**Supplemental figure caption descriptions**

**Figure 1.** **(A)** Epicentral locations for the 22 February 2011 Mw 6.2, 13 June 2011 Mw 6.0, and 23 December 2011 Mw 6.0 earthquakes are indicated. Epicenters for other liquefaction triggering earthquakes during the Canterbury earthquake sequence (CES) are also displayed. The 4 September 2010 Mw 7.1 mainshock epicenter (not shown) was located approximately 40 km west of Christchurch. **(B)** Approximate locations of the 7-1 ka shorelines indicated with respect to the Avondale Park and Porritt Park study sites, Avonside (research area for Bastin et al., 2015), and Central Business District (CBD). Note the presence of alluvial sands and silts at both study locations. **(C)** The DEM depicts ground surface elevation (above mean sea level) for post-December 2011. The Sullivan Park (Bastin et al., 2015) and 11 Bracken Street (Quigley et al., 2013) liquefaction study sites are shown. **(D)** Ground surface observations were not recorded at the Porritt Park and Avondale Park locations but adjacent residential sections reveal the degree of cracking and sand ejection. **(F - inset)** Liquefaction ejecta (red) highly localized around edges of stands, interpreted to reflect effects of building loading and localization of shear stresses on distributions of liquefaction ejecta. Green arrow denotes eastern stand. **(F - main)** The eastern stand (green arrow) has subsided more than 0.5 to 1 m (pink) relative to surrounding sediment as a result of enhanced loading on liquefied sediments. **(G)** Anthropogenic influence of telephone pole on liquefaction ejecta localization; sand blow fed by feeder dikes that used telephone pole to eject to surface.

**Figure 2.** Modifications to the Avon River, including straightening of the river near Porritt Park and widening of the channel began sometime after 1949 and was completed before 1955. Sediment removed from the river during widening is a probable source for early anthropogenic fill placed in the area. East-west oriented subdrain lines were constructed at Porritt Park during the 1970s (see Fig. 3A). Grading and development of homes progressed toward the North and East (yellow dashed line), with final placement of anthropogenic fills at Avondale Park occurring sometime around ~1990.

**Figure 3. (B)** Note the locations for the pre-existing subdrain lines and distribution of liquefaction ejecta. **(C)** The aerial extent of surface manifested liquefaction (i.e. sand blows and sand blow arrays) was mapped using high-resolution aerial photographs following each of the main shaking episodes. The June and December surface ejecta comprise ~68% and 23% of the February output, respectively. No ejecta were observed at the study site during the 4 September mainshock event. Locations for Trench 1, Trench 2, and SCPT-1 are indicated. **(D)** Linear sand blow arrays show alignment with irrigation lines (see ‘a’ and ‘b’) and the NE and NW boundaries (see ‘a’ and ‘c’) of playing field.

**Figure 4.** **(A)** CES liquefaction features are observed crosscutting the natural sediment (NS) and anthropogenic fill stratigraphy and injecting into fill layers. Sill morphologies occur at fill layer boundaries, while pervasive sub-horizontal to irregularly shaped injection features are contained within F2 and F3. At least two episodes of liquefaction are defined by crosscutting relationships in Trench 1. LD2 dike terminates in a subdrain trench. **(B)** T1 displays the highest degree of fill layer deformation from liquefaction. Sill morphologies are observed at the boundaries between NS and F4, and F2-F3 and F1. Pervasive injection of liquefied sand into F2-F3 is observed. Liquefied sand is injected into the gravel backfill within the subdrain trench, with the probable source being the large sill (S2) developed at the F2-F3 and F1 fill boundary. Auger Boring 1 (~1.6-3.4 m) indicates the trench is underlain by silty clay changing to fine sand with minor silt and occasional granules at a depth of ~2.0 m.

**Figure 5. (A)** Sill development is observed at the boundaries between F1a and F2-F3, and between F2-F3 and F4. Chaotic injection of liquefied sediment is focused primarily into fill layers containing abundant gravel (i.e. F2-F3) and mm- to cm-scale sediment clasts. The gravel surfaces are oxidized, presumably from the interaction with Fe-rich fluids during shaking episodes. **(B)** Rip-up clasts with similar composition to underlying F2 suggest fluid velocities are high enough to capture fragments from host fill. **(C)** Lobate repositories for liquefied sand and silt form in the pre-existing liquefaction sand. Stalling (silt drapes) within the CES dikes is evident. **(D)** The CES dikes are typically vertical to subvertical within NS and become more irregularly oriented within the anthropogenic fill layers. **(E)** Fine sand is observed penetrating and wrapping around gravel and large (cm-scale) silty-clay fragments. The thin sill at the F3-F4 boundary is highly oxidized (orange-red) and could represent liquefaction during the earliest shaking episode (i.e. 4 September mainshock). **(F)** We note that oxidation is high and probably influenced by the chemical composition of the host fill sediments. **(G)** Injected sand filled the perforated pipe and penetrated the surrounding gravel backfill.

**Figure 6.** The CES liquefaction dikes (LD1-LD3) crosscut the natural sediment (NS) and anthropogenic fill (F1-F4) stratigraphy. LD1 and LD3 extend to surface. No sill development is evident within Trench 2. Soil development is evident at the top of NS implying a former ground surface. Numerous trash items (n = 24) are observed within F4, suggesting that initial placement of fill above the natural sediment was uncertified and probably dumped from a nearby source (e.g. river dredgings). The location and result of the 14C sample are indicated. Auger Boring 2 (~1.7-2.9 m) indicates the trench is underlain by well sorted, fine sand that contains occasional granules.

**Figure 7.** Photos of CES liquefaction features in T2. **(A)** CES liquefaction dike crosscuts natural sediment and anthropogenic fill layers in T2. **(B)** Sand is observed penetrating gravel deposits and sediment fragments. **(C)** Oxidation of the CES liquefaction dike within F4 has occurred within the last ~7 years. **(D)** Liquefaction dikes display a general NW-SE orientation, consistent with the alignment of the corresponding sand blow array at surface. Dike orientation suggests negligible influence from the Avon River, located as close as ~300 meters to the North. **(E)** Mottling (yellow-orange) from oxidation is evident in the surrounding natural sediment but not at dike boundaries. We find no evidence of pre-CES liquefaction dikes in T2 trench bottom.

**Figure 8.** The amount of surface ejecta was highest during the February (15141 m2) and June 2011 (11821 m2) earthquakes. During the February earthquake, ~41% of Porritt Park was covered by liquefaction ejecta. Note the strong east-west trend of liquefaction ejecta attributed to the influence of the underlying 1970 subdrain system and NW-SE trend of ejecta (most evident in NW section of park) attributed to the underlying effect of meander scroll bars.

**Figure 9.** **(A)** Observed (n=692) and inferred (655) sand blow centers are shown. Three distinct linear trends are shown and are established from the geometry/orientation of ejecta polygons and the alignment of linear sand blow arrays. The red lines (E-W) depict locations for 1970 drainage pipes. The yellow (NW-SE) and blue (NE-SW) lines are attributed to the influence of underlying meander scroll bars. **(B)** Total area of recurrent liquefaction was 4115 m2 and represented ~11% of the Porritt Park area. The red polygons with white diagonal lines depict areas of recurrent surface liquefaction occurring above the 1970 subdrain system. Total area of recurrent liquefaction overlying the 1970s subdrain lines was 1533 m2 and comprised ~37% of the total recurrent liquefaction area (~4% of Porritt Park area). **(C)** Total % area of surface liquefaction ejecta as a function of average median PGA and Mw 7.5-weighted PGA per Bradley and Hughes (2012a,b) and O’Rourke et al. (2012) for each of the major CES events (4 September 2010, 22 February 2011, 13 June 2011, and 23 December 2011) at Avondale Park and Porritt Park. A positive correlation is obtained between the areal extent of liquefaction ejecta and the intensity of shaking at Avondale Park and Porritt Park.

**Figure 10.** 100 MHz and 200 MHz frequency are depicted. The 200 MHz trace reveals subsurface pipes not apparent in the post-CES aerial photographs. It appears that ground deformation is most severe in areas where subsurface drainpipes and distinct scroll bar reflections interact (see C and D), although this could be partially influenced by lateral spreading.