. In Figure 39 we can see the fault offset continued to creep for 48 hours after the earthquake. This suggests that bridges over faults need to be carefully monitored and possibly shored up to prevent a possible collapse as the fault continues to slip. This also suggest it may not be necessary to design for the largest ground shaking displacement plus the largest fault offset displacement if the shaking ends before the full offset occurs. Finally, the fault was observed to rupture on several traces and to step between faults. This suggests it may be prudent to design for the offset at every span since we can't be certain where it will occur.

Figure 39. Fault offset across State Route 12 continued to slip for 48 hours after the earthquake.

The South Napa earthquake provided a number of opportunities to learn more about earthquakes and how they impact bridges. We can incorporate strong motion records to validate the latest ground motion prediction equations (GMPE). We can use the vertical array data at the Carquinez Bridge to validate our 1D and 2D site response models. We can use the response of bridges on liquefiable soil to improve our equations for determining demands on bridges due to liquefaction and lateral spreading.

Caltrans bridge screening program performed well. All 412 state-owned bridges in the area were able to carry traffic after the earthquake. Bridge retrofits performed well. The Sonoma Creek Bridge with large diameter piles protecting vulnerable battered pile extensions had no damage while the nearby Napa Slough Bridge (a similar bridge without a substructure retrofit) had serious damage to the pile extensions. New bridges also performed well. The recently-built Carquinez Suspension Bridge had no damage despite the large ground motion recorded nearby. However, Caltrans must continue to advance the seismic performance of bridges in anticipation of the next 'big one.'

Appendix A: Caltrans OSMI report for state owned bridges.

Bridge #	Bridge Name	Dist-Co-Rte-PM	1 SA (g)	Damage Observed	Recommended Repair	Date Inspected
20 0022	SONOMA CREEK	04-SON-121-R7.3	0.11			9/27/0214
20 0023	ARROYO SECO	04-SON-121-8.43	0.12			9/27/0214
20 0090	TOLAY CREEK	04-SON-037-4.04	0.11			9/27/0214
20 0121	BRANCH ARROYO SECO	04-SON-121-8.51	0.12			9/27/0214
20 0135	GRIZZLY CATTLEPASS	04-SON-121-4.91	0.10			9/27/0214
21 0001	HUICHICA CREEK	04-NAP-121-.75	0.13			8/24/2014
21 0002	CARNEROS CREEK	04-NAP-121-2.4	0.18			8/24/2014
21 0003	TULUCAY CREEK	04-NAP-121-6.42-NAP	0.17			8/24/2014
21 0022L	NAPA CREEK	04-NAP-029-11.65-NAP	0.16			9/27/0214
21 0022R	NAPA CREEK	04-NAP-029-11.65-NAP	0.16			9/27/0214
21 0039	BASALT ROAD UC	04-NAP-221-1.5-NAP	0.18			8/24/2014
21 0040	AMERICAN CANYON CREEK	04-NAP-029-.56	0.19			9/27/0214
21 0043L	LOMBARD OH	04-NAP-029-R2.37	0.19			8/24/2014
21 0043R	LOMBARD OH	04-NAP-029-R2.37	0.19			8/24/2014
21 0048	CRAIG CREEK	04-NAP-029-14.11-NAP	0.11			9/27/0214
21 0049	NAPA RIVER BOH	04-NAP-029-R6.99	0.31	Abutment 14, left side wingwall settled one inch and rotated outward 2 inches; abutment is spalled 6 inches x 6 feet with exposed rebar at abutment/wingwall joint	Replace wingwall and patch spall by saw cutting and recasting	8/24/2014
21 0071L	SUSCOL CREEK	04-NAP-029-R6.08	0.16			9/27/0214
21 0071R	SUSCOL CREEK	04-NAP-029-R6.08	0.16			9/27/0214
21 0077	TULUCAY CREEK (CAYETANO CREEK)	04-NAP-121-R5.71	0.18			8/24/2014
21 0086L	IMOLA AVENUE SEPARATION (29-121)	04-NAP-029-R10.38-NAP	0.15	Abutment 1, crack and delaminated concrete at corner	Remove unsound concrete and recast damaged area	8/24/2014
21 0086R	IMOLA AVENUE SEPARATION (29-121)	04-NAP-029-R10.38-NAP	0.15			8/24/2014
21 0087	OLD SONOMA ROAD OC	04-NAP-029-10.7-NAP	0.16	Existing rail and curb spalls on a rail in fair condition made worse by the EQ	Repair the bridge rail approach rail and curb spalls	8/24/2014
21 0088	FIRST STREET OC	04-NAP-029-11.55-NAP	0.16	4 inch wide x 24 inch long x 4 inch deep deck soffit spall in the deck overhang on the right side of the Bent 2 expansion joint	Patch the spall in the deck overhang	8/24/2014
21 0089	LINCOLN AVENUE OC	04-NAP-029-12.04-NAP	0.14	Damage was determined to be an existing condition	no action required	9/27/0214
21 0094L	FIFTH AVENUE UC	04-NAP-029-R6.63	0.20			8/24/2014
21 0094R	FIFTH AVENUE UC	04-NAP-029-R6.64	0.20			8/24/2014
21 0098	STANLEY CREEK	04-NAP-029-R8.33	0.25			8/24/2014
21 0101	TRANCAS STREET OC	04-NAP-029-13-NAP	0.12			9/27/0214
21 0102	NORTH NAPA UP	04-NAP-029-12.91-NAP	0.12			8/25/2014
21 0107	NORTH NAPA POC	04-NAP-029-12.9-NAP	0.12			9/27/0214
21 0108L/R	NAPA RIVER (W IMOLA AVE)	04-NAP-121-R5.3-NAP	0.19	Evidence of large movements at all four abutments (bin abutments) of these parallel bridges due to foam forming material on the ground in front of the abutments; 4 ft x 6 ft concrete spall at top corner of Abutment shear keys, typical at 6 of 8 locations. Abutment 1 external shear keys broken. Type A seals at both abutments and strip seals at bin abutments are torn from transverse movement. Ends of bridge rail damaged at joints. Restrainers damaged.	Repair shear keys on each side of each of 5 abutments. Replace 4 joint seals per bridge. Rebuild bridge rail. Replace broken restrainers.	8/24/2014
23 0004	GREEN VALLEY CRK	04-SOL-080-12.91-FRFD	0.12			9/27/0214
23 0004G	N680-E80 CONNECTOR	04-SOL-680-13.12-FRFD	0.12			9/28/2014
23 0014L	LYNCH ROAD UC	04-SOL-080-R9.65	0.10			9/27/0214

Bridge #	Bridge Name	Dist-Co-Rte-PM	1 SA (g)	Damage Observed	Recommended Repair	Date Inspected
23 0014R	LYNCH ROAD UC	04-SOL-080-R9.65	0.10			9/27/0214
23 0063	SONOMA CREEK	04-SOL-037-R.01	0.20			9/27/0214
23 0064	NAPA RIVER	04-SOL-037-R7.39-VAL	0.15	Rail tube separation, joint seal damage, UBIT Inspection Pending	Repair spalled bridge rail - $2600; Replace compression seals - $15,000; Reconnect Aluminum rail tube - $2600	8/24/2014
23 0066	MAGAZINE STREET OC	04-SOL-080-1.78-VAL	0.11			9/27/0214
23 0081	ROUTE 80-37 SEPARATION	04-SOL-080-5.63-VAL	0.11			8/24/2014
23 0088	BENICIA ROAD OC	04-SOL-080-2.44	0.11			9/27/0214
23 0089	SPRINGS ROAD OC	04-SOL-080-3.23-VAL	0.12			9/27/0214
23 0094L	SAGE STREET UC	04-SOL-037-R11.22-VAL	0.13			9/27/0214
23 0094R	SAGE STREET UC	04-SOL-037-R11.22-VAL	0.13			9/27/0214
23 0098	TENNESSEE STREET OC	04-SOL-080-3.49-VAL	0.12			9/27/0214
23 0108	GEORGIA STREET OC	04-SOL-080-2.88-VAL	0.11			9/27/0214
23 0109	WALNUT STREET OC	04-SOL-037-R7.21-VAL	0.15			8/28/2014
23 0114	REDWOOD STREET OC	04-SOL-080-4.43-VAL	0.10			9/27/0214
23 0117	ROUTE 80-780 SEPARATION	04-SOL-080-2.22	0.10			9/27/0214
23 0119	LAUREL STREET OC	04-SOL-780-7.07-BEN	0.10			9/28/2014
23 0127	RINDLER CREEK	04-SOL-080-5.5	0.11			9/27/0214
23 0127L	WEST ARSENAL UC	04-SOL-780-1.21-BEN	0.10			9/28/2014
23 0127R	WEST ARSENAL UC	04-SOL-780-1.21-BEN	0.10			9/28/2014
23 0135E	GREEN VALLEY CRK	04-SOL-080-12.9-FRFD	0.12			9/27/0214
23 0138	GREEN VALLEY ROAD OC	04-SOL-080-12.75	0.12			9/27/0214
23 0139E	ROUTE 680-80 SEPARATION	04-SOL-680-13.09-FRFD	0.12			9/27/2014
23 0142L	CORDELIA OH	04-SOL-680-12.63-FRFD	0.12			9/27/2014
23 0142R	CORDELIA OH	04-SOL-680-12.63-FRFD	0.12			9/27/2014
23 0143L	BENICIA VIADUCT	04-SOL-680-R1.33-BEN	0.11			9/27/2014
23 0143R	BENICIA VIADUCT	04-SOL-680-R1.33-BEN	0.11			9/27/2014
23 0150	AMERICAN CANYON ROAD OC	04-SOL-080-8.1	0.11			9/27/0214
23 0161	PARISH ROAD OC	04-SOL-680-R5.02	0.12			9/27/2014
23 0162	MARSHVIEW ROAD OC	04-SOL-680-R7.32	0.11			9/27/2014
23 0163	GOLDHILL ROAD OC	04-SOL-680-R10.02-FRFD	0.12			9/27/2014
23 0166	AMERICAN CANYON CREEK	04-SOL-680-R10.67-FRFD	0.12			9/27/2014
23 0173G	EB 80-WB 37 CONNECTOR SEP	04-SOL-080-5.65-VAL	0.11			8/24/2014
23 0173K	WB COLUMBUS PKWY WB 80 RAMP OC	04-SOL-080-5.68-VAL	0.11			8/24/2014
23 0174G	E37-E80 CONNECTOR OC	04-SOL-037-R11.54-VAL	0.11			8/24/2014
23 0175G	E37-E80 CONNECTOR OC	04-SOL-037-R11.65-VAL	0.11			8/24/2014
23 0176K	WB COLUMBUS PKWY WB 80 RAMP UC	04-SOL-080-5.81-VAL	0.11			8/24/2014
23 0201K	COLUMBUS-WB 37 ON RAMP OC	04-SOL-037-R11.72-VAL	0.11			8/24/2014
23 0205L	FAIRGROUNDS UC	04-SOL-037-10.94-VAL	0.13			8/28/2014
23 0205R	FAIRGROUNDS UC	04-SOL-037-10.94-VAL	0.13			8/28/2014

Bridge #	Bridge Name	Dist-Co-Rte-PM	1 SA (g)	Damage Observed	Recommended Repair	Date Inspected
23 0212G	N680-W780 CONNECTOR and OH	04-SOL-780-R.48-BEN	0.13			9/28/2014
23 0214G	N680-W780-S680 CONNECTOR & SEP	04-SOL-680-M.8-BEN	0.13			9/28/2014
23 0215R	BENICIA-MARTINEZ APPROACH	04-SOL-680-M.9-BEN	0.12			9/28/2014
23 0217	SACRAMENTO STREET OC	04-SOL-037-8.46-VAL	0.15			9/27/0214
23 0218	ROUTE 37-29 SEPARATION	04-SOL-037-R9.52-VAL	0.15	Damage to interior shear key at abutment and damage to expansion joints	make all needed repairs	9/25/2014
23 0219	BROADWAY OH	04-SOL-037-R9.82-VAL	0.15	Shear key spalls with exposed rebar at Abutment 1, right exterior key and interior shear keys. Minor spalls at rail joints; bridge shifted toward Abut 1 but may be an old condition	Patch shear keys as needed	8/26/2014
23 0220	MINI DRIVE UC	04-SOL-037-R9.98-VAL	0.15			9/27/0214
23 0221G	N29-E37 CONNECTOR	04-SOL-029-4.83-VAL	0.00	Damage to interior shear key at abutment and damage to expansion joints	make all needed repairs	9/27/0214
23 0222F	W37-N and S29 CONNECTOR OH	04-SOL-037-R9.84-VAL	0.15	One inch deep spalls along joint armor at Abutment 1. up to 3/4 inch vertical offset across joint on right side; left shear key spalled at Abutment 1.	Replace strip seal at Abutment 1; patch spalled shear key	8/26/2014
23 0223F	S29-W37 CONNECTOR	04-SOL-029-4.92-VAL	0.15	Spalls around Abutment 1	Patch the spalled and delaminated areas at the Abutment 1 exterior edges of deck: Estimated cost $2600	9/27/0214
23 0237	CHABOT CREEK	04-SOL-029-4.9-VAL	0.15			9/27/0214
23 0238	WHITE SLOUGH	04-SOL-037-8.91-VAL	0.21			9/27/0214
28 0153L	BENICIA-MARTINEZ BOH	04-CC-680-25.04-MTZ	0.12			8/24/2014
28 0153R	BENICIA-MARTINEZ BRIDGE and OH	04-CC-680-25.04-MTZ	0.12			8/24/2014

Appendix B: Caltrans OSMI report for locally-owned bridges.

Bridge #	Bridge Name	Road	Agency	Damage Observed	Recommended Repair
21C0010	Napa Creek	Jefferson Street	City of Napa		
21C0011	Napa River	Lincoln Avenue	City of Napa	Damaged keeper plates @ both abutments.	Replace bearings $181,250
21C0012	Napa River	Third Street	City of Napa		
21C0017	Carneros Creek	Old Sonoma Rd	County of Napa		
21C0038	American Canyon Creek	American Canyon Rd	City of American Canyon		
21C0039	Napa River	Soscol Ave	City of Napa		
21C0041	Redwood Creek	Redwood Road	City of Napa		
21C0044	Napa Creek	Main Street	City of Napa	Cracking and spall @ A2 approach curb. Left sidewalk.	Minor concrete patch $3,625
21C0045	American Canyon Creek	Broadway	City of American Canyon		
21C0047	Fagan Creek	Airport Rd	County of Napa		
21C0053	Soscol Creek	Devlin Road	County of Napa		

Bridge #	Bridge Name	Road	Agency	Damage Observed	Recommended Repair
21C0078	Huichicha Creek	Duhig Road	County of Napa		
21C0081	Carneros Creek	Las Amigas Rd	County of Napa		
21C0086	Tulocay Cr (Cayetano Cr)	Shurtleff Ave	City of Napa		
21C0092	Napa Creek	Seminary St	City of Napa		
21C0097	Napa Creek	Pearl St	City of Napa	Left rail damage to the masonry pilasters. All 4 are loose. Sidewalk is fenced off. Left sidewalk is closed.	Repoint masonry $181,250
21C0099	Redwood Creek	West Pueblo Ave	City of Napa		
21C0117	Napa Slough	Skaggs Island Rd	County of Napa		
21C0122	Napa Creek	California Blvd	City of Napa		
21C0123	Murphy Creek	Fourth Ave	County of Napa		
21C0126	Napa River Bypass	Soscol Ave	City of Napa		
21C0127	Napa Cr & River Overflow	First Street	City of Napa	Left shear key damage @ Abut 4. Approx. 10 sqft of delaminated concrete	Repalce Shear Key $72,500
21C0130	Napa River	First Street	City of Napa		
21C0132	Napa Valley RR	Devlin Road	City of American Canyon	Approach AC settlement at one abutment	Overlay approach $72,500
21C0003	Napa River	Trancas St	City of Napa	Cracks in internal shear keys	Epoxy injection $54,375
21C0006	Soda Springs Creek	Silverado Trail	County of Napa		
21C0015	Napa River Overflow	Silverado Trail	County of Napa		
21C0016	Napa River Overflow	Silverado Trail	County of Napa		
21C0020	Dry Creek	Solano Ave	County of Napa		
21C0021	Dry Creek	Washington St	County of Napa		
21C0022	Napa River Overflow	Hardman Avenue	County of Napa		
21C0026	Milliken Creek	Trancas St	County of Napa		
21C0032	Milliken Creek	Atlas Peak Road	County of Napa		
21C0043	Redwood Creek	Redwood Road	County of Napa		
21C0050	Salvador Overflow	Big Ranch Road	County of Napa		
21C0051	Milliken Creek	Trancas St	County of Napa		
21C0055	Dry Creek	Dry Creek Rd	County of Napa		
21C0059	Milliken Creek	Hedgeside Avenue	County of Napa		
21C0067	Napa River	Oak Knoll Ave	County of Napa		
21C0068	Napa River Overflow	Oak Knoll Ave	County of Napa		
21C0073	Redwood Creek	Redwood Road	County of Napa		
21C0080	Soda Creek	Loma Vista Dr	County of Napa		
21C0084	Napa River Overflow	Ragatz Lane	County of Napa		
21C0085	Yountville Overflow	Ragatz Lane	County of Napa		

Bridge #	Bridge Name	Road	Agency	Damage Observed	Recommended Repair
21C0104	Napa River Overflow	Oak Knoll Ave	County of Napa		
21C0111	Napa Drain	Wine Country Ave	City of Napa		
21C0125	Silverado Creek	Villa Lane	City of Napa		
21C0028	Napa Drain	Jefferson St	City of Napa		
21C0029	Napa Drain	Trower Ave	City of Napa		
21C0001	Bell Canyon Creek	Silverado Trail	County of Napa		
21C0002	Napa River	Zinfandel Lane	County of Napa		
21C0004	Napa River	Cook Road	County of Napa		
21C0019	Rector Creek	Silverado Trail	County of Napa		
21C0023	Napa River	Deer Park Road	County of Napa		
21C0028	No Name Creek	Silverado Trail	County of Napa		
21C0033	Wooden Valley Creek	Wooden Valley Rd	County of Napa		
21C0055	Dry Creek	Dry Cr Rd	County of Napa		
21C0064	Napa River	Lodi Lane	County of Napa		
21C0065	Dry Creek	Mt Veeder Rd	County of Napa		
21C0069	Napa River	Oakville Cross Rd	County of Napa		
21C0072	Napa River	Pratt Avenue	City of Saint Helena		
21C0075	Chiles Creek	Chiles-Pope Vly Rd	County of Napa		
21C0077	Conn Creek	Conn Valley Rd	County of Napa		
21C0082	Conn Creek Overflow	Oakville Cross Rd	County of Napa		
21C0083	Conn Creek	Oakville Cross Rd	County of Napa		
21C0087	Conn Creek	Skellenger Lane	County of Napa	Cracking in abutment wingwall	Replace Wingwall $108,750
21C0088	Soda Creek	Soda Cyn Rd	County of Napa		
21C0100	Hopper Creek	Mulberry St	Town of Yountville		
21C0101	Capell Creek	Capell Cross Rd	County of Napa		
21C0102	Suisun Creek	Wooden Vly Cros Rd	County of Napa		
21C0105	Chiles Creek	Chiles Pope Vly Rd	County of Napa		
21C0109	Napa River	Pope St	City of Saint Helena		
21C0110	Sulphur Creek	Pope St	City of Saint Helena		
21C0112	Sulphur Creek	Valleyview St	City of Saint Helena		
21C0113	York Creek	Spring Mountain Rd	City of Saint Helena		
21C0116	Napa River	Yountville Cross R	County of Napa	Cracks in external shear keys and approach AC settlement	Remove and replace $217,400

Bridge #	Bridge Name	Road	Agency	Damage Observed	Recommended Repair
21C0025	Napa River	Dunaweal Lane	County of Napa		
21C0030	Dutch Henry Creek	Silverado Trail	County of Napa		
21C0031	Simmons Canyon Crk	Silverado Trail	County of Napa		
21C0042	Garnett Creek	Greenwood Ave	County of Napa	Bridge was closed by Napa County after the earthquake. Please see BIR dated 9/4/2014. There is permanent barrier in place. K-rail @ Abut 1 approach. Please see photos.	Replace Bridge $1,812,500
21C0048	Napa River	Bale Lane	County of Napa		
21C0054	Bell Creek	Crystal Springs Rd	County of Napa		
21C0057	Napa River	Evey Rd	County of Napa		
21C0061	Napa River	Larkmead Lane	County of Napa		
21C0062	Troutdale Creek	Livermore Rd	County of Napa		
21C0063	Vanness Creek	Livermore Rd	County of Napa		
21C0066	Napa River	Myrtledale Rd	City of Calistoga		
21C0103	Garnett Creek	Grant St	City of Calistoga		
21C0108	Dutch Henry Creek	Larkmead Lane	County of Napa		
21C0115	Napa River	Berry St	City of Calistoga		
21C0119	Cyrus Creek	Petrified Forst Rd	County of Napa		
21C0013	Pope Creek	Knoxv-Berryessa Rd	County of Napa		
21C0014	Putah Creek	Knoxv-Berryessa Rd	County of Napa		
21C0034	Fp Creek	Butts Canyon Rd	County of Napa		
21C0035	James Creek	Butts Canyon Rd	County of Napa		
21C0036	Duvall Creek	Pope Valley Rd	County of Napa		
21C0046	Swartz Creek	Aetna Springs Rd	County of Napa		
21C0049	Burton Creek	Barnett Rd	County of Napa		
21C0058	Maxwell Creek	Hardin Rd	County of Napa		
21C0074	Eticuera Creek	Berryessa-Knoxvlle	County of Napa		
21C0089	Butts Creek	Stage Coach Cyn Rd	County of Napa		
21C0090	Butts Creek	Stage Coach Cyn Rd	County of Napa		
21C0106	Yokel Creek	Pope Canyon Rd	County of Napa		
21C0118	Pope Creek	Pope Canyon Rd	County of Napa		