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

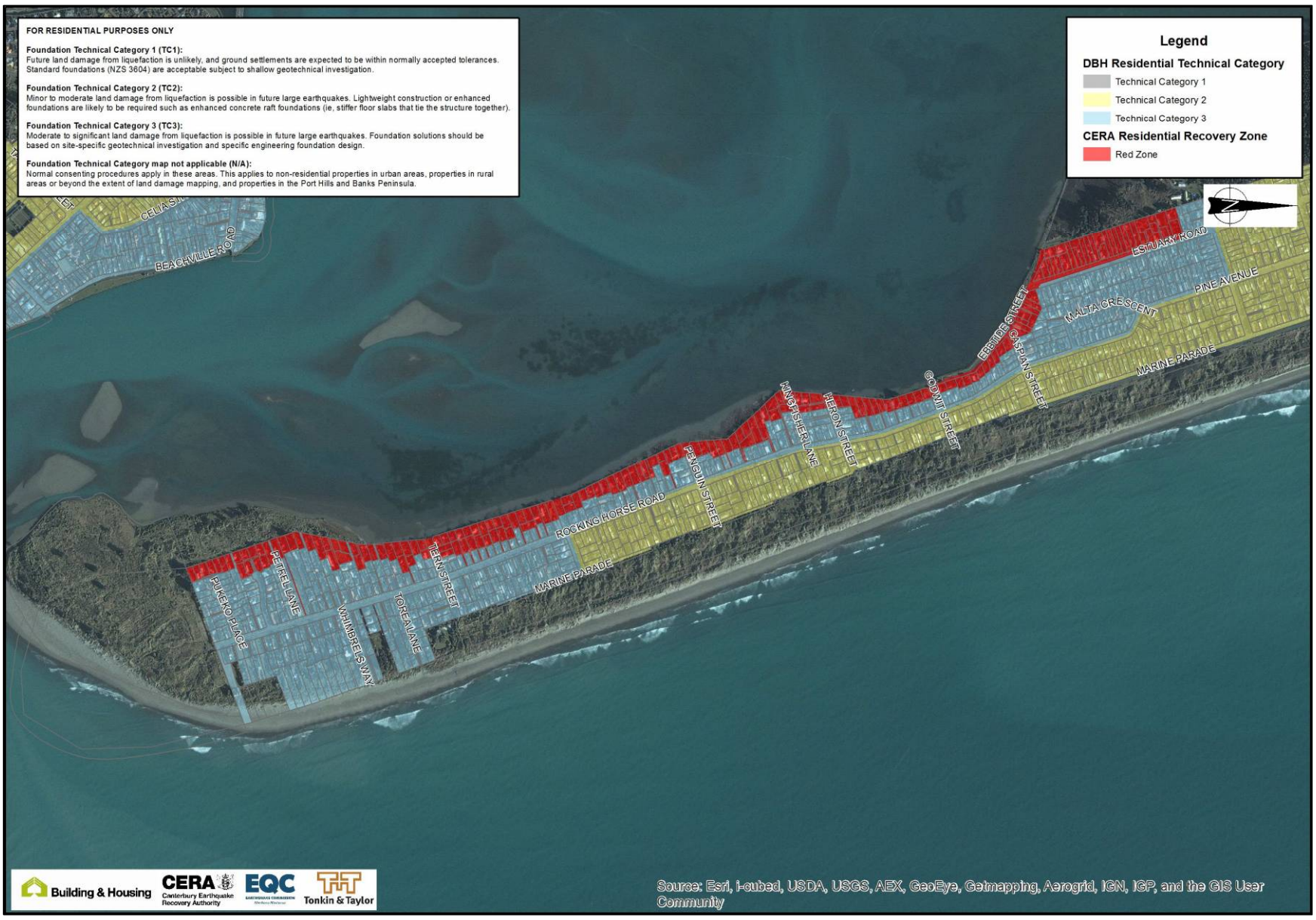



Figure 2 – Observed ground crack locations

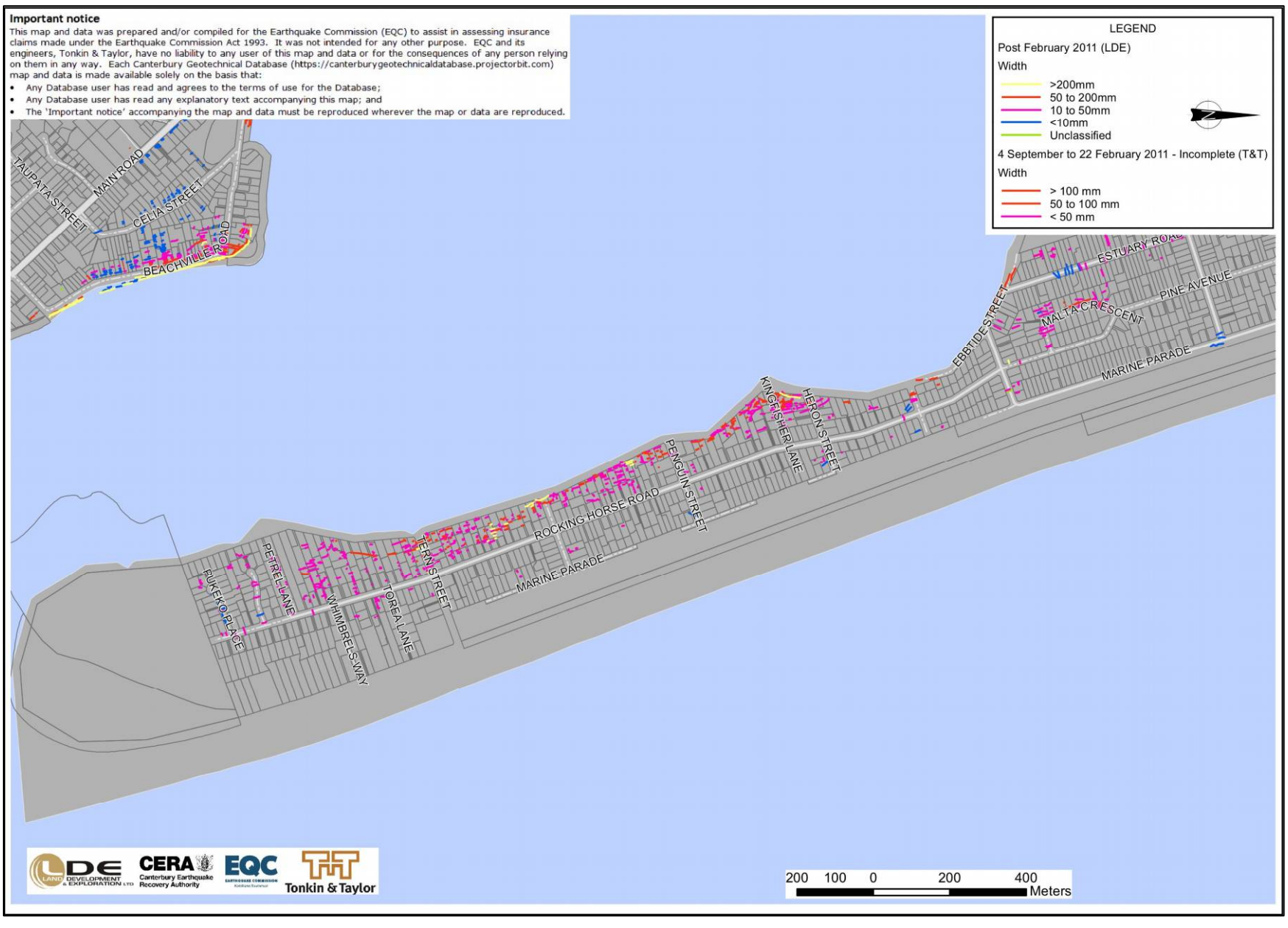


Figure 3 – Ground surface observations of liquefaction and lateral spreading following 4th September 2010 earthquake (from property-level ground mapping)

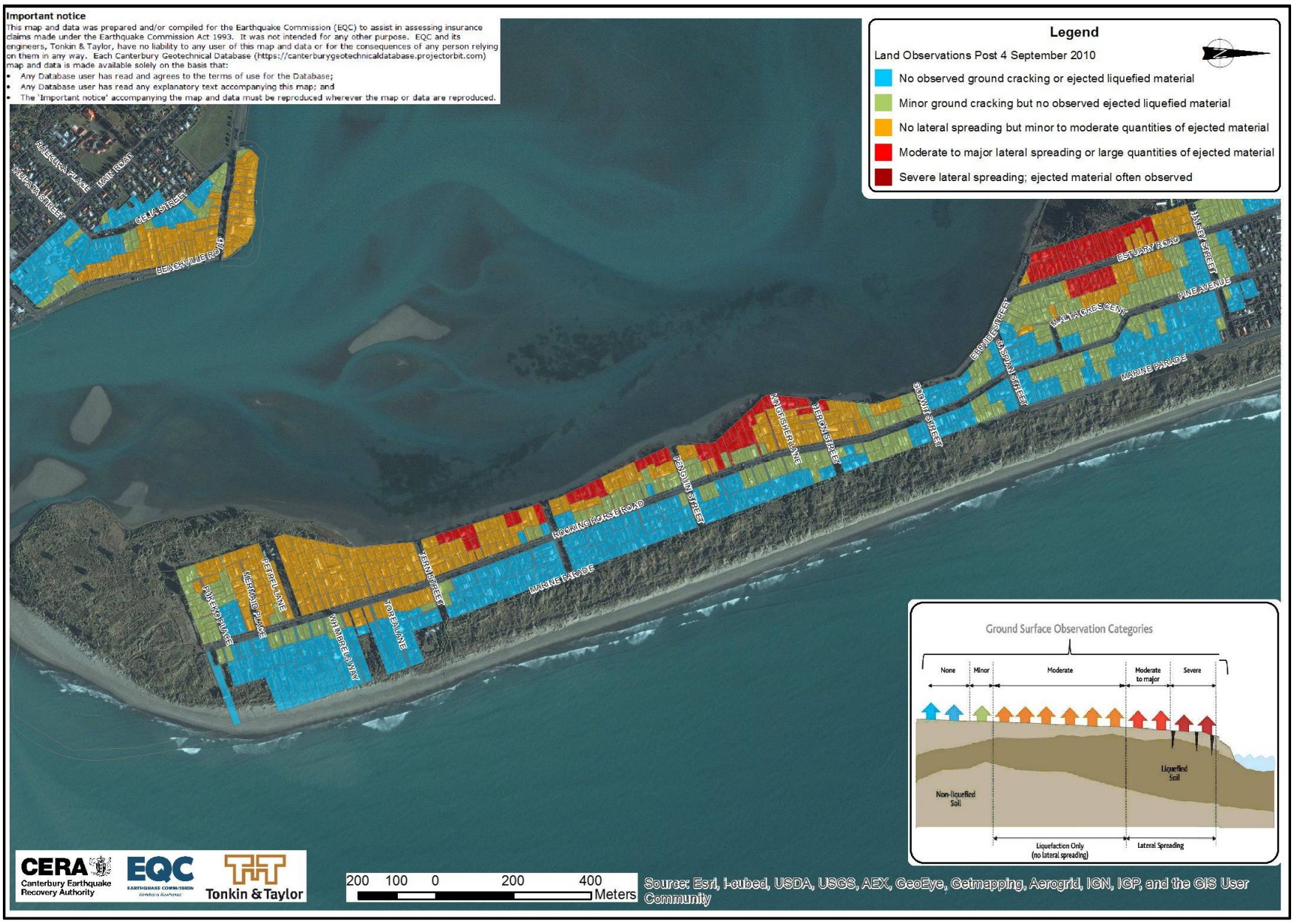
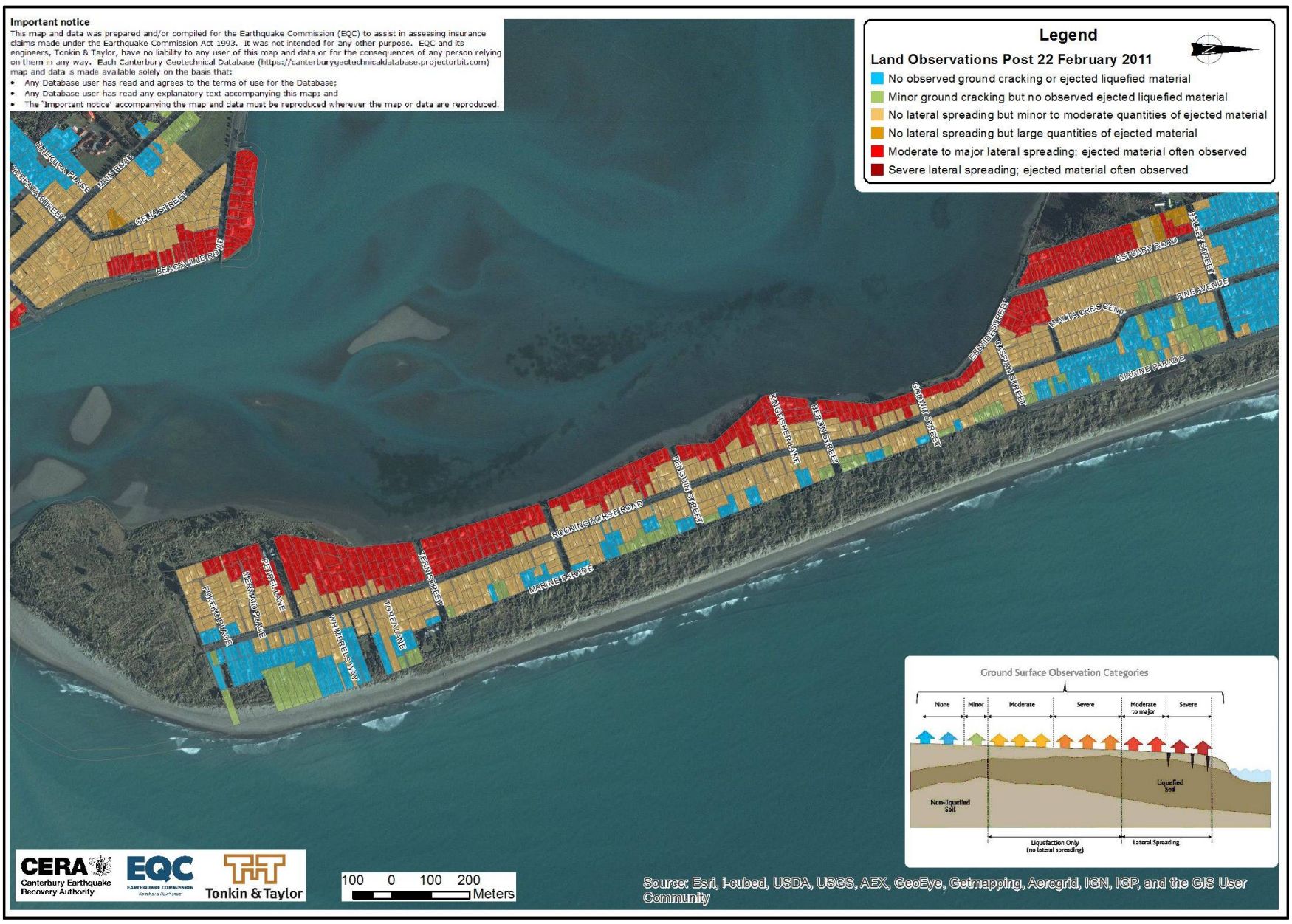



Figure 4 – Ground surface observations of liquefaction and lateral spreading following 22nd February 2011 earthquake (from property-level ground mapping)




*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)

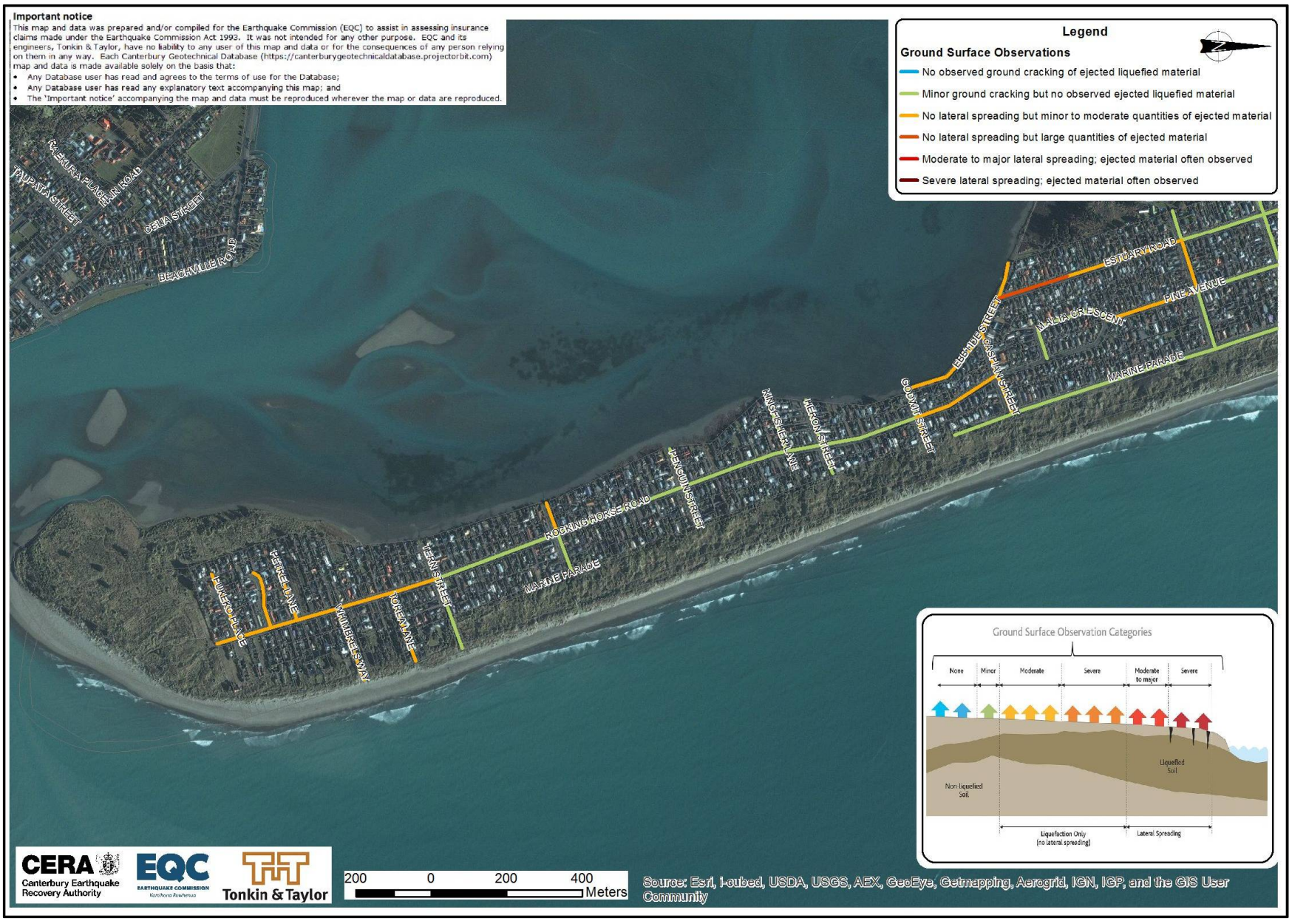
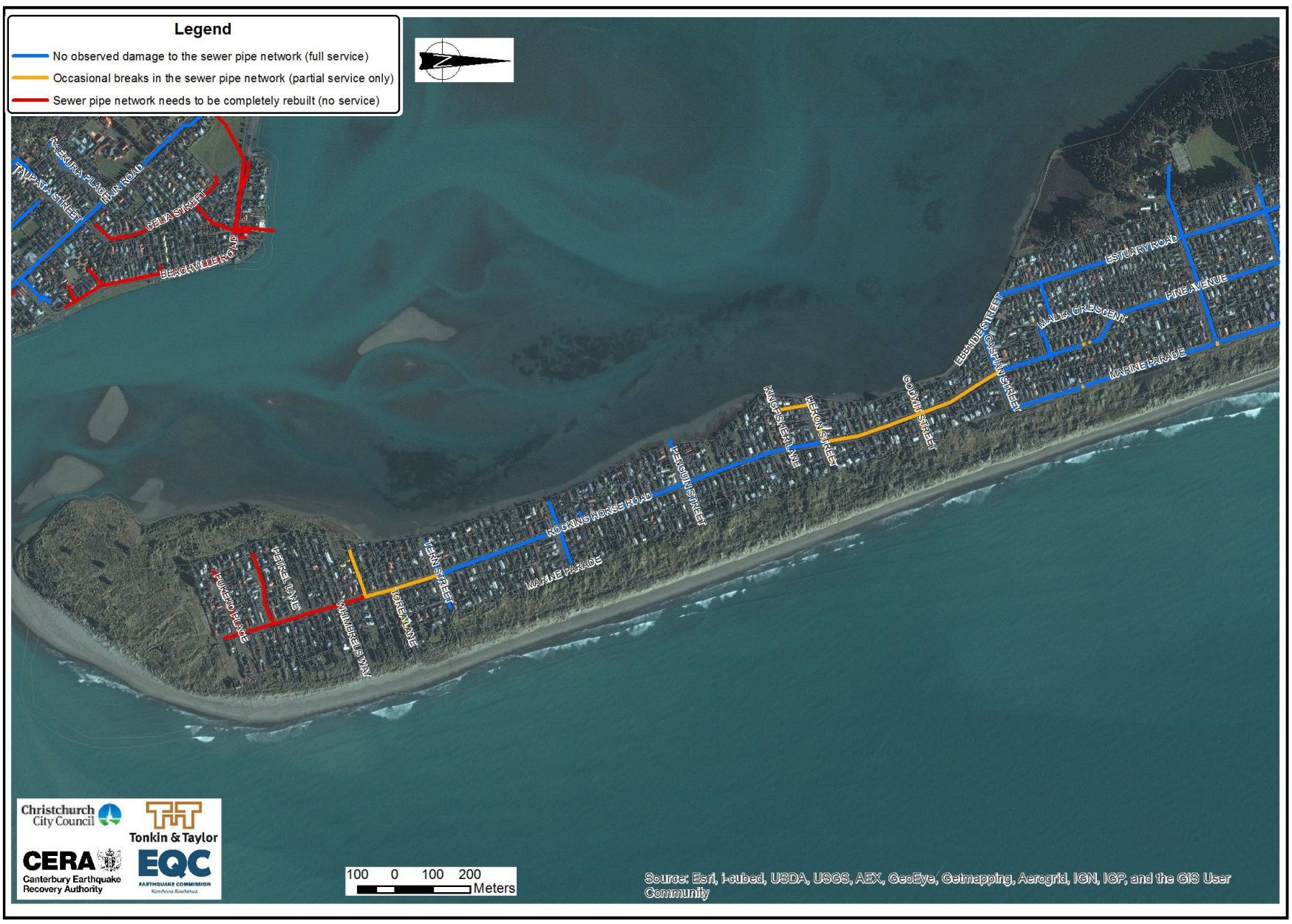



Figure 6 – Status of wastewater network as assessed at 20th April 2011 (NOW SUPERSEDED)




*Since this map was compiled there has been significant additional assessment of the infrastructure network, so this map is now superseded. It is included only to show the best available information at the time of the zoning decisions. For an up to date assessment of the infrastructure network, SCIRT or the City Council should be consulted.*

Figure 7 – Ground surface elevation from February 2011 LiDAR survey

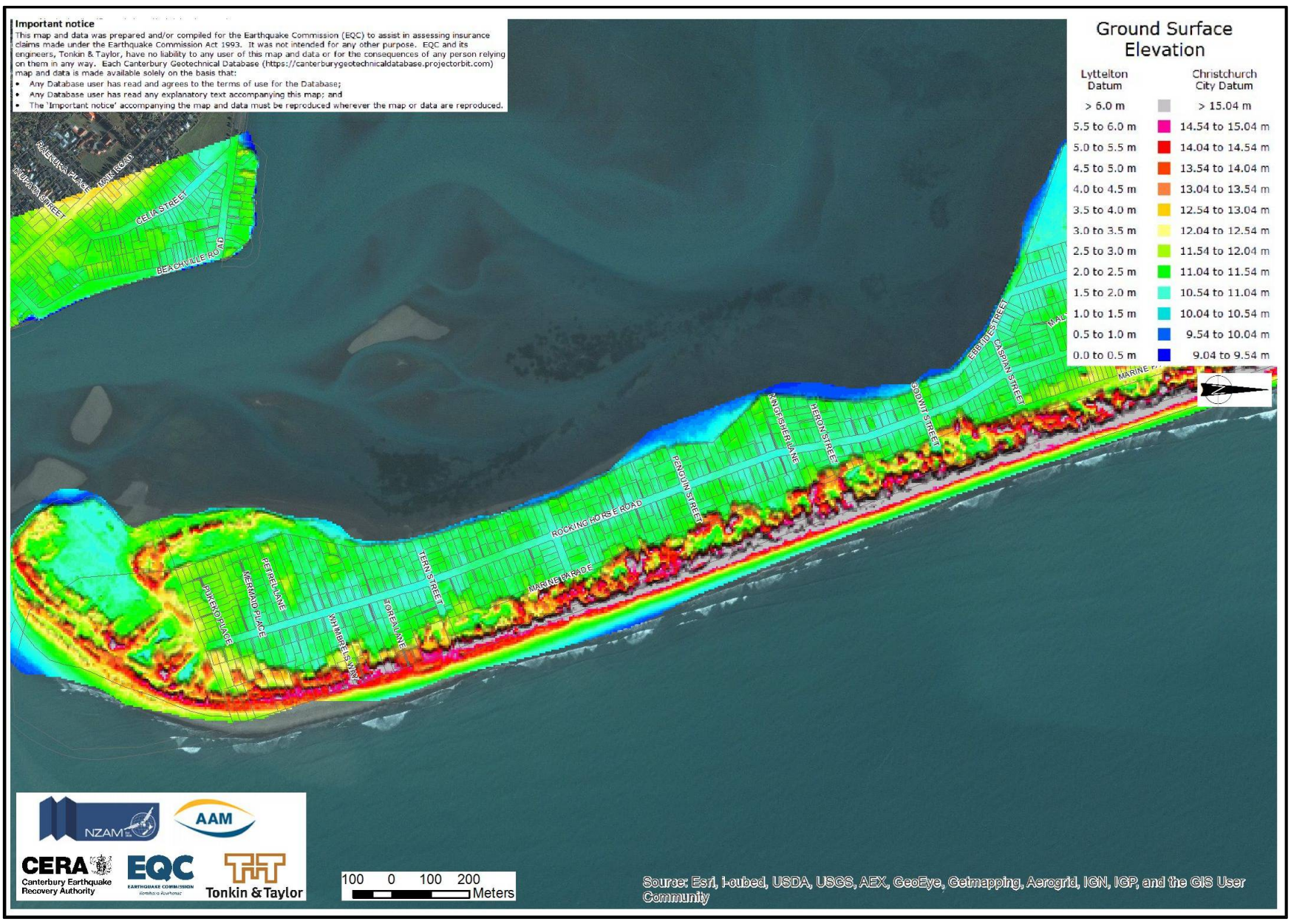



Figure 8 – Change in ground elevation between LiDAR in July 2003 and February 2012, with regional tectonic component of ground displacement removed

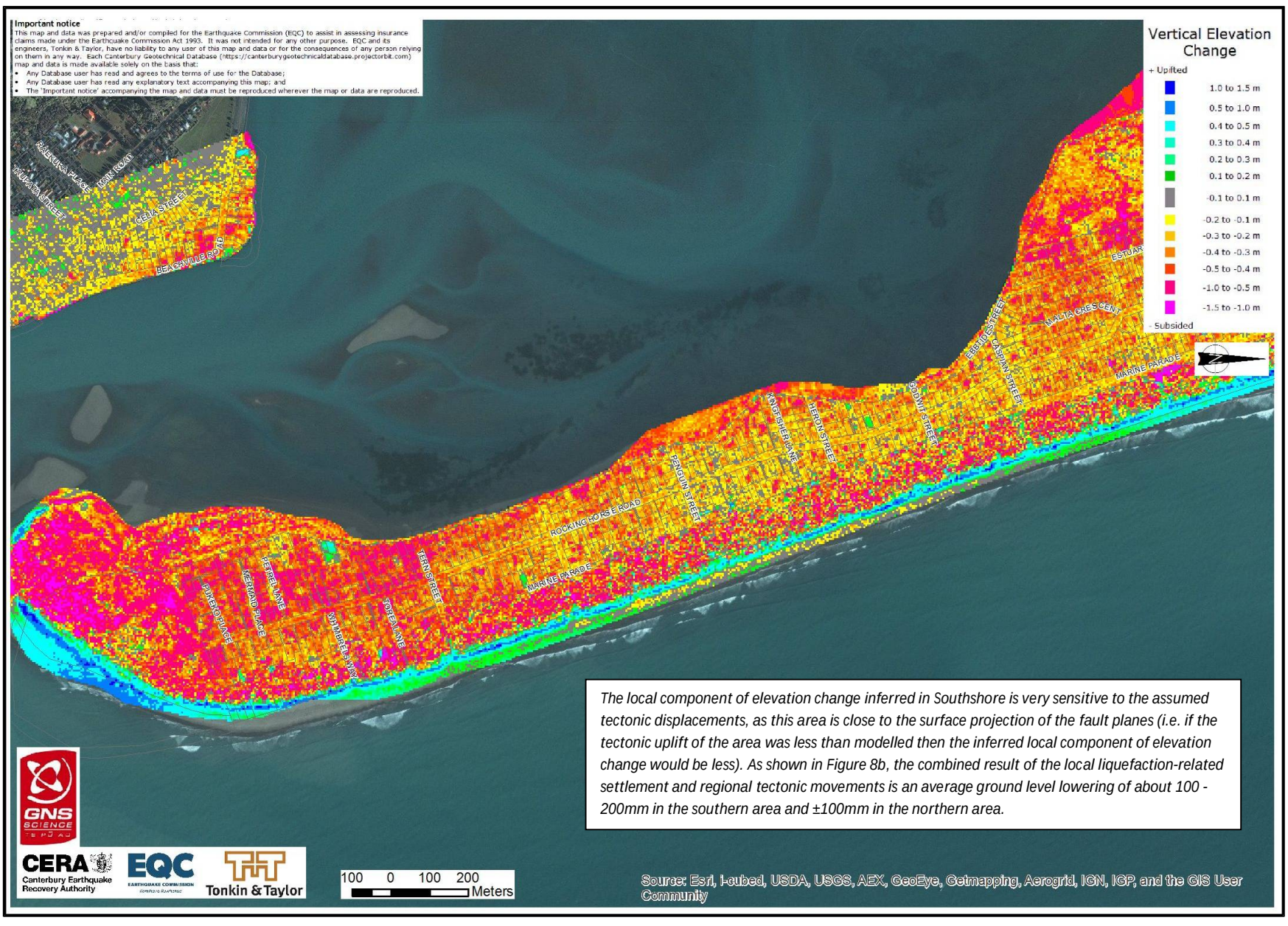


Figure 8b – Total change in ground elevation between LiDAR in Jul-03 and Feb-12 (i.e. without regional tectonic component of ground displacement removed)

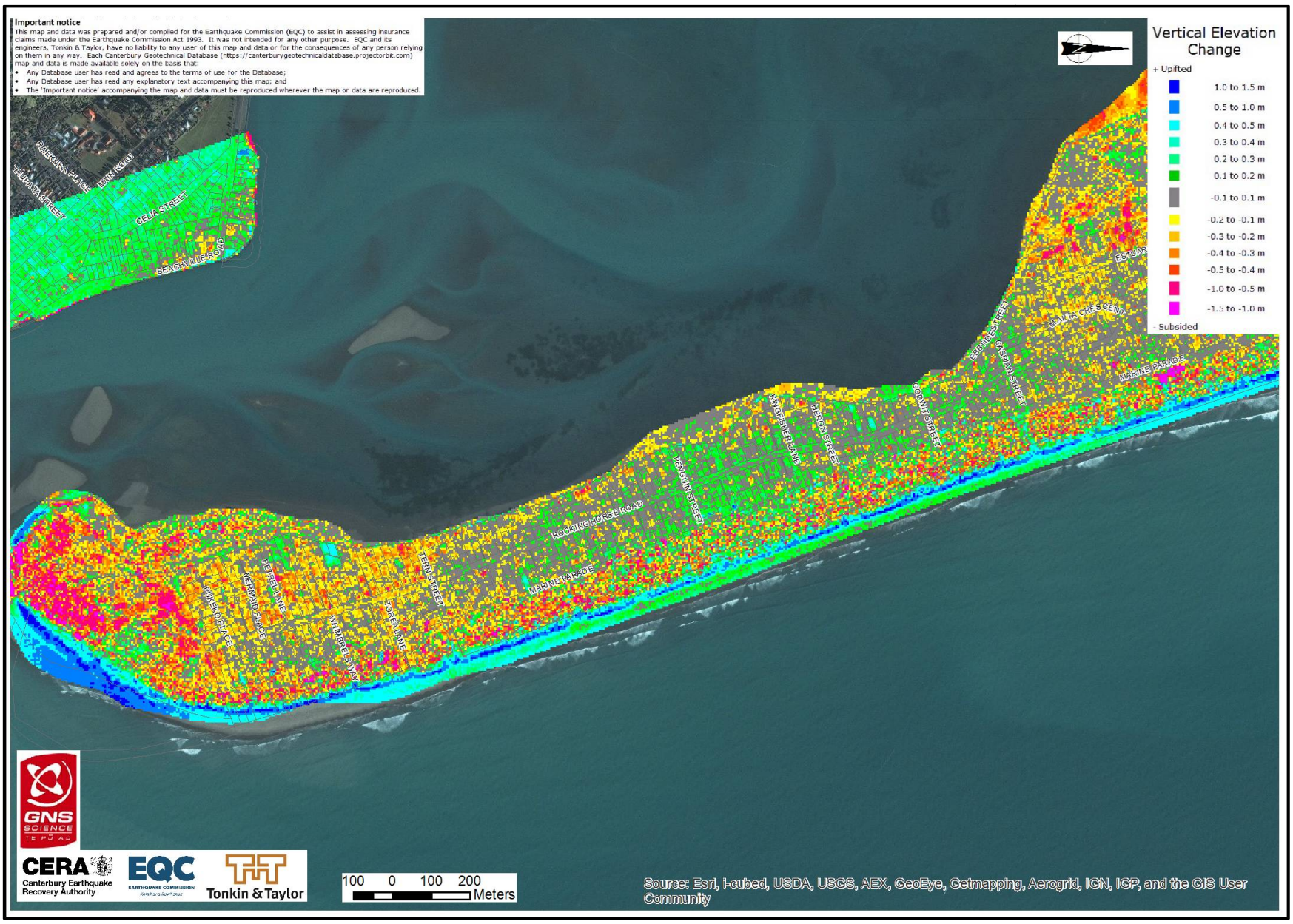
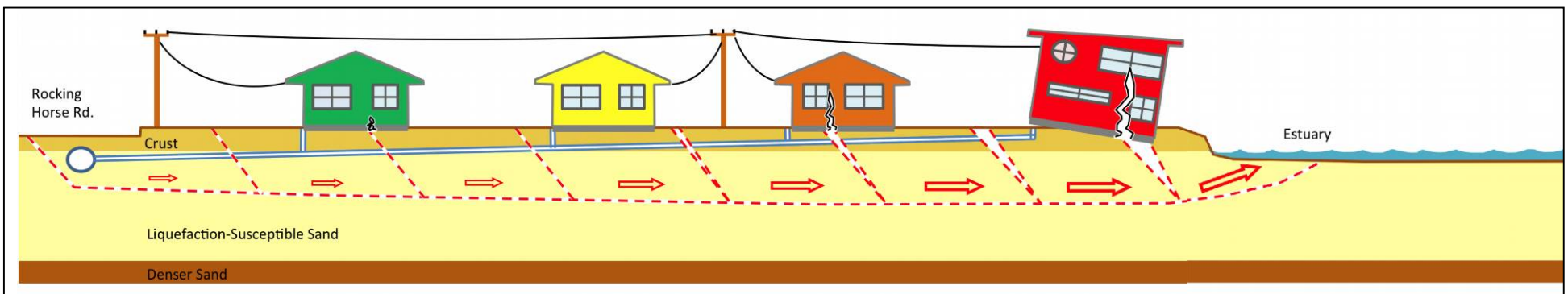
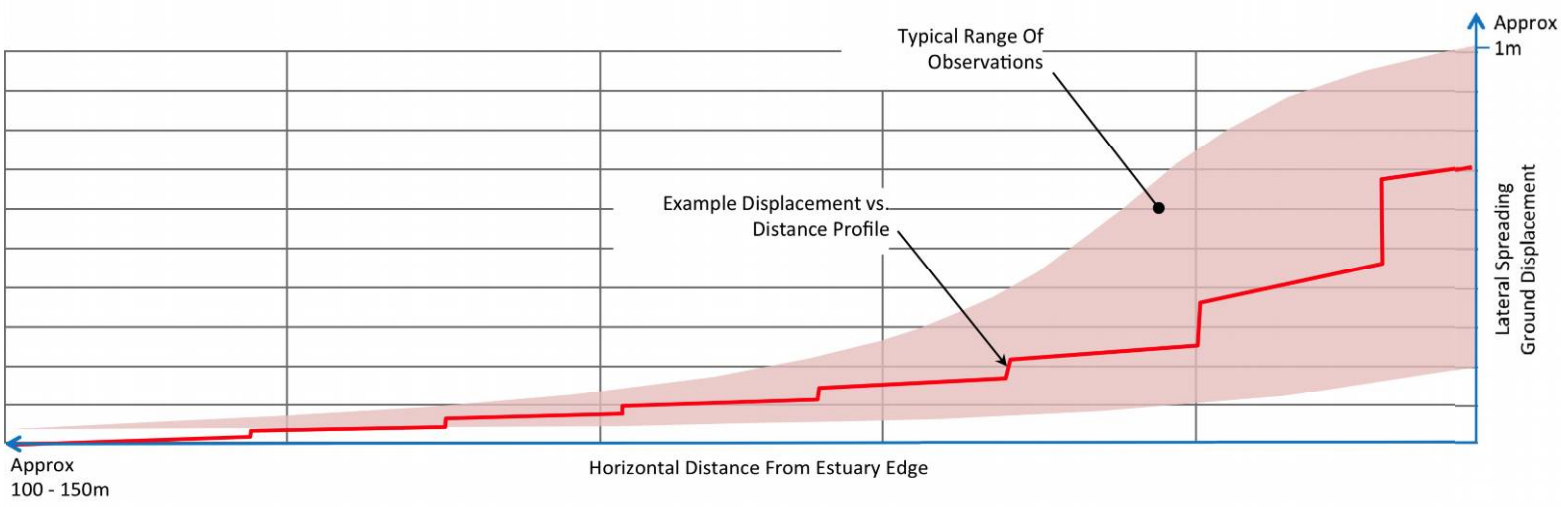



Figure 9 - Typical Post-Earthquake Observations - From Sep-10, Feb-11 & Jun-11 Earthquakes Combined




***Observed land performance: Earthquake shaking between SLS and ULS design levels experienced, but with short duration of shaking (lateral spreading may be more severe in longer design EQ)***

| | | | | |
|---|---|---|---|---|
| **Global Lateral Movement** *(DBH Guidance C2.2.1)* | Minor 0 - 100mm | Minor to Moderate 50 - 200mm | Moderate to Major 100 - 500mm | Major, with some Severe 600 - 1000mm in some areas 100 - 400mm in remaining areas |
| **Lateral Ground Stretching** *(DBH Guidance C2.2.2)* | Minor 0 - 50mm across footprint | Minor to Moderate 0 - 150mm across footprint | Moderate to Major 100 - 400mm across footprint | Major, with some Severe 200 - 500+ mm across footprint |
| **Building Damage - Old** *(For existing old foundations)* | Mostly minor to moderate damage, relatively simple repair | Moderate damage, generally repairable | High % with major damage, some able to be repaired | High % damaged beyond economic repair |
| **Infrastructure Damage** | Widespread major damage to trunk pipelines and lateral lines due to lateral stretching and general liquefaction. Moderate damage to roads due to stretching and general liquefaction. Localised streching of powerlines. | | | |
| **Post-EQ Habitability** | Most homes remain safe and habitable. Short-term loss of services due to damaged public trunk lines. | | Some homes uninhabitable. Medium-term loss of services due to damaged private lateral lines. | Many homes unsafe. |



F igure 10 – Locations of suburb-wide ground investigations undertaken by EQC following September 2010 and February 2011 earthquakes

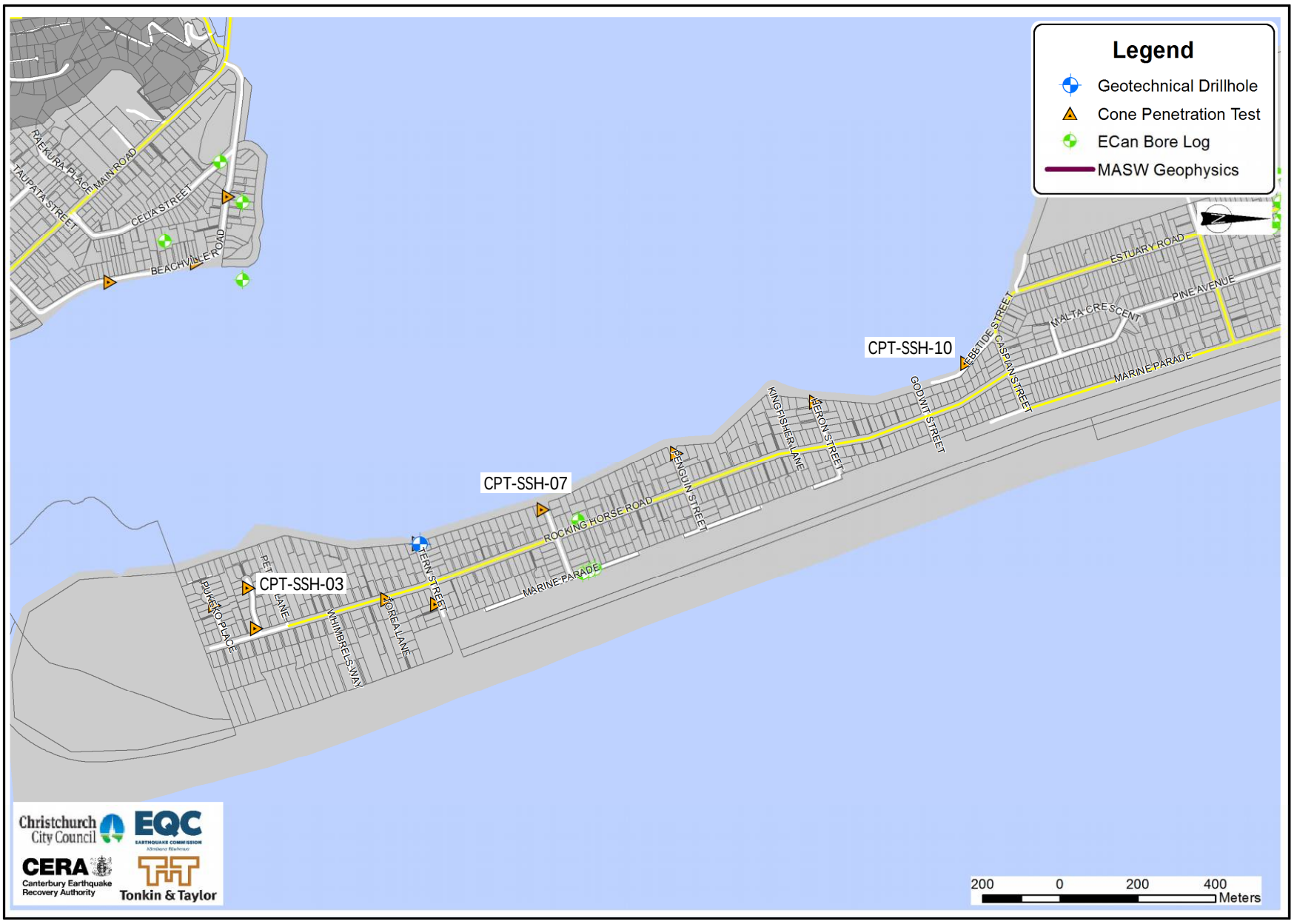



Figure 11 – Example cone penetration test (CPT) results

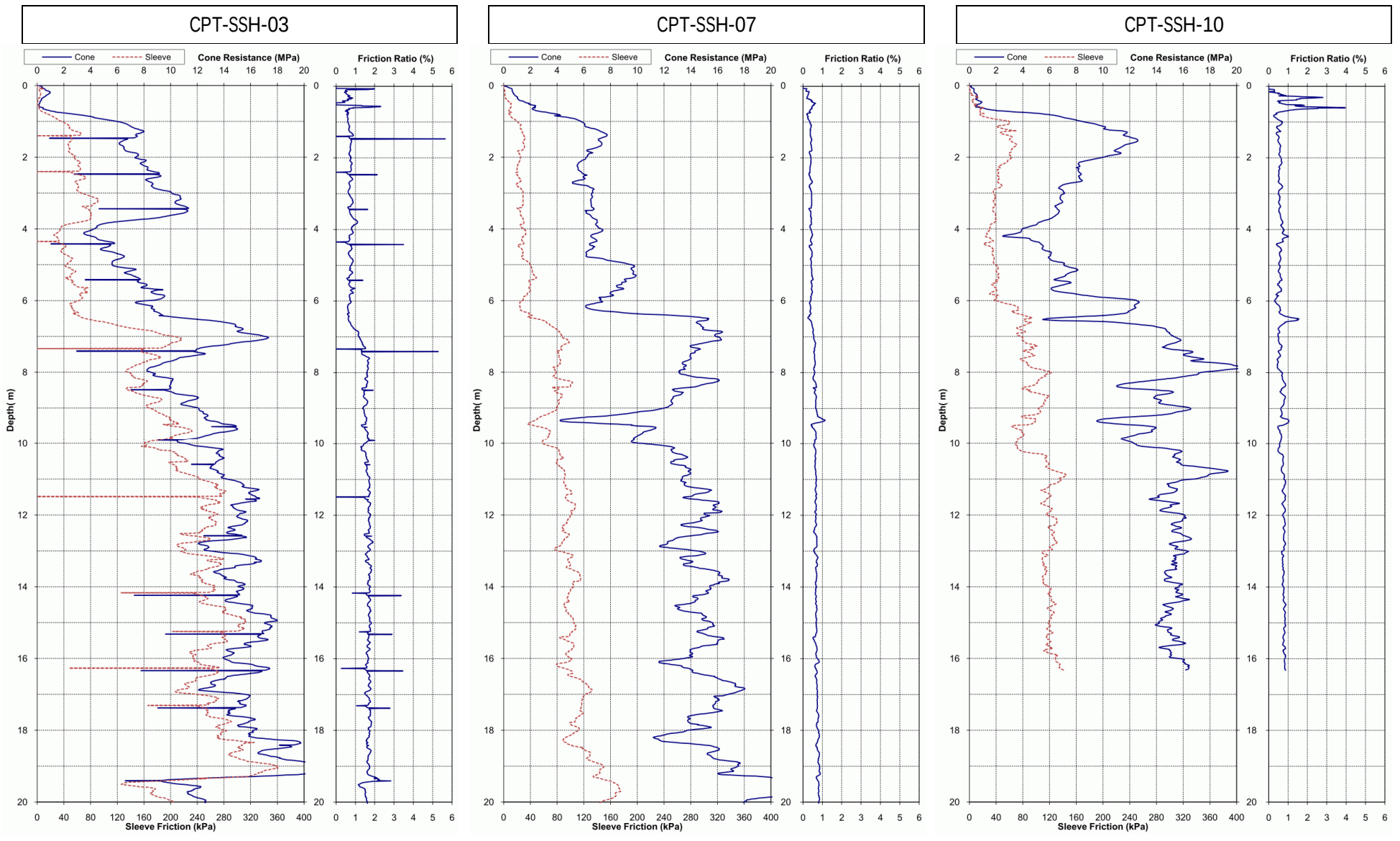


Table 1 – Area-wide geotechnical and engineering considerations for Southshore to Redcliffs

| Location | Area-wide geotechnical issues | Area-wide engineering works which would be required to enable repair and rebuilding to occur |
|---|---|---|
| Current red zone | Extensive moderate to major large-scale lateral spreading has occurred towards the Estuary. | *Area-wide perimeter treatment works required:*<br>Large-scale deep perimeter treatment works would be required to reduce the potential for lateral spreading 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.<br>These works would likely need to comprise a strip of ground improvement about 10m deep and about 20 - 40m wide, along the full length of the estuary edge in this area. |
| Current green zone – TC3 areas | Widespread moderate liquefaction has occurred, with some properties experiencing moderate local-scale lateral ground movements. | *No area-wide works required:*<br>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".<br>Based on the initial suburb-wide ground investigations, it appears that all of the TC3-type foundation systems included in the DBH guidance document are likely to be feasible in various parts of this area: shallow or deep site ground improvement, surface structures with shallow foundations, or deep piles (may not be suitable in some areas where lateral ground movements are possible). |
| Current green zone – TC2 areas | Evidence of liquefaction observed at the ground surface (such as ejected sand or ground cracking) ranged from none to moderate. | *No area-wide works required:*<br>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".<br>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 & 8b 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 & 8b 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 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 & 8b* 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 the 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.