6 PERFORMANCE OF GROUND AND BURIED UTILITIES

6.1 Introduction

Preliminary reconnaissance efforts were made outside the zone of surface fault rupture and associated very near fault ground deformation on August 24, 2014 by GEER team members in the cities of Napa, Vallejo, including Mare Island, American Canyon, and surrounding areas (Figure 6.1). Most notable in this reconnaissance was the absence of ground failure, including that due to liquefaction, relative to what has been observed after previous earthquakes of this size or larger in the San Francisco Bay area. Several isolated instances of broken underground pipelines and masonry building damage were observed, but overall ground performance was good. Several GEER teams focused on trying to find locations with evidence of soil liquefaction (e.g., sand boils). However, instances of liquefaction or lateral spreading were observed in only two locations with no significant effects on the supporting system or adjacent structures. Detailed observations and select photographs of ground performance during the M6 South Napa earthquake are provided in Appendix E of this report.

The American Society of Civil Engineers Technical Council on Lifeline Earthquake Engineering (ASCE-TCLEE) published a quick report on September 1, 2014 (*South Napa M 6.0 Earthquake of August 24, 2014*, ASCE TCLEE Quick Reconnaissance Report, Revision A) detailing the performance of power systems, water and wastewater systems, highway bridges and roads, and communication systems during and after the earthquake. Their report also includes information on regional geology, seismic hazard, recorded ground motions, and surface fault rupture. The ASCE-TCLEE report can be downloaded at: http://www.asce.org/Technical-Groups-and-Institutes/TCLEE/ASCE-TCLEE-Preliminary-Reconnaissance-Report-of-the-August-2014-South-Napa-Earthquake/. There are additional quick reports being prepared by lifeline organizations, such as Caltrans and PEER, which should be referred to for additional information. This section focuses on information collected by GEER team members.

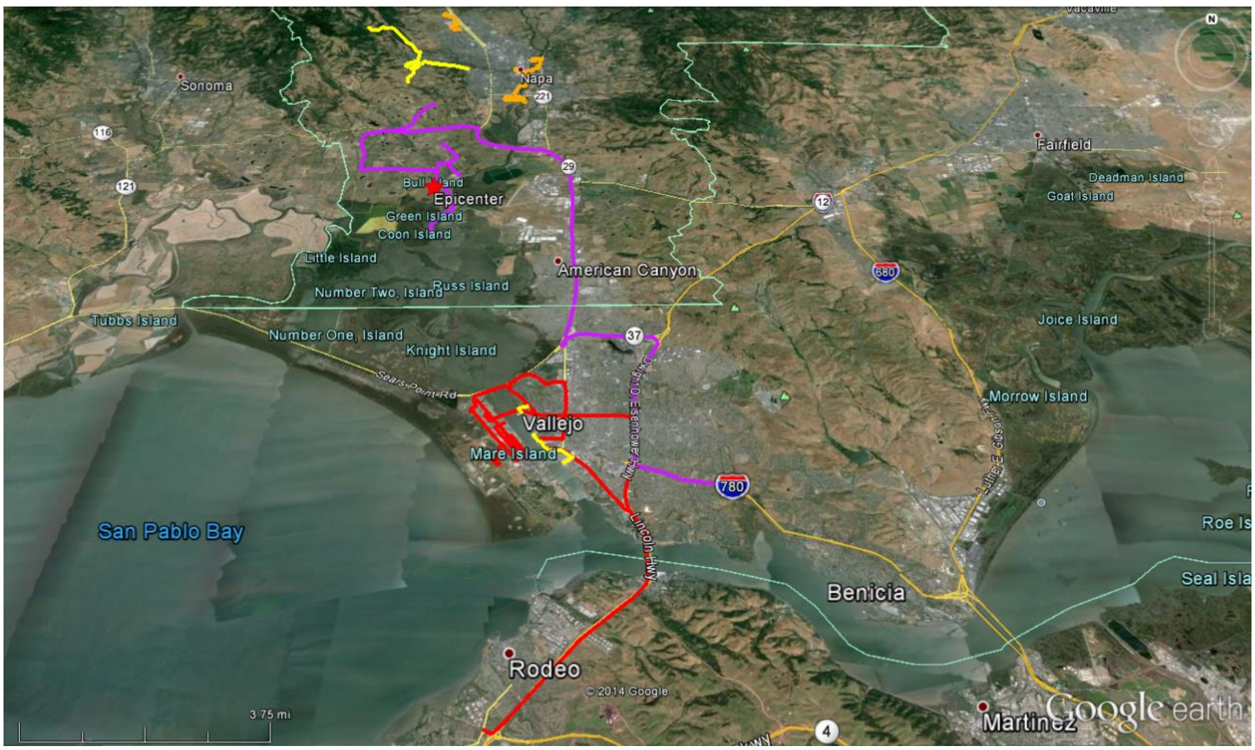

Figure 6.1: GPS tracks for GEER reconnaissance teams that focused on ground failure observations; produced in Google Earth; [NSF-GEER; Vallejo, CA and Napa, CA; 8/24/14]

6.2 City of Vallejo

6.2.1 Vallejo Waterfront (east side of Mare Island Straight)

Along Mare Island Way and at the Vallejo Marina up to the Ferry Terminal, no damage was noted except for two broken water pipes along the road. Observations for the Vallejo waterfront are summarized in Table E.3 in Appendix E. Based on telephone discussions with the City of Vallejo, no fires were reported within the city limits.

6.2.2 Highway 37 Bridge

No significant damage was observed along the Highway 37 Bridge alignment. The bridge was observed from vantage points at the east and west abutments and from a vehicle while crossing. The eastern abutment was observed in greater detail (Figure 6.2). There was an absence of ground cracking and ground deformation, indicating good performance of the ground at the site.

Figure 6.2: Highway 37 Bridge pier with no significant ground damage; [NSF-GEER; Mare Island, Vallejo, CA; GPS N38.122 W122.276; 08/24/14; 18:24]

6.2.3 Water, power, and fire

A total of 13 water main breaks were reported by the City of Vallejo on August 24, 2014, the day of the earthquake, and 8 additional breaks were reported on August 25, based on conversations with city representatives and press releases. A total of 6 water main breaks were observed during GEER reconnaissance. Four of the water main breaks were observed on Mare Island, and two breaks were observed along Mare Island Way on the Vallejo waterfront. Locations of the additional breaks will be reported upon receipt of a report from the City of Vallejo. Of the four water main breaks on Mare Island, two breaks were located along Pintado Road in the vicinity of Railroad Avenue, and one break was visible on Railroad Avenue, just north of G Street. Repairs were underway on these three water main breaks. The fourth water main break was observed on the north end of the island adjacent to Earthquake Protection Systems, just west of Azuar Drive and L Street. A second water main break may have occurred in this vicinity; however, repairs were not yet underway at these locations and were not confirmed.

No fires were reported in the City of Vallejo. Several power outages occurred, based on discussions with City representatives, but the locations were unavailable. Power was observed to be out at a number of intersections across the Mare Island base, however conversations with Lennar Mare Island (LMI) indicated that power had been intentionally turned off in those locations due to safety concerns during inspections and repairs, and there were no unplanned outages on the base. LMI representatives indicated that some buildings, particularly those in the historic core, experienced water leaks within the sprinkler systems or water delivery systems inside several structures. Examples of this were observed on during GEER reconnaissance on August 24, 2014.

6.2.4 Mare Island

6.2.4.1 Officers' Quarters on Walnut Avenue

While investigating the occurrence of ground deformation, the GEER team members observed the performance of some structures. Brick chimneys were observed to have fallen from a number of the historic structures on Walnut Avenue (Figure 6.3), many formerly used as Officer's Quarters by the Navy. Of the 19 structures along Walnut Avenue, 5 had metal chimneys with no visible damage, 11 had brick chimneys with some degree of damage, 2 had brick chimneys with no visible damage, and 1 had no visible chimney or damage. Observations of external structural damage are summarized in Table E.1 in Appendix E.

Figure 6.3: Brick chimney damage; [NSF-GEER; Mare Island, Vallejo, CA; GPS N38.099 W122.273; 08/24/14; 14:19]

6.2.4.2 Mare Island Waterfront and Historic Core

Several buildings along the historic Mare Island waterfront, opposite the dry docks on the west side of Nimitz Avenue were observed to have brick façade or corrugated siding damage (Figure 6.4). The buildings consist of mix of industrial and commercial buildings and warehouses, formerly associated with the Mare Island Naval Base and now under civilian use, owned and leased by LMI. Cracks were observed along corner columns and around windows of some brick structures. No signs of collapse were evident, though some buildings were blocked off and red-tagged pending structural inspection. Several buildings also had broken glass windows although it was unclear by observation which instances were due to earthquake damage. Deformation of rollup doors was evident on one of the waterfront structures. Ground deformation was not widespread, but was observed in localized pockets near one of the larger, more modern structures. Observations of external structural damage are summarized in Table E.2 in Appendix E.

Figure 6.4: Brick facade damage; [NSF-GEER; Mare Island, Vallejo, CA; N38.095 W122.268; 08/24/14; 15:38]

6.2.4.3 Ground Cracking

Deformed pavement was visible in localized areas around structures of the historic core (e.g., Figure 6.5). Paving stones along sidewalks and walkways along Walnut Avenue appeared to be slightly out of place. Evidence of persistent ground rupture in the vicinity of Mare Island was not observed by GEER team members, nor was evidence of significant ground rupture reported by representatives of LMI, who inspected much of the island with representatives of the City of Vallejo and ENGEO Incorporated, their engineering consultant. Linear east west running berms associated with the Navy's former firing range were viewed from a nearby vantage point and ground rupture was not apparent.

Figure 6.5: Pavement damage at hydrant; [NSF-GEER; Mare Island, Vallejo, CA; GPS N38.098 W122.269; 08/24/14; 14:37]

6.2.4.4 Mare Island Causeway Bridge

The Mare Island Causeway Bridge, a historic drawbridge providing access to Mare Island from Highway 80 via Tennessee Street, was observed to be intact and under unrestricted access during a visit on August 24, 2014. No damage was visible that could be attributed to the earthquake. A railing appeared to be down for repair near the west abutment; however, the railing was under repair for reasons unrelated to the August 24 earthquake, according to LMI representatives.

6.2.4.5 Residences along Flagship Drive

Perimeter slopes of residential communities, which were mapped by the USGS as having a high likelihood of liquefaction (i.e., USGS OFR-06-1037, Sheet 2 of 2, Liquefaction Susceptibility), were inspected where access was possible. A sound-wall along Flagship Drive at Klein Avenue was inspected for signs of cracking. A single crack on the order of 6 mm or smaller was observed in the stucco of the wall. This small, isolated crack and the general absence of ground cracking was considered to be evidence of good performance of the slope. Surcharge slopes located south of Kirkland Avenue were inspected for geotechnical damage, and no damage was observed in this area.

6.2.4.6 Saint Peter's Chapel

Saint Peter's Chapel, located on Walnut Avenue at Azuar Drive, appeared to be undamaged. Paving stones along the access pathways may have been displaced as some stones were unstable, but the pre-earthquake condition of the stones is unknown. A perimeter walkover revealed no visible damage to the structure of the chapel. The chapel's rare Tiffany stained glass windows appeared to be intact, though close inspection from inside the chapel was not made to observe whether hairline cracks had damaged the windows.

6.3 Napa River, Downtown Napa and Mobile Home Park Observations

6.3.1 Napa River Observations

GEER team members walked along the Napa River from North (Lincoln Bridge) to South (Napa Marina) looking for any ground related damage. The observations are described below for locations with similar damage. Some additional observations of the downtown Napa levees and floodwalls are presented in Section 7 of this report.

6.3.1.1 Lincoln Bridge and 1st St. Bridge

The Lincoln and 1st St. Bridges cross over the Napa River in an EW direction. No ground or structural damage was observed at these two locations.

6.3.1.2 Railroad and Soscol Bridge

These two bridges cross the Napa River in a NS direction. They showed similar cracking at the interface between the foundation of the abutments and the adjacent soil. The cracks were primarily oriented parallel to the sloped free face. At the south abutment of Soscol Bridge an old masonry retaining wall failed, as shown in Figure 6.6. The Soscol Ave. pavement also settled with respect to the South end of the bridge deck.

Figure 6.6: Failure of masonry retaining wall below the south abutment of Soscol Bridge [NSF-GEER; N 38.2997 W -122.2834; 08/24/14 13:09]

6.3.1.3 **Excavation Site near 1st St. Bridge**

A sheet pile wall installed south of the 1st St. Bridge serves as the supporting structure for an excavation associated with the construction of a new bypass around an ox-bow section of the Napa River, allowing for improved flow of flood waters. The day of the earthquake the dewatered area was flooded and the water was being pumped into the Napa River. According to the superintendent for the contractor, the flooding was produced by water main breaks that flowed into an upstream channel and then to the dewatered area. The sheet pile wall did not show any evident damage.

6.3.1.4 **3rd Street Bridge**

The 3rd St. Bridge crosses the Napa River in an EW direction. The bridge has 2 intermediate piers, which consist of two large reinforced concrete columns. A detailed account of observations in the 3rd Street bridge area is provided in Section 7.5.1 as part of a discussion of levee performance along the Napa River. Site visits revealed overall good performance of embankments and structures with evidence of localized lateral spreading, sand boils, and liquefaction settlements and ground cracking in the vicinity of the 3rd Street Bridge. Specifically:

- Between the eastern pier of the bridge and the East abutment a natural sand deposit has formed (Point Bar). Minor liquefaction-induced ground deformation was observed in this area. Ground cracking and sand boils observed on the east bank of the river, south of the 3rd Street Bridge. On August 24th, the area photographed was under 15 to 30 cm of water. Dry conditions at these locations allowed for closer inspection, revealing signs of liquefaction and sand boils as discussed in Section 7.5.1.
- Ground cracking parallel to the shore to the south and north of the bridge
- Around 5 cm of horizontal displacement of the deck at each abutment
- Separation of approximately 2 cm between concrete walkway and adjacent floodwalls below the west abutment

- Settlement of soils around the western column on the order of 5 cm and 25 cm. Around the columns of the pier, cracks spaced every 25 cm to 30 cm were observed in a radial pattern

Figure 6.7, Figure 6.8, and Figure 6.9 show the ground cracks in the 3rd St. Bridge area.

Figure 6.7: Ground cracking and submerged sand boils due to liquefaction in Napa River point bar, east bank, south of 3rd St. Bridge [NSF-GEER; N 38.2980 W -122.2830; 08/24/14 14:44]

Figure 6.8: Ground cracking due to liquefaction in Napa River point bar below 3rd St. Bridge, between the two columns of the eastern pier. [NSF-GEER; N 38.2980 W -122.2840; 08/24/14 14:44]

Figure 6.9: Ground cracking and settlement due to liquefaction in Napa River point bar below 3rd St. Bridge [NSF-GEER; N 38.2980 W -122.2840; 08/24/14 14:44]

6.3.1.5 Napa River West Bank from Riverside Park to Napa Marina

GEER members drove south along the western shore of the Napa River looking for liquefaction damage or slope stability failures. None were found. Stops were made at Riverside Park, the Napa Valley Yacht Club, a parking lot in the Tannery area, and the Napa Marina. The embankments and slopes in all these places did not reflect any damage.

6.3.2 Downtown Napa

6.3.2.1 Pedestrian Bridge at Coombs Street

A pedestrian bridge crosses the Napa Creek in a SW-NE direction, from Coombs St. (SW) to Clinton St. (NE). It consists of a single steel beam supported by 2 reinforced concrete abutments. Along the SW side of the bridge, on Coombs St., parallel to the creek (NW-SE direction), there is a retaining wall of approximately 3 m in height. This retaining wall supports the North end of Coombs Street, pedestrian bridge South abutment and a house. A large crack was observed parallel to the retaining wall and about three meters behind the wall face. The crack was observed at the interface between the soil and a sheet pile wall (Figure 6.10). At the north of Coombs St. a crack was observed indicating the deformation of the backfill, which was also confirmed by 30 cm of settlement of the pavement adjacent to the retaining wall. Figure 6.11 shows the pavement crack, and Figure 6.12 shows the settlement in the pavement. At the NW end of the bridge, the deck was observed to be 15 cm above the bridge access ramp. Also in the parking lot located N of the abutment, tension cracks were found parallel to the creek.

Figure 6.10: Crack along sheet pile wall behind the retaining wall in the Pedestrian Bridge [NSF-GEER; N 38.3003 W -122.2881; 08/24/14 17:58]

Figure 6.11: Crack in pavement behind the retaining wall in the pedestrian bridge [NSF-GEER; N 38.3003 W -122.2881; 08/24/14 17:58]

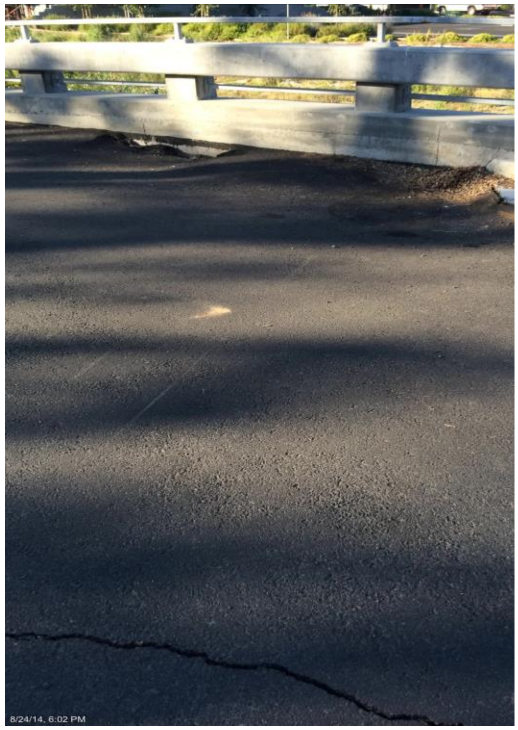

Figure 6.12: Settlement of backfill near the retaining wall in the pedestrian bridge [NSF-GEER; N 38.3003 W -122.2881; 08/24/14 17:58]

6.3.2.2 Water main breaks

Several water main breaks were reported on the day of the earthquake in Downtown Napa. The GEER members in Downtown Napa documented three of them, one on Arroyo Dr. and two on Brown St. Arroyo Dr. is located just north of the NW abutment of the Pedestrian Bridge and is oriented parallel to the Napa Creek. The water main break occurred where recent trench work was apparent. The pavement around the break is also uneven with a large depression towards the East. According to the residents this depression occurred during recent construction along the Napa Creek. The other two water main breaks were observed on Browns St., at its intersection with Napa St. and Caymus St. All of these water line breaks ejected trench sand to the ground surface. An example is shown on Figure 6.13.

Figure 6.13: Soil ejected from water main break in Arroyo Dr. [NSF-GEER; N 38.3008 W -122.2894; 08/24/14 16:34]

6.3.3 Napa Valley Mobile Home Park (NVMHP)

The NVMHP is located in NW Napa near HW 29 and is where a fire took place and the press focused much of its attention. It does not appear that the fire was produced due to breakage of a gas-line generated by ground movement. The ground conditions at this site were dry. A creek located west of the complex did not show flow of water, and no cracks were observed in the crest of the slope to suggest any ground deformation.

6.4 Napa Winery Landslide Stability

6.4.1 Background

In 1995, Cotton, Shires, & Associates (CSA) began an initial landslide investigation of the subject Napa winery site, following the failure of a slope that destroyed the primary access road and decorative entrance fountain located just east of the main winery building. Based upon this investigation, CSA identified three large, deep-seated landslides that impacted the winery building and access roads, labeled Landslides A, B, and C on the winery landslide map (Appendix E). These landslides likely failed in late Quaternary time and remained relatively dormant prior to site development, although they appear very obvious on aerial photographs. The active landslide that impacted the road and fountain was a reactivated portion of Landslide A that failed on sheared claystone beds within the Huichica Formation.

Following the investigation, CSA designed a tied-back shear pin wall and shear cleats to protect the upper access road, fountain area and large winery building that sits at the top of the hill from active and potentially expanded movement of Landslide A. A large grading repair, consisting of a mid-slope shear key, was constructed to buttress Landslide A and provide a stable fill platform for the primary access road to cross over/through that landslide. Later, additional tied-back shear pins were also installed at the top of the slope to protect the winery building from Landslides B and C. In addition to protecting facilities at the top of the slope, these shear pin walls also relieved some of the driving force from the landslide masses that remained downslope of the walls. No mitigation measures were installed in the lower portions of Landslides B and C, so they remain somewhat vulnerable to reactivation. Following completion of various phases of shear pin and tieback installation, as well as installation of the shear key, slope inclinometers were installed in the locations shown on the site map. These slope inclinometers have been monitored annually by CSA since installation (in the late 1990's) during the late spring of each year. The last inclinometer reading before the earthquake was recorded in June of 2014.

6.4.2 **Post-Earthquake Response**

The Napa winery site is located approximately 6.6 km from the epicenter of the M6.0 South Napa Earthquake and 1.7 km from the fault trace that experienced coseismic slip. Based upon peak ground acceleration (PGA) data provided by the USGS, the PGA at the winery site was approximately 0.5g during the main shock. During the afternoon of August 24, 2014, approximately 10 hours after the M6.0 earthquake, CSA performed a site reconnaissance. CSA observed no evidence of active landsliding such as scarps, ground cracks, bulging ground, or displacement of roads or rows of grape vines. On the following day, CSA monitored the site slope inclinometers and determined that most of them remained static (Appendix E). However, discrete deflections of 0.1 to 0.3 inch were recorded in slope inclinometers SI-1A, SI-14, SI-15, and SI-17 located downslope from the shear pin walls and slope inclinometers SI-10A and SI-3 located upslope of the shear pin walls. CSA interprets the small deflections that occurred in slope inclinometers located above the shear pins as limited seismic displacement that was absorbed by the shear pin and tieback system as they reached their reserve capacity. Of the slope inclinometers installed downslope of the shear pin walls, only SI-14 was within the formerly active portion of Landslide A. Displacement of over 0.3 inch at the depth of the existing landslide plane in SI-14 appears to represent loading of the shear key buttress by the landslide mass that was left in place upslope of the buttress. Deep deflections (in the range of 0.2 to 0.3 inch) in slope inclinometers SI-1A and SI-15 indicate reactivation of previously static portions of Landslides A and B below the shear pin walls. SI-17 is located outside of the mapped landslides in an area where Huichica Formation is exposed. Thus, CSA interprets the deep deflection in SI-17 (0.2 inch) as new landslide activity that was triggered by strong ground motion. CSA will continue to monitor this inclinometer to see if it will continue to deflect in the absence of strong ground motion.

Very little earthquake-related damage was sustained by the winery, other than items falling from shelves in the tasting room, a few cases of wine bottles breaking, and a few wine barrels that fell and broke open.

In conclusion, it appears that the shear pin and tieback walls successfully protected the winery building from significant seismic displacements resulting from intense ground shaking and high PGA values. The landslide debris that remained in place below the protection walls experienced small, localized displacements in response to strong ground motion. Below average rainfall over the preceding two years (with resulting low pore-water pressures) likely helped to minimize seismic slope displacements at the winery site during the South Napa Earthquake.

6.5 References

U.S. Geological Survey, *Maps of Quaternary Deposits and Liquefaction Susceptibility in the Central San Francisco Bay Region, California*, Open-File Report 2006-1037, Sheet 2 of 2, Liquefaction Susceptibility

ASCE-TCLEE, *South Napa M 6.0 Earthquake of August 24, 2014*, Quick Reconnaissance Report, http://www.asce.org/Technical-Groups-and-Institutes/TCLEE/ASCE-TCLEE-Preliminary-Reconnaissance-Report-of-the-August-2014-South-Napa-Earthquake/ (Accessed 09-15-2014)