Part B: Technical information

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8. Insurance and regulatory requirements

8.1 Insurance requirements

This section focuses on insurance principles and requirements of the Earthquake Commission Act 1993 (EQC Act) for damage to residential buildings arising from the Canterbury earthquakes or aftershocks. This is a summary only and in the event of difference, the EQC Act will prevail. Refer to www.eqc.govt.nz for full details of the scope of EQC cover. Further information on claims to EQC arising from land damage or claims for damage to personal property can also be found at: www.eqc.govt.nz

8.1.1 Earthquake Commission (EQC)

EQC was established by the Government in 1945 to provide earthquake and war damage cover for purchasers of fire insurance. Later, cover for other natural disasters was included and, later still, cover for war damage dropped. EQC is a government-owned Crown entity.

EQC covers New Zealand residential property owners for some damage caused by earthquake, natural landslip, volcanic eruption, hydrothermal activity, tsunami; in the case of residential land, a storm or flood; or fire caused by any of these events.

EQC automatically covers people who hold fire insurance that covers their dwelling and personal property (most 'home and contents' policies include fire insurance cover).

The claimants' insurance policies are a legal contract between the insured and the private insurer. EQC cover insures the insured's dwelling and any structures associated with the dwelling up to a maximum of $100,000 plus GST. The private insurer will be liable for a damage claim beyond this level in accordance with the individual terms and conditions of the contract.

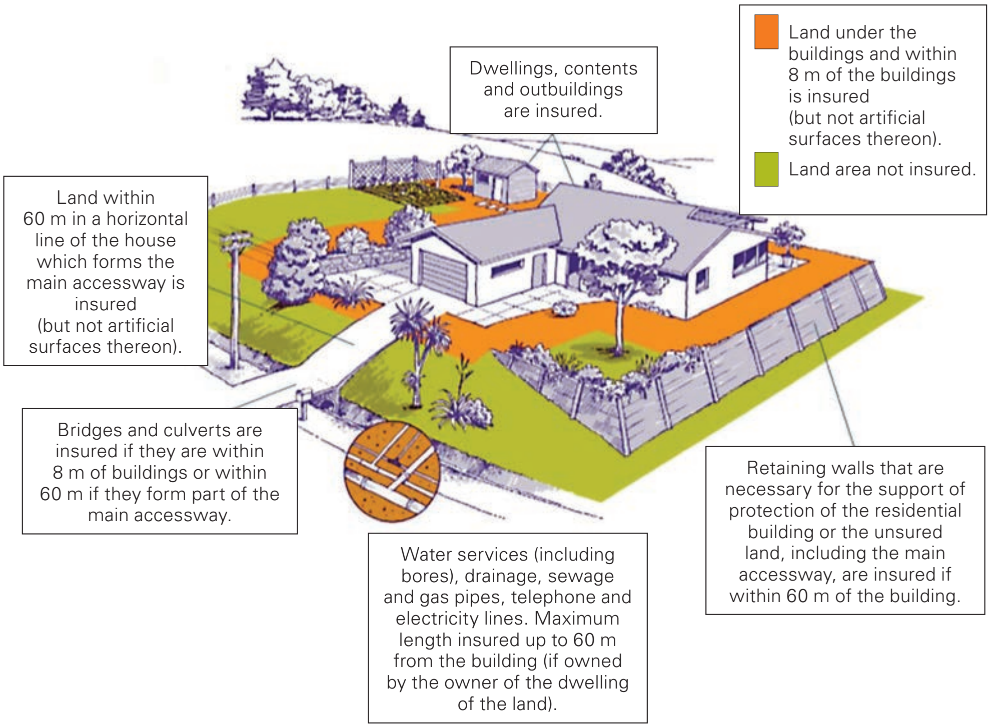
Dwellings are insured by EQC on a 'replacement value' basis. A 'dwelling' means any self-contained premises that are somebody's home or holiday home or that are capable of being, and are intended by the owner to be, somebody's home or holiday home. EQC also insures separate buildings used by the occupiers of a dwelling, such as a garage or shed.

EQC does not cover any dwelling that is not insured against fire, and it does not cover a dwelling if the relevant insurance policy has lapsed or has been cancelled at the time of the natural disaster, or where EQC has cancelled the EQC cover. Nor does it cover consequential losses that might occur after a natural disaster, such as theft or vandalism.

In most cases EQC will settle claims which exceed the maximum amount of EQC cover by paying that amount to the owner(s) of the dwelling or other person with an insurable interest in the dwelling (eg, a mortgagee bank). For any damage above that amount, an owner must claim against his or her private insurer.

Cover is also provided by EQC for land damage: refer to Figure 8.1 for an indication of the extent of land insured by EQC.

Figure 8.1: A guide to property insured by EQC under the Earthquake Commission Act 1993



Under the EQC Act, a homeowner must 'take reasonable precautions' for the safety of their property. The owner must in particular take all reasonable steps to preserve the insured property from further natural disaster damage.

For dwelling claims where the damage does not exceed the amount of EQC cover available, EQC may, at its option (instead of paying the amount of the damage), replace or reinstate the building to a condition substantially the same as, but not better or more extensive than, the building's condition when new. EQC's obligation to reinstate or replace to 'replacement value' includes costs reasonably incurred in the course of reinstating or replacing the building, including fees for architects, surveyors and engineers, and fees payable to local authorities. For dwelling claims where the damage does not exceed the amount of EQC cover available, EQC has chosen to reinstate the damage or repair through its project manager Fletcher/EQR. For these claims:

- repairs to any damaged portion of a dwelling must be undertaken to a level that meets applicable laws, including current building regulations (refer to section 8.2)
- the EQC Act definition of 'replacement value' provides that, where EQC opts to replace or reinstate, repair work will return a dwelling to a condition 'substantially the same' as its condition when new, but not better or more extensive. EQC is not required to replace or reinstate exactly or completely, but only as the circumstances permit and in a 'reasonably sufficient manner'.

8.1.2 Private insurers

The following are the obligations of private insurers:

1. The reinstatement obligations of the private insurer will depend on the terms of the contract between that insurer and the insured person.
2. These obligations can vary between insurers and even between different policy wordings provided by the same insurer. For example, it is understood that one insurer provides two different policies which respectively require it to:
   – repair the building to the state it was in before the damage or pay the cost of repairing, allowing for depreciation and wear and tear, or
   – repair or rebuild to an 'as new' condition.

The latter wording is more like the EQC insurance, but does not have the proviso that the repair may be limited to a 'reasonably sufficient manner'. On the other hand, the former policy is more limited than the EQC cover and only provides for repair on an indemnity rather than a replacement basis.

8.2 Regulatory requirements

8.2.1 Building Act 2004

This section sets out some of the matters under the Building Act 2004 that will need to be considered when houses damaged by the sequence of Canterbury earthquakes are being repaired or reconstructed.

The requirements will vary depending on the particular circumstances of the repairs or rebuild. The sections below provide a general explanation of the key regulatory factors. However, the particular circumstances of each repair or reconstruction need to be considered.

Building activities must comply with the requirements of the Building Act 2004 (the Act) and the relevant regulations. The Building Code is a regulation made under the Building Act 2004 (Schedule 1 of the Building Regulations 1992) and for Canterbury/greater Christchurch the Building Act 2004 has been modified by Canterbury Earthquake (Building Act) Order 2011.

UPDATE:
December 2012

The Building Code is performance-based, outlining the performance that needs to be achieved under each of the Building Code clauses. Acceptable Solutions and Verification Methods published by the Ministry, if followed, will result in building work that is deemed to comply with the Building Code. However, alternative solutions can be proposed and consented if sufficient evidence to satisfy the 'reasonable grounds' test that Building Code performance requirements will be met is provided to the building consent authority. Much of the guidance in this document is not included in the current Acceptable Solutions. The options are therefore alternative solutions. This document aims to provide 'reasonable grounds' for building consent authorities to consent such designs.

All building work[1] must comply with the Building Code regardless of whether a building consent is required[2] (Building Act section 17), or whether the building work is to construct a new building or carry out alterations[3] or repairs to an existing building.

When deciding whether to grant a building consent, the building consent authority needs to be 'satisfied on reasonable grounds that the provisions of the Building Code would be met if the building work were properly completed in accordance with the plans and specifications that accompanied the application.' (Building Act section 49).

Work related to the rebuild in Christchurch will include:

- repair of building elements or systems (eg, relevelling of floor slab and repair of any cracks in it, repair of bracing elements in superstructure and repair of cracks in internal or external walls (see section 8.2.2)), or
- replacement of all or parts of building elements (eg, a new foundation or replacement of part of the perimeter foundation wall), or
- the construction of completely new houses, whether on the same site or a new building site (see section 8.2.3).

8.2.2 Regulatory requirements for repairing damaged houses

All work undertaken to repair damage is 'building work' and needs to comply with Building Code requirements (section 17).

The obligations for most provisions of the Code apply to one of the following subjects:

- a building or household unit
- building elements
- building systems within a building
- building facilities.

Building work to alter or repair a building only has to comply with the relevant Building Code obligations that apply to that building work. For example, structural repairs to a wall only have to comply with the provisions of B1 that are applicable to that wall (a building element), not with the Code obligations that apply to a whole building or to other building elements/walls that are not being repaired.

(1) Under section 7 of the Act, building work means work 'for, or in connection with, the construction, alteration, demolition, or removal of a building …' and includes sitework.
(2) The circumstances when a building consent is not required are set out in section 41 of the Act, including work that is exempt from the requirement to obtain a building consent under Schedule 1 of the Act.
(3) Alter, in relation to a building, includes rebuilding, re-erecting, repairing, enlarging, and extending the building.

There are however provisions in the Act that require other parts of a building being repaired to be upgraded as follows:

- Additional work may be required for a building that is being repaired to ensure that for means of escape from fire and access and facilities for persons with disabilities, the building complies as nearly as is reasonably practicable with the requirements of the Building Code (section 112(1)(a)). Provisions for access and facilities for persons with disabilities do not apply to private houses, while special fire safety requirements for houses are essentially limited to the installation of domestic smoke alarms. (If the house is not fully detached there may be other requirements.)
- There is an exception to section 112(1)(a) that allows a partial upgrade (ie, less than 'as nearly as reasonably practicable') where even though the alterations will not comply with section 112(1)(a), the benefits of upgrading outweigh the detriment of not complying with section 112(1)(a) (section 112(2)).
- If the use of the building is changed or a household unit is added as part of the repairs, there are further upgrade requirements that a building must comply with (section 115).
- There are specific upgrade requirements for buildings to which the public has access to ensure reasonable and adequate provision by way of access, parking provisions and sanitary facilities for persons with disabilities (section 118).
- There are prohibitions on certain types of repair, including that:
  - a repair cannot result in a building complying with the Building Code to a lesser extent than before the repair (section 112(1)(b))
  - a repair may not accelerate or worsen a natural hazard on the land or any other property (section 71). (Note that earthquakes are not included in the definition of natural hazards (section 71(3)). Therefore, building on land with the potential to liquefy in an earthquake would not require the building consent authority to notify the Register-General of Land identifying a natural hazard (section 73)).

Section 112 of the Building Act

Section 112 of the Act contains specific requirements for alterations (referred to above) relating to the compliance of the altered building (which is the whole building as altered, not merely the alteration). It does not detract from the section 17 requirement that all building work must comply with the Building Code, or the provisions of sections 67 to 70 on waivers or modifications to the Building Code.

Therefore, section 112(1)(b) prevents a building consent authority from issuing a building consent for an alteration if one of the effects of the proposed building work will be to reduce the extent of the compliance of the existing building with the Building Code. Before a building consent authority can issue a building consent for alterations, it must be 'satisfied that, after the alteration, the building will continue to comply with the other provisions of the Building Code to at least the same extent as before the alteration'.

8.2.3 Regulatory requirements for rebuilding the entire house

Rebuilt houses are considered to be new houses, and they must comply fully with the Building Code, subject to any waiver or modification granted by the territorial authority (Building Act section 67). Some of the specific Building Code requirements that are particularly relevant to rebuilding in Canterbury are highlighted below.

Building Code requirements to prevent structural collapse (B1.3.1)

To satisfy the objective B1.1(a) of the Building Code – to safeguard people from injury caused by structural failure – Clause B1 Structure requires new building work to have a low probability of rupture, becoming unstable or collapsing (Clause B1.3.1).

This requirement has been well quantified by structural engineers. AS/NZS 1170 is widely used by engineers as a guide to meet the requirements of Building Code Clause B1 and is referenced in Verification Method B1/VM1 which, if followed, is treated as complying with Clause B1.

Buildings that are designed using AS/NZS 1170 are required to satisfy the ultimate limit state primary design case.

Ultimate limit state (ULS)

The ULS design case is an extreme action, or extreme combination of actions, that the building needs to withstand. ULS seismic loads for residential properties are based on a one in 500 year earthquake (a 10% chance of exceedance in 50 years, the nominal life of the building). A building is expected to suffer moderate to significant structural damage, but not to collapse, when it is subjected to a ULS load.

The following points should also be made with regard to ULS loads:

- It may be uneconomic and/or not feasible to repair a building or structure that has been subjected to an ULS load.
- A building is likely to collapse if it is subjected to a load which is significantly greater than the ULS load for which it has been designed, although this likelihood is reduced if the building is robust.
- All buildings are at risk of being subjected to a level of seismic shaking that is greater than their design ULS seismic load. It should be noted, however, that this probability of exceedance is considered to be acceptably low.

Building Code requirements to prevent loss of amenity (B1.3.2)

To satisfy the objective B1.1(b) of the Building Code – to safeguard people from loss of amenity caused by structural behaviour – Clause B1 Structure requires new building work to have a low probability of causing loss of amenity through undue deformation, vibratory response, degradation or other physical characteristics throughout its life (Clause B1.3.2).

Amenity is defined as 'an attribute of a building which contributes to the health, physical independence and well-being of the building's user but which is not associated with disease or a specific illness'.

Current Acceptable Solutions, Verification Methods and Standards do not provide an explanation of what is meant by 'loss of amenity'. Loss of amenity might include loss of services such as sewer and water connections, damage to sanitary fixtures (bathroom, kitchen, laundry), parts of the house being no longer available for use, significant cracking and deformation of flooring, or the building envelope not being weathertight.

For this document, loss of amenity is taken as the exceedance of the following tolerable impact:

> All parts of the structure shall remain functional so that the building can continue to perform its intended purpose. Minor damage to structure. Some damage to building contents, fabric and lining. Readily repairable. Building accessible and safe to occupy. No loss of life. No injuries. Criteria on repairability are provided in Table 8.1.

Buildings designed using AS/NZS 1170 are required to satisfy the serviceability limit state primary design case, which reflects the requirement to prevent loss of amenity.

Serviceability limit state (SLS)

The SLS design case is a load, or combination of loads, that a building or structure is likely to be subjected to more frequently during its design life. If properly designed and constructed, a building should suffer little or no structural damage when it is subjected to an SLS load. All parts of the building should remain accessible and safe to occupy.

UPDATE:
December 2012

Services should be readily repairable at the perimeter and remain intact within the building. There may be minor damage to building fabric that is readily repairable, possibly including minor cracking, deflection and settlement that do not affect the structural, fire or weathertightness performance of the building. SLS seismic loads for residential properties are based on a one in 25 year earthquake (refer to AS/NZS 1170.0).

Readily repairable

Given the uncertainty of rebuilding on land where liquefaction has occurred in Canterbury, it is useful to base designs on minimising damage that might occur.

Table 8.1 provides criteria for the nature of future damage that corresponds to 'repairability'. This covers both timber-framed/light-clad dwellings and concrete-slab dwellings of any cladding type. It is intended that these criteria could only practically be applied to situations where lateral stretch of less than 50 mm across an individual building footprint is expected under serviceability limit state seismic actions in the future.

Table 8.1: Serviceability limit state performance expectations for rebuilt houses

Key terms	Element	Interpretation	Comment
Continue to function	Building	Occupiable as a dwelling (habitable)	Refer to Services below
Minor damage to structure	Foundation structure and floor	Timber: Able to be relevelled using standard procedures Stable in the interim	Require replacement of sections of subfloor cladding for relevelling access
		Concrete: No rupture but minor curvature possible Able to be relevelled simply Stable in the interim	No opportunity for ground moisture ingress
	Walls – exterior	Minor cracking at cladding panel joints and in plaster coatings (eg, EIFS)	Remains essentially weathertight
	Walls – interior	Minor cracking at lining joints	Lateral structural integrity maintained
	Roof	Roof claddings sound, intact and securely attached	Capable of remaining weathertight
Some damage to building fabric and lining		Some cracking of lining junctions above doorways and windows	
Readily repairable		Repairable without relocation of occupants for more than four weeks	Total cost of repairs at a level that is able to be covered by EQC (ie, within EQC insurance cap)
Building accessible and safe to occupy	Doors – interior	Minor jamming (ie, may need to ease)	Requires ability to occupy in this state for several months
	Doors – exterior and windows	Capable of being secured (ie, may need catch adjustment and easing)	
Other Aspects	Services	No damage to water, gas, and electrical service connections Readily repairable damage to sewer and stormwater pipes	Special design of utility connections into house to allow some movement Any loss of service relates to network issues Use of chemical toilets
	Residual wet silt beneath floor	Timber: May need to temporarily install polythene membrane over silt	Prevention of ground moisture from entering the living space
	Weathertightness	Not compromised if extent of water ingress is small and the effects are controllable	

Building Code requirements to prevent flood damage (Clause E1.3.2)
Refer to section 8.4 Flood risk and floor levels.

Building Code requirements for external moisture (Clause E2)
To safeguard people from illness or injury that could result from external moisture entering the building, the walls, floors, and structural elements in contact with or in close proximity to the ground must not absorb or transmit moisture that could cause undue dampness, damage to building elements, or both (Clause E2.3.3).

A means of satisfying this provision is provided in Acceptable Solution E2/AS1. Section 10 of E2/AS1 provides details for the protection and separation of elements. Details for minimum floor levels above ground are provided in Table 18 and Figure 65 of E2/AS1.

Rebuilding in ground-damaged areas of Canterbury
Liquefaction and lateral spread issues have not been specifically addressed in Standards, Verification Methods or Acceptable Solutions supporting the Building Code.

Houses that comply with Acceptable Solution B1/AS1 are treated as complying with Building Code Clause B1. B1/AS1 references NZS 3604 which has a definition of 'good ground' (refer to NZS 3604, section 3.1.3) aimed at ensuring there is adequate static bearing capacity for the standard foundation designs proposed. The definition of 'good ground' does not consider land with liquefaction ground damage potential. B1/AS1 was amended on 1 August 2011 to modify the referencing of NZS 3604 to exclude from the definition of 'good ground' any land in Canterbury that has the potential to liquefy. The Ministry has also issued guidance for the rest of New Zealand, recommending geotechnical investigations be undertaken when ground with the potential for liquefaction is identified (refer to www.dbh.govt.nz/liquefaction-construction-on-ground-guidance).

Superstructure
All new building elements must be built to current Building Code requirements (treated timber framing, drainage cavities for cladding where appropriate, insulation and double glazing, etc).

Where a house is being entirely rebuilt, the superstructure, if built in accordance with NZS 3604, will comply with Clause B1 as modified by B1/AS1.

UPDATE:
December 2012

8.2.4 Building consent processes

The Building Act 2004 establishes a building consenting framework to ensure the right checks and balances are applied to building work, and that buildings are designed and constructed to meet the performance requirements of the Building Code and are, therefore, safe and meet expected quality requirements.

In many cases building work will require a building consent from a building consent authority before it can commence, to allow an independent third party to check that the proposed building work will comply with the Building Code. Once the building consent has been issued, councils then undertake inspections of the building work at key points. When the building work is finished, councils can issue a code of compliance certificate if the building work satisfies the building consent.

Not all building work needs a building consent. Section 41 of the Building Act 2004 contains some specific exclusions – in particular, the types of building work described in Schedule 1 of the Building Act.

Following the earthquake, the Ministry encouraged the Canterbury councils to adopt a risk-based consenting approach.

A summary of the approach being adopted by Christchurch City Council is set out in Table 8.2.

Table 8.2: Summary of the risk-based consenting pathways for building work

Non-consented building work	• Building work automatically exempted from the usual consenting requirements because it meets one of exemptions (a)–(j) and (l) and (n) in Schedule 1 of the Building Act. This essentially covers repair and replacement with comparable material, components or systems, including some structural repairs.
	• Building work that a council has previously decided does not require consent applications. Council uses its discretion under item (k) in Schedule 1. Could be applied to any building work and would require council to publish scope and parameters.
	• Building work where a council decides on a case-by-case basis to exempt from requirements to obtain a consent. Council uses its discretion under item (k) in Schedule 1. Could be applied to any building work, but targeted at licensed building practitioner (LBP) designers and builders, with no inspections.
Streamlined consented approach	• Streamlined process for major earthquake repairs. A case-by-case decision is made by the council to reduce the usual plan checks and inspections (due to criteria such as the competence of the practitioners, location of building, type, nature and complexity of repair work, etc).
	• Streamlined process for new houses. For new houses within the scope of the Simple House Acceptable Solution (or similar criteria), there will be fewer plan checks and inspections (level yet to be determined). These will be agreed between the applicant and council.
	• Repairs and construction of commercial buildings with third-party quality assurance. This pathway is targeted at specialist design firms and construction companies. The applicant and council agree about a risk profile and quality assurance plan, which is then implemented.
Standard consented building work	• The standard building consenting, inspection and approval pathway is used for higher risk building work or where the other approaches are not appropriate.

Importantly, regardless of whether a building consent is required, all building work must comply with the Building Code (refer to section 17 of the Building Act 2004).

Owners may prefer to have a record on the council property file of the work undertaken, even if the work is of lower risk and there is no need for council consent and inspection to ensure the work meets Building Code requirements. It is recommended that homeowners keep a record (and photos) of all repair work done, regardless of whether a building consent is required.

UPDATE: December 2012

Since this guidance was first published, the Building Amendment Act (2012) has been passed and puts in place provision for a national stepped risk-based consent process, changing the current standard building consent process. These provisions are not yet in force and regulations are being developed to enable the new risk-based consenting to come into effect. Under risk-based consenting there will be four types of building consent – low-risk building consent, simple residential building consent, standard building consent, and commercial building consent. When risk-based consenting is brought into effect this section of the guidance will be updated.

UPDATE: December 2012

8.2.5 Canterbury Geotechnical Database

The Canterbury Earthquakes Royal Commission has provided a number of recommendations regarding the storage and access to land and building information http://canterbury.royalcommission.govt.nz/Final-Report---Summary-and-Recommendations.

The Canterbury Geotechnical Database http://canterburygeotechnicaldatabase.projectorbit.com is designed to satisfy these recommendations. It has been developed by CERA to be the repository for data on both the land and foundations collected during the rebuild of greater Christchurch. It provides a facility for storage and easy access to geotechnical investigation data, land mapping information, LiDAR and groundwater records, as well as the geotechnical assessments and fundamental data on the land and building foundations derived as part of the building consent process.

Use of the information drawn from the database for a project or site is on the basis that any data procured or developed for the project (including geotechnical investigations, geotechnical assessment and foundation data) is uploaded to the database. (Use of the database without uploading project data is in breach of the terms of use of the database).

The Ministry strongly endorses the use of this facility.

UPDATE: December 2012

8.2.6 Format of supporting information for building consents

As part of the building consent application process, some territorial authorities require the submission of summary ground information data (both factual and interpretive) and also summary building information, in standardised 'template' formats. The purpose of this requirement is to help make the processing of consent applications more efficient. Given the very large number of building consents that will need to be processed during the recovery period, the Ministry strongly endorses this approach.

A template summarising key geotechnical and structural information has been developed and is available on the CERA website www.cera.govt.nz.

8.3 Seismicity considerations

The 2010/11 Canterbury earthquakes have increased the seismic risk for Christchurch over the next few decades. Based on new knowledge about this risk, and after consultation with seismologists and structural engineers, the Ministry increased the seismic hazard factor, Z, in Christchurch from 0.22 to 0.3 from 19 May 2011.[4]

The minimum hazard factor Z (defined in Table 3.3 of NZS 1170.5) within the Christchurch City, Waimakariri District and Selwyn District Council boundaries shall be 0.3. Where factors within this region are greater than 0.3 as provided by NZS 1170 Part 5, then the higher value shall apply. The hazard factor for Christchurch City, Selwyn District and Waimakariri District shall apply to all structure periods less than 1.5 seconds (which encompasses detached residential construction). All structures with periods in excess of 1.5 seconds should be subject to specific investigation, pending further research.

The revised Z factor is intended only for use in the design and assessment of buildings and structures, pending further research. Seismic hazard factors for liquefaction analysis have been published (refer Part C, Appendix C2 – design PGAs for a Class D site and IL2 structures are 0.13 (SLS) and 0.35g (ULS)). Seismic hazard factors for other geotechnical analyses are being researched with the intention of publishing them in due course.

In addition, to reflect the short-term increase in seismic activities in the region, the risk factor for serviceability limit state, R_s, was raised from 0.25 to 0.33 (refer to NZS 1170.5 clause 3.1.5 and B1/VM1).

Recognition that liquefaction is now likely in a serviceability limit state event in some locations has led to the technical categorisation of land (TC1, TC2 and TC3). There are also changes to the foundation requirements for TC1. Ductile reinforcing must be used, and unreinforced slabs are no longer included in the Acceptable Solution.[5]

The additional bracing demand required for residential houses has been addressed by referencing NZS 3604:2011 in Acceptable Solution B1/AS1. The bracing demand is determined by the Zones described in NZS 3604. All the area within the Christchurch City Council boundary will be within Zone 2; and the lowest zone within the Selwyn or Waimakariri District Council boundaries will also be in Zone 2. This is consistent with the increased Z value of 0.3 in NZS 1170.5.

8.4 Flood risk and floor levels

UPDATE: December 2012

This section outlines the Building Act requirements for land subject to inundation. It also summarises the issues and requirements for each of the territorial authorities, when setting new finished floor levels for houses to be reconstructed or repaired in low-lying areas. **The current situation must be checked on a case-by-case basis with the relevant council[6].**

(4) Refer to www.dbh.govt.nz/bc-update-article-114
(5) Refer to www.dbh.govt.nz/earthquake-concrete-slabs-guidance
(6) Although voluntary, it may be an advantage to apply for and obtain a project information memorandum (PIM) from the relevant council before finalising building consent applications. This may assist to establish finished floor levels, finished ground levels and whether or not there will be any requirement for resource consent.

UPDATE:
December 2012

8.4.1 Floor levels

For many properties in Christchurch requiring repair, the building work may be the repair or replacement of foundations.

Building Code Clause E1 requires buildings and site work to be constructed in a way that protects people and other property from the adverse effects of surface water. Clause E1.3.2 requires that floor levels are set above the 50-year flood level.

Whether the repaired building will need to comply with the 50-year flood level requirement or whether section 112 applies (in that the building continues to comply with Clause E1 to the same extent as before the repair being undertaken) will depend on the specific circumstances. Note that the District Plan rules (imposed under the Resource Management Act 1991) may also require the floor level to be raised and are requirements additional to the Building Act.

It is likely that some existing houses that require repair will have floor levels below the 50-year flood level. This may be because the house was constructed before the requirements were enacted, or because there has been general land settlement from the earthquake, or the flood levels have changed from the earthquake, or because the effects of climate change have been incorporated into the flood model. The reason that an existing house has a floor level below the 50-year flood level does not affect the legislative requirements. Some applicants may argue they have existing use rights under the Resource Management Act 1991 with respect to their floor level. However as noted already, the Building Act requirements are separate to the Resource Management Act requirements and applicants will need to demonstrate compliance with the Building Act regardless of their status under the Resource Management Act.

In general, if the building work relating to foundations is confined to relevelling and repair work as defined in Part A (refer to section 4 and Tables 2.2. and 2.3) and Part C then the Clause E1.3.2 requirement will not apply because buildings and site works are not being constructed. In these cases, the existing foundations are being repaired and there is not an opportunity to raise the floor level. Section 112 will be met, in that compliance with Clause E1.3.2 will be no worse than before the repair.

If, however, the foundations need to be rebuilt (refer to Part A Section 5 and criteria from Tables 2.2 and 2.3) then Building Code Clause E1.3.2 will apply, setting the floor level to be no less than the 50-year flood level, plus the 400 mm freeboard if you are in Christchurch City's area.

Attached garages

For attached garages, there may be circumstances where new house foundations are required and the only way for the house floor level to comply with Clause E1.3.2 is for a suspended floor to be built on shallow piles. An attached garage with concrete floor could generally be built at a level that is below the 50-year flood level, i.e. below the level of the suspended floor, as Clause E1.3.2 does not apply to outbuildings (refer to Building Code Clause A1 for definitions of Classified Uses). Appropriate consideration must be given to how the two structures (house and garage) interact. The garage construction will need to be of water resistant materials to the minimum 50 year flood level (eg treated H3 framing).

UPDATE:
December 2012

8.4.2 Christchurch City Council

Within Flood Management Areas

To assist Christchurch City Council (CCC) to manage the potential effects of flooding and inundation in Christchurch, especially as a result of climate change and sea level rise, Variation 48 to the Proposed Christchurch City Plan became operative on 31 January 2011. Variation 48 introduced a package of measures. The measures most relevant to finished floor levels are those for Flood Management Areas (FMAs).

The areas most affected are located around the Lower Styx, Avon and Heathcote Rivers, in the Lansdowne Valley and also in some low-lying coastal areas including Redcliffs and Sumner.

The map of Flood Management Areas are published on the Council's website www.ccc.govt.nz/floodmanagementareas

Floor levels in residential homes in Christchurch

Updated floor levels have been released for properties in the Avon, Heathcote and Styx river catchments, as well as Sumner. These levels are based on the latest ground surface information and have a margin for data uncertainty and environmental effects.

It is important to remember that Christchurch is a flat, low-lying city and there have always been areas prone to flooding. The Council has always set minimum floor levels in these areas and updated these as required.

The Canterbury earthquakes have caused significant land damage throughout the city, with areas close to riverbanks and other waterways having been particularly hard-hit. Ground levels across large areas of the city have settled by as much as 200 mm to 300 mm, and by more in some smaller areas.

Floor levels in these areas have been updated to protect homes from the risk of future flooding. Actual floor levels for each property will be set as part of the building consent process and homeowners can expect these to be the same or similar to those indicated online:

> ***How do I find out the land information my property which has been released on 10 October 2012?*** This information is available online – www.ccc.govt.nz/floorlevels

Some of the areas (most notably the Avon and the Lower Styx) were badly affected by the earthquakes.

Variation 48 introduced flood risk and floor-level assessments by requiring resource consents (under the Resource Management Act) for new developments in these defined FMAs.

If a house is to be rebuilt on the same or similar footprint as before, existing use rights under the RMA to rebuild at the original floor level may apply, and there may be no requirement for resource consent for rebuilding. However, compliance with the New Zealand Building Code will still be required (see 'Outside Flood Management Area').

All new buildings not on the same or similar footprint, or additions to buildings within the specified FMAs (with limited exceptions – eg, in living zones, additions to existing buildings of a maximum 25 m² in any five-year period) will require resource consent as restricted discretionary activities. These consents will enable site-specific assessments in respect of flood-related issues.

Two of the main criteria for assessing buildings will be whether floor levels are above the 200-year flood level plus 400 mm freeboard and, in tidally influenced areas, at no less than 11.8 m above the Christchurch City Datum.

Building flood levels and hazards are assessed on a case-by-case basis. In most, but not all cases, it will be obvious which of these two is the higher level, and therefore the dominant criterion. These are not rules but effectively 'default positions'. There are also other assessment criteria which will be considered – for example, the effectiveness and environmental impact of any proposed (flood) mitigation measures, the effect on other properties of disturbances to surface drainage, etc. It is important to note that these resource consents will not require public notification or neighbour approvals.

Filling within a FMA will also require resource consent, except where the filling is only to achieve a building platform at the identified minimum floor level. Applications for resource consents for filling will require an assessment of whether there are other adversely affected parties.

The new rules will not apply to any development proposal where a land use consent or a building consent has already been issued before 31 January 2011.

Outside of Flood Management Areas or where existing use rights apply within the Flood Management Areas

Outside of FMAs, flood management rules under the City Plan will not apply. Under the Building Act (bearing in mind that every building consent application will be considered on its merits), finished floor levels of new dwellings or dwellings that are reinstated on completely new foundations (eg, completely repiled) or extended dwellings will need to be no less than the level established by a 2% AEP[7] plus 400 mm freeboard which in some cases may be higher than the original floor levels. If there is an alteration or addition to, or a partial repair of the dwelling, then the existing floor level will still apply. See also minimum standards set out below to avoid hazard notices.

(7) AEP means annual exceedence probability. A 2% AEP event is often referred to as a '1 in 50' year event, a 1% AEP event is often referred to as a '1 in 100' year event and a 10% AEP event is often referred to as a '1 in 10' year event.

Guidelines for avoiding hazard notices under the Building Act 2004

A section 72 (hazard) notice under the Building Act 2004 may be issued by the CCC where building work is being carried out on land subject to a natural hazard. When considering whether a natural hazard exists, the Council has developed the following tests:

a. The threshold under section 71 of the Building Act for considering whether land or a building is likely to flood will be reached if Council records or analysis indicate that there is at least a 1% AEP.

b. If the inundation risk does not exceed 1% AEP, the land is not likely to be subject to the hazard for the purposes of section 71. However (iii), (iv) and (v) below also apply.

c. The minimum finished floor level (FFL) in a non-Flood Management Area is set at the 2% AEP (Clause E1.3.2 of the Building Code) plus an allowance for freeboard, which is typically 400 mm.

d. The minimum building platform level will be set at 2% AEP extending 1.8 metres beyond the foundations of the house.

e. A building is not to be located within the waterway set back required in the City Plan.

f. If there is a risk that water may not be contained entirely within the legal road reserve beyond the 10% AEP event, flood depth must not exceed 0.4 m over the section surrounding the building platform, and flow velocity must not exceed 1.0 m/s.

g. In a Flood Management Area, the finished floor level will be determined by the resource consent process (see 'Within Flood Management Areas'), unless existing use rights apply.

Elements required for establishing existing use rights under the RMA

Existing use rights apply only in relation to the Resource Management Act 1991 (RMA). They do not allow rebuilding without a building consent and do not change the building consent process.

There are four elements that need to be met for a rebuild to claim existing use rights. The onus is on the property owner or applicant for consent to prove that these elements are met.

a. The residential use must have originally been lawfully established.

b. Effects of the use must be the same or similar in character, intensity and scale.

c. There must be no increase in the degree of non-compliance with the City Plan rules (other than the permitted extra 25 m2 footprint.)

d. There must be no discontinuance of use for a period exceeding 12 months, unless a discontinuance of use is as a result of earthquake damage and is beyond the control of the building owner. The residential use does not cease because the occupation of the building ceases temporarily as a result of earthquake damage. However, if delays in recommencing residential use are caused by the landowner, then the activity will be deemed to have discontinued.

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8.4.3 Waimakariri District Council

Unless specifically identified within a Localised Flooding Area, or required by a rule in their District Plan, Waimakariri District Council rely on compliance with the Building Code to establish finished floor levels. In particular, the minimum FFL will be set at 2% AEP (Clause E1.3.2), plus an allowance for freeboard. New floor levels to be no lower than pre-quake floor levels.

8.4.4 Selwyn District Council

The limited number of houses to be reconstructed in Selwyn District are generally rural residential and, where affected by possible flooding, are capable of individual site-based solutions that will not affect neighbouring property.

9. Observed land and building performance

This section outlines the current understanding of the performance of land and dwellings in the Canterbury earthquake sequence, particularly in relation to the effects of ground liquefaction. A summary of the effects of liquefaction is presented in Appendix B1.

9.1 Observations in areas subject to liquefaction

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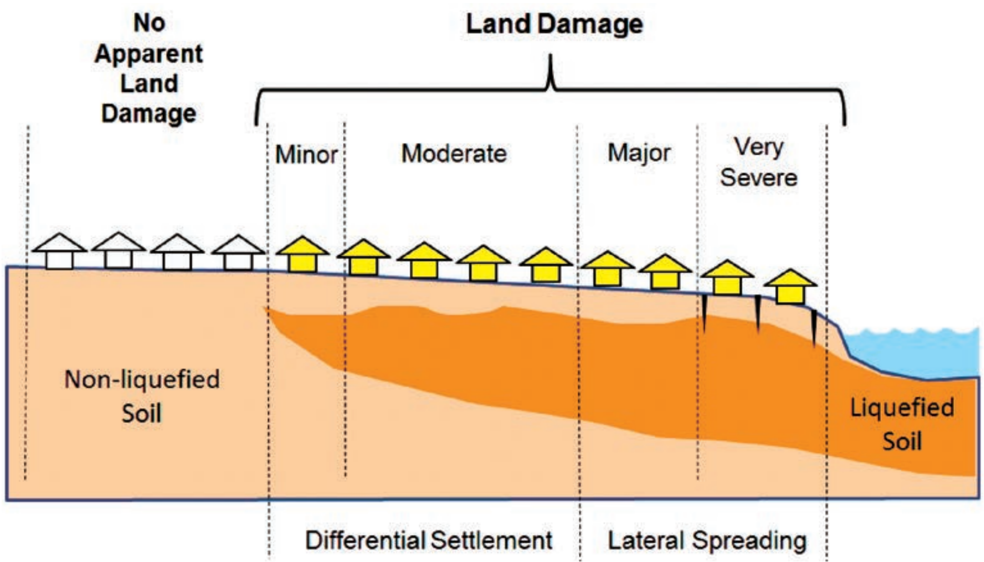
Immediately following both the 4 September 2010 earthquake and 22 February 2011 aftershock, a regional reconnaissance damage mapping exercise was undertaken by geotechnical engineers on behalf of EQC. From this mapping study, areas of minor to very severe land damage were identified.

Local land damage maps of the most affected suburbs of greater Christchurch have been completed for residential properties. The typical spatial distribution of the categories of land damage is illustrated in a generic cross-section shown in Figure 9.1.

Figure 9.1: Schematic section of liquefaction-induced land damage



Land damage from the earthquakes generally comprised lateral spreading close to watercourses/streams/rivers (major to very severe) and liquefaction-induced differential settlements (minor to very severe). The major to severe lateral spreading was greatest closest to streams and drainage channels, but in some cases extended up to 400 m laterally from watercourses with up to 4 m lateral ground movement. Minor spreading extended well beyond this in some parts of Christchurch. Settlements of up to 200 mm from liquefaction occurred over large areas, with significant differential settlements occurring over short distances. In the worst-affected areas, more than 500 mm settlement occurred.

9.2 Observations in areas subject to landslides and rockfalls in the Port Hills

A wide range of damage has been sustained by hillside properties. For the majority of properties, however, this has been limited to structural damage from earthquake shaking (although this damage has been severe in many cases, partially due to topographical enhancement effects – ie, increased ground accelerations on ridgelines, slope and cliff crests).

For some properties, further damage has been sustained due to movement issues with the land on which the dwelling is situated or from conditions some distance from the property. A listing of typical issues is given in Table 9.1.

Table 9.1: Land damage mechanisms on the hillsides and observed effects

Mechanism	Result
Rockfall (cliff collapse above building)	A small number of houses have been destroyed or inundated at the base of cliffs, and other houses have sustained major to minor damage from rock impact. Some houses are identified as being at risk from future damage.
Rockfall (boulder roll)	A small number of houses have been totally destroyed, and other houses have sustained major to minor damage from boulder impact. Many houses are identified as being at risk from future damage.
Landslide (soil slope, wide area failure)	Several potential global landslip features have been identified and are currently being monitored and investigated to determine whether they pose an ongoing threat to a number of houses deemed to be either on or below the failure area.
Landslide (ground cracking)	Large numbers of soil cracks have been observed throughout the Port Hills – many of these are several hundred metres in length. The significance and implications of these features are yet to be determined.
Landslide (soil slope, localised failure)	Some localised soil slope failures have taken place that affect single dwellings by undermining foundations or depositing debris against building exteriors.
Landslide (cliff collapse below building)	A small number of houses have been undermined (or are threatened by undermining) from loss of ground due to cliff collapse. (This involves both soil and rock materials.)
Retaining wall failure	A number of retaining wall failures have been observed – from rotation, translation and structural failures. This has sometimes resulted in land instability that has also induced localised landslip failures.
Settlement (foundation failure)	Foundation settlement has been observed in a number of houses, likely due to high vertical accelerations greatly increasing bearing stresses and therefore settlements. In some cases, localised bearing capacity failures may have occurred due to the presence of weak fill, or saturation of soils from a number of potential sources.
Settlement (subsurface void collapse)	Tunnel gullies or 'under-runners' are common on the Port Hills – these are subsurface erosion features ranging in aperture from a few millimetres to 2 m or more. A number of these have collapsed during earthquake shaking, leading to 'sinkholes' and sometimes the undermining of overlying foundations.

Mechanism	Result
Spring formation	Increases in pore water pressures in the underlying rock strata have resulted in the formation of surface springs in some places, in particular on the lower soil slopes. This has resulted in land and basement floodings, foundation settlement (due to saturation of the foundation soils) and slope failures or creep movements (due to saturation).

Some of the land issues listed above also have public safety implications that are beyond the scope of the Building Act.

9.3 Observed building performance

Building damage can be divided into two broad categories: damage that was caused solely by earthquake shaking; and damage that resulted from ground deformation including liquefaction, lateral spreading or landslip.

While shaking damage to dwellings has been observed on the flat, the February and June 2011 aftershocks in particular caused significant shaking damage to hillside houses. The observed high vertical accelerations were responsible for severe damage sustained by tile roofs and brick veneers, and unreinforced foundations were often severely cracked.

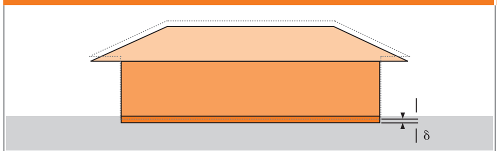
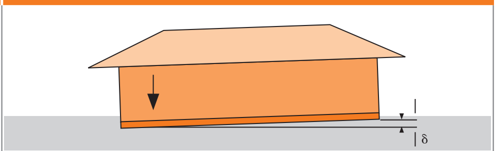
Liquefaction effects on buildings

Liquefaction-induced ground movement has caused stretching, hogging, dishing, racking/twisting, tilt, differential settlement, differential displacement or any combination of the above to buildings. The severity of the damage is dependent on the damage type, the type of building, the building geometry and the amount of foundation movement that has occurred.

To assist with the understanding of the descriptions provided in this Guide, the following pictorial definitions for floor displacement are provided:

(i) Simple settlement cases

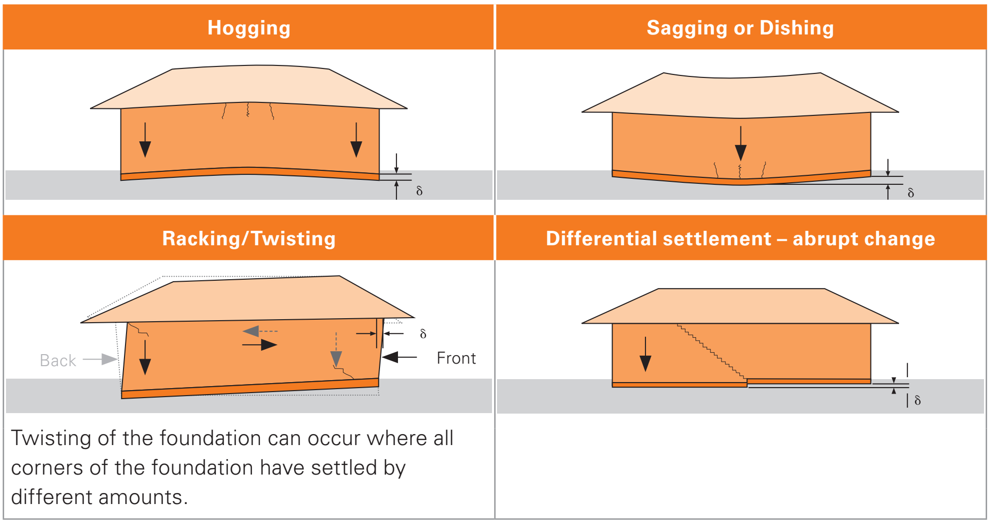
Figure 9.2: Simple settlement cases (i)

Uniform settlement	Tilt settlement
	
For uniform settlement, the complete foundation has settled by the same amount over the area of the foundation.	With tilt settlement, the whole foundation tilts as a rigid body.

(ii) Differential settlement cases

Parts of the foundation settle by different amounts resulting in uneven slopes in the floor. Differential settlement is the most difficult behaviour for which to set acceptable limits.

Figure 9.3: Differential settlement cases (ii)

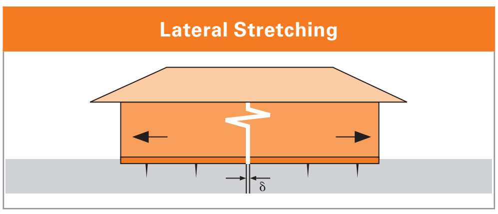


(iii) Lateral stretching

Lateral stretching of a foundation may occur when the ground beneath it spreads laterally during the ground shaking. This action is often accompanied by liquefaction and associated ground settlement. If the floor plate of the dwelling is not strong enough, then the lateral spreading will cause an extension of the floor plate (ie, the concrete floor slab will crack or the timber floor will fracture generally at joints between framing members).

Combinations of any of the above settlement cases and also combinations of settlement and stretching are possible.

Figure 9.4: Lateral stretching



9.4 Linking land and building performance

The Building Code requirements are described in section 8. The Earthquake Loadings Standard, NZS 1170.5:2004, is cited as a Verification Method (B1/VM1) for the satisfaction of Building Code performance requirements.

The NZS 1170.5 performance requirements are however specific to the building structure only, and no reference is made to the land performance on which the building is founded. At SLS levels of shaking, no significant building damage is expected. The geotechnical issue is what is expected of the ground under such levels of shaking.

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Liquefaction areas

In the areas where liquefaction occurred, the residential houses have been considered to have broadly met the ULS performance requirements (ie, there were no observed collapsed houses or loss of life in areas of liquefaction). A number of house foundations did rupture during the Canterbury earthquake sequence.

In the very severe land damage zone, the houses were in varying states. In many parts of this zone, the habitability of dwellings was compromised by excessive land movement.

Where buildings require demolition because they cannot be repaired within the building value, but have remained safely habitable, these buildings can be considered as having met the ULS performance requirements of the Building Code.

Hillside areas

The hillside areas are currently subject to ongoing work by Christchurch City Council, CERA, EQC and GNS Science to investigate causes and implications of various forms of damage. In particular, areas of rockfall, cliff collapse and boulder roll are being evaluated to determine appropriate remediation or retreat options. Some larger-scale apparent landslide mechanisms and wide-area ground cracking are also being investigated for similar reasons. Outside these areas it is envisioned that repairs and reconstruction will be able to proceed subject to site-specific investigation and design, as outlined in section 6.

10. Future liquefaction performance expectations for land and buildings

10.1 Future land performance

Based on observations of the distribution of land damage in the Canterbury earthquake sequence, it is apparent that the performance of the ground across Canterbury in potential future seismic events will vary considerably from location to location. The potential for liquefaction (based on the soil type, soil strength and depth to groundwater) is variable across the region, ranging from negligible liquefaction potential in some areas to high liquefaction potential in other areas.

For any given site, the actual degree of liquefaction in future events will also be variable, depending on the location of the earthquake in relation to the site, the depth of rupture, the magnitude of the event and the duration of shaking. Furthermore, the surface manifestation of damage (degree of land settlement, sand boils, surface rupture, lateral spread, etc) will vary depending on subsurface stratigraphy and geometrical landform differences (eg, relative levels, proximity to free edges such as rivers, ground slope etc).

It is considered that land that liquefied in any of the 4 September 2010, 22 February 2011, 13 June 2011, or 23 December 2011 events has a relatively high likelihood of liquefaction in future strong shaking events. However, the degree and consequences of liquefaction will be highly variable. Furthermore, future events could be of longer duration, higher energy, and in different locations. Therefore other areas that were not affected by the recent earthquakes may be affected in future strong shaking events.

It is possible to improve the performance of land by various means to reduce the severity and impact of liquefaction. It is also feasible to increase the resilience of foundation systems to reduce the impacts of liquefaction on building structures where the land liquefaction performance is within certain limits.

Land that has been shown to be most susceptible to severe damage in the recent events has been zoned 'Red' by the Government and CERA. Within the Red Zone it is difficult to improve the future performance without large-scale civil engineering works requiring the demolition of whole suburbs to efficiently complete. In the 'Red Zone', it is seen as impractical, uneconomic and too disruptive to undertake such extensive works. However, most land in the remaining areas on the flat (the 'Green Zone') is expected to be repaired on an individual basis should land remediation be required; otherwise foundation systems can be constructed to cope in an appropriate manner with the expected future liquefaction performance of the land.

Foundation Technical Category Maps for areas on the flat

Foundation Technical Category Maps for each of Christchurch City, Waimakariri District and Selwyn District have been prepared in conjunction with this document. These maps are shown in Figures 3.1a, b and c.

The foundation technical category areas have been identified as being at low, medium and high probability of future liquefaction, primarily based on the performance of land from the 4 September 2010 earthquake and 22 February 2011 aftershock, together with observed land performance from a number of the large aftershocks experienced up to and including 23 December 2011. In addition to this, borehole data, together with limited historic groundwater data, were considered in the preparation of the maps.

Because the 22 February 2011 aftershock was located immediately to the southeast of central Christchurch, it was considered a good test case for the central, southern and eastern areas of Christchurch.

The Selwyn District and portions of northern Christchurch up to Waimakariri District experienced ground accelerations significantly less than the surrounding areas, and therefore the land performance from the earthquakes in these areas gives less of a guide to future seismic land performance. For this reason, the foundation technical categories for these areas are only partly based on observed performance from the earthquakes, and take more account of known soil types and groundwater depths.

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The correlation between the three foundation technical categories and observed land performance is summarised in Table 10.1.

These foundation technical categories allow resources to be channelled to those areas where uncertainty exists or significant liquefaction could occur in the future, while providing an efficient method of foundation design for those areas at low risk of future liquefaction-induced land damage. The expected future performance of the land in each of the technical categories is outlined in Table 3.1 in Part A.

Technical categories for hillside areas

Currently no foundation technical categories (or their equivalent) are proposed for the hillside areas. Specific investigation and design will likely be required for any hillside repair or reconstruction project. Broad guidance for hillside areas is provided in section 6.

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Table 10.1: Observed land performance and proposed technical categories

Foundation technical category	Observed land performance
TC1	TC1 covers those areas of greater Christchurch where *on an area-wide basis*, no significant land deformation occurred as a result of liquefaction from either the 4 September 2010 earthquake or the 22 February 2011 aftershock and there is generally greater than 3 m depth to groundwater.
TC2	TC2 covers those areas of greater Christchurch where *on an area-wide basis* no or negligible land deformation occurred as a result of liquefaction from the 4 September 2010 earthquake and only relatively small amounts of land deformations occurred as a result of the 22 February 2011 aftershock. It also includes some areas in Selwyn District and northern Christchurch that did not suffer land damage but are considered at some risk of potential ground damage from liquefaction until proved otherwise.
TC3	TC3 covers those areas of greater Christchurch where *on an area-wide basis*, land deformation occurred as a result of liquefaction from the 4 September 2010 earthquake and moderate to severe land deformations occurred as a result of or the 22 February 2011 aftershock, together with the areas identified at high future probability of ground damage until proved otherwise.
Un-categorised	Uncategorised areas include: parks, commercial areas and properties greater that 4,000 m^2, together with those areas that were not mapped for damage from the 4 September 2010 or the 22 February 2011 earthquakes.

10.2 Future building performance

The future performance expectations of property owners, insurance companies and territorial authorities is likely to include building some resilience into reconstructed dwellings, so that the overall performance of dwellings will be better than the performance observed from the Canterbury earthquake sequence. The seismic risk for the region has increased in the short to medium term, and the construction of more resilient structures will help to significantly limit losses and disruption from future earthquakes. At the same time, it is impractical to expect no damage in a future event. The philosophy of the Building Code is to limit damage in small to medium-sized earthquakes, particularly to critical elements, while preventing collapse of structures in large earthquakes.

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There are a range of performance expectations that repaired and reconstructed dwellings should meet, including the following:

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1. Existing structural elements should not comply to any lesser extent than before the alteration, repair or reconstruction, notwithstanding any Gazetted change in seismic hazard for the site.
2. New structural elements must to meet the performance requirements of the Building Code.
3. New dwelling foundations must be constructed to accommodate the land performance expectations in Table 3.1.
4. Foundation solutions for new dwellings should include provision for some resilience to be incorporated into the structure.

In areas where future land damage is considered unlikely (TC1), the practical approach for new construction is to ensure the foundation is tied together (eg, reinforced slab). In many cases where land damage is expected to be moderate (TC2), it is more practical to manage building performance by improving building and foundation resilience to ground movements, rather than trying to prevent the land from being damaged in a future moderate to large earthquake. This is easier to achieve by reconstructing dwellings than by adding resilience to repaired dwellings.

For new and remediated buildings, foundation systems and the buildings themselves need to be designed to accommodate total settlements, differential settlements and lateral strains of the ground that may occur in a future event. The foundations and buildings need to be sufficiently stiff and strong to ensure expected ground movements do not result in severe building distortion.

Repaired foundations

Those dwellings with foundations that can be repaired (see section 4) will need to be assessed on a case-by-case basis to determine the degree of additional resilience that can be practically included in the repair at reasonable cost. Accordingly, a different approach is recommended for **rebuilt** foundations (see section 5). This may require ground strengthening to improve liquefaction performance or reduce liquefaction susceptibility.

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Housing stock with foundation damage that is repaired without any foundation improvement is likely to have a similar level of foundation performance to that observed in the recent Canterbury earthquake sequence, when subjected to future similar levels of shaking.

New foundations and new dwellings

For new foundations beneath existing superstructures and new dwellings, the foundations should be designed to be able to resist possible lateral spreading of the ground beneath the foundation and to limit future distortion of the foundation to the criteria provided in Table 3.1.

Where houses are rebuilt, the option exists to build light-weight dwellings and construct a more robust foundation to provide a greater level of performance in a future liquefaction event, particularly with respect to amenity. A stiff foundation system where all the elements are tied together will better tolerate differential ground settlement than the unreinforced slabs and unconnected strip footings present in many of the damaged

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dwellings. This will limit the amount of differential movement experienced by the superstructure, and significantly reduce damage following any future liquefaction event.

In TC1, the future ground deformation expectations are such that the NZS 3604 shallow piled foundations and slab-on-grade foundations (with B1/AS1 modifications), will provide appropriate future foundation performance. NZS 3604 implies in its definition of 'good ground' that settlements of up to 25 mm are acceptable.

In TC2, future land deformations expected beneath the dwelling may result in total and differential settlements as indicated in Table 5.3. Stiffened slab options, as described in section 5, are proposed for TC2 to provide an appropriate future foundation performance.

In TC3 (subject to confirmation by specific investigation), the potential future land deformations are likely to be greater than could be expected to be accommodated by any of the solutions proposed for TC1 and TC2.

Possible solutions for TC3 are provided in Part C .

Expectations for services in liquefaction areas

The potential for lateral spreading and liquefaction on a property will place excessive stress on services between the street and the dwelling unless they are designed to accommodate the expected movements. Guidance on measures to alleviate the stress on services is provided in section 5.6.

It is also recommended that extra grade be provided for piped services that rely on gravity for operation (eg, sewer and stormwater), together with more flexibility at service connections.

Subdivisions

A set of guidelines for the investigation and assessment of subdivisions can be found in Section D of this guidance or at: www.dbh.govt.nz/subdivisions-assessment-guide. It is required that all subdivisions are investigated following these guidelines, and the expected land performance is aligned to one of the three foundation technical categories. At subdivision consent stage, appropriate general foundation solutions should be proposed for buildings on the land. In some cases it will be advantageous for the land to be improved on a subdivision-wide basis, so a different foundation technical category (and therefore set of foundation solutions) is appropriate.

Any proposed future residential subdivisions will need to be specifically investigated regardless of any Technical Category classification (with the exception of very small subdivisions on land that is already classified as TC1 or TC2 by the Ministry, see Part D, sections 6 and 7).

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Appendix B1: Summary of the effects of liquefaction

The following explanation is provided for liquefaction, lateral spreading and bearing-capacity failure associated with the Canterbury earthquake sequence.

Loose granular soil deposits tend to compact ('contract') when subject to shearing from strong earthquake shaking. If the soils are unsaturated, the ground surface will generally just settle as the soil densifies. Where these soils are saturated, however, the readjustment of the soil particles within the soils as it tries to contract leads to a build-up of pressure within the inter-granular ('pore') water, which has to be 'squeezed out' of the inter-granular spaces ('voids') to allow this contraction of the soil particles to occur.

In liquefiable soils, the soil permeability is not high enough to allow rapid dissipation of this excess pore water pressure. During strong earthquake shaking, the rapid rate of increase in the pore water pressure can cause the pore water pressure to exceed the soil overburden pressure. (The overburden pressure is derived from the weight of the overlying soil mass and gives rise to the soil's frictional strength.) Once this occurs, the soil inter-granular contact pressure (and therefore the soil's frictional strength) is lost – the soil then behaves as a dense fluid – ie, it 'liquefies'.

Liquefaction requires three key elements to occur:

- the presence of loose, non-cohesive material that will tend to densify under seismic shaking (loose fine sands and many loose silt-sand mixtures are particularly susceptible to liquefaction)
- ground saturation (ie, the material susceptible to liquefaction lies below the groundwater table)
- sufficient shaking to trigger liquefaction – it should be noted that the level of seismic shaking to trigger liquefaction can vary significantly from site to site.

Once liquefaction has occurred, it can lead to a number of secondary effects, including:

- lateral spreading and the associated development of 'graben' features (ie, the ground shifts sideways and tension cracks develop where the ground has torn apart)
- bearing-capacity failure of foundations
- rotational slope failure or ground movement and the development of lines of differential settlement (ie, a semi-circular rotational failure of the ground occurs and this creates a step in the ground surface at the head and toe of the failure surface)
- sand boils (ie, liquefied material is ejected from within the ground to the surface through defects in the ground such as holes, structural penetrations, graben features and tension cracks)
- settlement of the ground surface additional to that caused by the initial shaking densification (usually from sand boils ejecting liquefied material)
- the floatation of buried services and 'buoyant' structures such as pipelines, manholes, swimming pools and tanks.

Observations indicate that lateral spreading, rotational failures and settlement have caused a large portion of the most severe building damage attributable to the Canterbury earthquake sequence.

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Lateral spreading may occur if all or part of a sloping soil mass liquefies and results in the horizontal movement of the ground surface. Liquefaction of deeper material may cause a 'crust' to slide towards a topographically lower area such as a river-bed or pond. Lateral spreading can occur with or without permanent stretch (ie, strain) at the ground surface. Where there is permanent ground surface strain, surface cracks and fissures (ie, graben feature or tension crack/tear zone) will occur. The foundations of buildings located in these areas can potentially suffer from damage due to the lateral extension forces generated, and any design will have to consider these. Horizontal movement can also occur without ground surface strain where the main slide occurs as a single mass. In these areas buildings with shallow foundations can move without suffering significant damage. However, where deep piles are embedded into a deeper bearing layer this may give rise to issues of pile verticality and any design would need to address this. Significant lateral spreading is principally only likely in TC3.

The excess pore water pressures are expected to gradually dissipate after the seismic shaking has ceased. With time, the liquefied ground stabilises and usually rests in a slightly denser state than before. Anecdotal evidence from liquefied areas within Christchurch indicates the ejection of groundwater, silt and sand material to the ground surface generally continued for between one and 30 minutes after the primary ground shaking ceased.

In general, the excess groundwater pressures due to seismic shaking are expected to take between two and eight weeks to fully dissipate and essentially return to a level which existed before the earthquake. It should be noted, however, that in some cases the groundwater pressures may take somewhat longer to dissipate if the ground conditions are particularly unfavourable. It should also be noted that ground settlements may result in groundwater levels coming closer to the surface (ie, reduced crust thickness).

During the post-liquefaction period, the ground surface may settle and/or creep as the soils reconsolidate to a denser state. Once the excess pore pressures have fully dissipated the geotechnical conditions, including soil density, strength, stiffness and bearing capacity, are mostly expected to return to a condition close to and perhaps marginally better than that which existed before the beginning of the Canterbury earthquake sequence.

In general, all soils that experienced liquefaction during any of the events in the Canterbury earthquake sequence are expected to be at risk of liquefaction during a future severe seismic event.

There are a number of publications that provide further detailed discussion on liquefaction and its effects. For further information and detail, see the recent NZ Geotechnical Society guidelines (NZGS, 2010).

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The guidelines for the investigation and assessment of subdivisions can be found at www.dbh.govt.nz/subdivisions-assessment-guide. .