Christchurch City Council

PRK_0275_BLDG_015
Burnside Park Water Tower
336 Avonhead Road, Burnside

QUANTITATIVE ASSESSMENT REPORT

FINAL

- Rev B
- 03 October 2013

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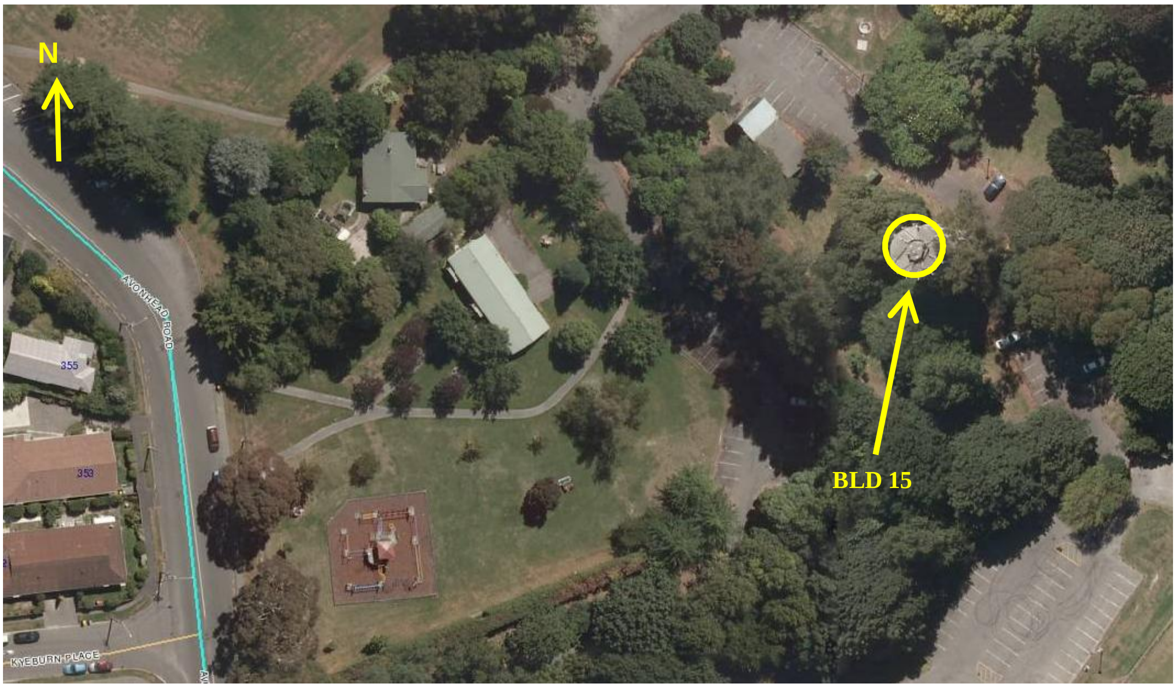
1. Executive Summary

1.1. Background

A Quantitative Assessment was carried out on the Water Tower structure located at 336 Avonhead Road. The structure is comprised of a circular reinforced concrete tower structure with a large tank at the top. The tower is supported on an octagonal shaped reinforced concrete foundation which is founded at approximately 2metres below ground level. The structure is no longer used for the storage of water and instead is used for electrical and transmitting equipment. An aerial photograph illustrating these areas is shown below in Figure 1. The structure is assumed to be constructed in the early 1980s completely from reinforced concrete. Detailed descriptions outlining the age and construction type of the structure is provided in Section 5 of this report.



- **Figure 1 Aerial Photograph of Burnside Park**

This Quantitative report for the structure is based on the Detailed Engineering Evaluation Procedure document (draft) issued by the Structural Advisory Group on 19 July 2011, visual inspections in November 2012, intrusive investigation on 15 August 2013 and basic hand calculations.

1.2. Key Damage Observed

Key damage observed includes:-

- Cracking of concrete foundation visible at ground level

1.3. Critical Structural Weaknesses

No potential critical structural weaknesses have been identified for this structure.

1.4. Indicative Strength

As described in the Engineering Advisory Group's "Guidance on Detailed Engineering Evaluation of Earthquake Affected Non-residential Buildings" (from July 2011) we have assessed the percentage of new building standard seismic resistance using the quantitative method. Our assessment included consideration of geotechnical conditions, existing earthquake damage to the structure and structural engineering calculations to assess both strength and ductility/resilience.

The assessments were based on the following:

- On-site investigation to assess the extent of existing earthquake damage including limited intrusive investigation.
- A geotechnical investigation has been undertaken, a copy of which is included here as Appendix B. We have based our assessment on the geotechnical findings from the report.
- Calculation assessment of the strength of the existing structures taking account of the current condition.

Based on the information available, and using the Quantitative Assessment Procedure, the structures original capacity has been assessed to be between 7% and 33% of NBS. The structures post-earthquake capacity remains unaltered. This assessment has been made without full structural drawings and is accordingly limited.

The structure has been assessed to have a seismic capacity less than 33% NBS and is therefore classified as earthquake prone. This assessment assumes that the structure continues to be used as a cell tower and is not returned to its previous use as a water tower.

Please note that structural strengthening is required by law for structures that are confirmed to have a seismic capacity of less than 33% NBS.

1.5. Recommendations

It is recommended that:

a) There is no damage to the structure that would cause it to be unsafe for workers to enter or the public within the park.

b) Options to strengthen or demolish the structure are considered. Some preliminary strengthening concepts have been provided in section 7.3.

c) We consider that barriers around the structure are not necessary.

2. Introduction

Sinclair Knight Merz was engaged by Christchurch City Council to carry out a Quantitative Assessment of the seismic performance of the Water Tower Structure located in Burnside Park at 336 Avonhead Road, Christchurch.

The scope of this quantitative analysis includes the following:

- Analysis of the seismic load carrying capacity of the structure compared with current seismic loading requirements or New Buildings Standard (NBS). It should be noted that this analysis considers the structure in its damaged state where appropriate.
- Identify any critical structural weaknesses which may exist in the structure and include these in the assessed %NBS of the structure.
- Preparation of a summary report outlining the areas of concern in the structure.

The recommendations from the Engineering Advisory Group[1] were followed to assess the likely performance of the structures in a seismic event relative to the New Building Standard (NBS). 100% NBS is equivalent to the strength of a structure that fully complies with current codes. This includes a recent increase of the Christchurch seismic hazard factor from 0.22 to 0.3[2].

At the time of this report an intrusive site investigation to determine the size of the foundations had been carried out on 15 August 2013. Structural drawings were not available and as such our assessment has been made based on assumed reinforcing contents. The structure description below is based on a review of the site measurements and our visual inspections.

[1] EAG 2011, *Guidance on Detailed Engineering Evaluation of Earthquake Affected Non-residential Buildings in Canterbury - Draft*, p 10
[2] http://www.dbh.govt.nz/seismicity-info

3. Compliance

This section contains a summary of the requirements of the various statutes and authorities that control activities in relation to buildings in Christchurch at present.

3.1. Canterbury Earthquake Recovery Authority (CERA)

CERA was established on 28 March 2011 to take control of the recovery of Christchurch using powers established by the Canterbury Earthquake Recovery Act enacted on 18 April 2011. This act gives the Chief Executive Officer of CERA wide powers in relation to building safety, demolition and repair. Two relevant sections are:

Section 38 – Works

This section outlines a process in which the chief executive can give notice that a building is to be demolished and if the owner does not carry out the demolition, the chief executive can commission the demolition and recover the costs from the owner or by placing a charge on the owners' land.

Section 51 – Requiring Structural Survey

This section enables the chief executive to require a building owner, insurer or mortgagee carry out a full structural survey before the building is re-occupied.

We understand that CERA will require a detailed engineering evaluation to be carried out for all buildings (other than those exempt from the Earthquake Prone Building definition in the Building Act). It is anticipated that CERA will adopt the Detailed Engineering Evaluation Procedure document (draft) issued by the Structural Advisory Group on 19 July 2011. This document sets out a methodology for both qualitative and quantitative assessments.

The qualitative assessment is a desk-top and site inspection assessment. It is based on a thorough visual inspection of the building coupled with a review of available documentation such as drawings and specifications. The quantitative assessment involves analytical calculation of the buildings strength and may require non-destructive or destructive material testing, geotechnical testing and intrusive investigation.

It is anticipated that factors determining the extent of evaluation and strengthening level required will include:

- The importance level and occupancy of the building
- The placard status and amount of damage
- The age and structural type of the building

- Consideration of any critical structural weaknesses
- The extent of any earthquake damage

3.2. Building Act

Several sections of the Building Act are relevant when considering structural requirements:

3.2.1. Section 112 – Alterations

This section requires that an existing building complies with the relevant sections of the Building Code to at least the extent that it did prior to any alteration. This effectively means that a building cannot be weakened as a result of an alteration (including partial demolition).

3.2.2. Section 115 – Change of Use

This section requires that the territorial authority (in this case Christchurch City Council (CCC)) be satisfied that the building with a new use complies with the relevant sections of the Building Code 'as near as is reasonably practicable'. Regarding seismic capacity 'as near as reasonably practicable' has previously been interpreted by CCC as achieving a minimum of 67%NBS however where practical achieving 100%NBS is desirable. The New Zealand Society for Earthquake Engineering (NZSEE) recommend a minimum of 67%NBS.

3.2.3. Section 121 – Dangerous Buildings

The definition of dangerous building in the Act was extended by the Canterbury Earthquake (Building Act) Order 2010, and it now defines a building as dangerous if:

- in the ordinary course of events (excluding the occurrence of an earthquake), the building is likely to cause injury or death or damage to other property; or
- in the event of fire, injury or death to any persons in the building or on other property is likely because of fire hazard or the occupancy of the building; or
- there is a risk that the building could collapse or otherwise cause injury or death as a result of earthquake shaking that is less than a 'moderate earthquake' (refer to Section 122 below); or
- there is a risk that that other property could collapse or otherwise cause injury or death; or
- a territorial authority has not been able to undertake an inspection to determine whether the building is dangerous.

3.2.4. Section 122 – Earthquake Prone Buildings

This section defines a building as earthquake prone if its ultimate capacity would be exceeded in a 'moderate earthquake' and it would be likely to collapse causing injury or death, or damage to other property. A moderate earthquake is defined by the building regulations as one that would generate ground shaking 33% of the shaking used to design an equivalent new building.

3.2.5. Section 124 – Powers of Territorial Authorities

This section gives the territorial authority the power to require strengthening work within specified timeframes or to close and prevent occupancy to any building defined as dangerous or earthquake prone.

3.2.6. Section 131 – Earthquake Prone Building Policy

This section requires the territorial authority to adopt a specific policy for earthquake prone, dangerous and insanitary buildings.

3.3. Christchurch City Council Policy

Christchurch City Council adopted their Earthquake Prone, Dangerous and Insanitary Building Policy in 2006. This policy was amended immediately following the Darfield Earthquake of the 4th September 2010.

The 2010 amendment includes the following:

- A process for identifying, categorising and prioritising Earthquake Prone Buildings, commencing on 1 July 2012;
- A strengthening target level of 67% of a new building for buildings that are Earthquake Prone. Council recognises that it may not be practicable for some repairs to meet that target. The council will work closely with building owners to achieve sensible, safe outcomes;
- A timeframe of 15-30 years for Earthquake Prone Buildings to be strengthened; and,
- Repair works for buildings damaged by earthquakes will be required to comply with the above.

The council has stated their willingness to consider retrofit proposals on a case by case basis, considering the economic impact of such a retrofit.

We anticipate that any building with a capacity of less than 34%NBS (including consideration of critical structural weaknesses) will need to be strengthened to a target of 67%NBS of new building standard as recommended by the Policy.

If strengthening works are undertaken, a building consent will be required. A requirement of the consent will require upgrade of the building to comply ‘as near as is reasonably practicable’ with:

- The accessibility requirements of the Building Code.
- The fire requirements of the Building Code. This is likely to require a fire report to be submitted with the building consent application.

3.4. Building Code

The building code outlines performance standards for buildings and the Building Act requires that all new buildings comply with this code. Compliance Documents published by The Department of Building and Housing can be used to demonstrate compliance with the Building Code.

After the February Earthquake, on 19 May 2011, Compliance Document B1: Structure was amended to include increased seismic design requirements for Canterbury as follows:

a) Hazard Factor increased from 0.22 to 0.3 (36% increase in the basic seismic design load)
b) Serviceability Return Period Factor increased from 0.25 to 0.33 (80% increase in the serviceability design loads when combined with the Hazard Factor increase)

The increase in the above factors has resulted in a reduction in the level of compliance of an existing building relative to a new building despite the capacity of the existing building not changing.

4. Earthquake Resistance Standards

For this assessment, the building's earthquake resistance is compared with the current New Zealand Building Code requirements for a new building constructed on the site. This is expressed as a percentage of new building standard (%NBS). The new building standard load requirements have been determined in accordance with the current earthquake loading standard (NZS 1170.5:2004 Structural design actions - Earthquake actions - New Zealand).

The likely capacity of this building has been derived in accordance with the New Zealand Society for Earthquake Engineering (NZSEE) guidelines 'Assessment and Improvement of the Structural Performance of Buildings in Earthquakes' (AISPBE), 2006. These guidelines provide an Initial Evaluation Procedure that assesses a buildings capacity based on a comparison of loading codes from when the building was designed and currently. It is a quick high-level procedure that can be used when undertaking a Qualitative analysis of a building. The guidelines also provide guidance on calculating a modified Ultimate Limit State capacity of the building which is much more accurate and can be used when undertaking a Quantitative analysis.

The New Zealand Society for Earthquake Engineering has proposed a way for classifying earthquake risk for existing buildings in terms of %NBS and this is shown in Figure 2 below.

Description	Grade	Risk	%NBS	Existing Building Structural Performance	Improvement of Structural Performance	
					Legal Requirement	NZSEE Recommendation
Low Risk Building	A or B	Low	Above 67	Acceptable (improvement may be desirable)	The Building Act sets no required level of structural improvement (unless change in use) This is for each TA to decide. Improvement is not limited to 34%NBS.	100%NBS desirable. Improvement should achieve at least 67%NBS
Moderate Risk Building	B or C	Moderate	34 to 66	Acceptable legally. Improvement recommended		Not recommended. Acceptable only in exceptional circumstances
High Risk Building	D or E	High	33 or lower	Unacceptable (Improvement	Unacceptable	Unacceptable

- **Figure 2: NZSEE Risk Classifications Extracted from table 2.2 of the NZSEE 2006 AISPBE Guidelines**

Table 1 below provides an indication of the risk of failure for an existing building with a given percentage NBS, relative to the risk of failure for a new building that has been designed to meet current Building Code criteria (the annual probability of exceedance specified by current earthquake design standards for a building of 'normal' importance is 1/500, or 0.2% in the next year, which is equivalent to 10% probability of exceedance in the next 50 years).

- **Table 1: %NBS compared to relative risk of failure**

Percentage of New Building Standard (%NBS)	Relative Risk (Approximate)
>100	<1 time
80-100	1-2 times
67-80	2-5 times
33-67	5-10 times
20-33	10-25 times
<20	>25 times

5. Structure Details

Our evaluation was based on visual and non-invasive inspections and our site sketches. As no structural drawings were available we have carried out a cover meter survey using a reinforcing ferro scanner to determine reinforcing spacing and cover, and we have made conservative assumptions as to the likely reinforcing diameters that would have been expected at the time of construction. Since these are assumptions only, our assessment is accordingly limited. Further investigation in the form of removing cover concrete could provide larger bar diameters and hence a higher capacity, however these investigations have not been carried out at this stage and the investigation may only confirm our assumptions.

5.1. Structure description

It is thought that the structure was built in the early 1980s or late 1970s as a water tower. The structure is now used as a cell tower which significantly reduces the demand on the structure. The foundations consist of an octagon shaped concrete pad on compacted fill that is founded at approximately 2 metres below ground level. The superstructure is made up of a cylindrical concrete wall which supports a concrete tank at around 18m above ground level.

5.2. Gravity Load Resisting system

Gravity loads in the structure are carried down to the foundations through the concrete walls of the tower and are then spread into the ground by the pad foundation.

5.3. Seismic Load Resisting system

Seismic loads in the structure are resisted by the tower concrete walls in shear which carries the load to the foundations in shear and overturning. The foundation then removes the shear and overturning loads by spreading them into the supporting soils. Since the structure is circular the along and across directions are meaning less and hence are not defined.

5.4. Structure Damage

SKM undertook visual inspections to consider damage in November 2012. A further intrusive investigation to determine the size of the foundation was carried out on 15 August 2013.

The following areas of damage were observed during the inspections:

General

1) No visual evidence of settlement was noted at this site and neighbouring sites are classified as TC1 land[3]. Therefore a level survey is not required at this stage of assessment.

Damage

1) Hairline cracks in external concrete ground slab at the entrance door and to the north of the entrance.
2) Water leakage was suggested from calcium carbonate build-up beneath the top storey extension on the east side of the structure.

Photos of the above damage can be found in Appendix A.

[3] http://cera.govt.nz/maps/technical-categories

6. Available Information and Assumptions

6.1. Available Information

Following our inspections in November 2012 and August 2013, SKM carried out a seismic review on the structures. This review was undertaken using the available information which was as follows:

- SKM site measurements and inspection findings.

6.2. Survey

No survey has been carried out as there are no concerns. The verticality of the structure was reviewed using a hand-held 600mm long digital spirit level. This check showed that there were no consistent lean on the structure indicating that there was at worst a negligible lean.

6.3. Design Criteria and Assumptions

The following design criteria and assumptions made in undertaking the assessment include:

- The soil on site is class D as described in AS/NZS1170.5:2004, Clause 3.1.3, Soft Soil. The ultimate bearing capacity has been found to be around 580kPa for the existing foundation. Liquefaction was not noted in the areas around the site and as such liquefaction can be ignored.
- Standard design criteria for "normal" buildings as described in AS/NZS1170.0:2002:
  - 50 year design life, which is the default NZ Building Code design life.
  - Structure Importance Level 2. This level of importance is described as 'normal' with medium or considerable consequence for loss of human life, or considerable economic, social or environmental consequence of failure.
- The structure has a short period less than 0.4 seconds (note: detailed analysis may well prove that the period of the structure is greater than 0.4 seconds which will reduce the seismic loads and increase the %NBS of the structure, however in the absence of this detailed analysis an assumed period of 0.4 seconds has been used).
- Site hazard factor, Z = 0.3, NZBC, Clause B1 Structure, Amendment 11 effective from 1 August 2011
- The structure continues to be used as a cell tower and is not returned to its previous use as a water tower.
- The mass of equipment within the tower has been ignored since it is likely to be significantly less than the mass of the structure itself and hence is unlikely to significantly alter the findings presented below.

- The following material properties were used in the analyses:
- **Table 2: Material Properties**

Material	Material Property
Concrete	Compressive strength 30MPa
Reinforcing Steel	Yield Stress 250MPa
Unit weight of soil	γ = 17kN/m3
Soil	Ultimate bearing capacity beneath the foundations 580kPa. A factor of safety of 2.0 has been used for seismic loads.

The detailed engineering analysis is a post construction evaluation therefore it has the following limitations:

- It is not likely to pick up on any concealed construction errors (if they exist)
- Other possible issues that could affect the performance of the structure such as corrosion and modifications to the structure will not be identified unless they are visible, have been specifically mentioned in this report and will affect the capacity of the structure.
- The detailed engineering evaluation deals only with the structural aspects of the structure. Other aspects such as building services are not covered.

6.4. The Detailed Engineering Evaluation (DEE) process

The DEE is a procedure written by the Department of Building and Housing's Engineering Advisory Group and grades buildings according to their likely performance in a seismic event. The procedure is not yet recognised by the NZ Building Code but is widely used and recognised by the Christchurch City Council as the preferred method for preliminary seismic investigations of buildings[4].

The procedure of the DEE is as follows:

1) Quantitative procedure
    a. Carry out a geotechnical investigation if required by the qualitative assessment
    b. Analyse the building according to current building codes and standards. Analysis accounts for damage to the structure.

The DEE assessment ranks buildings according to how well they are likely to perform relative to a new building designed to current earthquake standards, as shown in Table 3. The building rank is indicated by the percentage of the required New Building Standard (%NBS) strength that the

[4] http://resources.ccc.govt.nz/files/EarthquakeProneDangerousAndInsanitaryBuildingsPolicy2010.pdf

structure is considered to have. Earthquake prone buildings are defined as having less than 34 %NBS strength which correlates to an increased risk of approximately 20 times that of 100% NBS[5]. Structures that are identified to be earthquake prone are required by law to be strengthened within 30 years of the owner being notified that the structure is potentially earthquake prone[6]. This timeframe is likely to be adjusted by CERA and Table 3 below contains the likely new recommendations.

Table 3: DEE Risk classifications

Description	Grade	Risk	%NBS	Structural performance
Low risk building	A+	Low	> 100	Acceptable. Improvement may be desirable.
	A		100 to 80	
	B		80 to 67	
Moderate risk building	C	Moderate	67 to 33	Acceptable legally. Improvement recommended.
High risk building	D	High	33 to 20	Unacceptable. Improvement required.
	E		< 20	

The DEE method rates structures based on the plans (if available) and other information known about the structure and some more subjective parameters associated with how the structure is detailed and so it is possible that %NBS derived from different engineers may differ.

This assessment describes only the likely seismic Ultimate Limit State (ULS) performance of the structure. The ULS is the level of earthquake that can be resisted by the structure without catastrophic failure. The DEE does also consider Serviceability Limit State (SLS) performance of the structure and or the level of earthquake that would start to cause damage to the structure but this result is secondary to the ULS performance.

The NZ Building Code describes that the relevant codes for determining %NBS are primarily:

- AS/NZS 1170 Structural Design Actions
- NZS 3101:2006 Concrete Structures Standard

[5] NZSEE 2006, *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes*, p 2-2

[6] http://resources.ccc.govt.nz/files/EarthquakeProneDangerousAndInsanitaryBuildingsPolicy2010.pdf

7. Results and Discussions

7.1. Critical Structural Weaknesses

No potential critical structural weaknesses have been identified for this structure.

7.2. Analysis Results

The equivalent static force method was used to analyse the seismic capacity of the structure. The results of the analysis are reported in the following table as %NBS. The results below are calculated for the structure in its damaged state. The structure results have been broken down into their seismic resisting elements.

(%NBS = probable strength / new building standards)

- **Table 4: DEE Results**

Seismic Resisting Element	Action	Seismic Rating %NBS
Concrete walls above foundation	Bending	7% (<33%)
Foundation overturning	Overturning	Approximately 43%
Foundation reinforcing	Bending	Approximately 47%

7.3. Recommendations

The quantitative assessment carried out on the water tower structure indicates that it has a seismic capacity less than 34% of NBS and is therefore classed as being in the category of a ‘High Risk Building’.

It is recommended the structure be strengthened to a target of at least 67%.

Strengthening is likely to involve the following:

- Detailed design and drawings of the strengthening.
- Extension of the existing foundations to reduce the bearing stresses.
- Strengthening of the existing concrete walls either by adding additional reinforced concrete internally or by applying FRP to the walls which would be anchored into the foundation.

8. Conclusion

SKM carried out a quantitative assessment on the Burnside Water Tower structure located at 336 Avonhead Road, Christchurch. This assessment concluded that the structure is classified as Earthquake Prone having a capacity less than 33% of NBS.

- **Table 5: Quantitative assessment summary**

Description	Grade	Risk	%NBS	Structural Performance
Water Tower	D or E	High	<33%	Unacceptable

This assessment assumes that the structure continues to be used as a cell tower and is not returned to its previous use as a water tower.

Strengthening is recommended on the structure to bring the seismic capacity up to at a minimum of 67% of NBS. If strengthening is not cost-effective the building should be demolished to remove the risk of severe injury or death to the public.

It is recommended that:

a) There is no damage to the structure that would cause it to be unsafe for workers to enter or the public within the park.
b) Options to strengthen or demolish the structure are considered. Some preliminary strengthening concepts have been provided in section 7.3.
c) We consider that barriers around the structure are not necessary.

9. Limitation Statement

This report has been prepared on behalf of, and for the exclusive use of, SKM's client, and is subject to, and issued in accordance with, the provisions of the contract between SKM and the Client. It is not possible to make a proper assessment of this report without a clear understanding of the terms of engagement under which it has been prepared, including the scope of the instructions and directions given to, and the assumptions made by, SKM. The report may not address issues which would need to be considered for another party if that party's particular circumstances, requirements and experience were known and, further, may make assumptions about matters of which a third party is not aware. No responsibility or liability to any third party is accepted for any loss or damage whatsoever arising out of the use of or reliance on this report by any third party.

Without limiting any of the above, in the event of any liability, SKM's liability, whether under the law of contract, tort, statute, equity or otherwise, is limited in as set out in the terms of the engagement with the Client.

It is not within SKM's scope or responsibility to identify the presence of asbestos, nor the responsibility of SKM to identify possible sources of asbestos. Therefore for any property pre-dating 1989, the presence of asbestos materials should be considered when costing remedial measures or possible demolition.

Should there be any further significant earthquake event, of a magnitude 5 or greater, it will be necessary to conduct a follow-up investigation, as the observations, conclusions and recommendations of this report may no longer apply Earthquake of a lower magnitude may also cause damage, and SKM should be advised immediately if further damage is visible or suspected.

Appendix A Photos

Photo 1: Typical elevation looking west

Photo 2: Top of foundation at joint with tower walls.

Photo 3: Entrance on the north side of structure

Photo 4: Hairline crack located at entrance in top of concrete foundation

	
Photo 5: Hairline cracks in top of concrete foundation to the north of the entrance	Photo 6: Pipework on the south side of the structure
	
Photo 7: 450mm high shuttering marks in concrete wall.	Photo 8: Shuttering marks

	
Photo 9: Telecommunications equipment seen on the top storey	Photo 10: Grated openings (4 per level)
	
Photo 11: Telecommunications equipment on the ground floor	Photo 12: 280mm thick concrete wall

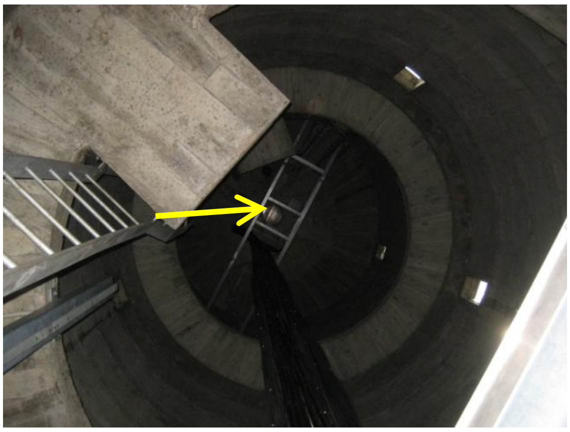
	
Photo 13: Interior of tower from ground level showing the 850mm wide ledges and ladders	Photo 14: Circular entrance to the top level can be seen
	
Photo 15: Joint between 850mm wide concrete ledge and concrete wall	Photo 16: Joint between the concrete foundation and concrete wall

	
Photo 17: Telecommunications equipment on the ground level	Photo 18: Steel beams for telecommunications equipment anchored to the concrete wall
	
Photo 19: Build up of calcium carbonate noted on the underside of the top level extension indicating water leakage.	Photo 20: Close-up at the underside of the tank

Photo 21: Foundation profile as exposed during excavation.

Appendix B Geotechnical Interpretive Report

Christchurch City Council
PRK_0275_BLDG_015
Burnside Park Water Tower
336 Avonhead Road, Burnside

PRELIMINARY GEOTECHNICAL INTERPRETATIVE REPORT

FINAL

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1. Introduction

SKM has been commissioned by Christchurch City Council to provide a quantitative Detailed Engineering Evaluation (DEE) for the Water Tower structure located at 336 Avonhead Road, Burnside.

A limited site geotechnical investigation was undertaken as part of the evaluation to provide a quantitative assessment of the ultimate bearing capacity of the foundation under earthquake loading and a basic visual assessment of liquefaction potential.

The scope of geotechnical works comprised the following:

- Undertaking subsurface investigations involving one machine excavated trial pit. One hand-auger hole and two dynamic cone penetrometer (DCP) tests were completed in the base of the pit
- Assessment of aerial photography
- Assessment of the ultimate bearing capacity under earthquake loading
- Preparation of a preliminary interpretative report identifying shallow ground conditions at the site

2. Site description

The site is located at 336 Avonhead Road, Burnside, to the north west of Christchurch CBD. The site has flat topography at approximately 20 metres above sea level. The Department of Building and Housing technical category (TC) is not applicable since the site is urban non-residential; however the nearby residential properties are categorised as TC 1 suggesting liquefaction damage is unlikely in future large earthquakes.

The structure on site comprises a circular reinforced concrete tower with a large tank at the top. The tower is supported on an octagonal shaped reinforced concrete foundation.

- **Figure 1: Aerial photograph of the site, Avonhead Road, Burnside. Site marked in yellow (*Xplore*, SKM database).**

3. Existing geotechnical information

3.1. Investigation by third parties

Reference to the Environment Canterbury GIS database found seven boreholes in the vicinity of the site (<50 m). The closest available borehole log (M35/2454) is located approximately 20 m to the north west, drilled to 16.4 mbgl. Subsurface material generally consists of silt and clay to 2 mbgl, overlying sandy gravels. The ground water table is noted to be 2.5 mbgl.

3.2. Regional geology

The 1:25,000 geological map of the Christchurch urban area (Brown and Weeber, 1992) indicates that the site is predominantly underlain by alluvial sand and silt overbank deposits of the Springston Formation.

4. Geotechnical investigation

4.1. General

The ground investigation was carried out on 15 August 2013. It comprised one machine excavated trial pit and one hand-auger hole with DCP tests adjacent to the auger hole. The trial pit was carried out to expose the footing. The underside of the footing was found to be at 2 mbgl and the trial pit was terminated at this depth. The hand-auger hole and DCP tests were then performed in the base of the trial pit to 4.2 mbgl. The approximate location of the trial pit is shown on the site plan in Appendix A.

A Geotechnical Engineer from SKM was onsite and logged the underlying material in accordance with New Zealand Geotechnical Society (NZGS) guidelines. The logs are provided in Appendix B. The DCP test results are shown on the logs.

4.1.1. Subsurface Profile

Based on the ground investigation, the following subsurface profile for the site can be inferred:

- **Table 1 – Subsurface Profile**

Depth range (mBLG)	Soil type
0 – 0.7	Sandy fine to coarse gravel with trace cobbles; loosely packed [FILL]
0.7 – 4.2	Silty sand to sand; medium dense to dense [Springston Formation]

Ground investigation logs are provided in Appendix B.

4.2. Groundwater observations

The water table was encountered at approximately 3.9 mbgl.

5. Geotechnical Considerations

5.1. Seismic site subsoil class

The scope of ground investigation was limited to a shallow depth of 4.2 m; therefore, the site has been evaluated as NZS1170.5 Class D (deep or soft soils) based on estimates of the depth to underlying rock from published data.

5.2. Liquefaction

Aerial photography taken after the 22 February 2011 earthquake indicates no evidence of liquefaction in the vicinity of the site. Based purely on visual evidence, future land damage from liquefaction is unlikely. Please note however that further ground investigations are required to carry out a liquefaction potential assessment of the site.

5.3. Lateral spread

The site is at negligible risk for lateral spreading movement due to the distance (>1 km) from any unrestricted boundaries (i.e. river or water body).

5.4. Foundation capacity

The ultimate bearing capacity of the foundation under earthquake loading has been estimated based on the New Zealand Building Code B1/VM4 prepared by the Department of Housing and Building. For the purposes of this assessment the following assumptions have been made:

1) The foundation is a circular pad with a diameter of 9.8 m and is founded at a depth of 2 mbgl

2) The footing is founded on medium dense sand with a frictional angle of 35°. It is assumed that the soil profile beneath the footing is relatively constant with depth.

3) The loads applied at the top of the foundation are V*=7,480 kN, H*=1,860 kN, M*=28,870 kNm

The ultimate bearing capacity under earthquake loading has been estimated to be 580 kPa with an effective foundation area of 8.4 m^2. An appropriate soil strength reduction factor (ϕ_{bc}) of 0.9 should be used for the assessment of the ULS bearing capacity.

6. Conclusions / Recommendations

- Shallow ground investigation consisting of one trial pit and one hand-auger hole with DCP tests confirmed the site to be underlain by fill to approximately 0.7 m, overlying silty sand to sand to a refusal depth of 4.2 mbgl.
- Groundwater table was encountered in the hand-auger hole at approximately 3.9 mbgl.
- Based on a visual inspection of the site, future land damage from liquefaction is considered unlikely. However it is recommended that a liquefaction potential assessment is carried out for the site.
- Based on the vertical, horizontal loads and moment outlined in section 5.4 applied at the top of the foundation due to earthquake loading, the ultimate bearing capacity of the foundation is estimated to be 580 kPa with an effective foundation area of 8.4 m^2. An appropriate soil strength reduction factor (ϕ_{bc}) of 0.9 should be used for the assessment of the ULS bearing capacity.
- Further ground investigations are required to confirm the ground conditions and to assess the liquefaction potential of the site prior to detailed design.

7. Limitations

This report is project specific. It was prepared to address geotechnical issues relating to the existing structure at 336 Avonhead Road, Burnside, Christchurch in accordance with the scope of works as defined in the contract between SKM and our Client. This report has been prepared on behalf of, and for the exclusive use of, our Client, and is subject to, and issued in accordance with, the provisions of the contract between SKM and our Client. The findings presented in this report should not be applied to another site or another development within the same site without consulting SKM.

Geotechnical conditions can change and will vary across any site and between investigation locations. The findings of this geotechnical report reflect the geotechnical conditions at the identified locations and at the time of the investigation. If this report is being referenced after some period of time has elapsed since it was drafted then it is recommended that SKM be consulted regarding the current validity of this report.

Not all of the ground conditions that exist at the site may have been identified in this report. All reports and conclusions that deal with sub-surface conditions are based on interpretation and judgement and as a result have uncertainty attached to them. You should be aware that this report contains interpretations and conclusions which are uncertain due to the nature of the investigations. Sampling techniques, by definition, cannot determine the conditions between the sample points and so this report cannot be taken to be a full representation of the sub-surface conditions. This report only provides an indication of the likely sub surface conditions. No study or investigation can eliminate every risk and conclusively identify all the ground conditions within a site.

This report is based on assumptions that the site conditions as revealed through sampling are indicative of conditions throughout the site. The findings are the result of standard assessment techniques used in accordance with normal practices and standards, and they represent a reasonable interpretation of the current conditions on the site.

This report should be read in full and no excerpts are to be taken as representative of the findings. It must not be copied in parts, have parts removed, redrawn or otherwise altered without the written consent of SKM.

8. References

Brown LJ and Weeber JH. 1992: Geology of the Christchurch Urban Area. Scale 1:25,000. Institute of Geological and Nuclear Sciences geological map1. 1 sheet + 104 p. Institute of Geological and Nuclear Sciences Ltd, Lower Hutt, New Zealand.

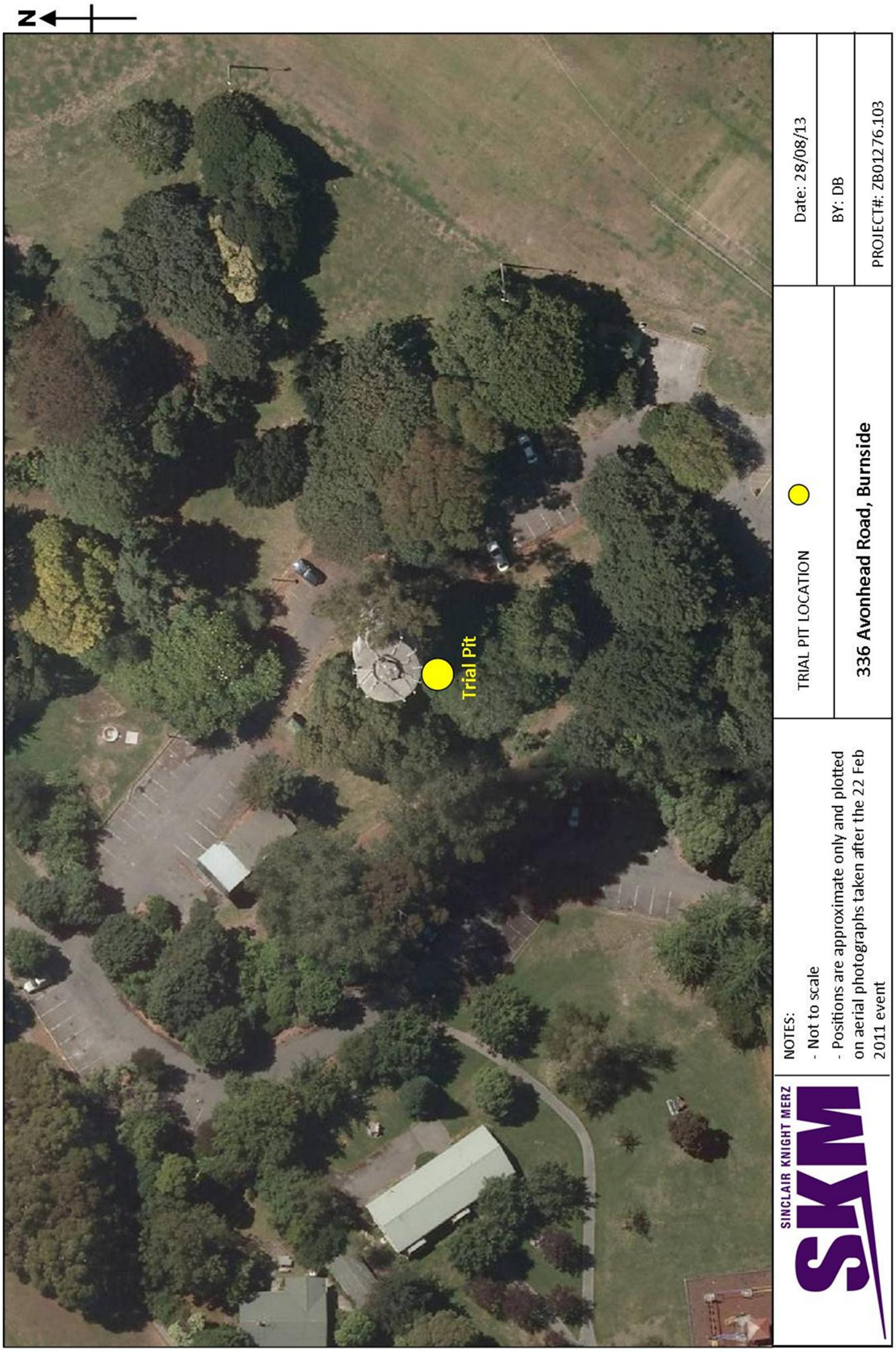
Compliance Document for New Zealand Building Code Clause B1 Structure, Department of Building and Housing (Amendment 11, 2011)

Ministry of Business Innovation and Employment (MBIE) guidance: Repairing and rebuilding houses affected by the Canterbury earthquakes (December 2012)

New Zealand Geotechnical Society, 2005. *Guidelines for the Field Classification and Description of Soil and Rock for Engineering Purposes*.

Standards New Zealand, "NZS 3604, Timber Framed Structures", 2011

Appendix A Site Plan


N
Trial Pit
TRIAL PIT LOCATION
336 Avonhead Road, Burnside
Date: 28/08/13
BY: DB
PROJECT#: ZB01276.103
NOTES:
- Not to scale
- Positions are approximate only and plotted on aerial photographs taken after the 22 Feb 2011 event
SINCLAIR KNIGHT MERZ
SKM

Appendix B Borehole Logs

SINCLAIR KNIGHT MERZ
SKM

Preliminary Log of Investigation

Project: ZB01276.103 - Hand Augering & DCP Tests

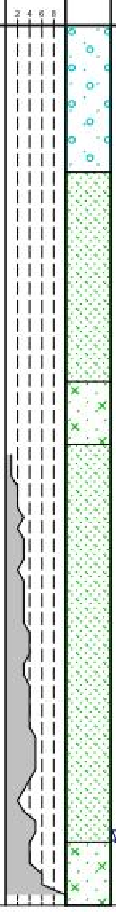
Location: **336 Avonhead Road, Burnside** Project No: **ZB01276.103**

Hole ID: **1**

Client: **Christchurch City Council**

Date: **15/08/2013**

R.L. (m)	Depth (m)	Drilling Method	In-Situ Testing	Sampling	DCP (Blows per Drive)	Geology Legend	GroundWater	Description of Strata	Geological Unit	Backfill / Installation
	0.0–0.7							Sandy fine to coarse GRAVEL with trace silt and cobbles, brown. Loosely packed, moist, subangular to subrounded, well graded; sand is fine to medium; cobbles up to 150 mm. **(Fill)**		
	0.7–1.7 (1.0)							Fine to medium SAND with minor silt, brown. Loose to medium dense, moist. **(Springston Formation)**	Spy	
	1.7–2.0							Silty fine to medium SAND, brown. Medium dense, moist. **(Springston Formation)**	Spy	
	2.0–3.9 (2.0, 3.0)						1 (3.9 m)	Fine to medium SAND with trace silt, grey. Medium dense, moist. **(Springston Formation)** *2.80m: becomes dense* *3.00m: with some silt* *3.40m: with trace silt; becomes orange brown* *3.60m: becomes dark brown* *3.80m: becomes grey*	Spy	
	3.9–4.2 (4.0)							Silty fine to medium SAND, grey. Dense, wet. **(Springston Formation)** *3.90m: becomes wet*	Spy	



1 terminated at 4.20m. Unable to advance - too hard

Started: 15/08/2013
Finished: 15/08/2013
Driller:
Plant:
Logged: DB
Checked: ME

Depth Related Remarks
From *Remarks*

Groundwater Observations

No.	*Struck (m)*	*Date*	*Observations*	*Standing (m)*
1.	3.9m			

Co-ordinates:
5183037.00mN
1564744.00mE

Inclination: -90°

Remarks
Co-ordinates recorded from aerial photography.

Page 1 of 1

Data Template: DATA TEMPLATE.GDT Output Form: AUGERHOLE Project File Name: HANDAUGER LOGS + DCP.GPJ 2/9/13

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

SINCLAIR KNIGHT MERZ SKM

SKM

Preliminary Log of Investigation

Dynamic Cone Penetrometer

Project: **ZB01276.103 - Hand Augering & DCP Tests**

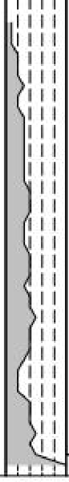
Location: **336 Avonhead Road, Burnside** Project No: **ZB01276.103**

Hole ID: **2**

Client: **Christchurch City Council**

Date: **15/08/2013**

R.L. (m)	Depth (m)	Drilling Method	In-Situ Testing	Sampling	DCP (Blows per Drive)	Geology Legend	GroundWater	Description of Strata	Geological Unit	Backfill / Installation
	1.0 2.0 3.0 4.0				2 4 6 8		1	This log only shows the second DCP test results. Please refer to Hole ID: 1 for stratum description.		



2 terminated at 4.20m. Unable to advance - too hard

Started: 15/08/2013
Finished: 15/08/2013
Driller:
Plant:
Logged: DB
Checked: ME

Depth Related Remarks
From *Remarks*

Groundwater Observations

No.	*Struck (m)*	*Date*	*Observations*	*Standing (m)*
1.	3.9m	16/08/2013		

Remarks
Co-ordinates recorded from aerial photography.

Co-ordinates:
5183037.00mN
1564744.00mE

Inclination: -90°

Page 1 of 1

Data Template: DATA TEMPLATE.GDT Output Form: AUGERHOLE Project File Name: HANDAUGER LOGS + DCP.GPJ 2/9/13

Version 1.6 28/06/2006 - S.Humphreys

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Appendix C CERA Standardised Report Form

Detailed Engineering Evaluation Summary Data V1.11

Location

Building Name:	Burnside Park Water Tower
Building Address:	Unit: / No: 336 / Street: Avonhead Road, Burnside
Legal Description:	
GPS south: (Degrees / Min / Sec)	
GPS east:	
Building Unique Identifier (CCC):	PRK_0275_BLDG_015
Reviewer:	N Calvert
CPEng No:	242062
Company:	SKM
Company project number:	ZB01276.103
Company phone number:	09 928 5500
Date of submission:	9-Oct
Inspection Date:	15/08/2013
Revision:	B
Is there a full report with this summary?	yes

Site

Site slope:	flat
Soil type:	
Site Class (to NZS1170.5):	D
Proximity to waterway (m, if <100m):	
Proximity to clifftop (m, if < 100m):	
Proximity to cliff base (m,if <100m):	
Max retaining height (m):	
Soil Profile (if available):	
If Ground improvement on site, describe:	
Approx site elevation (m):	

Building

No. of storeys above ground:	4 (single storey = 1)
Ground floor split?	no
Storeys below ground	0
Foundation type:	mat slab
Building height (m):	26.00
Floor footprint area (approx):	29
Age of Building (years):	45
Ground floor elevation (Absolute) (m):	
Ground floor elevation above ground (m):	
if Foundation type is other, describe:	
height from ground to level of uppermost seismic mass (for IEP only) (m):	26
Date of design:	1935-1965
Strengthening present?	no
If so, when (year)?	
And what load level (%g)?	
Brief strengthening description:	
Use (ground floor):	commercial
Use (upper floors):	commercial
Use notes (if required):	Telecommunications equipment
Importance level (to NZS1170.5):	IL2

Gravity Structure

Gravity System:	load bearing walls
Roof:	concrete (slab thickness (mm): Unknown)
Floors:	concrete flat slab (slab thickness (mm): Unknown)
Beams:	none (overall depth x width (mm x mm): None)
Columns:	none (typical dimensions (mm x mm): None)
Walls:	load bearing concrete (#N/A)

Lateral load resisting structure

Note: Define along and across in detailed report!

Lateral system along:	concrete shear wall
note total length of wall at ground (m):	4.5
Ductility assumed, μ:	1.25
wall thickness (m):	
Period along:	0.40 ##### enter height above at H31
estimate or calculation?	estimated
Total deflection (ULS) (mm):	20
estimate or calculation?	estimated
maximum interstorey deflection (ULS) (mm):	
estimate or calculation?	estimated
Lateral system across:	concrete shear wall
note total length of wall at ground (m):	4.5
Ductility assumed, μ:	1.25
wall thickness (m):	
Period across:	0.40 ##### enter height above at H31
estimate or calculation?	estimated
Total deflection (ULS) (mm):	20
estimate or calculation?	estimated
maximum interstorey deflection (ULS) (mm):	
estimate or calculation?	estimated

Separations: (leave blank if not relevant)

north (mm):	
east (mm):	
south (mm):	
west (mm):	

Non-structural elements

Stairs:	
Wall cladding:	exposed structure (describe: Concrete walls)
Roof Cladding:	
Glazing:	
Ceilings:	
Services(list):	Unknown

Available documentation

Architectural	none	original designer name/date:
Structural	none	original designer name/date:
Mechanical	none	original designer name/date:
Electrical	none	original designer name/date:
Geotech report	partial	original designer name/date:

Damage

Site: (refer DEE Table 4-2)

Site performance:		Describe damage:
Settlement:	none observed	notes (if applicable):
Differential settlement:	none observed	notes (if applicable):
Liquefaction:	none apparent	notes (if applicable):
Lateral Spread:	none apparent	notes (if applicable):
Differential lateral spread:	none apparent	notes (if applicable):
Ground cracks:	none apparent	notes (if applicable):
Damage to area:	none apparent	notes (if applicable):

Building:

Current Placard Status: green

Along	Damage ratio:	0%
	Describe (summary):	Cracking in concrete ground slab
Across	Damage ratio:	0%
	Describe (summary):	Cracking in concrete ground slab

Describe how damage ratio arrived at: Current damage noted will not diminish the capacity of the building.

$$Damage\_Ratio = \frac{(\% NBS\,(before) - \% NBS\,(after))}{\% NBS\,(before)}$$

Diaphragms	Damage?: no	Describe:
CSWs:	Damage?: no	Describe:
Pounding:	Damage?: no	Describe:
Non-structural:	Damage?: yes	Describe: Cracking in concrete ground slab.

Recommendations

Level of repair/strengthening required:	minor non-structural	Describe:
Building Consent required:	no	Describe:
Interim occupancy recommendations:	full occupancy	Describe: Not an immediate collapse hazard.

Along	Assessed %NBS before:	7%	%NBS from IEP below
	Assessed %NBS after:	7%	
Across	Assessed %NBS before:	7%	%NBS from IEP below
	Assessed %NBS after:	7%	

If IEP not used, please detail assessment methodology: SKM Quantitative Assessment (refer attached report)