CERA

Canterbury Earthquake Recovery Authority

Area-wide geotechnical information summary for CERA zoning review panel

This document contains all the area-wide geotechnical information which was considered by CERA as part of the process for making flat-land zoning decisions, and the subsequent zoning review.

The report includes mapping of ground cracking, liquefaction and lateral spreading observations, LiDAR ground elevation and vertical ground movements. At the end of the report is a summary of the area-wide geotechnical considerations and map citations. They are written in plain English where possible, but do contain technical information where this is necessary to accurately explain the nature of investigations, and the effects of the earthquakes on the land.

Green zones were declared by CERA in areas where damage can be addressed on an individual basis. Many properties in the green zone have experienced significant land and building damage. The important difference between these properties and those in the red zone is that it is possible to address this damage on an individual property-by-property basis. Technical guidance documents have been developed by Building & Housing to provide recommended processes for assessment, repair and rebuilding of homes in all parts of the green zone which have been damaged by the Canterbury earthquakes.

Red zones were declared by CERA in areas where there is area-wide damage (implying an area-wide solution) and an area-wide engineering solution to remediate the land damage would be uncertain, disruptive, not timely, nor cost effective. There was a range of land and building damage experienced across red zone areas – damage was mostly severe, but on some individual properties there may have only been minor damage. The important difference between these properties and those in the green zone is the need to address the engineering challenges faced by the wider area before individual properties can be repaired or rebuilt.

For more information on the criteria agreed by Cabinet to determine green and red zones please refer to the June 2011 Cabinet minute at http://cera.govt.nz/cabinet-papers

More information on the findings of the review is available on the CERA website at http://cera.govt.nz/zoning-review, including the following documents:

- Cabinet Minute and Paper – Zoning Review Framework
- Cabinet Minute and Paper – Findings of the Canterbury Zoning Review Advisory Group
- Zoning Review Advisory Group minutes

Further area-wide geotechnical information, including suburb-specific factsheets, is also available on the EQC website at http://canterbury.eqc.govt.nz/news/reports

Figure 1 – CERA residential red zone and Department of Building & Housing (DBH) technical categories

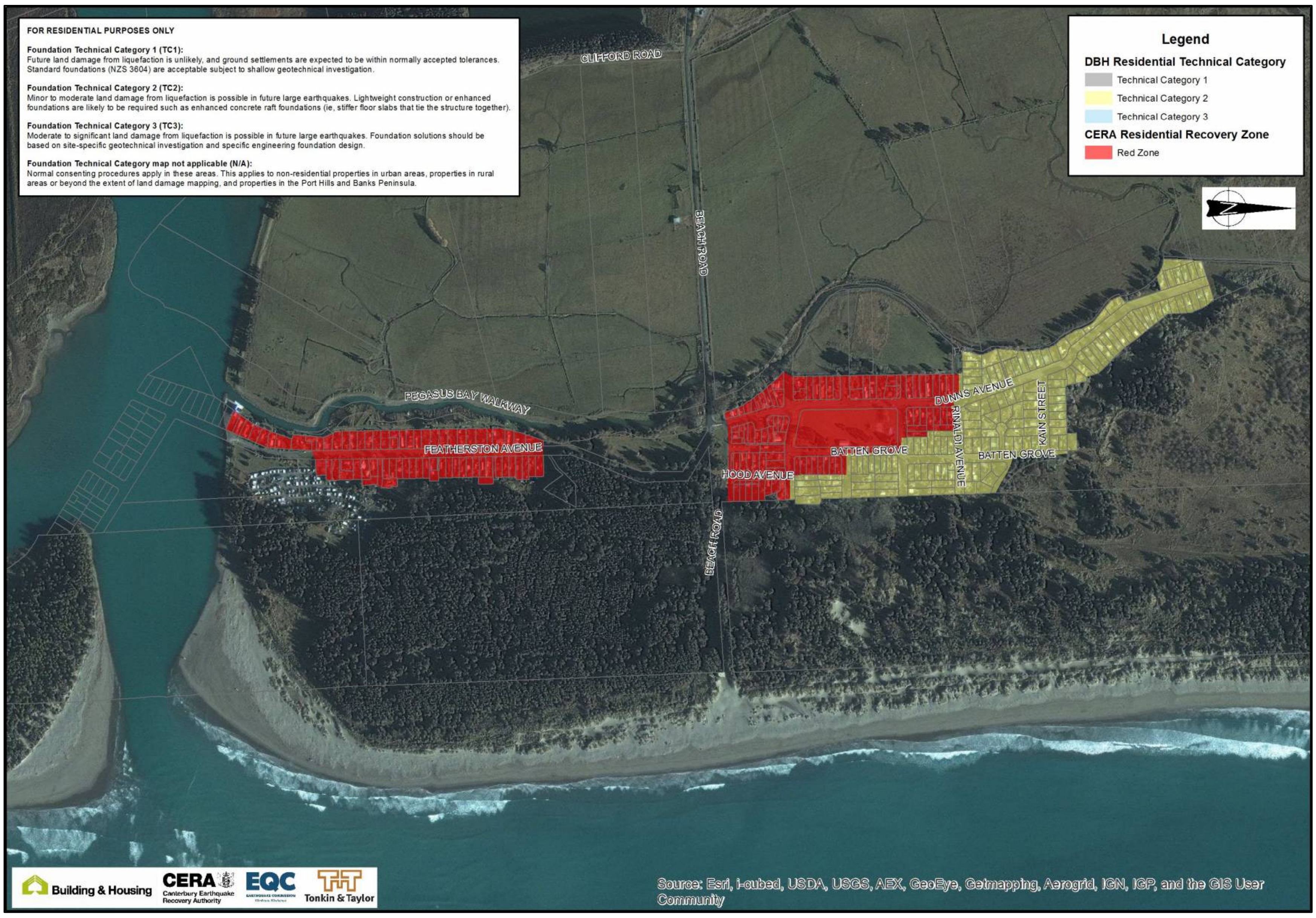


Figure 2 – Observed ground crack locations

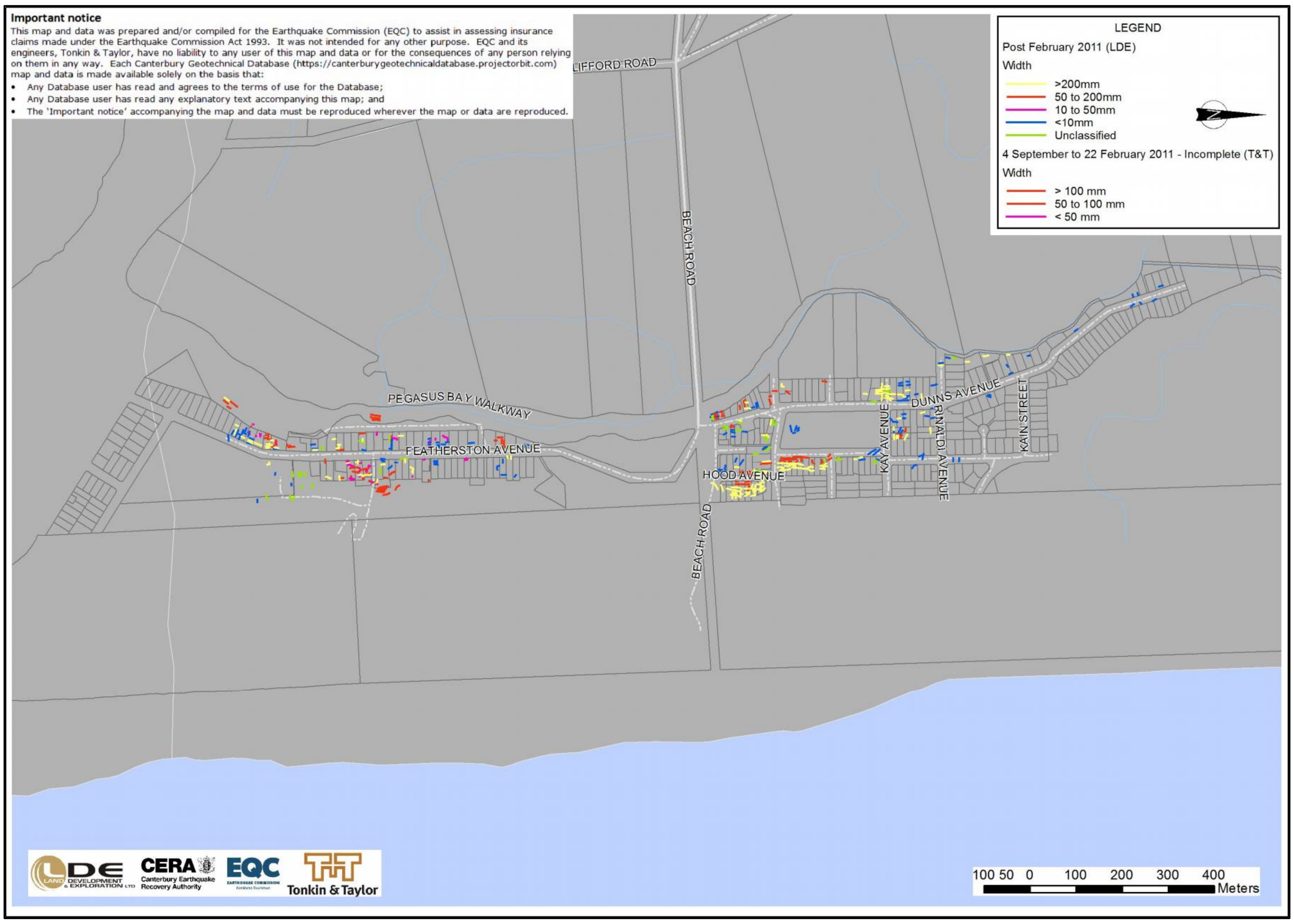


Figure 3 – Ground surface observations of liquefaction and lateral spreading following 4th September 2010 earthquake (from property-level ground mapping)

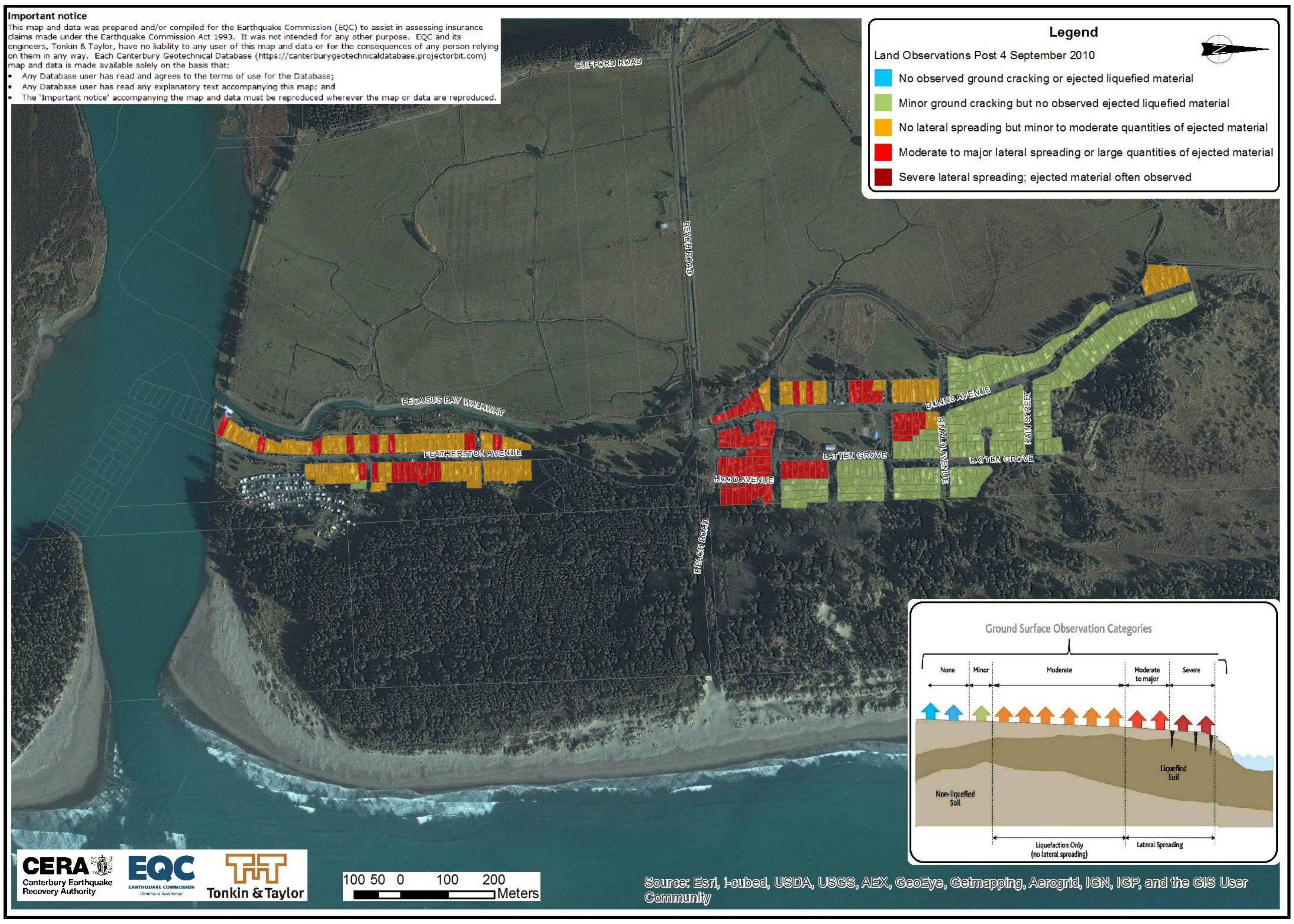
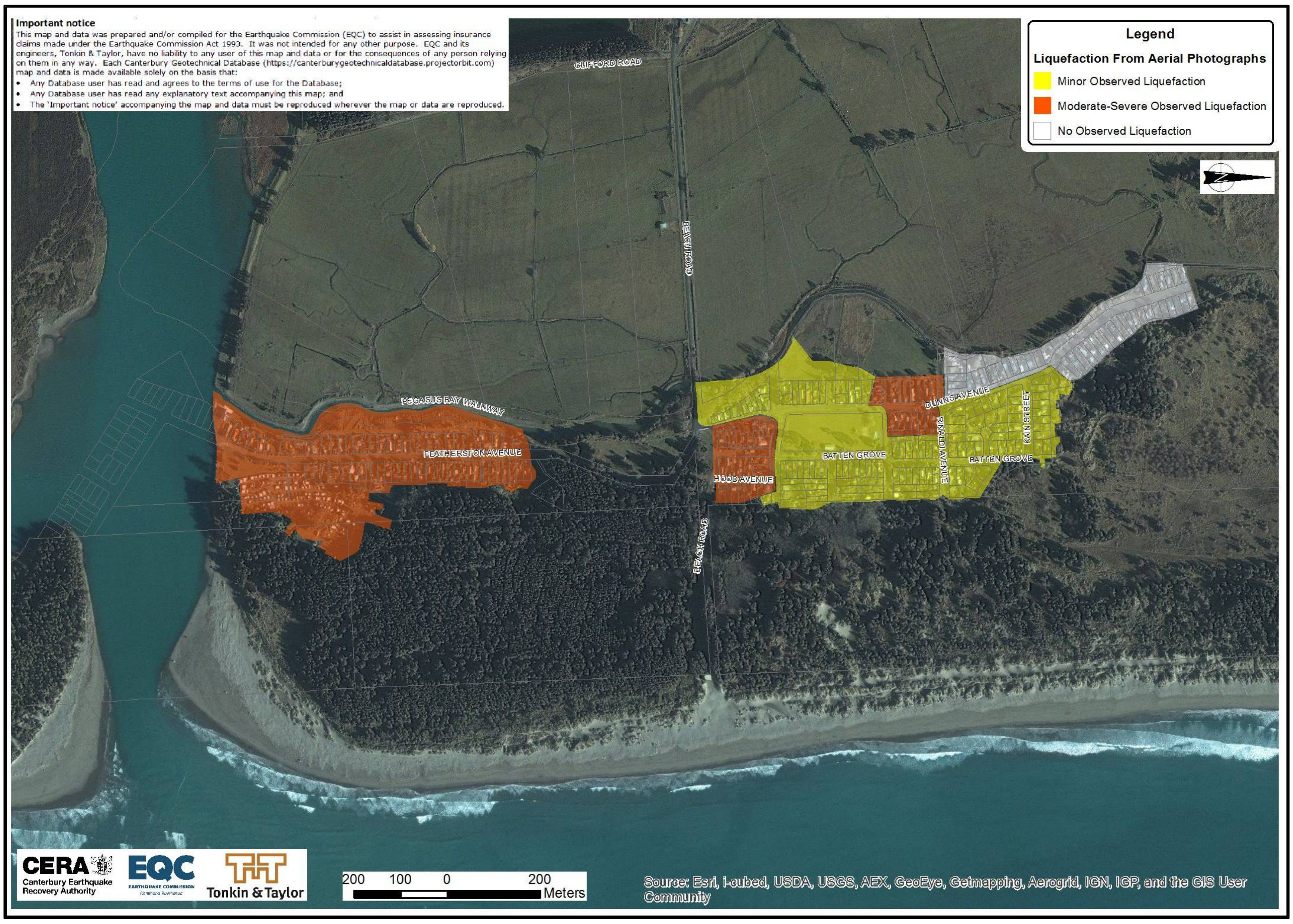


Figure 4 – Ground surface observations of liquefaction and lateral spreading following 22nd February 2011 earthquake (from air-photo interpretation)



Please note that the colour coding used on these ground surface observation maps has completely different meaning to colours used by CERA for land zoning and DBH for technical categories.

Figure 5 – Ground surface observations of liquefaction and lateral spreading following 13th June 2011 earthquake (from steet-level ground mapping)

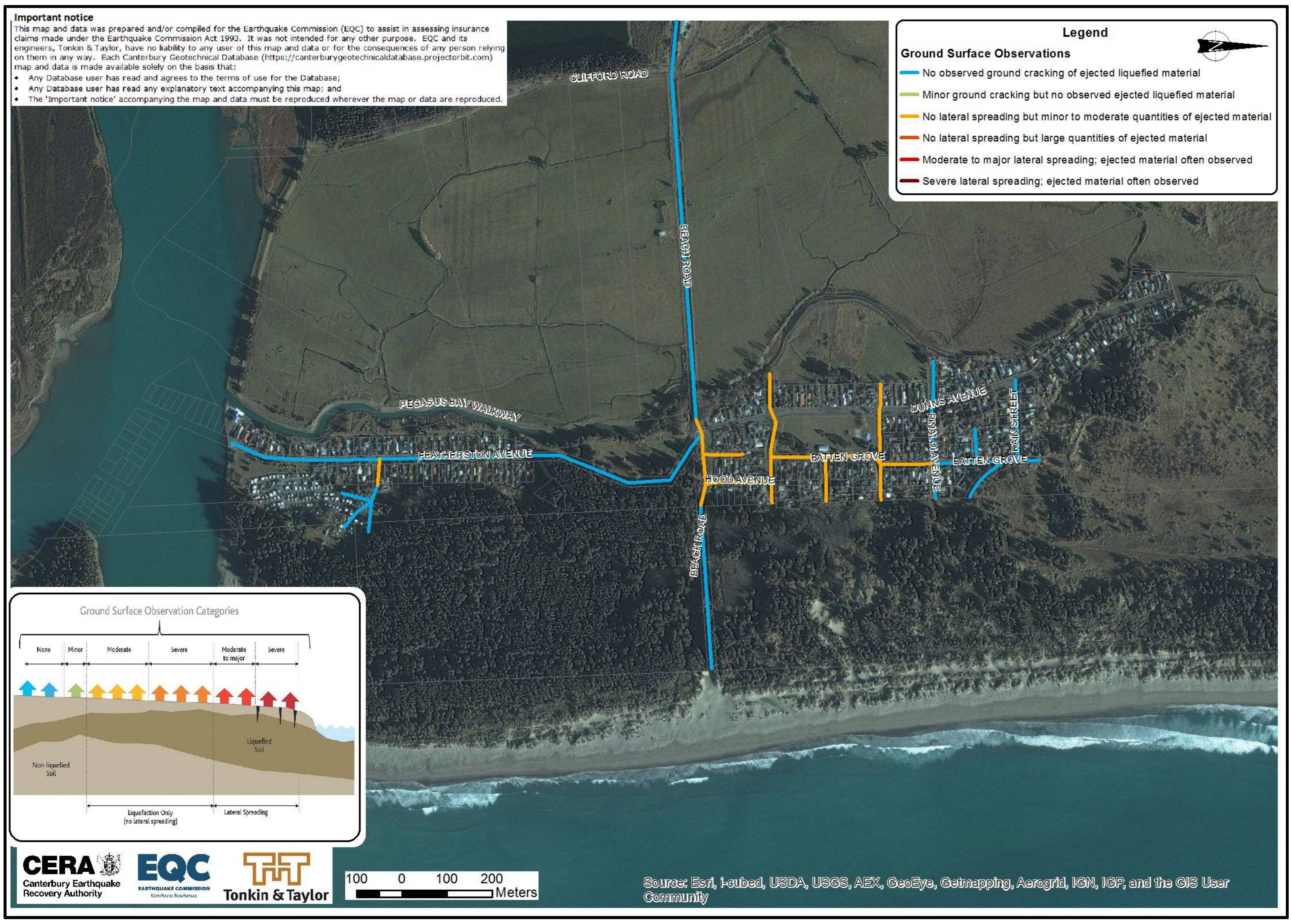


Figure 6 – Status of wastewater network

This area is not covered by the wastewater network maps we have obtained from Waimakariri District Council.

For an up to date assessment of the infrastructure network, the Council should be consulted.

Figure 7 – Ground surface elevation from February 2012 LiDAR survey

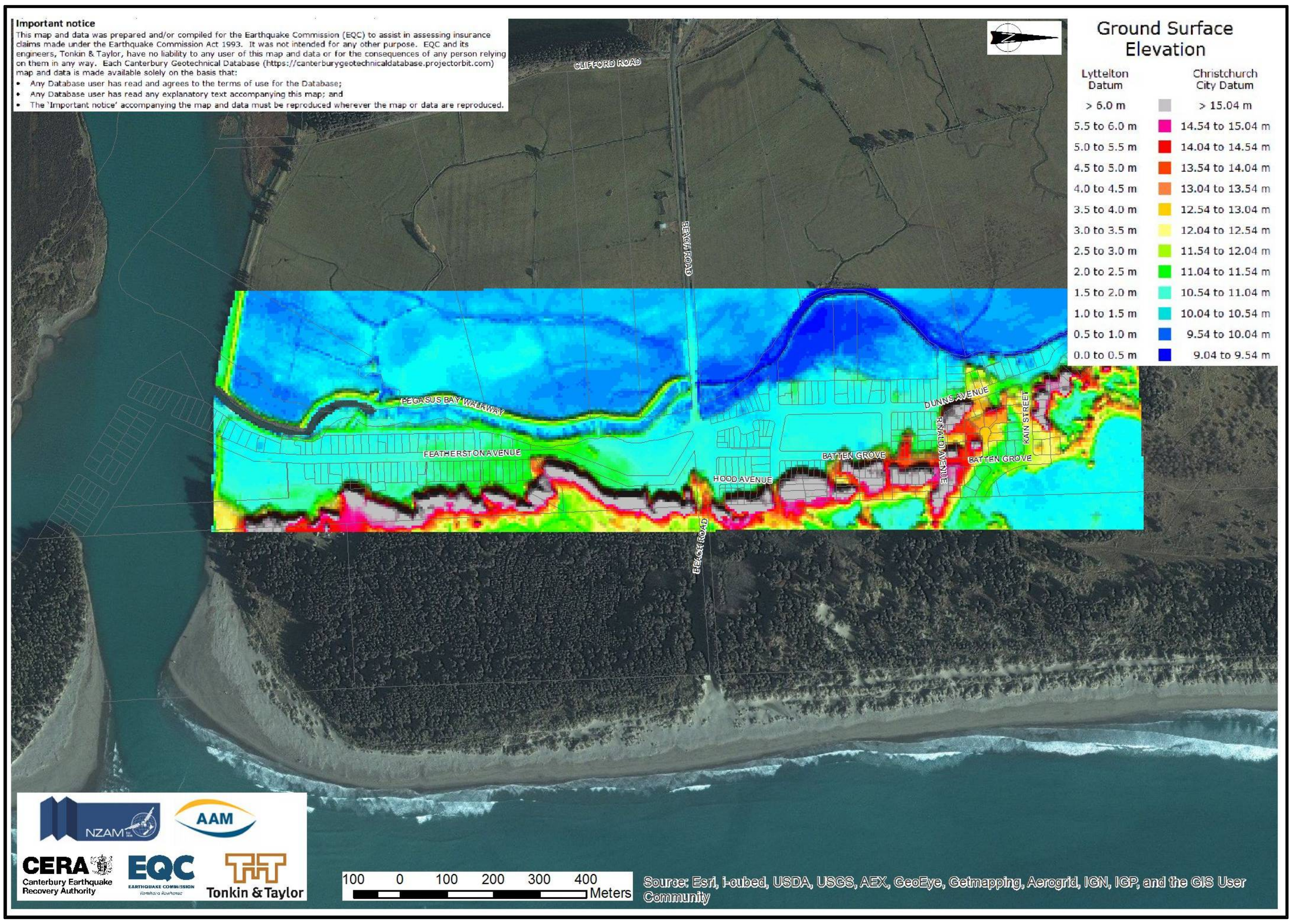


Figure 8 – Change in ground elevation between LiDAR in July 2005 and February 2012, with regional tectonic component of ground displacement removed

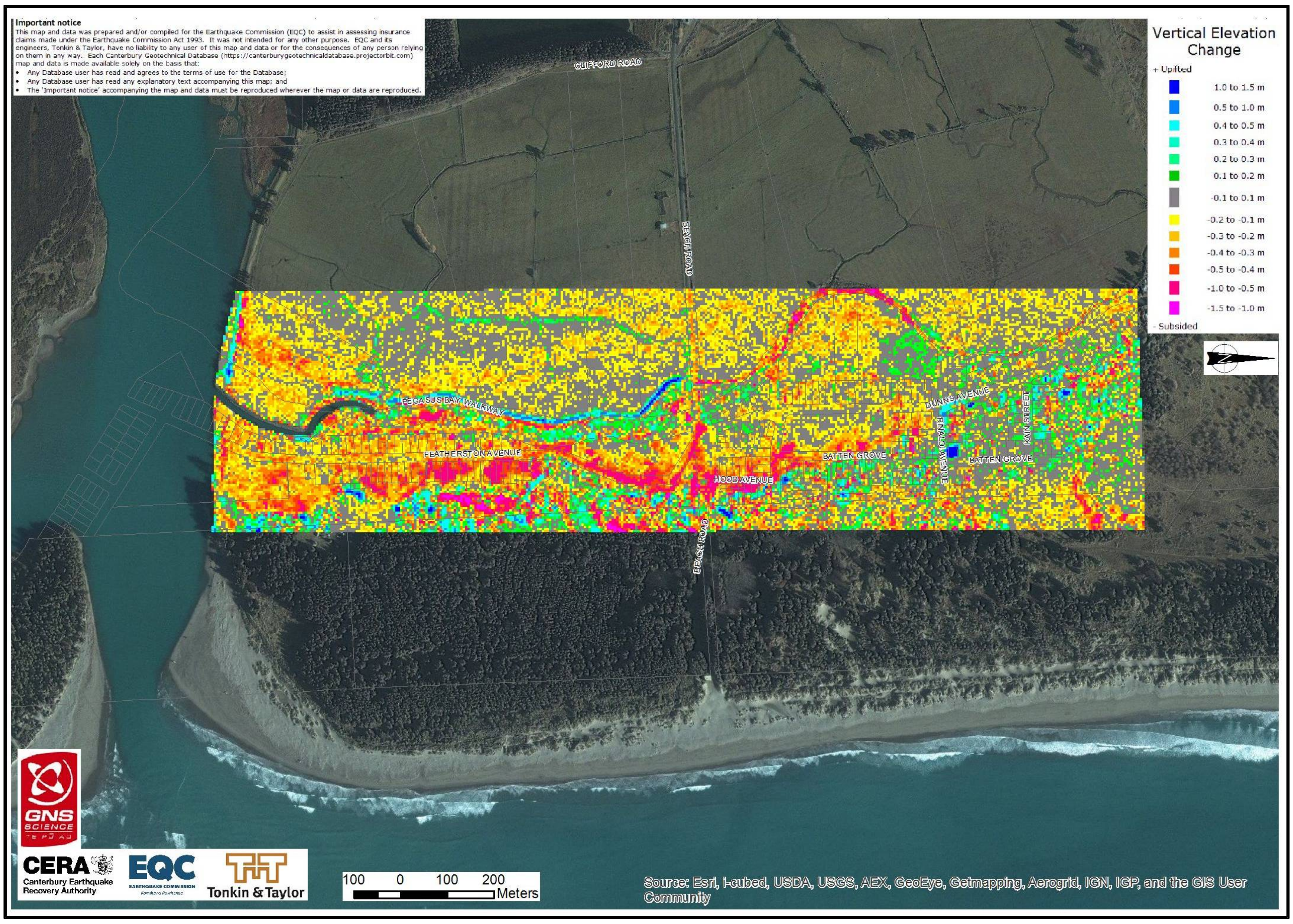


Figure 9 – Locations of suburb-wide ground investigations undertaken by EQC following September 2010 and February 2011 earthquakes

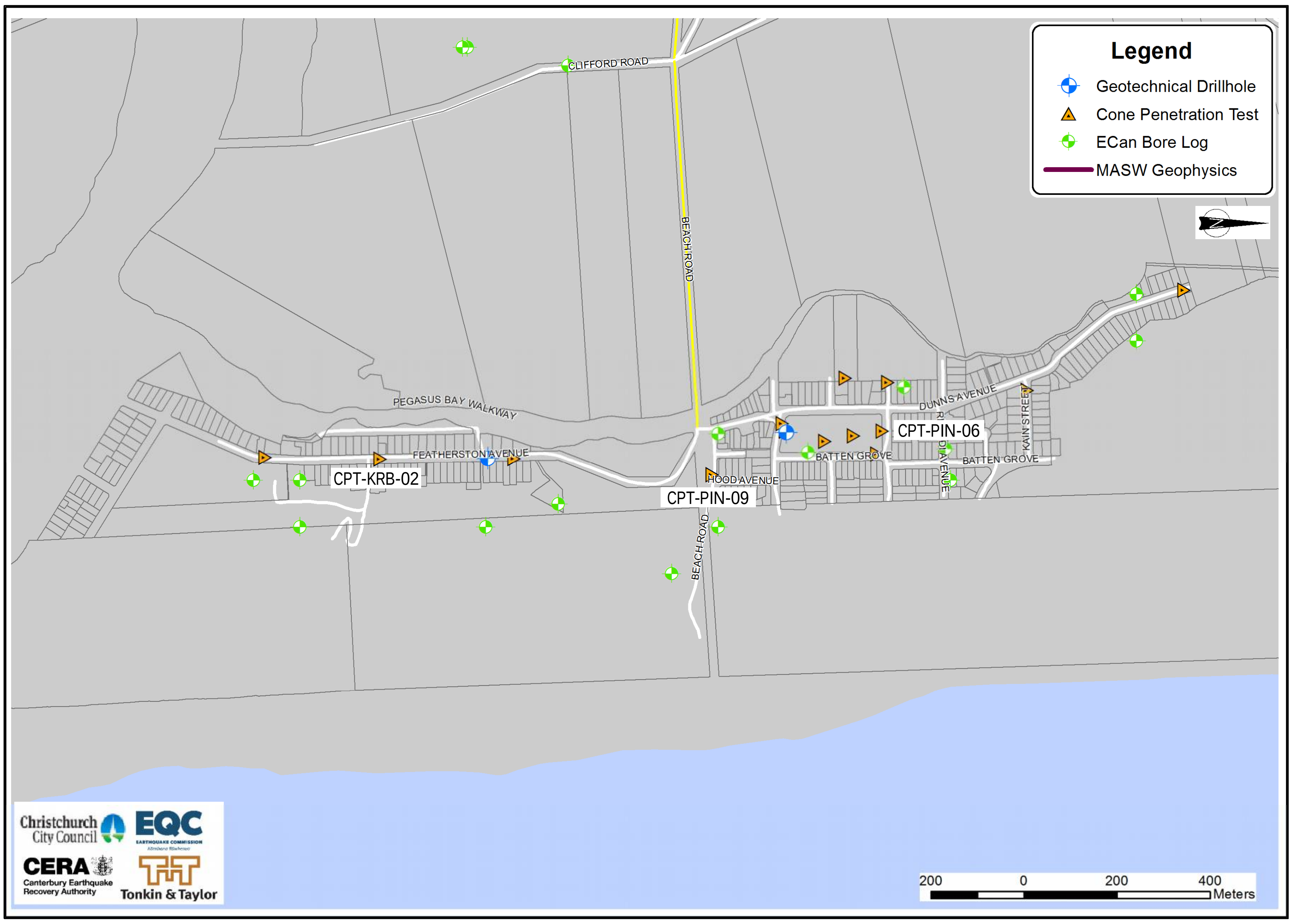


Figure 10 – Example cone penetration test (CPT) results

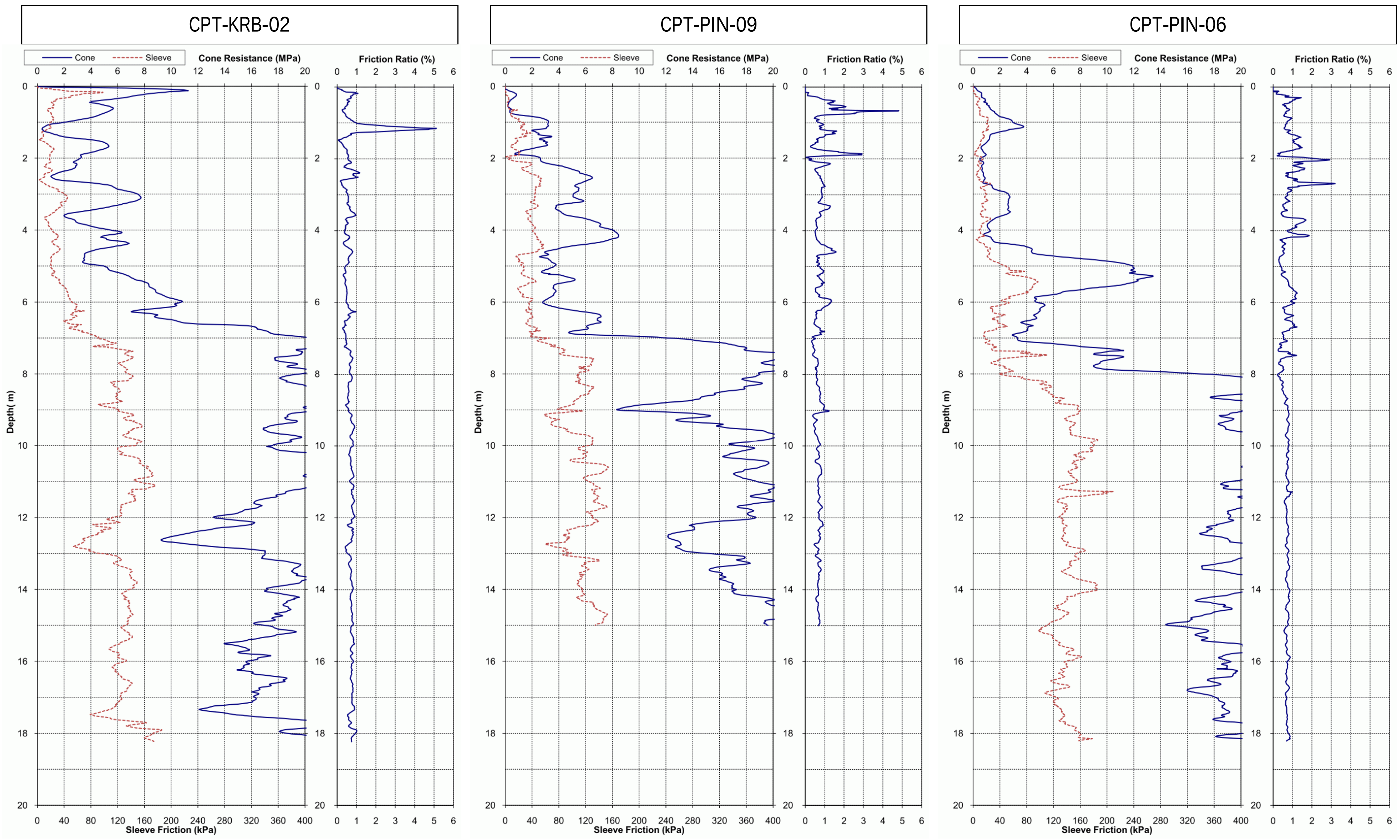


Table 1 – Area-wide geotechnical and engineering considerations for Pines Beach to Kairaki Beach

Location	Area-wide geotechnical issues	Area-wide engineering works which would be required to enable repair and rebuilding to occur
Current red zone, adjacent to Kairaki Creek and at the sand dune edge.	Extensive moderate large-scale lateral ground movement has occurred towards Kairaki Creek, and in the sloping ground at the front edge of the sand dunes.	*Area-wide perimeter treatment works required:* Large-scale deep perimeter treatment works would be required to reduce the potential for lateral ground displacement in future earthquakes to a level that can be tolerated by robust TC3-type house foundations. As well as mitigating the existing lateral spreading hazard, these works would also need to protect against the additional driving force for lateral spreading which would be created by filling up the land to provide suitable building platforms for rebuilding. These works would likely need to comprise a strip of ground improvement about 8m deep and about 15 - 30m wide, along the full length of the riverbank in this area. Significant area-wide engineering works would also be required to stabilise the sloping ground at the front edge of the sand dunes. This could take the form of deep ground improvements and/or flattening and reinforcement of the sand dune edge.
Current red zone	Moderate to severe liquefaction has occurred. Very low lying ground with very shallow groundwater and deep deposits of soils with high susceptibility to severe liquefaction.	*Area-wide earthworks required:* Due to the very thin and weak surface crust in this area, combined with the deep thickness of soft and highly liquefiable soils, standard individual foundation solutions are unlikely to be feasible. Up to about 1m of new fill would be required to raise the land to provide a suitable building platform for rebuilding houses. Due to the height of fill required, combined with the weak and highly liquefiable soils, it is unlikely to be feasible to place this fill on an individual property-by-property basis. Placing this thickness of fill on individual properties in this situation would give a high risk of large ground deformations in a future earthquake, and worsen the already significant existing lateral spreading hazard. To construct this fill, even on an area-wide basis, it would be necessary to implement specialised engineering strengthening or retention works to mitigate these issues. Filling of individual properties may also lead to issues of stormwater ponding on adjacent properties that are not raised. These area-wide earthworks would require all structures and vegetation (and possibly also infrastructure) to be removed to allow filling to be efficiently undertaken, effectively the same as developing a new subdivision from scratch.
Current green zone	Little or no evidence of liquefaction was observed at the ground surface (such as ejected sand). In some areas minor ground cracking was observed, likely to be related to minor liquefaction at depth and/or shaking movements of the sand dunes.	*No area-wide works required:* The observed land performance, and the general ground conditions inferred from the suburb-wide ground investigations, indicate that insurance claim settlement, repair or rebuilding is likely to be feasible on an individual property-by-property basis, following the guidance provided in the DBH document "Revised guidance on repairing and rebuilding houses affected by the Canterbury earthquake sequence". Based on the initial suburb-wide ground investigations, it appears that all TC2-type foundation systems included in the DBH guidance document are likely to be feasible in this area: robust raft slabs, deep piles, or surface structures with shallow foundations.

Important notice:

Figures 2, 3, 4, 5, 7 & 8 were created from maps and/or data extracted from the Canterbury Geotechnical Database (https://canterburygeotechnicaldatabase.projectorbit.com), which were prepared and/or compiled for the Earthquake Commission (EQC) to assist in assessing insurance claims made under the Earthquake Commission Act 1993. The source maps and data were not intended for any other purpose. EQC and its engineers, Tonkin & Taylor, have no liability for any use of the maps and data or for the consequences of any person relying on them in any way. This "Important notice" must be reproduced wherever Figures 2, 3, 4, 5, 7 & 8 or any derivatives are reproduced.

Map citations and background details:

Fig 2 Canterbury Geotechnical Database (2012) *"Observed Ground Crack Locations"*, Map Layer CGD0400 - 23 May 2012, retrieved 6 July 2012 from https://canterburygeotechnicaldatabase.projectorbit.com/

Crack locations were mapped in order to infer the general direction, magnitude and extent of the lateral ground movements. The mapping objectives changed in response to the varying situation following the two earthquakes. Observations after the 4 Sept 2010 Earthquake were principally for insurance claim settlements. The crack widths were recorded in property-by-property observations, but cracks were not tracked across property boundaries and only a portion of properties were mapped before the 22 Feb 2011 Earthquake. Cracks were mapped at a scale of 1:5000 to 1:10000 for about two weeks following the 22 Feb 2011 Earthquake in order to rapidly identify the extent of lateral spreading following the earthquake. The individual crack widths were not recorded. From early March 2011, cracks were generally mapped at a scale of 1:2000 and classified according to their maximum width. Cracks were tracked through properties in order to identify regional patterns.

The crack mapping is incomplete and only observations made by the mapping teams are presented. In particular, the mapping following the 4 Sept 2010 Earthquake was incomplete before the 22 Feb 2011 Earthquake occurred and subsequent mapping remains incomplete within the residential 'red zone' areas. Also, cracks in roads were often not able to be mapped because many were filled and the roads resealed before a mapping team arrived.

Fig 3 & 5 Canterbury Geotechnical Database (2012) *"Liquefaction and Lateral Spreading Observations"*, Map Layer CGD0300 - 23 May 2012, retrieved 6 July 2012 from https://canterburygeotechnicaldatabase.projectorbit.com/

The quantities of material ejected due to liquefaction and observations of lateral spreading were collated from on-foot rapid inspection of individual properties following each significant earthquake. The observations were categorized according to the quantity of ejected material observed on the ground surface and according to the presence or absence of evidence of lateral spreading. Each of these three categories was further subdivided according to the severity. The colour coding used on these maps has completely different meaning to colours used by CERA for land zoning and DBH for technical categories.

The observations were collected for the Earthquake Commission and were only made in residential areas. The mapping only identified liquefaction and lateral spreading that was visible at the surface at the time of inspection. Liquefaction may have occurred at depth without obvious evidence at the surface and evidence of liquefaction may have been removed before the inspection. (Removed material may be identifiable within the aerial photographs that were taken within a day or two of the earthquake.)

The properties were not all inspected between each pair of consecutive earthquakes (e.g. between 4 Sept 2010 and 22 Feb 2011) so the extent of the land deformations is most likely incomplete. Also, some observations following the 22 Feb 2011 and 13 Jun 2011 earthquakes could have been induced by preceding earthquakes.

Fig 4 Canterbury Canterbury Geotechnical Database (2012) *"Liquefaction Interpreted from Aerial Photography"*, Map Layer CGD0200 - 23 May 2012, retrieved 6 July 2012 from https://canterburygeotechnicaldatabase.projectorbit.com/

A regional-scale map showing the extents of ejected liquefaction material interpreted from aerial photographs. The quantity of ejected liquefaction material deposited on the streets was visually identified using the aerial photographs. The region boundaries were aligned with road centre-lines and property boundaries rather than the boundaries of the individual surface features being mapped.

MODERATE to SEVERE: Roads had either ejected material or wet patches wider than a typical vehicle width. Ejected material in grass or on roads. Groups of 2-3 ejected material 'boils' within properties or parks.
MINOR: Roads had either ejected material or wet patches narrower than a typical vehicle. One or two ejected material 'boils' within a property or park.
NONE: None of the above features were observed.

The photographs were of varying quality and light conditions. Shadows from low sun angles in some areas and sets of photographs may have been misidentified as ejected liquefaction material. Water from burst pipes or springs could also be misidentified as ejected material. Conversely, ejected material may have been obscured from view or removed before the photographs were taken. Photographs were not available for all areas of the city. These maps should be used in conjunction with the associated Aerial Photograph and property-scale observations to form a complete picture of the extent and severity of the liquefaction.

Fig 7 Canterbury Geotechnical Database (2012) *"LiDAR and Digital Elevation Models"*, Map Layer CGD0500 - 23 May 2012, retrieved 6 July 2012 from https://canterburygeotechnicaldatabase.projectorbit.com/

LiDAR was acquired following each of the significant earthquakes. A digital elevation model was developed from each supplied LiDAR set by averaging the ground-return elevations within a 10 m radius of each grid point. Metadata supplied with the source LiDAR indicates a vertical accuracy of ±0.07 to ±0.15 m (excluding GPS error and Geoid modelling error) and 0.40 to 0.55 m horizontal. The pre-earthquake LiDAR has lower accuracy and sparser LiDAR point sets than the post-earthquake sets.

Fig 8 Canterbury Geotechnical Database (2012) *"Vertical Ground Movements"*, Map Layer CGD0600 - 23 May 2012, retrieved 6 July 2012 from https://canterburygeotechnicaldatabase.projectorbit.com/

Vertical elevation changes between LiDAR sets that approximate the vertical ground movements during significant earthquakes Elevation changes were calculated as differences between pairs of Digital Elevation Models (DEM). Local vertical movements were calculated as differences between the 'observed' elevation differences and the regional tectonic displacement from GNS Science dislocation models of the vertical tectonic movements during each earthquake.

All of the movements are differences between DEMs and are inherently less accurate than their source DEM's. The pre-earthquake source DEM is less accurate than the post-earthquake DEMs. Some of the DEMs have visually distinguishable lines or ripples within the colour bands that are almost certainly artefacts from the data acquisition and subsequent processing rather than from physical vertical movements. Notable examples are several approximately NNE-SSW swathes visible in the Feb 2011 difference set and an almost E-W line at 43.48°S in the 13 Jun 2011 difference set.