SINCLAIR KNIGHT MERZ
SKM

CHRISTCHURCH CITY COUNCIL
BU 0450-003 EQ2
Fendalton Library - Caged Fuel Tank
4 Jeffreys Road, Fendalton

QUALITATIVE ASSESSMENT REPORT
FINAL

- Rev B
- 21 September 2012

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Contents

Document history and status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
A	03/08/2012	C Paverd	N Calvert	03/08/2012	Draft for Client Approval
B	20/09/2012	N Calvert	N Calvert	20/09/2012	Final Issue

Approval

	Signature	Date	Name	Title
Author		21/09/2012	Willow Patterson-Kane	Structural Engineer
Approver		21/09/2012	Nick Calvert	Senior Structural Engineer

Distribution of copies

Revision	Copy no	Quantity	Issued to
A	1	1	CCC
B	1	1	CCC

Printed:	21 September 2012
Last saved:	21 September 2012 01:02 PM
File name:	ZB01276.141_CCC_BU_0450_003_EQ2_Qualitative Assmt.docx
Author:	Willow Patterson-Kane
Project manager:	Nick Calvert
Name of organisation:	Christchurch City Council
Name of project:	Christchurch City Council Structures Panel
Name of document:	Fendalton Library - Caged Fuel Tank Qualitative Assessment
Document version:	B
Project number:	ZB01276.141

1. Executive Summary

1.1. Background

A Qualitative Assessment was carried out on the building located behind the Fendalton Library at 4 Jeffreys Road, Fendalton. The building is single storey and is currently utilised as storage for fuel tanks. It is believed to be constructed from partially reinforced masonry walls on the south and west sides, with steel hollow section columns propping the timber-framed lightweight roof on the north and east sides. An aerial photograph illustrating this area is shown below in Figure 1. Detailed descriptions outlining the buildings age and construction type is given in Section 5 of this report.

- **Figure 1 Aerial Photograph of the fuel storage shed at 4 Jeffreys Road**

The qualitative assessment includes a summary of the building damage as well as an initial assessment of the current seismic capacity compared with current seismic code loads using the Initial Evaluation Procedure (IEP).

This Qualitative report for the building structure is based on the Detailed Engineering Evaluation Procedure document (draft) issued by the Structural Advisory Group on 19 July 2011 and a visual inspection on 22 May 2012.

1.2. Key Damage Observed

No external or internal damage was observed during our site inspection.

1.3. Critical Structural Weaknesses

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

1.4. Indicative Building Strength (from IEP and CSW assessment)

Based on the information available, and using the NZSEE Initial Evaluation Procedure, the buildings original capacity has been assessed to be in the order of 42% NBS. No damage was observed during the site investigation therefore the post earthquake capacity will not change as a result of earthquake damage.

The building has been assessed to have a seismic capacity less than 67% NBS and is therefore a potential earthquake risk.

1.5. Recommendations

It is recommended that:

a) The current placard status of the building of Green 1 remain as is.
b) Due to the low importance level of this structure, it is not likely to be cost-effective to carry out a quantitative assessment and strengthening, therefore no further work is recommended.
c) We consider that barriers around the building are not necessary.

2. Introduction

Sinclair Knight Merz was engaged by Christchurch City Council to prepare a qualitative assessment report for the building located behind the Fendalton Library at 4 Jeffreys Road following the magnitude 6.3 earthquake which occurred in the afternoon of the 22nd of February 2011 and the subsequent aftershocks.

The Qualitative Assessment uses the methodology recommended in the Engineering Advisory Group draft document "Guidance on Detailed Engineering Evaluation of Earthquake affected Non-residential Buildings in Canterbury", issued 19 July 2011. The qualitative assessment includes a summary of the building damage as well as an initial assessment of the likely current Seismic Capacity compared with current seismic code requirements.

A qualitative assessment involves inspections of the building and a desktop review of existing structural and geotechnical information, including existing drawings and calculations, if available.

The purpose of the assessment is to determine the likely building performance and damage patterns, to identify any potential critical structural weaknesses or collapse hazards, and to make an initial assessment of the likely building strength in terms of percentage of new building standard (%NBS).

This report describes the structural damage observed during our inspection and indicates suggested remediation measures. The inspection was undertaken from floor levels and was a visual inspection only. Our report reflects the situation at the time of the inspection and does not take account of changes caused by any events following our inspection. A full description of the basis on which we have undertaken our visual inspection is set out in Section 7.

The NZ Society for Earthquake Engineering (NZSEE) Initial Evaluation Procedure (IEP) was used to assess the likely performance of the building in a seismic event relative to the New Building Standard (NBS). 100% NBS is equivalent to the strength of a building that fully complies with current codes. This includes a recent increase of the Christchurch seismic hazard factor from 0.22 to 0.3[1].

At the time of this report, no intrusive site investigation, detailed analysis, or modelling of the building structure had been carried out. The building description below is based on our visual inspections.

[1] http://www.dbh.govt.nz/seismicity-info

3. Compliance

This section contains a brief 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 33%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. Building Details

5.1. Building description

The building is located behind the Fendalton Library at 4 Jeffreys Road. There is only one building on this site. The building has one storey that is currently utilised as storage for fuel tanks. The building is believed to be constructed from partially reinforced masonry walls on the south and west sides, with steel hollow sections propping the timber-framed lightweight roof on the north and east sides. The ground floor appears to be supported on a concrete slab foundation. The steel columns appear to be anchored within the concrete slab. It is assumed the building was designed and constructed in the late 1960's, along with the main library structure.

Our evaluation was based on the visual inspection carried out on 22 May 2012. Drawings were not available to verify the foundation system and the date of construction.

5.2. Gravity Load Resisting system

It appears that the gravity loads are taken by the masonry block walls and steel hollow section columns, with direct transfer into the concrete slab foundation below.

5.3. Seismic Load Resisting system

Lateral loads acting across and along the building will be resisted by the masonry walls in shear, with the steel hollow section columns acting as cantilevers in both directions.

Note that for this building the 'across direction' has been taken as east-west and the 'along direction' has been taken as north-south.

5.4. Geotechnical Conditions

A geotechnical desktop study was carried out for this site. The main conclusions from this report are:

- In accordance with NZS1170.5 the site is likely to be seismic subsoil Class D (deep or soft soil) ground performance and properties.
- The liquefaction risk for this site is expected to be low. The available liquefaction map and aerial photographs show no significant evidence that any form of liquefaction occurred on site. Additionally, no surface expression of liquefied ejecta, cracking or undulation of the pavement and land area as a direct consequence of the 22 February earthquake was apparent during the external site walkover.

If Building Consent is required for the structure, more detailed site specific investigation would be required. Additional investigations that may be suitable are:

- Two boreholes to a depth of 20m with standard penetration tests taken at 1.5m intervals.

6. Damage Summary and Remediation

SKM undertook an inspection on 22 May 2012. The following areas of damage were observed during the time of inspection:

General

1) No visual evidence of settlement was noted at this site, therefore a level survey is not required at this stage of assessment.

Building Damage

1) No earthquake-related damage was observed during our site inspection.
2) Impact damage was noted on the west masonry wall. This is not believed to be earthquake-related damage.

Photos of the above damage can be found in Appendix 1 – Photos.

Only damage thought to be the cause of the earthquakes have been considered for reinstatement.

7. Initial Seismic Evaluation

7.1. The Initial Evaluation Procedure Process

This section covers the initial seismic evaluation of the building as detailed in the NZSEE 'Assessment and Improvement of the Structural Performance of Buildings in Earthquakes'. The IEP 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[2].

The IEP is a coarse screening process designed to identify buildings that are likely to be earthquake prone. The IEP process 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 2. The building rank is indicated by the percent of the required New Building Standard (%NBS) strength that the building is considered to have. Earthquake prone buildings are defined as having less than 33% NBS strength which correlates to an increased risk of approximately 20 times that of 100% NBS[3]. Buildings that are identified to be earthquake prone are required by law to be followed up with a detailed assessment and strengthening work within 30 years of the owner being notified that the building is potentially earthquake prone[4].

[2] http://resources.ccc.govt.nz/files/EarthquakeProneDangerousAndInsanitaryBuildingsPolicy2010.pdf
[3] NZSEE 2006, *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes,* p 2-2
[4] http://resources.ccc.govt.nz/files/EarthquakeProneDangerousAndInsanitaryBuildingsPolicy2010.pdf

Table 2: IEP 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 IEP is a simple desktop study that is useful for risk management. No detailed calculations are done and so it relies on an inspection of the building and its plans to identify the structural members and describe the likely performance of the building in a seismic event. A review of the plans is also likely to identify any critical structural weaknesses. The IEP assumes that the building was properly designed and built according to the relevant codes at the time of construction. The IEP method rates buildings based on the code used at the time of construction and some more subjective parameters associated with how the building 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 building. The ULS is the level of earthquake that can be resisted by the building without catastrophic failure. The IEP does not attempt to estimate Serviceability Limit State (SLS) performance of the building, or the level of earthquake that would start to cause damage to the building[5]. This assessment concentrates on matters relating to life safety as damage to the building is a secondary consideration. SLS performance of the building can be estimated by scaling the current code levels if required.

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

- AS/NZS 1170 Structural Design Actions
- NZS 3101:2006 Concrete Structures Standard
- NZS 3404:1997 Steel Structures Standard

[5] NZSEE 2006, *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes,* p2-9

7.2. Available Information, Assumptions and Limitations

Following our inspection on 22 May 2012, SKM carried out a preliminary structural review. The structural review was undertaken using the available information which was as follows:

- SKM site measurements and external and internal inspection findings of the building. Please note no intrusive investigations were undertaken.
- There were no drawings available to carry out our review.

The following assumptions and design criteria were used in this assessment:

- Standard design assumptions for typical office and factory buildings as described in AS/NZS1170.0:2002
  - 50 year design life, which is the default NZ Building Code design life.
  - Structure Importance Level 1. This level of importance is described as 'low' with small or moderate consequence of failure.
  - Ductility level of 1.25 in both directions, based on our assessment and code requirements at the time of design.
  - Site hazard factor, Z = 0.3, NZBC, Clause B1 Structure, Amendment 11 effective from 1 August 2011

This IEP was based on our external visual inspection of the building. Since it is not a full design and construction review, it has the following limitations:

- It is not likely to pick up on any original design or construction errors (if they exist)
- Other possible issues that could affect the performance of the building such as corrosion and modifications to the building will not be identified
- The IEP deals only with the structural aspects of the building. Other aspects such as building services are not covered.

7.3. Critical Structural Weaknesses

No critical structural weaknesses have been identified in this building.

7.4. Qualitative Assessment Results

The building has had its capacity assessed using the Initial Evaluation Procedure based on the information available. The buildings capacity is expressed as a percentage of new building standard (%NBS) and are in the order of that shown below in Table 3. This capacity is subject to confirmation by a quantitative analysis.

Table 3: Qualitative Assessment Summary

Item	%NBS
Likely Seismic Capacity of Building	42

Our qualitative assessment found that the building is likely to be classed as potentially earthquake prone and probably a 'Moderate Risk Building' (capacity less than 67% of NBS). The full IEP assessment form is detailed in Appendix 2 – IEP Reports.

Further investigation is required to confirm our initial findings and establish possible strengthening concepts.

The Council regulations state that if the %NBS of the building is less than 34%, this building is considered earthquake prone and is required to be strengthened.

The Engineering Advisory Group notes:

> *"For buildings with insignificant damage, but that have %NBS<33%, and buildings with significant damage, a quantitative assessment is required. Note that according to the extent of damage, it may be possible to complete a quantitative assessment for part only of the structure, with a qualitative analysis for the structure as a whole. This could be sufficient when there is highly localised severe damage but the building has otherwise suffered little or no damage."*

8. Further Investigation

Due to the lack of structural drawings and the likely seismic capacity of the building being less than 67% NBS, but greater than 33% NBS, a quantitative assessment would generally be recommended. However, given the low importance level of the structure and the likely cost of carrying out the quantitative assessment and the subsequent strengthening and repairs, it may be more cost-effective to carry out no further investigation work.

If a quantitative assessment is carried out then intrusive investigations will be required to confirm the following structural details:

- Foundation layout and size of elements.
- Connections sizes and layouts.

It is believed that a building consent will likely be required to strengthen the building.

9. Conclusion

A qualitative assessment was carried out on the building located behind the Fendalton Library at 4 Jeffreys Road, Fendalton. The building has sustained no earthquake-related damage. The building has been assessed to have a seismic capacity in the order of 42% NBS and is therefore a potential earthquake risk and is likely to be classified as a 'Moderate Risk Building' (capacity less than 67% NBS).

Further investigation would generally be recommended to confirm our initial findings and to establish possible strengthening concepts. This investigation will require carrying out a quantitative assessment on the building to determine if there is enough capacity in the structural elements to resist the required earthquake demand.

However, it is not likely to be cost-effective to carry out a quantitative analysis and the likely subsequent strengthening due to the low importance level of the structure and its likely seismic capacity being greater than 33% NBS. Therefore, no further work is recommended at this stage. If the building is to be strengthened, building consent will likely be required.

It is recommended that:

a) The current placard status of the building of Green 1 remain as is.
b) Due to the low importance level of this structure, it is not likely to be cost-effective to carry out a quantitative assessment and strengthening, therefore no further work is recommended.
c) We consider that barriers around the building are not necessary.

10. 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.

There is a risk of further movement and increased cracking due to subsequent aftershocks or settlement.

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.

11. Appendix 1 – Photos

	
Photo 1: East elevation	Photo 2: South elevation
	
Photo 3: West elevation	Photo 4: North elevation

	
Photo 5: Concrete strip footing directly under masonry walls.	Photo 6: South masonry wall and steel hollow section column on east side.
	
Photo 7: Timber-framed roof and masonry walls.	Photo 8: Bolted connection between steel hollow section column and timber roof edge beam.

	
Photo 9: Timber edge beam on east side.	Photo 10: Steel cap plate above east wall.
	
Photo 11: Timber-framed roof and west masonry wall.	Photo 12: Connection between steel hollow section column and timber roof edge beam on north east corner.

	
Photo 13: Steel hollow section column ground connection on north east corner.	Photo 14: Masonry wall extension past roof on west side.
	
Photo 15: Existing impact damage to west wall extension and traces of ceiling foam in an existing cavity.	Photo 16: Gutter above west masonry wall.

	
Photo 17: Gutter above south masonry wall.	Photo 18: Ground connection of steel hollow section columns (typical).

12. Appendix 2 – IEP Reports

Table IEP-1 **Initial Evaluation Procedure – Step 1**

(Refer Table IEP - 2 for Step 2; Table IEP - 3 for Step 3, Table IEP - 4 for Steps 4, 5 and 6)

Building Name:	Fendalton Library - Caged Fuel Tank	Ref.	ZB01276.141
Location:	4 Jeffreys Road, Fendalton	By	WPK
		Date	24/05/2012

Step 1 - General Information

1.1 Photos (attach sufficient to describe building)




1.2 Sketch of building plan

1.3 List relevant features

The building at 4 Jeffreys Road behind the Fendalton Library is one storey and is currently in use as storage for fuel tanks. The building consists of concrete masonry block walls on the south and west walls, with steel hollow section columns propping the timber-framed lightweight roof on the north and east walls. The main lateral load-resisting system appear to be the masonry walls acting as shear walls in the north-south and east-west direction, with the steel columns acting as cantilevers in both directions. The block walls appear to be founded on a concrete slab footing. The steel columns appear to be anchored to the concrete slab underneath the ground surface concrete. The building is assumed to have been constructed in the late 1960's, along with the main library building.

1.4 Note information sources

	Tick as appropriate
Visual Inspection of Exterior	✓
Visual Inspection of Interior	✓
Drawings (note type)	
Specifications	
Geotechical Reports	✓
Other (list)	

Table IEP-2 Initial Evaluation Procedure – Step 2

(Refer Table IEP - 1 for Step 1; Table IEP - 3 for Step 3, Table IEP - 4 for Steps 4, 5 and 6)

Building Name:	Fendalton Library - Caged Fuel Tank	Ref.	ZB01276.141
Location:	4 Jeffreys Road, Fendalton	By	WPK
Direction Considered:	**Longitudinal & Transverse**	Date	24/05/2012

(Choose worse case if clear at start. Complete IEP-2 and IEP-3 for each if in doubt)

Step 2 - Determination of (%NBS)b

2.1 Determine nominal (%NBS) = (%NBS)nom

Pre 1935			○	See also notes 1, 3
1935-1965			○	
1965-1976	Seismic Zone;	A	○	
		B	◉	
		C	○	See also note 2
1976-1992	Seismic Zone;	A	○	
		B	○	
		C	○	
1992-2004			○	

b) Soil Type

From NZS1170.5:2004, Cl 3.1.3

A or B Rock	○
C Shallow Soil	○
D Soft Soil	◉
E Very Soft Soil	○

From NZS4203:1992, Cl 4.6.2.2

(for 1992 to 2004 only and only if known)

a) Rigid	◉	N-A
b) Intermediate	○	

c) Estimate Period, T

building Ht = 3.1 meters

	Longitudinal	Transverse	
Ac =	13	8	m2

Can use following:

		Longitudinal	Transverse
$T = 0.09h_n^{0.75}$	for moment-resisting concrete frames	○ MRCF	○ MRCF
$T = 0.14h_n^{0.75}$	for moment-resisting steel frames	○ MRSF	○ MRSF
$T = 0.08h_n^{0.75}$	for eccentrically braced steel frames	○ EBSF	○ EBSF
$T = 0.06h_n^{0.75}$	for all other frame structures	○ Others	○ Others
$T = 0.09h_n^{0.75}/A_c^{0.5}$	for concrete shear walls	○ CSW	○ CSW
$T <= 0.4sec$	for masonry shear walls	◉ MSW	◉ MSW

Where hn = height in m from the base of the structure to the uppermost seismic weight or mass.

Ac = ΣAi(0.2 + Lwi/hn)2

Ai = cross-sectional shear area of shear wall i in the first storey of the building, in m2

lwi = length of shear wall i in the first storey in the direction parallel to the applied forces, in m

with the restriction that lwi/hn shall not exceed 0.9

Longitudinal	Transverse	
0.4	**0.4**	Seconds

d) (%NBS)nom determined from Figure 3.3

Longitudinal	5	$(\%NBS)_{nom}$
Transverse	5	$(\%NBS)_{nom}$

		Factor
Note 1: For buildings designed prior to 1965 and known to be designed as public buildings in accordance with the code of the time, multiply (%NBS)nom by 1.25.	No	1
For buildings designed 1965 - 1976 and known to be designed as public buildings in accordance with the code of the time, multiply (%NBS)nom by 1.33 - Zone A or 1.2 - Zone B	No	1
Note 2: For reinforced concrete buildings designed between 1976 -1984 (%NBS)nom by 1.2	No	1
Note 3: For buildings designed prior to 1935 multiply (%NBS)nom by 0.8 except for Wellington where the factor may be taken as 1.	No	1

Longitudinal	5.0	$(\%NBS)_{nom}$
Transverse	5.0	$(\%NBS)_{nom}$

Continued over page

Building Name:	Fendalton Library - Caged Fuel Tank	Ref.	ZB01276.141
Location:	4 Jeffreys Road, Fendalton	By	WPK
Direction Considered:	Longitudinal & Transverse	Date	24/05/2012

(Choose worse case if clear at start. Complete IEP-2 and IEP-3 for each if in doubt)

2.2 Near Fault Scaling Factor, Factor A
If T < 1.5sec, Factor A = 1

a) Near Fault Factor, N(T,D) 1
(from NZS1170.5:2004, Cl 3.1.6)

b) Near Fault Scaling Factor = 1/N(T,D) **Factor A** 1.00

2.3 Hazard Scaling Factor, Factor B

Select Location: Christchurch

a) Hazard Factor, Z, for site
(from NZS1170.5:2004, Table 3.3)

Z = 0.3
Z 1992 = 0.8

Auckland	0.6	Palm Nth	1.2
Wellington	1.2	Dunedin	0.6
Christchurch	0.8	Hamilton	0.67

b) Hazard Scaling Factor
For pre 1992 = 1/Z
\# For 1992 onwards = Z 1992/Z
(Where Z 1992 is the NZS4203:1992 Zone Factor from accompanying Figure 3.5(b))

Factor B 3.33

2.4 Return Period Scaling Factor, Factor C

a) Building Importance Level 1
(from NZS1170.0:2004, Table 3.1 and 3.2)

b) Return Period Scaling Factor from accompanying Table 3.1 **Factor C** 2.00

2.5 Ductility Scaling Factor, D

a) Assessed Ductility of Existing Structure, μ
(shall be less than maximum given in accompanying Table 3.2)

Longitudinal	**1.25**	μ Maximum = 2
Transverse	**1.25**	μ Maximum = 2

b) Ductility Scaling Factor
For pre 1976 = k_μ
For 1976 onwards = 1
(where k_μ is NZS1170.5:2005 Ductility Factor, from accompanying Table 3.3)

Longitudinal	**Factor D**	1.14
Transverse	**Factor D**	1.14

2.6 Structural Performance Scaling Factor, Factor E

Select Material of Lateral Load Resisting System
Longitudinal: Masonry Block
Transverse: Masonry Block

a) Structural Performance Factor, S_p
from accompanying Figure 3.4

Longitudinal	Sp	0.90
Transverse	Sp	0.90

b) Structural Performance Scaling Factor

Longitudinal	$1/S_p$	**Factor E**	1.11
Transverse	$1/S_p$	**Factor E**	1.11

2.7 Baseline %NBS for Building, $(\%NBS)_b$
(equals $(\%NSB)_{nom}$ x A x B x C x D x E)

Longitudinal	42.3	(%NBS)b
Transverse	42.3	(%NBS)b

Table IEP-3 Initial Evaluation Procedure – Step 3

(Refer Table IEP - 1 for Step 1; Table IEP - 2 for Step 2, Table IEP - 4 for Steps 4, 5 and 6)

Building Name:	Fendalton Library - Caged Fuel Tank	Ref.	ZB01276.141
Location:	4 Jeffreys Road, Fendalton	By	WPK
Direction Considered:	**a) Longitudinal**	Date	24/05/2012

(Choose worse case if clear at start. Complete IEP-2 and IEP-3 for each if in doubt)

Step 3 - Assessment of Performance Achievement Ratio (PAR)

(Refer Appendix B - Section B3.2)

Critical Structural Weakness	**Effect on Structural Performance** (Choose a value - Do not interpolate)				**Building Score**
	Severe	Significant	Insignificant		
3.1 Plan Irregularity Effect on Structural Performance	○	○	◉	**Factor A**	1
Comment					
3.2 Vertical Irregularity Effect on Structural Performance	○	○	◉	**Factor B**	1
Comment					
3.3 Short Columns Effect on Structural Performance	○	○	◉	**Factor C**	1
Comment					

3.4 Pounding Potential

(Estimate D1 and D2 and set D = the lower of the two, or =1.0 if no potential for pounding)

a) Factor D1: - Pounding Effect
Select appropriate value from Table

Note:
Values given assume the building has a frame structure. For stiff buildings (eg with shear walls), the effect of pounding may be reduced by taking the co-efficient to the right of the value applicable to frame buildings.

Factor D1 1

Table for Selection of Factor D1	Severe	Significant	Insignificant
Separation	0<Sep<.005H	.005<Sep<.01H	Sep>.01H
Alignment of Floors within 20% of Storey Height	○ 0.7	○ 0.8	◉ 1
Alignment of Floors not within 20% of Storey Height	○ 0.4	○ 0.7	○ 0.8

b) Factor D2: - Height Difference Effect
Select appropriate value from Table

Factor D2 1

Table for Selection of Factor D2	Severe	Significant	Insignificant
Separation	0<Sep<.005H	.005<Sep<.01H	Sep>.01H
Height Difference > 4 Storeys	○ 0.4	○ 0.7	○ 1
Height Difference 2 to 4 Storeys	○ 0.7	○ 0.9	○ 1
Height Difference < 2 Storeys	○ 1	○ 1	◉ 1

Factor D 1

(Set D = lesser of D1 and D2 or..
set D = 1.0 if no prospect of pounding)

3.5 Site Characteristics - (Stability, landslide threat, liquefaction etc)

Effect on Structural Performance	Severe	Significant	Insignificant		
	○ 0.5	○ 0.7	◉ 1	**Factor E**	1

3.6 Other Factors

For < 3 storeys - Maximum value 2.5,

otherwise - Maximum value 1.5. No minimum. **Factor F** 1

Record rationale for choice of Factor F:

3.7 Performance Achievement Ratio (PAR)
(equals A x B x C x D x E x F)

PAR 1

(Refer Table IEP - 1 for Step 1; Table IEP - 2 for Step 2, Table IEP - 4 for Steps 4, 5 and 6)

Building Name:	Fendalton Library - Caged Fuel Tank	Ref.	ZB01276.141
Location:	4 Jeffreys Road, Fendalton	By	WPK
Direction Considered:	**b) Transverse**	Date	24/05/2012

(Choose worse case if clear at start. Complete IEP-2 and IEP-3 for each if in doubt)

Step 3 - Assessment of Performance Achievement Ratio (PAR)

(Refer Appendix B - Section B3.2)

Critical Structural Weakness	**Effect on Structural Performance** (Choose a value - Do not interpolate)			**Building Score**
	Severe	Significant	Insignificant	
3.1 Plan Irregularity Effect on Structural Performance	○	○	●	**Factor A** 1
Comment				
3.2 Vertical Irregularity Effect on Structural Performance	○	○	●	**Factor B** 1
Comment				
3.3 Short Columns Effect on Structural Performance	○	○	●	**Factor C** 1
Comment				

3.4 Pounding Potential

(Estimate D1 and D2 and set D = the lower of the two, or =1.0 if no potential for pounding)

a) Factor D1: - Pounding Effect

Select appropriate value from Table

Note:
Values given assume the building has a frame structure. For stiff buildings (eg with shear walls), the effect of pounding may be reduced by taking the co-efficient to the right of the value applicable to frame buildings.

Factor D1 1

Table for Selection of Factor D1

	Severe	Significant	Insignificant
Separation	0<Sep<.005H	.005<Sep<.01H	Sep>.01H
Alignment of Floors within 20% of Storey Height	○ 0.7	○ 0.8	● 1
Alignment of Floors not within 20% of Storey Height	○ 0.4	○ 0.7	○ 0.8

b) Factor D2: - Height Difference Effect

Select appropriate value from Table

Factor D2 1

Table for Selection of Factor D2

	Severe	Significant	Insignificant
Separation	0<Sep<.005H	.005<Sep<.01H	Sep>.01H
Height Difference > 4 Storeys	○ 0.4	○ 0.7	○ 1
Height Difference 2 to 4 Storeys	○ 0.7	○ 0.9	○ 1
Height Difference < 2 Storeys	○ 1	○ 1	● 1

Factor D 1

(Set D = lesser of D1 and D2 or..
set D = 1.0 if no prospect of pounding)

3.5 Site Characteristics - (Stability, landslide threat, liquefaction etc)

Effect on Structural Performance	Severe	Significant	Insignificant	
	○ 0.5	○ 0.7	● 1	**Factor E** 1

3.6 Other Factors

For < 3 storeys - Maximum value 2.5,

otherwise - Maximum value 1.5. No minimum. **Factor F** 1

Record rationale for choice of Factor F:

3.7 Performance Achievement Ratio (PAR)
(equals A x B x C x D x E x F)

PAR 1

Initial Evaluation Procedure – Steps 4, 5 and 6

(Refer Table IEP - 1 for Step 1; Table IEP - 2 for Step 2, Table IEP - 3 for Step 3)

Building Name:	Fendalton Library - Caged Fuel Tank	Ref.	ZB01276.141
Location:	4 Jeffreys Road, Fendalton	By	WPK
Direction Considered:	**Longitudinal & Transverse**	Date	24/05/2012

(Choose worse case if clear at start. Complete IEP-2 and IEP-3 for each if in doubt)

Step 4 - Percentage of New Building Standard (%NBS)

	Longitudinal	Transverse
4.1 Assessed Baseline (%NBS)$_b$ (from Table IEP - 1)	42	42
4.2 Performance Achievement Ratio (PAR) (from Table IEP - 2)	1.00	1.00
4.3 PAR x Baseline (%NBS)$_b$	42	42
4.4 Percentage New Building Standard (%NBS) (Use lower of two values from Step 4.3)		42

Step 5 - Potentially Earthquake Prone?
(Mark as appropriate)

%NBS ≤ 33 — NO

Step 6 - Potentially Earthquake Risk?

%NBS < 67 — YES

Step 7 - Provisional Grading for Seismic Risk based on IEP

Seismic Grade — C

Evaluation Confirmed by

Signature

Nick Calvert — Name

242062 — CPEng. No

Relationship between Seismic Grade and % NBS :

Grade:	A+	A	B	C	D	E
%NBS:	> 100	100 to 80	80 to 67	67 to 33	33 to 20	< 20

13. Appendix 3 – CERA Standardised Report Form

Detailed Engineering Evaluation Summary Data V1.11

Location

Building Name:	Fendalton Library - Caged Fuel Tank
Building Address: Unit / No: / Street	4 Jeffreys Road, Fendalton
Legal Description:	
GPS south: Degrees / Min / Sec	
GPS east:	
Building Unique Identifier (CCC):	
Reviewer:	Nick Calvert
CPEng No:	242062
Company:	SKM
Company project number:	ZB01276.141
Company phone number:	09 928 5500
Date of submission:	
Inspection Date:	22/05/2012
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:	1 (single storey = 1)
Ground floor split?	no
Storeys below ground	0
Foundation type:	strip footings
Building height (m):	2.10
Floor footprint area (approx):	12
Age of Building (years):	50
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):	2.1
Date of design:	1965-1976
Strengthening present?	no
If so, when (year)?	
And what load level (%g)?	
Brief strengthening description:	
Use (ground floor):	public
Use (upper floors):	
Use notes (if required):	
Importance level (to NZS1170.5):	IL1

Gravity Structure

Gravity System:	load bearing walls		
Roof:	timber framed	rafter type, purlin type and cladding	100x500 timber members at 900mm spacing.
Floors:	concrete flat slab	slab thickness (mm)	Unknown
Beams:	timber	type	Timber roof edge beams
Columns:	structural steel	typical dimensions (mm x mm)	60 SHS
Walls:	partially filled concrete masonry	thickness (mm)	200

Lateral load resisting structure

Note: Define along and across in detailed report!

Lateral system along:	partially filled CMU		note total length of wall at ground (m):	6
Ductility assumed, μ:	1.25		wall thickness (m):	200
Period along:	0.40	0.40 from parameters in sheet	estimate or calculation?	estimated
Total deflection (ULS) (mm):	10		estimate or calculation?	estimated
maximum interstorey deflection (ULS) (mm):			estimate or calculation?	estimated
Lateral system across:	partially filled CMU		note total length of wall at ground (m):	2
Ductility assumed, μ:	1.25		wall thickness (m):	200
Period across:	0.40	0.40 from parameters in sheet	estimate or calculation?	estimated
Total deflection (ULS) (mm):	10		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	Masonry walls
Roof Cladding:	Metal	describe	Assumed. Lightweight
Glazing:			
Ceilings:	none		
Services(list):			

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:	No damage observed
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 how damage ratio arrived at:	No damage observed during our site inspection.
	Describe (summary):	No damage observed		
Across	Damage ratio:	0%		
	Describe (summary):	No damage observed		
Diaphragms	Damage?:	no	Describe:	
CSWs:	Damage?:	no	Describe:	
Pounding:	Damage?:	no	Describe:	
Non-structural:	Damage?:	no	Describe:	

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

Recommendations

Level of repair/strengthening required:	none	Describe:	
Building Consent required:	no	Describe:	
Interim occupancy recommendations:	full occupancy	Describe:	

Along	Assessed %NBS before:	42%	%NBS from IEP below	If IEP not used, please detail assessment methodology:	Qualitative Assessment carried out includes NZSEE IEP (refer to SKM report).
	Assessed %NBS after:	42%			
Across	Assessed %NBS before:	42%	%NBS from IEP below		
	Assessed %NBS after:	42%			

14. Appendix 4 – Geotechnical Desktop Study

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Web: www.globalskm.com

Christchurch City Council - Structural Engineering Service

Geotechnical Desk Study

SKM project number	ZB01276
SKM project site number	141
Address	Fendalton Library - Caged Fuel Tank 4 Jeffreys Road
Report date	10 July 2012
Author	Ananth Balachandra
Reviewer	Ross Roberts
Approved for issue	Yes

1. Introduction

This report outlines the geotechnical information that Sinclair Knight Merz (SKM) has been able to source from our database and other sources in relation to the property listed above. We understand that this information will be used as part of an initial qualitative DEE, and will be supplemented by more detailed information and investigations to allow detailed scoping of the repair or rebuild of the building.

2. Scope

This geotechnical desk top study incorporates information sourced from:

- Published geology
- Publically available borehole records
- Liquefaction records
- Aerial photography
- Council files
- A preliminary site walkover

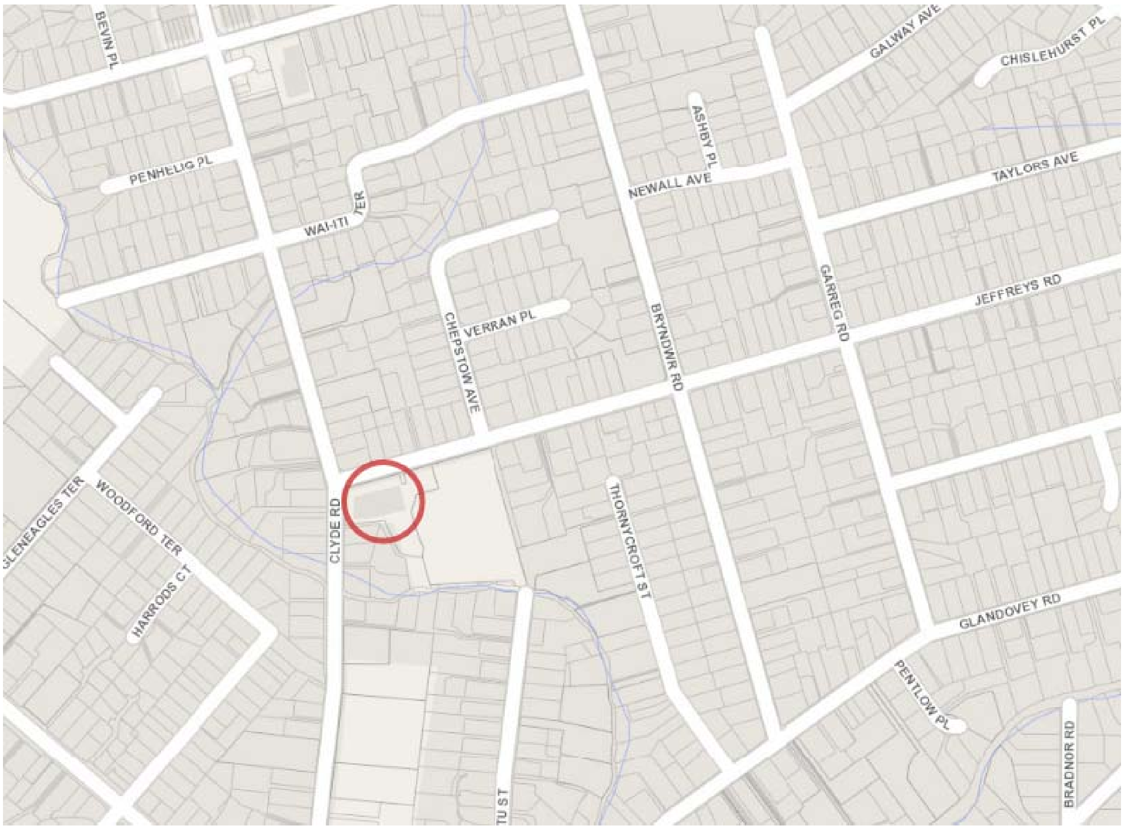
3. Limitations

This report was prepared to address geotechnical issues relating to the specific site 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.

The assessment undertaken by SKM was limited to a desktop review of the data described in this report. SKM has not undertaken any subsurface investigations, measurement or testing of materials from the site. In preparing this report, SKM has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by our Client, and from other sources as described in the report. Except as otherwise stated in this report, SKM has not attempted to verify the accuracy or completeness of any such information.

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.

4. Site location

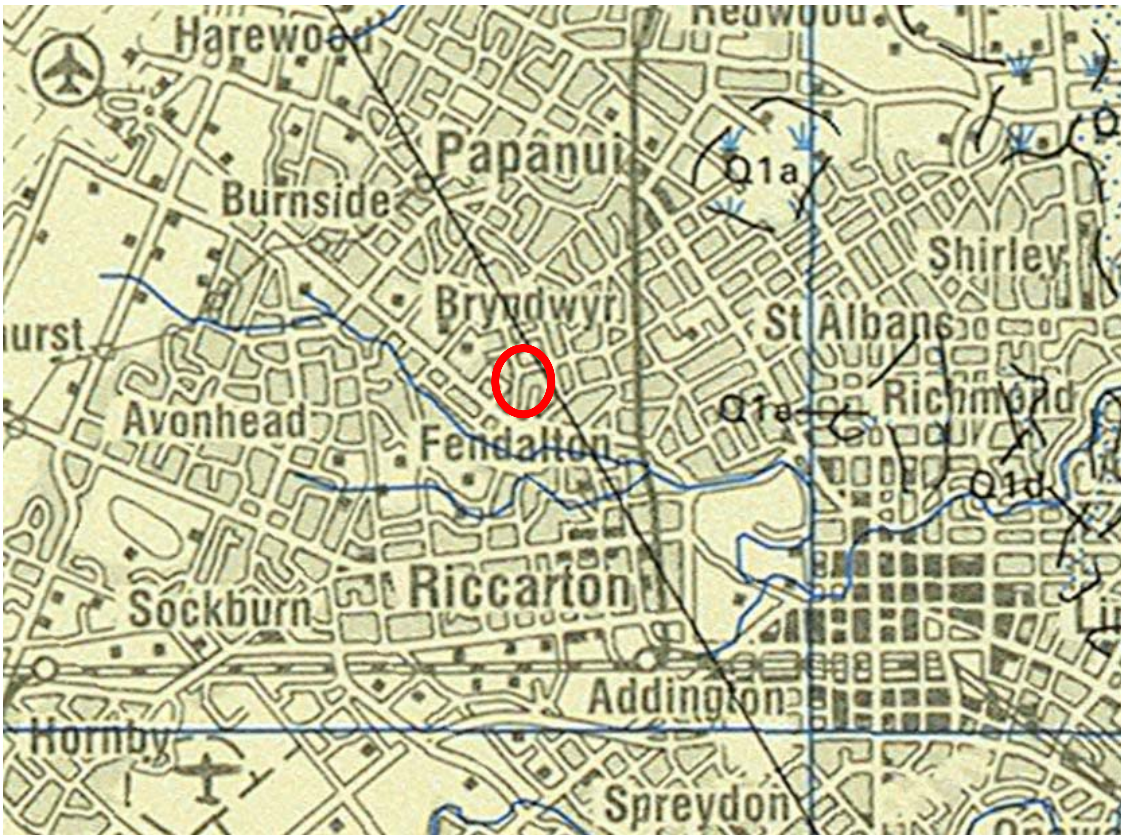


- **Figure 1 – Site location (courtesy of LINZ http://viewers.geospatial.govt.nz)**

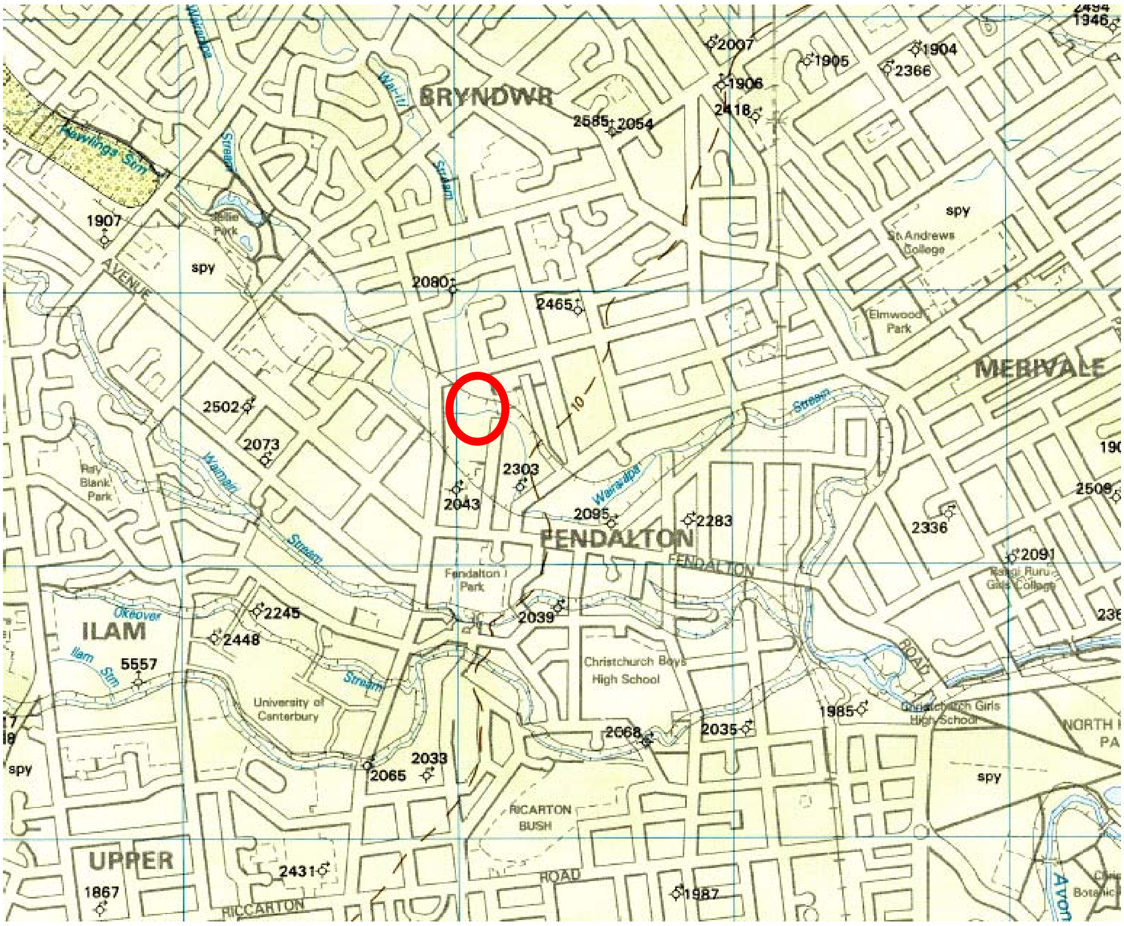
The structure is located on the corner of Clyde Road and Jeffreys Road at grid reference 1566982E, 5182035N (NZTM).

5. Review of available information

5.1 Geological maps



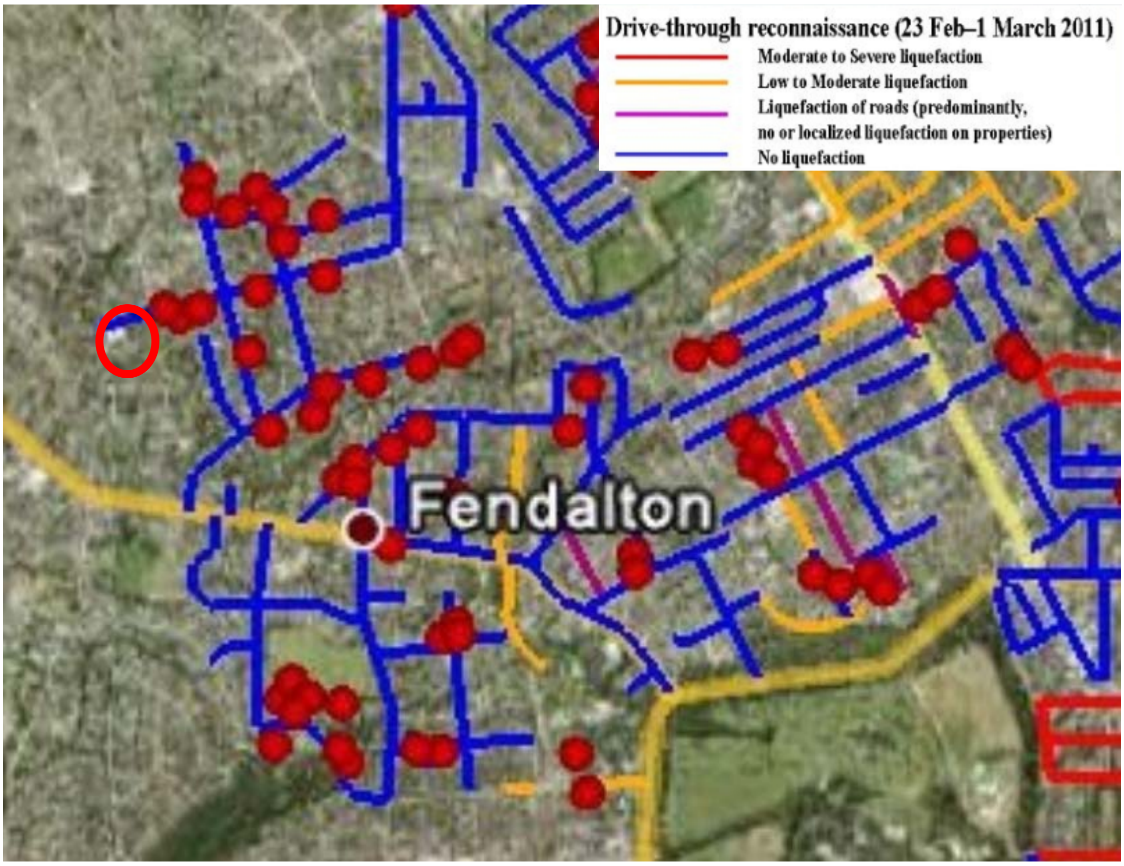
- **Figure 2 – Regional geological map (Forsyth et al, 2008). Site marked in red.**



- **Figure 3 – Local geological map (Brown et al, 1992). Site marked in red.**

The site is shown to be underlain by Holocene deposits comprising predominantly alluvial sand and silt overbank deposits of the Springston Formation.

5.2 Liquefaction map



- **Figure 4 – Liquefaction map (Cubrinovski & Taylor, 2011). Site marked in red.**

Following the 22 February 2011 event drive through reconnaissance was undertaken from 23 February until 1 March by M Cubrinovsko and M Taylor of Canterbury University. Their findings show no liquefaction was noted near the site.

5.3 Aerial photography

- **Figure 5 – Aerial photography from 24 Feb 2011 (http://viewers.geospatial.govt.nz/)**

Aerial photography shows an aerial view of the Fendalton Library. The structures housing the fuel tanks are not clearly visible in the aerial photograph. There appears to be no significant evidence that would suggest liquefaction occurred on site.

5.4 CERA classification

A review of the LINZ website (http://viewers.geospatial.govt.nz/) shows that the site is:

- Zone: Green
- DBH Technical Category: N/A (Urban Non-residential) – properties opposite and to east of the structure are classified as TC2. Some of properties immediately south of the structure are classified as TC3

5.5 Historical land use

Reference to historical documents (eg Appendix A) shows that the site lies immediately west of land that was recorded as marshland or swamp in 1856. Additional, stream or creek was recorded to have run near the site in 1856. This would suggest that soft or liquefiable soil may be present beneath the site.

5.6 Existing ground investigation data

- **Figure 6 – Local boreholes from Project Orbit and SKM files (https://canterburygeotechnicaldatabase.projectorbit.com/)**

Where available logs from these investigation locations are attached to this report (Appendix B), and the results are summarised in Appendix C.

5.7 Council property files

Council property files available for the site included building warrant of fitness documents, consent documents and proposed structural drawings for the some of the structures on site.

Shallow hand auger investigation to a depth of up to 2 m conducted by Soil and Foundation limited in 1992 for the car compound area indicate up to 0.5 m of fill comprising brown sandy gravel, underlain by natural deposits comprising medium dense silt and sand. The top of a gravel layer is indicated to be present 0.5 m to 1.5 m below ground level.

Due to presence of fuel tanks above ground and an indication of underground tanks that have since been removed in the council files, there is potential for contamination of the soil underlying the site.

No drawings for the fuel tank structure were available to gain a more detailed understanding of the foundation solution used for the structure. However, due to the small nature of the structure it is likely that a shallow foundation comprising a slab on grade floor with strip footing beneath the perimeter of the structure would have been used. If further analysis of the structure’s foundation is required, a detailed record of the foundation solution would be required.

5.8 Site walkover

A site walkover was conducted by an SKM engineer on 25 June 2012.

The fuel storage was noted to be a masonry block construction on the southern and western sides, with steel hollow section columns propping the timber-framed roof on the northern and eastern sides. The foundation solution appeared to be a concrete slab on grade footing. There was minor damage to masonry blocks at one location (on the western side); otherwise no significant structural damage was noted from the external site inspection.

During the external site inspection, it was noted that the original car garage had burned down and been replaced with steel cages.

There was no evidence of surface expression of liquefaction. Some cracking of the asphalt surface and undulating ground was noted on the driveway; however, this is not believed to be as a consequence of the earthquake event. No visual evidence of settlement or apparent land damage was observed within the site.

- **Figure 7 Overview of the fuel storage (eastern elevation)**

- **Figure 8 Observed undulating ground on the driveway**

- **Figure 9 Car garage replaced with steel cages**

6. Conclusions and recommendations

6.1 Site geology

An interpretation of the most relevant local investigation suggests that the site is underlain by:

Depth range (mBGL)	Soil type
0 - 3	Variable top soil with gravel content
3 - 4	Gravel and sand. Gravel medium in size
4 - 6	Clay
6 - 15	Sandy gravel and gravel from the Springston Formation
15+	Sandy gravel and gravel from the Riccarton Formation

6.2 Seismic site subsoil class

The site has been assessed as NZS1170.5 Class D (deep or soft soil including gravel below a depth of 100m) from adjacent borehole logs.

As described in NZS1170, the preferred site classification method is from site periods based on four times the shear wave travel time through material from the surface to the underlying rock. The next preferred methods are from borelogs including measurement of geotechnical properties or by evaluation of site periods from Nakamura ratios or from recorded earthquake motions. Lacking this information, classification may be based on boreholes with descriptors but no geotechnical measurements. The least preferred method is from surface geology and estimates of the depth to underlying rock.

In this case the third preferred method has been. Future site specific could result in the recommended site subsoil class being revised.

6.3 Building performance

No detailed records of the existing foundations for the structures on site are available. However, the performance to date noted during the site walkover suggests that the existing foundation are adequate for their current purpose.

6.4 Ground performance and properties

The liquefaction risk for this site is expected to be low.

Available liquefaction map and aerial photographs show no significant evidence that any form of liquefaction occurred on site. Additionally, no surface expression of liquefied ejecta, cracking or undulation of the pavement and land area as a direct consequence of the 22 February earthquake was apparent during the external site walkover. Even though the packing of the gravel layer is unknown, it is expected that the clay and gravel layer are not susceptible to liquefaction. Any lenses of sand that may be present in the sandy gravel layer are potentially susceptible to liquefaction.

As there is no significant evidence of liquefaction and investigation data in council files indicate medium dense sand and sandy gravel content at shallow depth on site, the following ground properties are recommended if a quantitative DEE is to be undertaken for the structure on site:

Parameter	Estimated value
Effective angle of friction	35 degrees
Apparent cohesion	0 kPa
Unit weight	18 kPa
Ultimate bearing capacity of a shallow square pad footing	300 kPa

It should be noted that the estimated ultimate bearing capacity may be conservative, as information regarding the size, shape, location of loading and any embedment of the footing was not available at the time of writing this report. The above parameters should not be used for design or consent purposes. If significant alterations are proposed, additional investigation would be required to perform a more detailed assessment of ground properties.

6.5 Further investigations

If consent if required for the structures on site, more detailed site specific investigation would be required. Additional investigations that may be suitable are:

- Two boreholes to a depth of 20m with standard penetration tests taken at 1.5m intervals

However, the scope of geotechnical investigation will be dependent on the proposed changes to the structures on site. Therefore it is possible that a more extensive set of geotechnical investigation may be required.

7. References

Brown LJ, Weeber JH, 1992. Geology of the Christchurch urban area. Scale 1:25,000. Institute of Geological & Nuclear Sciences geological map 1.

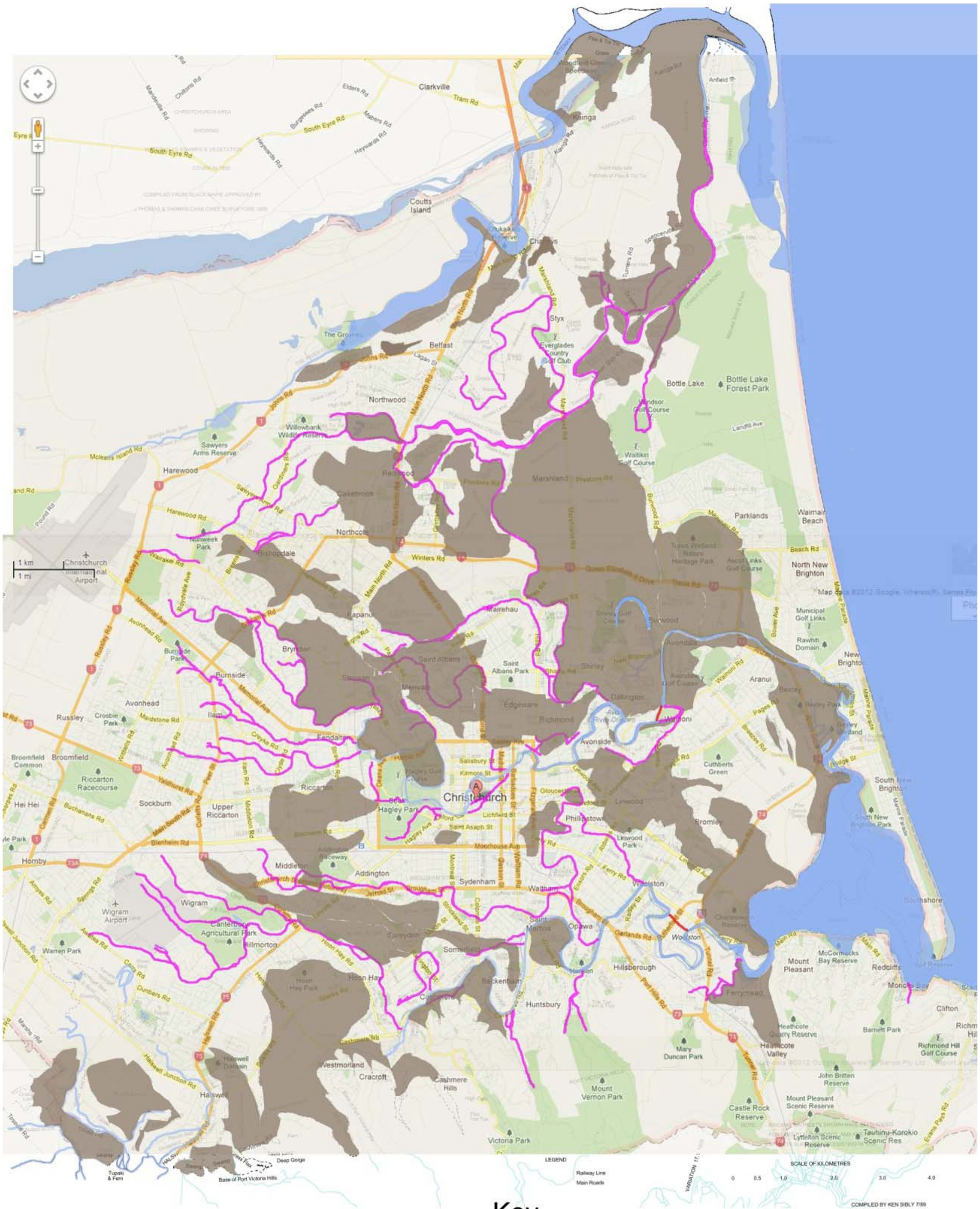
Cubrinovski & Taylor, 2011. Liquefaction map summarising preliminary assessment of liquefaction in urban areas following the 2010 Darfield Earthquake.

Forsyth PJ, Barrell DJA, Jongens R, 2008. Geology of the Christchurch area. Institute of Geological & Nuclear Sciences geological map 16.

Land Information New Zealand (LINZ) geospatial viewer (http://viewers.geospatial.govt.nz/)

EQC Project Orbit geotechnical viewer (https://canterburyrecovery.projectorbit.com/)

Appendix A – Christchurch 1856 land use



Key

- Previous creeks/rivers
- Existing creeks/rivers
- New creeks/rivers
- Swamp/Marshland

The swamps and previous creeks/rivers from 1856 have been overlayed onto a map of Christchurch in 2012

Appendix B – Existing ground investigation logs

Borelog for well M35/2043

Gridref: M35:7700-4352 Accuracy : 4 (1=high, 5=low)
Ground Level Altitude : 11.9 +MSD
Driller : Job Osborne (& Co/Ltd)
Drill Method : Hydraulic/Percussion
Drill Depth : -126.5m Drill Date : 7/12/1922

Water Level: -1.1CalcMin

Depth(m)	Full Drillers Description	Formation Code
- 12.1m	Brown shingle	sp?
- 15.2m	Brown sand	sp?
- 50.2m	Brown shingle	ri-br
- 51.5m	Yellow clay	br
- 62.7m	Brown shingle	li
- 65.8m	Brown sand & clay	li
- 81.1m	Brown shingle, water level +1.07m	li
- 85.6m	Clay & peat	he
- 93.6m	Brown shingle, water level +1.2m	he
- 95.1m	Yellow clay	he
- 98.1m	Brown shingle, water level +1.52m	he
- 99.7m	Yellow clay	he
- 109.1m	Brown shingle, water level +1.5m	bu
- 119.5m	Sand & clay	sh
- 126.5m	Brown shingle	wa

Borelog for well M35/2106

Gridref: M35:772-436 Accuracy : 4 (1=high, 5=low)
Ground Level Altitude : 11.9 +MSD
Driller : Job Osborne (& Co/Ltd)
Drill Method : Unknown
Drill Depth : -52.7m Drill Date : 7/12/1938

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Water Level: -1.0CalcMin

Depth(m)	Full Drillers Description	Formation Code
-0.30m	Soil	sp?
-6.00m	Shingle	sp?
-9.10m	Blue sand & clay	sp?
- 13.7m	Brown shingle	sp?
- 15.2m	Clay & peat	sp?
- 34.1m	Brown shingle (Water level +0.7m below ground level)	ri
- 37.5m	Clay and peat	br
- 46.0m	Brown shingle (Water level +0.6m)	br
- 46.9m	Yellow sand & clay	br
- 49.0m	Blue sand & clay	br
- 52.7m	Brown shingle	li-1

Scale(m): -10, -20, -30, -40, -50

Borelog for well M35/2389

Gridref: M35:769-436 Accuracy : 4 (1=high, 5=low)
Ground Level Altitude : 12.5 +MSD
Driller : Job Osborne (& Co/Ltd)
Drill Method : Hydraulic/Percussion
Drill Depth : -74.9m Drill Date : 30/03/1929

Water level: -1.3CalcMin

Depth(m)	Full Drillers Description	Formation Code
-3.00m	Blue clay	sp?
-5.09m	Blue shingle	sp?
-7.59m	Yellow clay	sp?
- 46.6m	Brown shingle	sp-ri
- 48.7m	Brown sand & Yellow clay	br
- 70.1m	Brown shingle	li
- 73.2m	Brown sand & Yellow clay	li
- 75.2m	Brown shingle	li

Borelog for well M35/2469

Gridref: M35:77084-43574 Accuracy : 2 (1=high, 5=low)
Ground Level Altitude : 12.7 +MSD
Driller : A M Bisley & Co
Drill Method : Cable Tool
Drill Depth : -22.5m Drill Date : 5/04/1960

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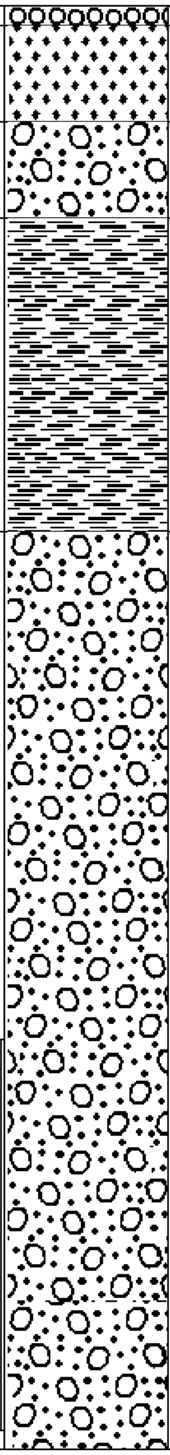
Water Level: -1.6CalcMin

Scale(m)	Water Level	Depth(m)	Full Drillers Description	Formation Code
		-0.30m	Surface soil & gravels	sp?
	-1.6CalcMin	-1.80m	Grey/Brown sand	sp?
		-3.30m	Medium gravel & sand	sp?
-5		-8.19m	Hard Grey/Blue clay	sp?
-10, -15, -20		- 22.5m	Fine to large gravel sand, fine to coarse sand	sp-ri



Borelog for well M35/6667

Gridref: M35:77124-43570 Accuracy : 2 (1=high, 5=low)
Ground Level Altitude : 11.9 +MSD
Driller : Clemence Drilling Contractors
Drill Method : Cable Tool
Drill Depth : -213.7m Drill Date : 1/01/1993

Depth(m)	Full Drillers Description	Formation Code
-2.90m	Big gravels & timber	sp?
-4.00m	Grey clayey silt with organics. Large pieces of Brown fibrous wood	sp?
-9.69m	Brown silt some light Brown very fine sands	sp?
- 14.0m	Yellow clay	sp?
- 14.7m	Good clean Blue gravel	ri
- 15.1m	Sandy Brown/Blue gravel	ri
- 17.0m	Good clean gravel	ri
- 20.0m	Sandy loose Grey gravel	ri
- 21.9m	Clean small gravel	ri
- 23.0m	Loose well sorted Brown gravel	ri
- 23.5m	Sandy Brown gravel	ri
- 24.1m	Good clean gravel	ri

Scale(m): -5, -10, -15, -20

Borelog for well M35/6667 page 2 of 9

Gridref: M35:77124-43570 Accuracy : 2 (1=high, 5=low)
Ground Level Altitude : 11.9 +MSD
Driller : Clemence Drilling Contractors
Drill Method : Cable Tool
Drill Depth : -213.7m Drill Date : 1/01/1993

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Depth(m)	Full Drillers Description	Formation Code
- 24.9m	Good clean gravel	ri
- 27.4m	Sandy Brown gravel	ri
- 28.0m	Very loose, very stained gravel	ri
- 30.0m	Grey sandy gravels. Sand light Brown medium. Gravel-pebbley 15-20mm ave.max=40mm,sub-rounded to rounded,mod.sorted	ri
- 30.5m	Clean Brown gravel	ri
- 33.4m	Grey & light Brown stained gravels Brown sand. Gravels pebbly to cobble max 130mm poorly sorted,clay at 31m Yellow/Br	ri
- 33.6m	Blue & Brown pebbly gravels (Some gravels heavy Brown stain) very sandy Grey & Brown clays	ri
- 36.8m	Grey slightly silty clay with occasional flecks of Brown & Black organic material,hard	br
- 38.2m	Clean Blue gravels	br
- 40.4m	Grey & light Brown stained gravels. Small amount silt minor Brown gravels-rough moderately sorted min size 8mm-max 75mm	br
- 43.2m	Sandy Br, Blue gravel	br
- 46.0m	Good Water-bearing gravel	br
- 46.4m	Grey sandy gravels with some golden silt & clays,gravels-pebbly to granular,Grey & Brown stain sub-rounded,sand med-br	br
- 47.4m	Yellow clay some gravel	br
- 48.0m		br

Scale(m): -25, -30, -35, -40, -45

Borelog for well M35/6667 page 3 of 9

Gridref: M35:77124-43570 Accuracy : 2 (1=high, 5=low)
Ground Level Altitude : 11.9 +MSD
Driller : Clemence Drilling Contractors
Drill Method : Cable Tool
Drill Depth : -213.7m Drill Date : 1/01/1993

Depth(m)	Full Drillers Description	Formation Code
- 48.0m	Blue silty pug & vegetation	br
- 48.3m	Grey/Yellow silty clay. Bands Black peat. Some iron staining, plastic but hard	br
- 54.0m	Grey & some lightly Brown stained sandy gravels, claywash. Gravels granular to pebbly Grey & br(Light),sand fine-med	li-1
- 54.7m	Grey sandy gravel, granular to cobble, angular to subrounded, poorly sorted, sand- Brown fine to medium	li-1
- 56.0m	Big loose Brown clay washed gravel	li-1
- 56.1m	Claybound gravel	li-1
- 56.9m	Blue/Grey gravel stained	li-1
- 58.3m	Grey sandy claybound gravels, granular to pebbly gr, some broken angular to rounded,sand-fine to med,clay-y,sty,hard	li-1
- 59.3m	Loose stained gravel	li-1
- 61.0m	Sandy Grey stained gravel	li-1
- 62.3m	Good Grey/Blue gravel, clay washed	li-1
- 63.1m	Grey/Brown stained very sandy claybound gravels. Thick lenses of Yellow clay	li-1
- 64.0m	Grey & some Brown stained very sandy gravels, some claywash	li-1
- 66.2m	Bands of hard Or /Brown stained silty clay Or layer of Brown iron	li-2
- 68.0m	Tight well sorted gravel & sand	li-2
- 69.1m	Claybound gravel	li-2
- 71.0m	Silty Yellow clay	li-2
- 71.6m	Silty Brown clay	li-2

Borelog for well M35/6667 page 4 of 9

Gridref: M35:77124-43570 Accuracy : 2 (1=high, 5=low)
Ground Level Altitude : 11.9 +MSD
Driller : Clemence Drilling Contractors
Drill Method : Cable Tool
Drill Depth : -213.7m Drill Date : 1/01/1993

Depth(m)	Full Drillers Description	Formation Code
- 72.0m	Silty Brown clay	li-2
- 73.0m	Harder Yellow clay	li-3
- 73.1m	Yellow clay & gravel	li-3
- 74.3m	Loose clean Brown & Grey gravel	li-3
- 75.3m	Grey & Brown stained sandy claybound gravels	li-3
- 76.3m	Loose stained sandy gravel	li-3
- 77.3m	Loose Brown & Grey gravel	li-3
- 79.0m	Brown & Grey gravel	li-3
- 79.1m	White clay	li-3
- 80.5m	Sandier Brown & Grey gravel Yellow clay	li-3
- 80.9m	Grey & some Brown stained very sandy claybound gravels	li-3
- 81.1m	Claybound Blue gravels fine silt sand clay (Mainly stiff)	li-3
- 82.0m	Blue/Green hard silty clay	he
- 83.6m	Brown & Black carbonaceous peat	he
- 86.5m	Grey silt with bits of Brown & Black fibrous carbonaceous material wood	he
- 87.2m	Layers of Yellow/Brown silt & gravels	he
- 87.3m	Yellow clay & gravels	he
- 89.0m	Sandy Brown stained gravels	he
- 92.3m	Grey & Brown stained gravels	he
- 92.4m	Silty Yellow clay	he
- 93.1m	Grey silty clay plastic soft few minor Brown organics	he
- 94.6m	Yellow/Brown slightly clayey sandy silt some Brown iron stained layers	he
- 95.2m	Yellow clay & gravel	bu

Borelog for well M35/6667 page 5 of 9

Gridref: M35:77124-43570 Accuracy : 2 (1=high, 5=low)
Ground Level Altitude : 11.9 +MSD
Driller : Clemence Drilling Contractors
Drill Method : Cable Tool
Drill Depth : -213.7m Drill Date : 1/01/1993

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Scale(m): -95, -100, -105, -110, -115

Depth(m)	Full Drillers Description	Formation Code
- 95.0m	Yellow clay & gravel	bu
- 96.0m	Brown/Grey gravel claywashed	bu
- 98.1m	Clean well sorted gravel	bu
- 99.9m	Brown/Grey claywashed gravel	bu
- 101.1m	Sandy tight gravel	bu
- 103.7m	Good clean large Brown gravel	bu
- 104.0m	Sandy stained Brown gravel	bu
- 104.2m	Yellow clay & stained gravel	bu
- 104.6m	Yellow clay	bu
- 105.4m	Grey very claybound gravels	bu
- 106.6m	Grey & Brown slightly sandy large gravels. Gravels pebbly to cobbley	bu
- 107.8m	Large rough gravels Grey & Brown stained sandy	bu
- 108.0m	Well sorted gravel	bu
- 109.3m	Tight claybound gravel	bu
- 110.0m	Strong, Brown stained sandy gravels	bu
- 110.1m	Blue clay pug & gravel	bu
- 110.5m	Blue gravels & some Grey sand	bu
- 113.9m	Grey clay & Black carbonaceous peat	sh
- 114.8m	Black carbonaceous peat, fibrous some Grey clay & some Brown peat	sh
- 115.7m	Layered Grey clay & Black & Brown peaty carbonaceous material - pliable	sh
- 117.3m	Blue/Grey slightly clayey silt with minor Blue & Brown organics	sh
- 118.7m	Hard Yellow/Brown clayey silt minor very fine sand,some Brown iron staining	sh

Borelog for well M35/6667 page 6 of 9

Gridref: M35:77124-43570 Accuracy : 2 (1=high, 5=low)
Ground Level Altitude : 11.9 +MSD
Driller : Clemence Drilling Contractors
Drill Method : Cable Tool
Drill Depth : -213.7m Drill Date : 1/01/1993

Depth(m)	Full Drillers Description	Formation Code
- 119.0m	Hard Yellow/Brown clayey silt minor very fine sand,some Brown iron staining	sh
- 121.0m	Tight claybound gravel	wa
- 122.6m	Clay washed gravel	wa
- 123.5m	Well sorted gravel	wa
- 124.5m	Clean loose gravel	wa
- 125.8m	Tight claywashed gravel	wa
- 128.5m	Clean gravel	wa
- 129.0m	Well sorted small gravel & grit	wa
- 129.3m	Large boulders	wa
- 129.6m	Tighter clay washed gravel	wa
- 133.0m	Loose clean gravel	wa
- 134.5m	Sandier gravel	wa
- 135.0m	Clean stained gravel	wa
- 135.8m	Claybound gravel	wa
- 136.2m	Yellow clay	aq5
- 136.7m	Yellow silt	aq5
- 141.0m	Fine to very fine sand with Brown clay adhering sands	aq5
- 141.9m	Sticky Brown clay	aq5
- 142.4m	Grey & Blue/Grey clayey silt some Brown slightly peaty clays	aq5
- 143.0m	Black carbonaceous peat some Brown Very hard	aq5

Scale(m): -120, -125, -130, -135, -140

Borelog for well M35/6667

Gridref: M35:77124-43570 Accuracy : 2 (1=high, 5=low)
Ground Level Altitude : 11.9 +MSD
Driller : Clemence Drilling Contractors
Drill Method : Cable Tool
Drill Depth : -213.7m Drill Date : 1/01/1993

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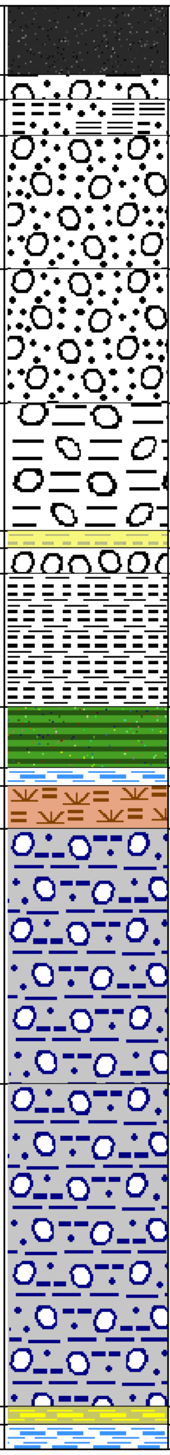

Scale(m)	Water Level	Depth(m)	Full Drillers Description	Formation Code
		- 143.6m	Black carbonaceous peat some Brown Very hard	aq5
		- 144.0m	Sand & gravel lenses sand fine Brown some clay. Gravel broken some round	aq5
		- 144.6m	Tight claybound grit silty clay	aq5
-145		- 146.8m	Slightly sandy Grey & Brown & Black iron stained gravel. Lots of water	aq5
		- 149.0m	Grey & Brown stained sandy gravels	aq5
-150		- 151.1m	Small coarse Brown gravel claybound	aq5
		- 151.4m	O/Yellow clayey silt mottled iron rich hard	aq5
		- 151.8m	Very tight claybound gravel	aq5
		- 154.0m	Blue/Green silty clay hard very minor Black organics	aq5
		- 155.0m	Dark Brown mainly Black peat.minor Grey clay & bits of wood	aq5
-155		- 155.3m	Blue clay	aq5
		- 156.0m	Green silt minor organic Brown also streaks of White material	aq5
		- 160.2m	Hard cemented clayey silty sandy gravels	aq5
-160		- 165.5m	Dirty Grey & Brown stained gravels cemented, clayey silty, sandy	aq5
-165		- 165.8m	Yellow clay	aq5
		- 166.6m	Blue pug	aq5

Borelog for well M35/6667 page 8 of 9

Gridref: M35:77124-43570 Accuracy : 2 (1=high, 5=low)
Ground Level Altitude : 11.9 +MSD
Driller : Clemence Drilling Contractors
Drill Method : Cable Tool
Drill Depth : -213.7m Drill Date : 1/01/1993

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Scale(m)	Water Level	Depth(m)	Full Drillers Description	Formation Code
		- 166.8m	Blue pug	aq5
-170		- 170.2m	Yellow clay	aq5
		- 172.0m	Grey cemented granular to pebbly gravels	aq5
-175		- 175.2m	Grey very sandy gravels.silty & claybound	aq5
		- 177.0m	Cleaner claywashed gravel	aq5
		- 179.5m	Brown gravel & sand	aq5
		- 179.9m	Clay washed gravel	aq5
-180		- 180.2m	Yellow clay	aq5
		- 182.0m	Grey & light Brown stained cemented gravels. Some heavy iron bands	aq5
		- 183.4m	Grey & slightly Brown stained clayey silty sandy gravels	aq5
		- 184.0m	Brown stained gravels	aq5
-185		- 185.3m	Grey & Brown large sandy gravels	aq5
		- 185.8m	Claybound gravel, Grey some silt & sand clay dominant light Yellow pliable	aq5
		- 186.8m	Yellow clay	aq5
		- 187.5m	Loosely claybound gravel very sand	aq5
		- 188.7m	Loose stained gravel	aq5
		- 189.4m	Sandy Brown gravel	aq5
		- 190.0m	Brown clay washed gravel	aq5

Borelog for well M35/6667 page 9 of 9

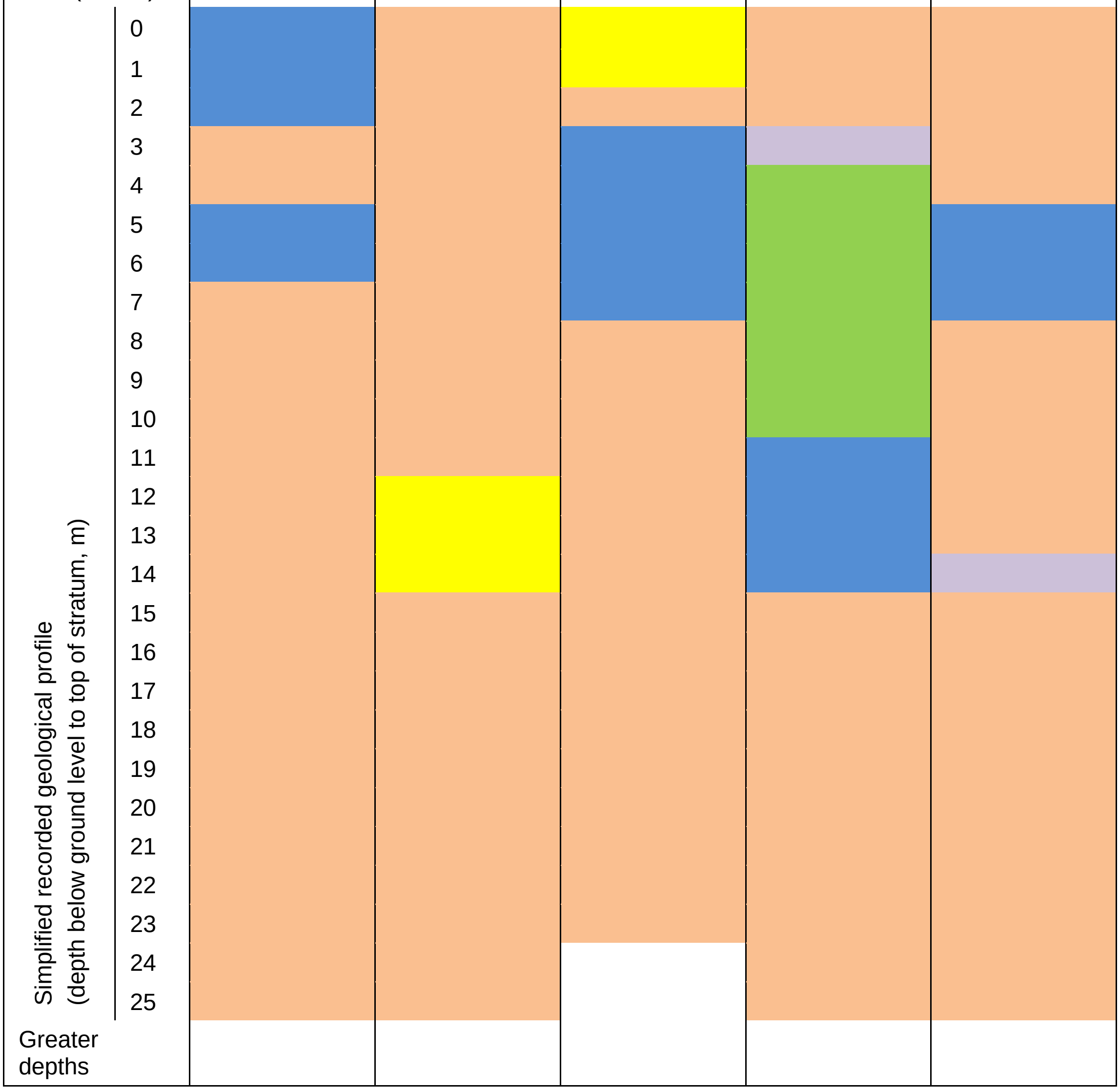
Gridref: M35:77124-43570 Accuracy : 2 (1=high, 5=low)
Ground Level Altitude : 11.9 +MSD
Driller : Clemence Drilling Contractors
Drill Method : Cable Tool
Drill Depth : -213.7m Drill Date : 1/01/1993

Depth(m)	Full Drillers Description	Formation Code
- 191.3m	Brown clay washed gravel	aq5
- 192.5m	Loose Brown gravel	aq5
- 193.6m	Loose stained gravel	aq5
- 194.0m	Green, Blue & some Brown cemented gravels	aq5
- 194.4m	Grey & Green cemented gravels	aq5
- 194.8m	Green sandy gravels chips of limestone	aq5
- 197.0m	Slightly Grey/Green clayey sandy silts with some Blue/Grey gravels	aq5
- 199.4m	Blue & Grey slightly clayey silt. Occasional fleck of Brown organic matter	aq5
- 208.0m	Light Grey hard clay some layering	aq5
- 209.0m	Hard Brown & Black organic peat some Grey clay & bits of hard wood	aq5
- 211.5m	Grey silt locked casing	aq5
- 213.7m	Grey silt	aq5

Appendix C – Geotechnical Investigation Summary

▪ Table 1 Summary of most relevant investigation data

ID	1	2	3	4	5
Type *	BH	BH	BH	BH	BH
Ref	M35-2389	M35-2043	M35-2469	M35-6667	M35-2106
Depth (m)	74.9	126.5	22.5	213.7	52.7
Distance from site (m)	90	140	130	130	225
Ground water level (mBGL)	N/A	N/A	N/A	N/A	N/A



*BH: Borehole, HA: Hand Auger, WW: Water Well, CPT: Cone Penetration Test

Sensitive or organic clay/silt; Clay to silty clay; Clayey silt to silt; Silty sand to silt; Clayey sand; Sand; Gravelly sand or gravel

VL = very loose, L = loose, MD = medium dense, D = dense, VD = very dense
VS = very soft, So = soft, F = firm, St = stiff, VS = very stiff, H = hard