7. EFFECTS ON LIFELINES

Over the past decade, the people of Canterbury have undertaken a deliberate and dedicated effort to increase the resiliency of the entire lifeline system within the region. And, with the exception of water and waste water distribution lines in the areas affected by liquefaction, lifelines performed quite well. The case for hardening of the lifelines was made in the report "Risks and Realities: A Multi-Disciplinary Approach to the Vulnerability of Lifelines to Natural Hazards" (CAENZ 1997). Following preparation of the report, a plan to enhance the resiliency of lifelines in Canterbury was developed and implemented across all sectors, including transportation, water, waste water, electric power, and communications. In addition, the interdependence of lifelines was recognized and addressed through detailed planning and coordination efforts.

This chapter includes the GEER-NZ Team observations for the transportation system (bridges, highways, rail, airports, and ports), water and wastewater systems, electric power, waste management and landfill, as well as other lifelines.

The Transportation System

While the transportation system did suffer some damage from the earthquake, mobility about the Canterbury region was essentially unaffected with few exceptions.

Bridges, abutments, and approach fills

In general, the performance of bridge foundations, abutments, and approach fills in the earthquake was satisfactory, as almost all bridges were serviceable after the event. According to post earthquake reconnaissance performed by the New Zealand Natural Hazard Platform Bridge Research Group, eight road bridges were out of service in the days following the earthquake, and five remained closed for at least 5 days. One bridge with a ruptured sewer line crossing it (the Kainga Road Bridge in Brooklands) remained out of service for more than 11 days after the earthquake. However, that bridge may have remained closed at the request of local authorities to limit access by outsiders to an area extensively damaged by liquefaction. Except for one bridge with structural damage, these bridge closures were due to damage to the approaches of the bridge, e.g. liquefaction, lateral spreading, and settlement of approach fills. However, none of the road bridges were damaged to the extent that they will need immediate replacement. Six pedestrian bridges were unserviceable after the earthquake and will need to be replaced. While these pedestrian bridges suffered significant structural damage, the primary factor inducing structural distress in most of these cases appears to have been liquefaction-induced lateral spreading at the abutments. In several cases minor leaks in water pipes crossing road bridges were reported. One railway bridge was reported to need repair.

The GEER-NZ Team conducted visual inspections of six road bridges, one railway bridge, and two pedestrian bridges. However, in some cases the inspection was limited to visual observation from a distance. There was no apparent major damage to bridge foundations, although one abutment wall founded on piles appears to have back-rotated slightly. At several of the vehicular bridges, liquefaction-induced lateral spreading was observed in the approach embankments, abutment fills, and in the banks adjacent to the bridge. At road bridge locations where lateral spreading, or incipient lateral spreading, was observed in the abutments, the tendency for the abutments to converge (move inwards towards the center of the span) appears to have been resisted by the bridge deck, though there was typically signs of lateral spreading of the approach embankments perpendicular to the roadway. Cracking of abutment retaining walls was observed at several of these road bridge locations. At the two pedestrian bridges that the Team visited the light deck did not have enough structural strength to resist movement into the channel at the abutments and the bridge decks buckled to accommodate the convergence of the abutments. At the Kainga Road Bridge, the ruptured sewer pipe crossing the bridge continued to discharge untreated sewage into the river for at least 12 days after the earthquake. More detailed descriptions of the GEER-NZ Team's findings follows.

South Brighton (Bridge Street) Bridge

Perhaps the most significant damage at the road bridges observed by the GEER-NZ Team was at the Bridge Street bridge in South Brighton (-43.5253˚, 172.7242˚), an approximately 70-m span with a center pier and seat type abutments and a slight skew (less than 30 degrees) spanning the Avon River. The bridge was reportedly closed for approximately 10 days following the earthquake due to differential settlement at the east abutment. When the Team arrived on the 11^{th} day after the earthquake, dense graded aggregate had been placed and compacted on the approach to the east abutment (Figure 7.1) and traffic was moving across the bridge once again. Cracking along the margins of the roadway and incipient lateral spreading perpendicular to the roadway was observed (Figure 7.2). There was also incipient spreading along the river bank on both sides of the east abutment (Figure 7.3). Closure of the gap between the bridge deck and abutment at the seat for the deck (Figure 7.4) as well as displacement on the bearing pads (Figure 7.5) suggests that the abutment moved slightly towards the channel. However, the abutment wall is supported on several rows of 14 inch octagonal precast, pre-stressed concrete piles, including a row of battered piles with a 3H:1V batter, as observed at the west abutment where the piles are exposed (Figure 7.6). Incipient lateral spreading of the bridge abutment, lateral spreading along the banks of the river (Figure 7.7), and closure of the gap at the bridge seat were also observed at the west abutment. The west abutment also appeared to have back-rotated slightly, possibly due to liquefaction-induced settlement of the approach fill, as evidenced by a gap between the back wall and the end fill (Figure 7.8) and tilting of the approach slab at the wing wall (Figure 7.9). There also appeared to have been some pounding between the south edge of the west end of the bridge deck and the abutment wall (Figure 7.4). The New Zealand Natural Hazard Platform Bridge Research Group has reported a thin horizontal crack just above the water line on the center pier of this structure. However, both the bridge superstructure and its foundations appeared to be structurally intact and the bridge has been reopened for traffic.

Christchurch Avon River Bridges (Swanns Road, Gayhurst Road, Pedestrian Bridge)

Incipient lateral spreading of the bridge approach fills and abutments walls and cracking of abutment walls were observed at bridges across the Avon River in Christchurch at Swanns Road (-43.5222˚, 172.6600˚) and Gayhurst Road (-43.5217˚, 172.6728˚). Both bridges are relative small (approximately 30 m) simple spans with integral abutments constructed in 1954. At both locations cracking in the roadway on the approaches to the bridge (Figure 7.10) and at Swanns Road lateral spreading of the approach fill (Figure 7.11), incipient lateral spreading at the abutments (Figures 7.12 and 7.13), and cracking of the abutment and retaining walls (Figure 7.14 and 7.15) was observed. However, both bridges remained serviceable. At the footbridge crossing over the river approximately midway between the Swanns Road and Gayhurst Road bridges, just south of where Medway Road joins River Road on the west bank of the Avon River (-43.531˚, 172.6656˚), the rather light deck of the bridge buckled to accommodate the lateral spreading at the abutments (Figure 7.16).

Kaiapoi Bridges (Williams Street, Pedestrian Bridges)

Behaviour similar to that observed along the Avon River in Christchurch was also observed at Kaiapoi River crossings. Incipient lateral spreading, cracking in the approach roadway, and cracking in the abutment walls was observed at the Williams Street Bridge (-43.3825˚, 172.6575˚) (Figures 7.17 and 7.18) and buckling of the lightweight deck of a pedestrian bridge due to convergence of abutments as a result of lateral spreading was observed just north of Williams Street, in the vicinity of Trousselot Park (-43.3811˚, 172.6558˚) (Figure 7.19). Evidence of liquefaction and incipient lateral spreading was also observed along the walking path from the Williams Street Bridge to Trousselot Park and in the park itself (Figure 7.20).

Waimakariri River Bridges (Chaneys Overpass, Highway 1 River Crossings)

Cracking and incipient lateral spreading was observed at the northern transition between the approach embankment and the abutment at Chaneys overpass (Figure 7.21), where Highway 1 crosses over the Christchurch Northern Motorway (-43.4300˚, 172.6464˚). The bridge is a three span bridge of about 80 m with what appeared to be seat-type abutments retrofit with cable restrainers (Figure 7.22). However, other than a few ruptured precast concrete tiles that covered the end embankment for the north abutment (Figure 7.23), there was no apparent damage to the bridge structure or its foundation, despite ample evidence of liquefaction beneath the bridge (Figure 7.24). The overpass is located in a low lying area that appears to be the flood plain of the Waimakariri River that was subject to extensive liquefaction (Figure 7.25). Cracking was observed in and adjacent to the roadway in the vicinity of the overpass (Figure 7.26) and road crews were busy regrading and paving the approach to the roadway that passed under the overpass (Figure 7.27), though it was not clear if this work was earthquake related.

The GEER-NZ Team also inspected the two main spans for the Highway 1 crossing of the Waimakariri River (-43.4153˚, 172.6467˚) (Figure 7.28) and the adjacent railroad bridge (-43.4128˚, 172.6508˚). While there was some evidence of liquefaction adjacent to several of the piers for the east span of the Highway 1 crossing (Figure 7.29), there was no indication of displacement of the foundation piers or structural damage to the bridge.

Kainga Road Bridge to Brooklands Residential Community

The Kainga Road Bridge is a short span bridge leading to the Brooklands residential community (Figure 7.30), and according to the New Zealand Natural Hazard Platform Bridge Research Group, the bridge remained closed at the time of the Team’s visit on 13 September 2010 at the request of local authorities to limit access to an adjacent area extensively damaged by liquefaction. Structurally, the 1963 mixed girder-slab reinforced concrete bridge was in good condition. However, movement of the northeast abutment wing wall resulted in damage to an 18-cm diameter sewage pipe that was rigidly connected along the bridge span (Figure 7.31). Raw sewage continued to flow into the river from the damaged pipe at the time of the site visit (Figure 7.32a). Posted signs and discussions with locals confirmed that the flow was contaminated liquid (Figure 7.32b). Directly below the bridge, a pipe of similar diameter suffered no damage, and the Team noted that its support to the abutment wall was filled with flexible foam (Figure 7.33). At the East abutment, the northern wing wall moved towards the river and developed a gap with its backfill soils of about 2 cm, whereas the southern wing wall appeared to remain fixed. Soil spread away from the east abutment south wing wall leaving a gap of about 4 – 6 cm at its toe. Surrounding low lying marshlands and old paddock fields (as indicated by a postal worker interviewed during our visit) showed evidence of liquefaction (Figure 7.34).

The fills at the east and west approaches to the bridge appeared to have settled, but were repaired prior to the Team's visit. This road is only one of two access routes into the communities of Brooklands and Spencerville, the other being Lower Styx Road. Extensive liquefaction was observed in Brooklands, including uplifting of sewer manholes along approximately 2 km of Lower Styx Road.

Figure 7.1 Repaired east approach to the Bridge Street Bridge. (-43.5253˚, 172.7242˚)

Figure 7.2 Cracking on margins of west approach embankment, Bridge Street Bridge. (-43.5253˚, 172.7242˚)

Figure 7.3 Lateral spreading of east banks adjacent to the Bridge Street Bridge. (-43.5253˚, 172.7242˚)

(a) (b)

Figure 7.4 Bridge Street Bridge expansion gap closure: (a) West abutment gap closure and spalling; and (b) East abutment gap closure. (-43.5253˚, 172.7242˚)

Figure 7.5 West abutment bearing pad displacement, Bridge Street Bridge (scale in Inches). (-43.5253˚, 172.7242˚)

Figure 7.6 West abutment battered pile, Bridge Street Bridge. (-43.5253˚, 172.7242˚)

Figure 7.7 Lateral spreading on west bank, Bridge Street Bridge. (-43.5253˚, 172.7242˚)

Figure 7.8 Gap between west abutment backwall and end embankment, Bridge Street Bridge. (-43.5253˚, 172.7242˚)

Figure 7.9 Back rotation of west abutment, Bridge Street Bridge. (-43.5253˚, 172.7242˚)

Figure 7.10 Cracking of roadway on west approach fill, Swanns Road Bridge. (-43.5222˚, 172.6600˚)

Figure 7.11 Lateral spreading on west approach fill, Swanns Road Bridge. (-43.5222˚, 172.6600˚)

Figure 7.12 Incipient lateral spreading at west abutment, Swanns Road Bridge. (-43.5222˚, 172.6600˚)

Figure 7.13 Incipient lateral spreading at north abutment, Gayhurst Road Bridge. (-43.52172˚, 172.6728˚)

Figure 7.14 Cracking of north abutment, Swanns Road Bridge. (-43.5222˚, 172.6600˚)

Figure 7.15 Cracking of retaining wall, north bank of the Avon River.

Figure 7.16 Footbridge on the Avon River near Medway Road: (a) Buckled span; and (b) Sheared bearing on east bank. (-43.5310˚, 172.6656˚)

Figure 7.17 Cracking of east approach roadway, Williams Road Bridge. (-43.3825˚, 172.6575˚)

Figure 7.18 Incipient lateral spreading of east abutment, Williams Road Bridge. (-43.3825˚, 172.6575˚)

Figure 7.19 Buckling of footbridge near Trousselot Park. (-43.3811˚, 172.6558˚)

Figure 7.20 Cracking of sidewalk and evience of liquefaction in Trousselot Park. (-43.3811˚, 172.6558˚)

Figure 7.21 Incipient lateral spreading at Chaneys Overpass north abutment. (-43.4300˚, 172.6464˚)

Figure 7.22 Cable Restrainers at north abutment, Chaneys Overpass. (-43.4300˚, 172.6464˚)

Figure 7.23 Displaced concrete tiles on end embankment for north abutment, Chaneys Overpass. (-43.4300˚, 172.6464˚)

Figure 7.24 Evidence of liquefaction beneath Chaneys Overpass. (-43.4300˚, 172.6464˚)

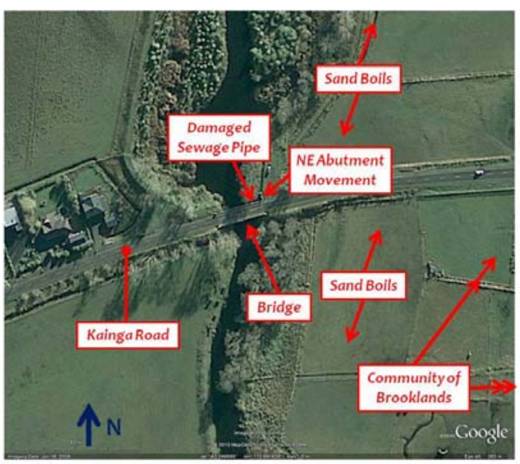
Figure 7.25 Evidence of liquefaction adjacent to Chaneys Overpass. (-43.4300˚, 172.6464˚)

Figure 7.26 Cracking in and along roadway adjacent to Chaneys Overpass. (-43.4300˚, 172.6464˚)

Figure 7.27 Road being repaved adjacent on south approach to Chaneys Overpass. (-43.4300˚, 172.6464˚)

Figure 7.28 Highway bridge across the Waimakariri River. (-43.4153˚, 172.6467˚)

Figure 7.29 Evidence of liquefaction at Highway 1 bridge piers on the north side of the Waimakariri River. (-43.4153˚, 172.6467˚)



(a)

(b)

Figure 7.30 Kainga Road Bridge to the Brooklands residential community (a) GoogleEarth image (-43.3998˚, 172.6910˚) and (b) overview of bridge looking west (-43.3997˚, 172.6916˚).

Figure 7.31 Damage to sewage pipe at the Kainga Road Bridge (-43.3997°, 172.6916°)

(a) (b)

Figure 7.32 Outflow from damaged pipe at Kainga Road Bridge and surrounding warnings to the community. (-43.3997°, 172.6916°)

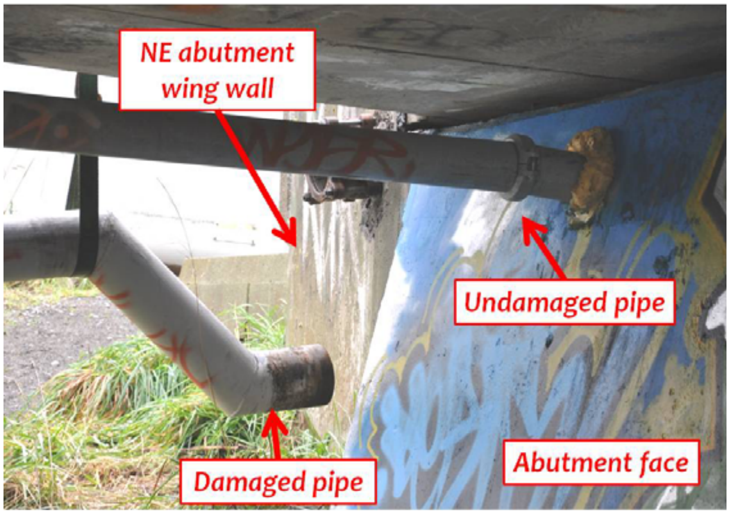


Figure 7.33 Below the East end of the Kainga road bridge (looking northeast). (-43.3998°, 172.6914°).

Figure 7.34 Evidence of liquefaction in surrounding low lying marshlands on the east side of the Kainga road bridge (-43.3995°, 172.6917°).

Highways

Most highways and major surface transportation routes remained open following the earthquake, or were only closed temporarily for inspection or minor repairs. Due to a rock fall along Highway 1 between Waipara and Kaikoura, the route remained closed 10 days following the earthquake, but it is not clear if the earthquake was a contributing factor since locals reported the section of roadway had had ongoing problems and there was heavy rainfall in the area prior to the earthquake. An alternative route along Highway 7 to Kaikoura was available. The Highway 74 tunnel from Christchurch to Lyttelton was briefly closed due to a rock fall, and Evans Pass Road was closed in the days following the earthquake due to a rock fall and remained closed after 10 days. While the closure of Evans Pass Road had only minor effect on mobility between the Lyttelton Port of Christchurch and the rest of the South Island, it is one of the primary alternative routes between the Port and Christchurch should the tunnel be closed. The tunnel closure, however, only lasted a few hours. In the communities affected by liquefaction, a few roads remained closed 10 days following the earthquake, but alternative access routes were available in all areas.

Rail System

The Canterbury region has a rail system used primarily to carrying coal to the Port for export as well as for tourism trains. Railroad bridges are primarily of steel construction. The New Zealand Natural Hazard Platform Bridge Research Group reported damage to one railroad bridge from the earthquake. Rail service was also impacted from bent rails fault trace and as a result of slumping ground in some locations.

Damage to railways embankments occurred near Rolleston (Figure 7.35) and Woodward Glenn, just south of Kaiapoi (Figure 7.36). In the former case, the damage was due to fault offset, while in the latter case the damage resulted from liquefaction and lateral spreading. By the Time the team arrived in Rolleston (13 days after the earthquake), the damage to the tracks had been repaired. The Team was informed that the damaged rail line at Rolleston was fixed the day of or the day after the earthquake and that the slumping rail lines at Woodford Glen had been repaired 4 days after the earthquake.

Figure 7.35 Railway Embankment at Rolleston. (photo by I. McGregor)

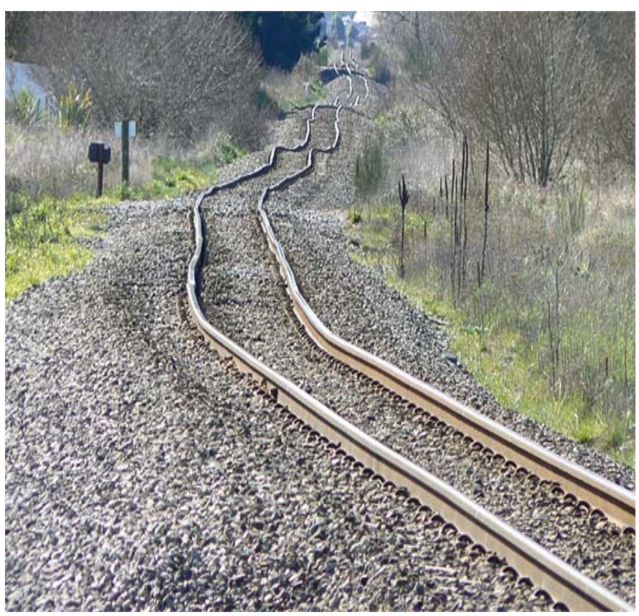


Figure 7.36 Damage to rail line at Woodford Glen. (photo by L.Matthews and J. Overend)

Christchurch International Airport

The Christchurch International Airport was closed temporarily for inspection and minor clean up, but was re-opened with full service within 9 hours after the earthquake. The airports' corporate offices were closed and temporarily relocated.

Lyttelton Port of Christchurch

Lyttelton Port of Christchurch (LPC) is the main port for the Canterbury region and is of critical importance to the economy of the South Island. It handles coal, automobiles and fuel products, and about 250,000 TEU of containerized cargo annually. The terminals at the port are of a variety of ages, ranging the 1880's to current.

The intensity of the Darfield Earthquake in the port area was essentially the operating basis earthquake for the port, having a PGA of 0.33g (as measured by a strong motion station within the Port). Port facilities are undergoing strengthening as part of the program to increase lifeline resilience in the region. While some Port facilities sustained significant damage, most Port facilities were operational within hours after the earthquake and no scheduled shipments were missed. By 0700 on 4 September 2010, the two main piers and a portion of the coal terminal were operational. The container terminal was opened by 1500 on 5 September 2010. The coal terminal was fully operational on 8 September 2010, and the liquefied petroleum gas (LPG) terminal was opened on 10 September 2010. Port officials were quite satisfied with the performance, but acknowledge that there will be significant repairs and rebuilding in the coming months.

LPC has three container cranes, each with a 19-m rail spacing. While there was some lateral (seaward) movement of the deck for the container terminal, no damage to the cranes was noted and they were still performing as intended after the earthquake. The crane rails are closely enough spaced that both rails fit on the wharf deck. Having both rails on the deck appears to have avoided differential movement of the rails (despite the lateral displacement of the deck) and contributed to the good performance of the Port facilities.

The soil profile at the Port typically consists of 10 m or more soft clay and silty sand layers underlain by rock, along with some un-engineered fill and boulder rip-rap. Liquefiable soils are limited to a few seams within the natural sediments and are believed to have had no impact on the performance of the port. All wharves are on vertical pile foundations, including hardwood timber piles, 600-mm diameter reinforced concrete piles, 600-mm square reinforced concrete piles, and steel pipe piles. Many are skin-friction piles that develop their vertical capacity within the underlying clay and sandy soil layers. No damage to any piles was observed, though some were noted to have apparently settled up to 0.3 m, becoming disengaged from the wharf deck.

All the wharves underwent limited settlement and lateral deformation, though limited to 0.2 to 0.3 m. Typical damage from settlement and lateral deformation are shown in Figures 7.37-7.39 .

The limited wharf movements did open up cracks in the asphalt pavement sections of the wharf deck. In order to keep the port operational, Port officials were considering different temporary repair alternatives, including grouting, sand infill, or crushed rock. Port engineers also expressed concerned that the concrete pavement in the backlands areas was bridging over voids that developed due to lateral displacement of retaining walls at the back of the wharves that accompanied lateral displacement of the deck.

The underground 11kV electric power network remained in service following the earthquake, though the single sub-station at the port did sustain some minor damage.

Figure 7.37 Settlement and lateral deformation at fuel transfer facility (-43.60750˚, 172.71332˚).

Figure 7.38 Temporary wooden support to accommodate settlement under fuel line (-43.60783˚, 172.71373˚)

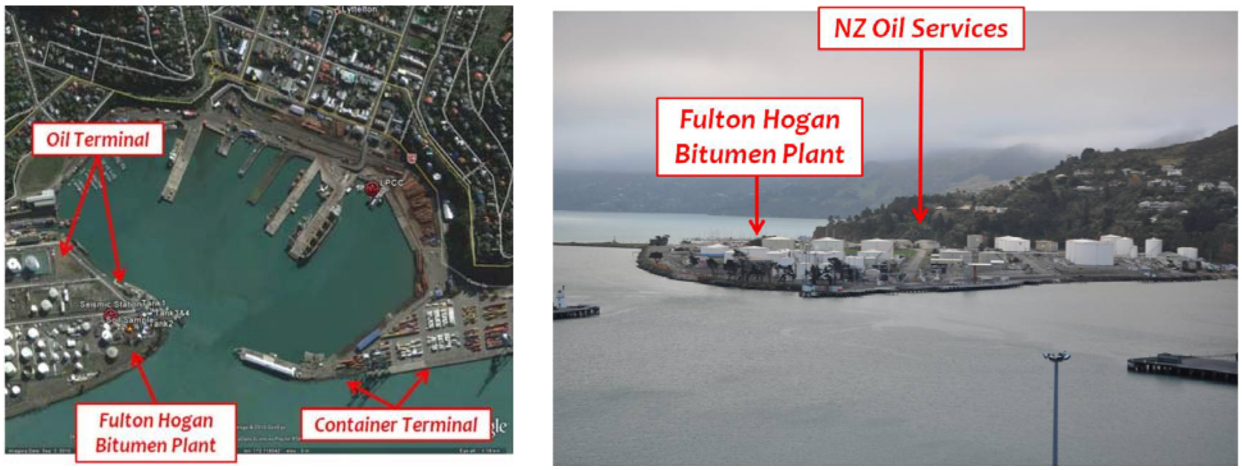
Figure 7.39 Cracking along jetty at eastern end of port (-43.61023˚, 172.73345˚).

Oil Terminal at the Lyttelton Port of Christchurch

The Team visited the Oil Terminal side of the Lyttelton Port of Christchurch (Figure 7.40) on 13 September 2010, and the most significant damage was the area leased to the Fulton Hogan Bitumen plant (fultonhogan.com). The Team visited this plant and discussed observations with the plant manager, Steve Platt. He was advised by port officials that approximately 10 cm of lateral spreading of the wharf supporting the plants facilities had occurred on the eastern water face of the terminal.

As a result of the lateral spreading, as well as liquefaction within the bitumen plant, four tanks and some supporting piping suffered movement and damage. These are noted in Figure 7.41 as Tanks 1-4. The most severe lateral movement was that of Tank 1 (located at -43.6085°, 172.7149°), which moved laterally 50 mm towards the water. Tank 2 (-43.608768°, 172.714651°) settled uniformly about 30 mm causing separation of the connecting bridge between it and a neighboring tank of like geometry (Figure 7.42). This tank, with dimensions of 12.8-m high by 13-m diameter, housed used oil and was nearly filled to capacity at the time of the main shock, weighing an estimated 550 tons. Tanks 3 and 4 (-43.6085°, 172.7149°) were side-by-side and each experienced movement that resulted in pullout of nearly all perimeter anchor bolts at their base. These tanks were 12.5-m tall by 6-m diameter with an estimated 150-ton weight at the time of the main shock. Crews were repairing the support anchorage for Tanks 3 and 4 with the retrofit shown in Figure 7.43. No structural damage to the tanks was observed and flexible connections survived the strong shaking with only minor leakage. Asphalt repair using cement injection to fill the lateral spread cracks was on-going during the Team's visit (Figure 7.44). Sand boils were also observed at several locations within the plants boundaries. Soil samples of the ejecta indicated the material was clean sand with little to no fines (Figure 7.45).

A seismograph station was located within the plants boundaries housed within the plant main entry building (-43.6086°, 172.7136°), but was not operational at the time of the main shock. Workers attempted to get it operating it following the main shock, and Mr. Platt believes it was running during the M_w5.1 aftershock centered below the Port Hills.



(a) (b)

Figure 7.40 Port of Lyttelton locating the oil terminal area (GoogleEarth image; -43.6088°, 172.7140°) and (b) Aerial view of the Fulton Hogan Bitumen Plant (image taken from -43.6068°, 172.7272°).

Figure 7.41 Zoomed into the region of the Fulton Hogan Bitumen Plant (GoogleEarth image; -43.6088°, 172.7140°).

Figure 7.42 Tank 2 (right most large white tank) with Tanks 3 and 4 shown to the left (smaller grey tanks) at the Fulton Hogan Bitumen Plant (-43.6088°, 172.7147°).

Figure 7.43 Typical repair to Tank 3 and 4 (addition of clamp plates). Note the pullout of the original anchorage. Fulton Hogan Bitumen Plant. (-43.6085°, 172.7149°).

Figure 7.44 Repair of lateral spread cracks within the Fulton Hogan Bitumen Plant, nearby Tank 3. (-43.6085°, 172.7150°)

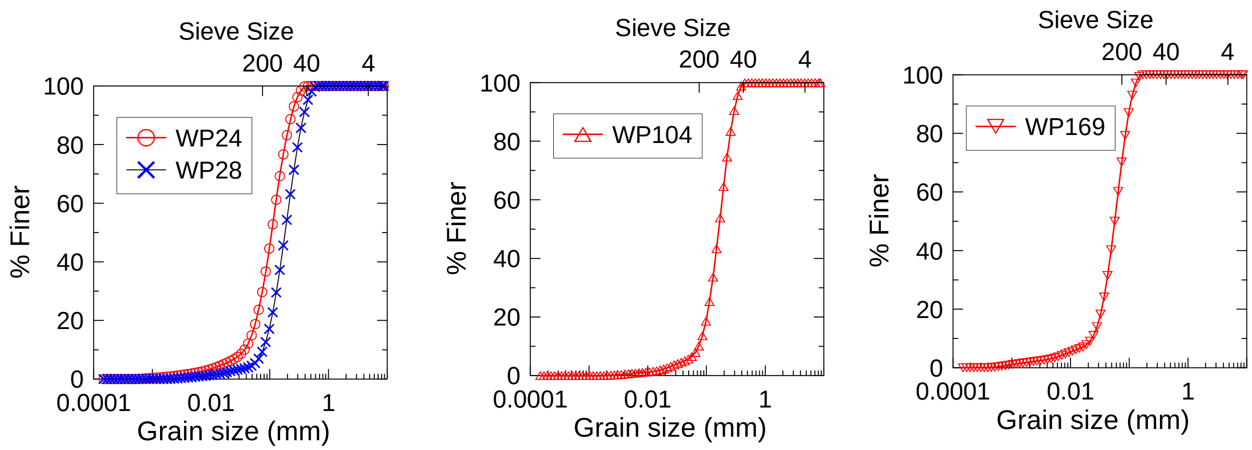


Figure 7.45 Laser diffraction tests of samples taken from ejecta observed at the Fulton Hogan Bitumen Plant. Sample WP169 taken at -43.6087°, 172.7142°.

Water and Wastewater Systems

By far the greatest impact on the community was the performance of water and wastewater systems in the Canterbury region. The Christchurch, Selwyn, and Waimakariri Districts all experienced damage to the pipe networks in areas affected by liquefaction, resulting in loss of service and discharge of untreated wastewater into the groundwater and surface water.

In all three districts, drinking water is untreated well water. Water mains are predominately asbestos-cement pipe, with newer pipes being HDPE. All wastewater pipes are concrete bell-and-spigot. Damage to both systems was concentrated in the areas affected by liquefaction.

Christchurch City Council

A precautionary water boil advisory was put in place immediately after the earthquake by the Christchurch City Council (CCC) and was lifted on 9 September 2010, with only two minor problems being reported. CCC officials estimate that 6 to 7 km of water mains will need to be replaced, and the replacement of similar lengths of wastewater pipes are expected. Officials observed that crews performed the equivalent of "a year's worth of maintenance in 6 days."

Damage to the CCC's system was predominately to the water and wastewater mains, as a result of ground movement and floating of manholes. A major problem with sewer lines was influx of liquefied sand and water through breaks in the line. Cleaning sand out of sewer pipes and pump stations was a major factor affecting restoration of service. Repair crews found pipes that were simply pulled apart, while others were crushed at the joints. No problems were associated with pipes crossing bridges that CCC officials were aware of. CCC officials expressed concern about voids that may have developed beneath pavements due to the estimated 11,000 tons of sand removed from pipes and pump stations (corresponding to a potential void volume of approximately 9,000 m^3).

All new pump stations have flexible joints and performed well. At older stations, one pipe with a rigid connection was sheared (at Halswell) and one water pump was lost (which was identified as vulnerable prior to the earthquake and was scheduled to be replaced). All pumping stations have back-up power supplies, and all worked as intended. The wastewater treatment plant in Christchurch was unaffected by the earthquake, though an increase of flows into the plant of up to 20% were observed as a result of groundwater inflow through the pipe breaks.

CCC officials indicated that restoration of drinking water took a priority over wastewater, and that work had yet to start on the storm sewer system. Ongoing problems included additional pipe breaks and removal of silt and sand from pipes and pumping stations. The CCC asset management plan calls for pipe replacement if three breaks are observed in any pipeline over the period of one year. They are now doing a cost analysis of clearing pipelines by jetting, Closed-

Circuit TV (CCTV) inspection, and repair of existing pipelines versus abandonment and replacement. As part of the efforts to improve resilience, CCC spends about 1% of their maintenance budget on resilience upgrades.

Selwyn District Council

Most of the water and wastewater networks in the Selwyn District council (SDC) performed well. Very few breaks were reported, mostly in foothill areas. A blanket water boil advisory was lifted 5 days after the earthquake. The biggest reported problem was the new (less than 3-yr-old) wastewater treatment plant had to be taken offline, eliminating 1500 m^3/day of capacity. Flows were fortunately redirected to the old plant that had been recently replaced, but had not yet been completely taken out of service. The new plant was running again in 9 days, near 100% after 10 days.

Loss of power to pumping facilities was the most common form of outage. Under established protocols, the power network shuts down automatically after a major earthquake, whether there is damage or not, and service is not restored until inspections indicate it can be restored safely. Most of the large facilities had stand-by power generators and some mobile generators were available and used. However, SDC engineers expressed the need for additional mobile units. The mobile generators that were available were rotated in order to provide residents with at least intermittent services. One complicating factor was the rise in the water level of several drinking water wells. According to SDC engineers, the water level in one well rose by 5.3 m, another by 3 m, and two went artesian and water was pouring out of the electrical connections in the well head.

Waimakariri District Council

While the types of problems were similar, the Waimakariri District Council (WDC) was much harder hit than Christchurch, primarily due to the extensive liquefaction and the associated lateral spreading in Kaiapoi. A precautionary boil water advisory was still in effect 10 days after the earthquake. It was to be lifted on 12 September 2010, but a single sample tested positive for E-Coli and the advisory was extended.

WDC officials estimate that the system was providing water to 70% of residents within one day of the earthquake, 85% after the second day, and nearly 100% by the ninth day (noting that the water was intentionally not restored to several damaged structures). This restoration was to the private property lines, beyond which service is the responsibility of individual property owners. However, WDC crews were also working with residents to provide service all the way to their homes. In hindsight when considering repairs, WDC officials wondered if they could have restored water service more quickly by using more temporary above-ground flexible piping, as was done on the final days of restoration. Nine days after the earthquake (on 13 September 2010), 60% of Kaiapoi’s wastewater was being collected and treated at the wastewater treatment plant. However, 40% of sewage system flows were still being discharged into the river untreated. City engineers estimated that the amount of untreated wastewater would be reduced to 5% by 17 September 2010.

WDC officials felt the biggest problems were the deep gravity wastewater mains. In many cases these mains were 3 to 4 meters below ground surface with ground water only 2-m deep. In addition, some of the mains are located in the backyards of private residences, making access and subsequent repairs more difficult.

Residential Communities of Spencerville and Brooklands

In a number of residential communities, sewage and potable water were problematic immediately following the main shock. Perhaps hardest hit were the communities of Spencerville and Brooklands. At the time of the Team's visit on 13 September 2010, neither community had functioning wastewater collection systems, and Brooklands did not have potable water. Liquefaction along Lower Styx road, the primary connection between these two communities, caused ground subsidence, a rise in the water table, and uplifting of 25 manholes (Figure 7.46). Construction workers were dewatering the region during the Team’s visit and informed us that the manholes were 4-m deep. The manholes were approximately 28-46 cm above the existing road surface (Figure 7.47).

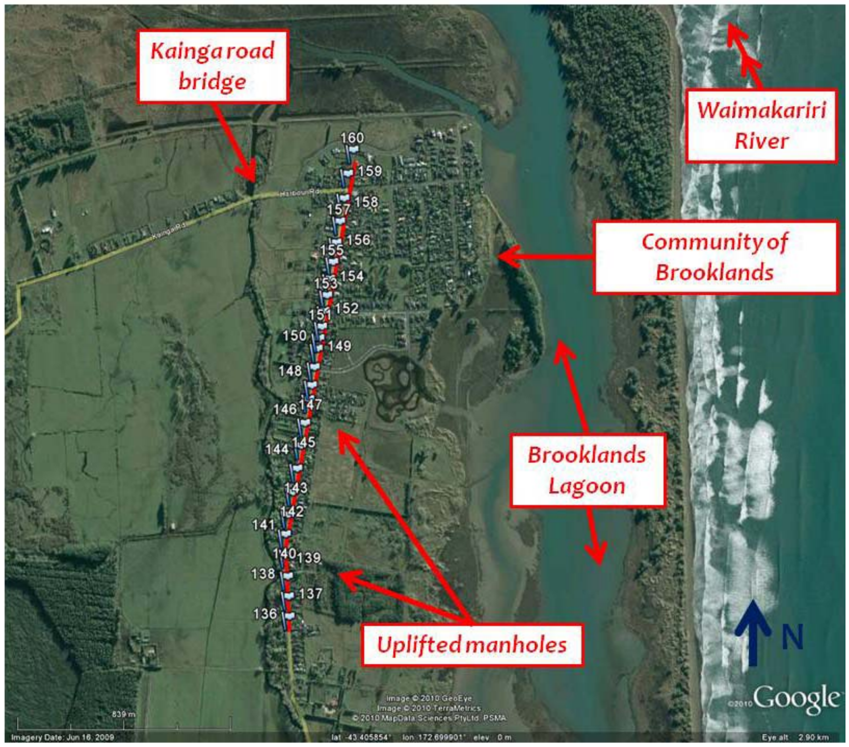


Figure 7.46 Approximately 2 km stretch along Lower Styx Road with observed uplifted manholes. (GoogleEarth image; -43.4059°, 172.6999°). Waypoints 136-160 represent locations of elevated manholes.

Figure 7.47 Uplifted manholes along Lower Styx Road, note the uplifted manholes in the background too. (-43.4113°, 172.6930°).

Electric Power

The electric power system performed well following the earthquake, with much of the good performance attributed to the hardening of the system over the last decade. No problems were noted with the generation or transmission system, and problems with the distribution systems were primarily associated with liquefaction.

Orion, the primary service provider in Christchurch, reported restoring power to 90% of customers within one day of the earthquake, with much of the remaining 10% not being restored as a precautionary measure. Each substation was individually inspected prior to restoring power, and many of the older switches were manually reset after being tripped during the earthquake. Both 66-kV and 11-kV lines are part of the system, with most of the lines located underground. The Christchurch network is old, and having many alternate routes, Orion was able to re-route power to provide service even though line breaks still existed. Of the 20 high voltage cable faults detected, 11still needed to be repaired 10 days after the earthquake. Only two substations in Christchurch went offline during the earthquake, both from settlement as a result of liquefaction. The last back-up generator was taken off-line on 8 September 2010.

Waste Management & Landfill

The Kate Valley Landfill, operated by Canterbury Waste Services, is the regional waste disposal facility for the affected area. However, the Christchurch City Council open up a cell at the closed Burwood Landfill facility to accommodate the increased volume of waste generated by earthquake recovery efforts. Furthermore, limits on the volume of incoming waste were temporarily waved at Kate Valley and the facility increased working hours to accommodate the increased volume of waste after the earthquake.

Canterbury Waste Services (CWS) resumed operation and house hold collection of waste two days after the earthquake. CWS uses collection centers throughout region and transfers the waste to Kate Valley Landfill approximately 65 kilometres north of the city. On Sunday, the day after the earthquake CWS began hauling waste collected before the earthquake from their collection centers to clear them in anticipation of increased waste tonnage. For a two week period following the event, the tonnage delivered to the landfill approximately doubled from 800-900 tons/day to 1700-1800 tons/day. Demolition debris collected in Christchurch was taken to recycling centers, with residual waste taken to the reopened cell at the Burwood landfill.

The CCC and CWS recycle approximately 70% of the total organic waste generated in the region, which means that most of the waste entering the regional landfill has a low water content and does not decompose. One of CWS's concerns was the increased amounts of high water content waste from grocery stores and grocery distribution centers entering the landfill after the earthquake and creating a potentially unstable waste body. CWS received permission to temporarily spread high-liquid waste loads on the ground at a local quarry to allow liquids to drain prior to disposal in the landfill. CWS also mixed incoming high water content wastes with MSW at the collection centers, thus reducing the water content prior to arrival of the waste at the landfill.

The Team visited the Kate Valley landfill and found that it performed as designed. The landfill is located approximately 85 kilometres from the epicenter. The landfill is a valley fill with 2.5:1 slide slopes. The lining configuration consists of an encapsulated membrane back geosynthetic clay line/geomembrane system composed of a 0.4-mm high density polyethylene (HDPE) geomembrane with 6 mm of dry bentonite adhered to it, overlain by a 1-mm HDPE liner. No slipping of the waste body or damage to the lining system was reported by the operator. No other lined structures such as dairy milking barn wastewater ponds or lined reservoirs had reported damage.

Other Lifelines

Other lifelines such as landline and cellular and telephones, fuel supply, television and radio performed well in the earthquake. While some land telephone lines were out of service, no interruption of cellular telephone service was observed. Service providers were aware of the potential for tower battery drawdown in an emergency, as was observed in the 2010 Chile Earthquake, but had installed generators at key locations and have agreements with local residents to keep them fuelled.

No interruption in fuel from Lyttelton Port of Christchurch was observed. Television broadcasting facility was undamaged and had four days of fuel in preparation for emergency power outages. The local bus service was restored on 7 September 2010.

References

Palermo et al. (2010) “Preliminary Bridge Findings,” report by the Darfield Earthquake Natural Hazard Platform Bridge Research Group