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Report

Cranford Basin Rezoning - Preliminary Geotechnical Assessment

Prepared for Christchurch City Council

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Contents

1 Introduction

1.1 Background

Beca Ltd (Beca) was engaged by the Christchurch City Council (CCC) to undertake a review of geotechnical, hydrogeological and stormwater evidence for Cranford Basin in Christchurch. This review was presented in Beca (2016) and included areas comprising Grassmere (submission 3193), Crozier (submission 3268) and Case (submission 3280) blocks as well as areas of land adjacent to Cranford Street and Meadow Street occupied in part by Christchurch Top 10 Holiday Park (Area A) and south of Winters Road east of Wiremu Street (Area B) shown in Figure 1.

CCC have been considering the suitability of rezoning approximately 50ha of land in parts of the Cranford Basin. This land, which is outside the “urban limits”, is being considered for residential zoning. This report provides a preliminary geotechnical assessment for the Grassmere (submission 3193) area.

Figure 1 - Location plan

CCC obtained technical advice and evidence from GHD in late 2015 in respect of the geotechnical aspects of rezoning. This did not oppose the rezoning from a technical perspective. This was presented at a hearing to the proposed District Plan in 2015 and was not disputed by submitters or the hearings panel.

CCC sought further opinion of the technical geotechnical evidence for the proposed rezoning and the findings of which were presented in Beca (2016).

1.2 Scope

The scope of this current Beca study, limited to the Grassmere block, comprises the aspects listed below, which follow from recommendations given in Beca (2016).

- Determine if the amount of existing geotechnical investigation data is between 0.2 to 0.5 exploratory holes per hectare (minimum of 5) recommended by MBIE (2012) and towards the 0.5 exploratory holes per hectare for complex and variable sites at plan change
- Carry out a liquefaction assessment of the existing geotechnical investigation data for the site in accordance with the recommendation given by MBIE (2015)
- Make a preliminary estimate of the 'non-development' ground subsidence due to i) seismic effects and ii) secondary (creep) settlement which could be expected over the design life of the sub-division(s), including an assessment of differential settlement
- If ground levels need to be raised by filling (based on minimum development elevations or a conceptual surcharging scheme), make a preliminary estimate of the induced settlements both in the study area and on the immediate neighbours over the design life of the sub-division(s), including an assessment of differential settlement

The purpose of this report is to assess the geotechnical points given above and provide a summary of the findings to CCC to inform their assessment of the proposed rezoning of the Grassmere Block.

2 Existing Data and Proposed Development

2.1 Sources of Data

The data used in preparing this assessment comprises:

- Beca (2016). Cranford Basin Rezoning - Review of Geotechnical, Hydrogeology and Stormwater Evidence, Prepared for Christchurch City Council, Beca Ltd (8 September 2016).
- Beca (2016). Spring identification and groundwater management for potential rezoning at the Grassmere Block, Prepared for Christchurch City Council, Beca Ltd (28 September 2016).
- BGL (2013).Geotechnical Report, Proposed 12.5-hectare Residential Subdivision, Grants Road, Papanui, Bell Geoconsulting Ltd (April 2013).
- GHD (2015-1). Rural-Cranford Basin, Appendix 1- Cranford Basin Geotechnical Desktop Report (February 2015) (http://resources.ccc.govt.nz/files/policiesreportsstrategies/chapter17-rural-cranfordbasin-s32-appendix1-cranfordbasin-geotechnicaldesktopreport.pdf).
- GHD (2015-2).Cranford Basin Geotechnical Investigation Report (September 2015).
- Webb, S. (2015). Statement of Evidence of Samantha Webb on behalf of Christchurch City Council-Geotechnical (10 December 2015) (http://www.chchplan.ihp.govt.nz/wp-content/uploads/2015/10/3723-CCC-Samantha-Webb-Evidence-Geotechnical-10-12-2015.pdf).
- MWD (1980). Ministry of Works Development – Appendix III, Winters Road Settlement Trial Records (March 1980).

2.2 Proposed Development

The study area is currently outside the "urban limits". The CCC is considering rezoning the area for residential development, the density of which is to be determined. The approach adopted for this geotechnical assessment is to consider at a high level how the seismic performance and potential settlement of the land may affect its suitability for residential development. It is expected that detailed geotechnical assessment(s) will form part of any subsequent considerations.

3 Geotechnical Investigation

3.1 Exploratory Holes

On the Grassmere block, BGL undertook 12 Cone Penetration Tests (CPTs) to between depths of between 3.8m and 8.1m below ground level (stating the termination depth was “effective refusal on dense sand and/or gravel at all locations”).

GHD undertook four sonic boreholes with associated SPTs to depths of between 11m and 17m and four CPTs to depths of between 17m and 18m in the Grassmere block.

With respect to requirements for ground investigation, BGL (2013) made reference to MBIE (2012a), September 2012 and GHD (2015-2) referred to MBIE (2012b) December 2012, Ministry of Business, Innovation and Employment (MBIE 2012) guidance; The current reference for ‘Part D: Subdivisions given on the MBIE (2012) website is the December 2012 version, which states:-

- a recommended density between 0.2 to 0.5 exploratory holes per hectare (ha), with the higher density towards the 0.5 holes per hectare for complex or variable ground conditions;
- a minimum of five exploratory holes for sites greater than 1 ha; and
- that appropriate geotechnical investigations shall be carried out to at least 15 m depth, unless the ground is known to be of acceptable quality from lesser depths

The Grassmere block is ~32 ha in area. BGL (2013) undertook two sonic boreholes and GHD undertook six exploratory holes, to greater than 15 m depth. A further ~21 CPT location have also been investigated across the area. Hence, for the Grassmere block, the density of exploratory holes is approximately 0.9 per ha. Given the complex nature of the land, the density of exploratory holes is considered to meet that recommended by MBIE for ‘plan change stage’ for complex and variable ground conditions.

4 Site Description

4.1 Topography

The ground level is variable, but generally falls slightly from the west and south across the block towards the centre of the Cranford Basin. Elevations above mean sea level vary between 5 to 11 mRL.

4.2 Ground Model

The ground conditions at shallow depths (upper 5m to 10m) and their expected characteristics are variable, with notable changes over short distances in the amount and distribution of silt, sand and peat. For the purposes of this assessment the ground profile inferred from CPT 102 has been adopted as being representative, comprising:

Table 1 - Typical Soil profile from CPT 102

Soil Unit	Description	Depth (mbgl)	Thickness (m)
Top Soil	Fill	0.6	0.6
Organic Deposits	Organic silt and peat	0.6-3.7	3.1*
Alluvium	Sands	3.7-8.6	4.9
	Silts and clay mixtures	8.6-10	1.4
	Sands	10-16.1	6.1
	Silts and clay mixtures	16.1-17.2	1.1
	Sands	17.2-18.1(EOH)	-

* Generally the thickness of Organic silt and peat from the CPT and Borehole data appears to vary between 3 to 4m. For the purpose of the settlement assessment, a 4m thick organic silt and peat layer has been considered in the analysis.

The Riccarton Gravel, which was inferred to be at 18.6m depth, was considered to be incompressible and based on its grading and density, not prone to liquefaction.

Groundwater has been assumed to be shallow at 0.5m depth (GNS, 2014). There is evidence of artesian groundwater head in the sand and gravel layers, which will likely increase the potential for liquefaction.

5 Results of Preliminary Analysis

5.1 Liquefaction Assessment

5.1.1 Methodology

A liquefaction assessment has been carried out for the Grassmere Block, following the guidance given in the MBIE (2012) requirements for repairing and rebuilding houses affected by the Canterbury earthquakes.

Input parameters were:

- Importance Level 2, 50 year design life.
- Class D subsoil
- Peak ground accelerations (PGA's) from MBIE guidelines, Appendix C2: Guidance on PGA values for geotechnical design in Canterbury:
  – 0.13g for Serviceability Limit State (SLS), with an annual probability of exceedance of 25 years
  – 0.35g for Ultimate Limit State (ULS), with an annual probability of exceedance of 500 years
- Earthquake Magnitude 7.5; and
- Groundwater levels at 0.5m bgl.
- Soil behaviour type index (Ic) cut-off assumed in the analysis - 2.6
- Method of fines correction considered in the analysis - Boulanger & Idriss (2014)

The liquefaction assessment was carried out using CLiq (CPT Liquefaction Assessment Software) following the Boulanger and Idriss (2014) method.

The range and mean of the estimated liquefaction induced settlements under SLS and ULS events are given in Table 2.

Table 2: Summary of Liquefaction induced Settlements

Location	CPT Depths (m)	Range of SLS Index Settlement (mm) (average in brackets)	Range of ULS Index Settlement (mm) (average in brackets)	Range of SLS Total Settlement (mm) (average in brackets)	Range of ULS Total Settlement (mm) (average in brackets)
Grassmere	17.0 - 18.1	40 – 110 (70)	50 – 140 (90)	70 – 150 (100)	140 – 230 (170)

Index values are calculated liquefaction induced settlements for the top 10 m of soils (refer to MBIE, 2012). Values given in Table 1 are based on exploratory holes that penetrated to 10m or deeper.

5.1.2 Broad Classification of Land

MBIE (2012) provides guidelines for various technical categories of land as a function of anticipated settlement under different limit states as follows:-

- Maximum SLS settlement is greater than 50mm - classified as TC3
- Maximum ULS settlement is greater than 100mm - classified as TC3

As the investigations have shown that a mix of land classifications might apply across the site, the site would be classified as a whole according to the most conservative classification. In this instance, the site would be classed as TC3. There is an option to micro-zone the site into multiple classifications, although this will likely require further investigations and would be subject to further analyses to confirm different technical categories.

5.2 Static Settlement Assessment

5.2.1 General

The settlement estimates presented below are preliminary assessments based on limited data to provide a broad overview of expected soil settlement behaviour. They will need to be reviewed and confirmed as development schemes are designed. Due to the uncertainties in estimating settlement it would be prudent to consider settlement values to range from -50% to +100% of those given below.

5.2.2 'Non-development' ground subsidence due to secondary (creep) settlement

It is well documented that the presence of organic soils can result in secondary or creep settlement which tend to occur over very long periods of time due possibly to decomposition of organic matter within the soil layers without any increase in stresses in the ground. Data provided by CCC has identified the presence of compressible soils which have settled over a period of 25 years.

Without increasing the effective stress in the ground, for instance by placing fill on the surface or by lowering the groundwater, creep settlement can be expected at this site. Records suggest that approximately 400mm of settlement has occurred over the past 25 years including creep and water fluctuation consolidation settlements. Generally the rate of creep settlement decreases over time with each log cycle of time. Over the next 50 years, this could result in additional secondary settlement in the order of 150mm to 200mm. A more accurate assessment of this settlement could be undertaken if settlement monitoring records in individual years over the past 25 years were to be made available.

5.2.3 Settlement due to filling

Preliminary information from CCC indicates that the final design level of the site will need to be raised approximately 0.6m above existing ground level in order to raise any development above flood levels identified in the district plan. Due to long term consolidation and secondary settlements, an indicative fill height would be in the order of 1.5m to 1.85m with total settlements expected to be in the range of 900mm to 1250mm, of which 150mm to 200mm comprise secondary settlements occurring over a 50 year design life.

The effects of settlements on neighbouring structures and infrastructure will need to be assessed during design. Based on a preliminary assessment and subject to the configuration of fill, a set-back distance in the order of 10m to 20m may be required from the edge of fill to any surrounding neighbours or infrastructure, to mitigate the settlement effects to tolerable levels.

5.2.4 Surcharging

Options to reduce the secondary compression settlement might be to consider surcharging the area with additional fill, incorporating staged construction and embankment basal geo-reinforcement. Indicatively, an additional 1.5m of surcharge left in place for 3 months could reduce secondary compression settlements to approximately 50mm over a 50 year design life. Set-back distances as discussed above should be similarly addressed.

6 Summary

Presented below is a summary of the scope and findings.

1. *Where the amount of existing geotechnical investigation data is less than the 0.5 exploratory holes per hectare (minimum of 5) recommended by MBIE[1] for complex and variable sites at plan change, further investigation be undertaken to meet the MBIE recommendations.*

   For the Grassmere block, the density of exploratory holes is above that recommended by MBIE for ‘plan change stage’ for complex and variable ground conditions.

2. *Carry out a liquefaction assessment of the site in accordance with the recommendation given by MBIE.*

   Liquefaction is expected during an SLS (1/25 years) and ULS (1/500 years) event.

3. *Make a preliminary estimate of the ‘non-development’ ground subsidence due to i) seismic effects and ii) secondary (creep) settlement, which could be expected over the design life of the sub-division(s), including an assessment of differential settlement.*

   Liquefaction is expected to result in total free-field settlements in the order of 150mm and 230mm under SLS and ULS seismic events respectively. Long-term static secondary (creep) settlement is expected.

   For a final design ground level of 600mm above existing ground levels (to account for flood levels), an indicative fill height would be in the order of 1.5 to 1.85m with total settlements expected to be in the range of 900 to 1250mm, of which 150 to 200mm comprise secondary settlements occurring over a 50 year design life.

For liquefaction induced settlement, the minimum amount of differential settlement is recommended to be two-thirds of the total predicted free-field liquefaction settlement unless sufficient data is available to refine this assessment (refer NZGS Module 3 and Martin et. al., 1999). Martins et al (1999) also suggest that the differential settlement estimates be used as representative of the minimum differential settlement between adjacent supports (spacing between adjacent columns or footings or bearing walls, whoever is smaller). Hence a preliminary assessment indicates that between 100mm to 150mm of differential settlement (SLS and ULS liquefaction cases respectively) should be allowed for.

4. *Classify the study area according to the liquefaction and secondary settlement assessments either i) as a whole or ii) as micro-zones if variable subsidence is predicted.*

Based on the available data the site would be classified as TC3. There is an option to micro-zone the site into multiple classifications, although this will require further investigations to more tightly define these areas.

5. *If ground levels need to be raised by filling (based on minimum development elevations) make a preliminary estimate of the induced settlements both in the study area and on neighbours over the design life of the sub-division(s), including an assessment of differential settlement.*

Placing 1.5m to 1.85m of fill to locally raise the ground above the flood level is expected to induce total settlements in the range of 900 to 1250mm, with secondary settlements estimated to be in the range of 150 - 200mm over a 50 year design life. To mitigate the effect on neighbours and adjacent infrastructure a preliminary assessment suggests a setback distance of 10m to 20m from the edge of filling may be required.

Conceptually, surcharging with additional fill, incorporating staged construction and embankment basal geo-reinforcement can be considered to reduce the secondary compression settlement. Indicatively, an additional 1.5m of surcharge left in place for 3 months could reduce secondary compression settlements to approximately 50mm over a 50 year design life.

As identified previously, foundations on the compressible soils will need to be designed to accommodate settlement (Cranford Basin Rezoning - Review of Geotechnical, Hydrogeology and Stormwater Evidence, Beca Ltd (8 September 2016)). While piles could feasibly provide a suitable foundation option, they may need to be designed to have a greater load capacity than that required to resist just super-structure loading due to ground settlement induced loading.

Preloading or surcharging the ground is a recognised method for reducing the effects of settlement. Where suitably designed, robust shallow foundations (e.g. raft foundations) could be adopted instead of piles.

The design, construction and maintenance of certain infrastructure supporting any residential sub-divisions on the study area will need to take account of the total settlement. We understand that potable water and sewer systems are proposed to be pressure systems, hence the effects of settlement are less than for gravity systems, although the estimated settlements will need to be taken account of. Specific consideration will need to be given to how stormwater can be dealt with including the feasibility of open ditches to maintain the necessary flows through the design life of the development and how road levels may vary.

It is recommended that the indicative settlement estimates presented above be reviewed and confirmed as any scheme is developed. Additionally it is recommended that the applicability of the current CCC Infrastructure Design Standards are reviewed in relation to development of land within the Cranford Basin. This needs to consider the specific local ground conditions, their effect on any development and how any adverse effects can be adequately mitigated.

7 References

1. Beca (2016). Cranford Basin Rezoning - Review of Geotechnical, Hydrogeology and Stormwater Evidence, prepared for Christchurch City Council, Beca Ltd (8 September 2016).

2. BGL (2013).Geotechnical Report, Proposed 12.5-hectare Residential Subdivision, Grants Road, Papanui, Bell Geoconsulting Ltd (April 2013).

3. GHD (2015-1). Rural-Cranford Basin, Appendix 1- Cranford Basin Geotechnical Desktop Report (February 2015) (http://resources.ccc.govt.nz/files/policiesreportsstrategies/chapter17-rural-cranfordbasin-s32-appendix1-cranfordbasin-geotechnicaldesktopreport.pdf).

4. GHD (2015-2).Cranford Basin Geotechnical Investigation Report (September 2015).

5. Martin, G.R. et al. (1999). 'Recommended Procedure for implementation of DMG,' Special Publication 117: Guidelines for Analysing and Mitigating Liquefaction in California, SC EC, University of Southern California.

6. MBIE (2012). Ministry of Business, Innovation and Employment (MBIE) requirements for Repairing and rebuilding houses affected by the Canterbury earthquakes, Part D: Guidelines for the geotechnical investigation and assessment of subdivisions in the Canterbury region, December 2012, Version 2.

7. MBIE (2015). Ministry of Business, Innovation and Employment (MBIE) requirements for Repairing and rebuilding houses affected by the Canterbury earthquakes, Part C: Assessing, repairing and rebuilding foundations in TC3.

8. MWD (1980). Ministry of Works Development – Appendix III, Winters Road Settlement Trial Records (March 1980).

9. NZGS (2016). New Zealand Geotechnical Society, May 2016. Module 3: Identification, assessment and mitigation of liquefaction hazards.

10. Van Ballegooy, S.; Cox, S. C.; Thurlow, C.; Rutter, H. K.; Reynolds, T.; Harrington, G.; Fraser, J.; Smith, T. (2014) Median water table elevation in Christchurch and surrounding area after the 4 September 2010 Darfield Earthquake: Version 2, GNS Science Report 2014/18, April 2014. ISBN 978-1-927278-41-3. 79 p and 8 Appendices.

11. Webb, S. (2015). Statement of Evidence of Samantha Webb on behalf of Christchurch City Council-Geotechnical (10 December 2015) (http://www.chchplan.ihp.govt.nz/wp-content/uploads/2015/10/3723-CCC-Samantha-Webb-Evidence-Geotechnical-10-12-2015.pdf).