The Lakes Residential Subdivision

Stage 2H

Geotechnical Completion Report

Prepared for: **The Lakes (2012) Ltd**
Reference 20533
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1.0 Introduction

Construction of Stage 2H of The Lakes residential subdivision is complete including the roading and underground services.

This report is presented as the "Geotechnical Completion Report" in terms of Section QA-4.4.2 of the Tauranga City Council Infrastructure Development Code and provides information to enable residential building sites to be located and developed. The geotechnical issues relating to this residential development are

- Ground bearing capacities for the support of residential buildings on surface or shallow foundation systems
- The stability of batters leading into the adjacent lake from the building areas and appropriate building restriction lines adjacent to these batters
- The potential for the effects of seismic activity which may induce lateral and vertical displacements as a consequence of liquefaction occurring within some of the subsoils that are present

Reference drawings are referred to and these drawings are contained in Appendix 1 of the report. Included in Appendix 1 is drawing 134463-2H-RC01 Revision R1 prepared by Harrison Grierson which shows the positions of eleven residential lots within Stage 2H. These lots are numbered 430 to 440 inclusive. Also incorporated in this stage of development are Lot 1001 which is the access road to vest and Lot 1002 which is to be a local purpose reserve.

The sizes and dimensions of these lots are shown on DP 472593, also prepared by Harrison Grierson, in Appendix 1.

Approval for the subdivision within the Stage 2H area was granted by the Tauranga City Council on 4 October 2013.

Condition 6 of the approval required that

The Consent Holder shall provide to the Council a "Geotechnical Completion Report" compiled by a Category 1 Geo-Professional. The report shall:

- *Comply with the Councils IDC QA4 requirements;*
- *Display the position of all designated building platform and building restriction lines where applicable;*
- *Provide recommendations for the on going development of the lots (i.e. maximum cut/fill heights, management of steep slopes, etc.);*
- *Confirm earthworks and/or building platforms have been constructed to comply with the New Zealand Code requirements;*

- *Certify that any residential settlement or differential settlement that may still occur shall not exceed the manufacturers recommendations with respect to the installed underground pipe networks to be vested in Council or exceed accepted design techniques with respect to road settlement or long term deflection, or exceed the settlement limitations as detailed in the New Zealand Building Code.*

Pursuant to Section 221 of the Resource Management Act 1991, the Council may review this condition, upon receipt of the "Geotechnical Completion Report", and require a Consent Notice to be registered on the Certificate of Title of any allotments to which the recommendations of the "Geotechnical Completion Report" relate to.

This report has been prepared for the section 224C Certificate application for DP 472593 and describes the site development earthworks and summaries the stability of the prepared ground in cut and fill for future urban housing development.

2.0 Original Landform and Geology

The landform prior to the commencement of The Lakes development in 2004 comprised:

- Elevated areas along the eastern side as a central plateau described locally as the Te Ranga Tablelands. These areas have been variously used for farming and horticultural cropping. The existing Pyes Pa residential area further to the east had been established on similar level areas of the same elevation
- Lower lying areas mainly along and adjacent to the Kopurererua Stream to the west and extending eastwards.
- Transitional slopes of varying steepness between the lower lying areas and the elevated central plateau. Re entrant erosion gullies were present on some of these slopes but most were uniform in slope gradient, albeit steep in some locations.

The geological setting for the development area can be derived from the publication "Occasional Report 22 – Department of Earth Sciences University of Waikato" - "Geology of the Tauranga Area" by Briggs et al – 1996.

Stage 2H is located on and around a small "hill" that rose above the lower lying areas adjacent to the Kopurererua Stream. The crest of the hill was at RL 16.0 m (Moturiki) and the surrounding flat ground was at RL 5.0 m. Subsoil investigations undertaken by S & L Consultants Ltd (SL) in 2003 involved the putting down of fifty two machine drilled boreholes and the excavation of twenty six pits to identify the subsoils that were present in the Lakes development area that extended from State Highway 29 to the north to Pyes Pa Road to the south. Adjacent to or within the Stage 2H area, boreholes 21 and 22 and pit 26 were located. The boreholes identified spongy youthful dark brown peat to depths of 4.5 m and 4.0 m respectively below the surface paddock grass cover. Low strength light grey clays and pumiceous

silts were present below the peat to the depths of the boreholes at 9 m. Pit 26 found similar organic silts to a depth of 3 m. Groundwater levels were recorded at depths of 0.5 to 1.0 m below the original ground surface.

Attached drawing 20533-01 in Appendix 1 shows the original ground contours at the Stage 2H area with the extent of the building area formed by the sub division earthworks superimposed.

Unlogged hand augered holes and inspections of exposed subsoils identified that the "hill" rising from the surrounding flat peat land comprised the volcanic ash derivative soils found elsewhere on elevated ground to the east within the development area.

3.0 Development Earthworks

The crest of the hill to a maximum height of RL 16.0 m was reduced to the present level of the Stage 2H development area of RL 9.2 to 10.0 m during the summer earthworks season of 2007. The extent of the cut to reduce original ground levels is on 20533-01. Below the cut level excavation continued around the lowered hill and into the peats that had been identified by the pre subdivision boreholes. Removal of the peat down to the underlying estuarine valley soils was undertaken to the capability of the earthmoving machinery on the site and the cost effectiveness of removal of the peat and undertaking its replacement with filling obtained from the reduction of the "hill" and from elsewhere within the subdivision area.

The extents of undercut are indicated on attached drawing 20533-02 where undercut depths below the finished ground levels are shown. Filling then took place back to the current stage 2H development levels of RL 9.2 m to RL 10.0 m during February to April 2007 and was completed during the period of November 2007 to January 2008.

The earthworks were supervised by site engineering technicians employed by the developer, Grasshopper Farms Ltd, and observed by engineering staff from S & L Consultants during specific site inspections.

The earthworks were undertaken by Hick Bros Earthmoving in compliance with consent 62387 issued by Environment Bay of Plenty.

The performance specification required of the Contractor for the earthworks was based on the guidelines contained in NZS 4431: 1989 "Code of Practice for Earthfill for Residential Development". Compliance with the compaction requirements listed below satisfies the standards listed in Section 7 of the NZS 4431.

Air voids percentage (as defined in NZS 4402: Part 1:1980)

- Average value less than 10% (any 10 tests)
- Maximum single value 12%

Undrained shear strength (measured by in situ vane)

- Average value not less than 150 kPa (any 10 tests)
- Minimum single value 100 kPa

All of the 37 compaction test positions are shown on attached drawing 20533-03 and the results are listed in Appendix 3 to show that this specification was achieved by the contractor.

Concurrent with the earthworks being undertaken in the Stage 2H development area, excavations were also undertaken by Bay Excavators Ltd to form the lake that is now present around the western, southern and eastern sides of the Stage 2H area. The lake formation required the removal of surface soils, which comprised mostly peat, to levels of RL 2.30 m to 3.0 m, with depths of excavation ranging from 2.5 to 3.0 m.

For the completion of the earthworks to the final ground levels present, additional filling was placed from the horizontal extent of the undercut indicated on 20533-02 over the ground that was not undercut down to the lake ambient inundation level at a general slope of 1 in 5 (11.5 degrees). This additional filling was placed over the peat that was not removed in the undercut. The depths of this filling ranged from 1.5 m to 3.5 m as shown on drawings 20533-05 and 20533-06.

4.0 Post Bulk Earthworks Surveillance and Testing

After placement of the filling for Stage 2H in 2007, four settlement markers were installed at locations shown on 20533-03. The levels on these markers were surveyed regularly in the period of 13 June 2007 to 15 October 2008 and then at three further occasions on 2 October 2012, 20 June 2013 and 1 August 2013. The survey results are within Appendix 3. The degrees of settlement fluctuated over the monitoring period with variations up or down possibly due to the expected accuracy of the survey. Recorded monthly settlements over the period of 13 June 2007 to 15 October 2008 were in the range of 17 to 33mm. The trends during that monitoring period indicated that any future settlement would be within tolerable limits for future buildings constructed on surface foundations.

In the period from 15 October 2008 to 1 August 2013 (58 months) settlements at markers 34 to 36 were in the range of 2 to 6 m while at settlement marker 37, 29 mm of settlement had taken place of which 6 mm occurred in the past 10 months (less than 1 mm per month).

To confirm the positions of transitions between the peat replacement filling and the filling that was placed over the peat that was not removed, additional boreholes were machined drilled at positions shown on 20533-04 in June 2013. Boreholes were put down at four cross section positions, with one borehole each side of the line determined by past survey as being the limits of the peat removal by excavation. Three further boreholes numbered 5, 6 and 8 were located within the peat removal area to the south and one borehole (borehole 7) was located at the position of the deepest cut achieved in lowering the "hill" from RL 16m to RL 9.5 m. Concurrent with the drilling of these holes, static cone

penetrometer (CPT) tests were undertaken to confirm the depths of the filling present and the strengths and continuity of the underlying ground to a depth of 20 m below existing ground levels.

Summary logs of the soils encountered in the machine drilled boreholes of June 2013 are contained in Appendix 4. Plots of the CPT cone resistance and inferred soil types with depths are also appended.

5.0 Subdivision Construction Earthworks

The earthworks undertaken in 2007 created a near flat platform in the areas of cut and fill. For the subdivision development proposed at that time the alignment of the proposed accessway was cut to a subgrade level below the finished earthworks levels.

The subsequent construction of Stage 2H to the lot arrangement shown on the approved scheme plan of 4 October 2013 required the original accessway alignment to be moved westwards. The original cutting which would now be located on the western frontages of lots 430 to 436 inclusive was filled with the soils excavated from the new alignment of the accessway during the recent subdivision construction. The depths of the filling on the old alignment varied from 0.5 to 0.7 m.

This filling was tested by recording developed undrained shear strengths from the compaction of the filling using a shear vane pushed in advance of hand drilled boreholes. One borehole was put down on each of lots 430 to 436. The summary logs of the soils found in these boreholes are attached in Appendix 3. The test positions are shown on attached plan 20533-10.

The undrained shear strengths meet the standards in Section 3.0. These tests confirmed that the filling placed may be considered as "good ground" in terms of NZS 3604:2011.

6.0 Recommendations for Building Development

6.1 Building Support Conditions

Observations and tests during the placement of filling within the Stage 2H area both in 2007/2008 and recently in 2014 and subsequent CPT tests undertaken during June 2013 indicate that the subsoils present in the areas of cut and supervised filling are suitable for the support of vertical loads from buildings supported on shallow surface foundations. For the detailing of such foundations an ultimate ground bearing capacity in the limit state may be taken at 300 kPa.

6.2 Stability Issues

Stability issues exist where batters are present around the prepared platform and lead down to and below the ambient lake levels at RL 5.45 m (Moturiki). Such instability has been considered by numerical analysis in which the remaining peat and overlaying non structural filling could possibly be mobilised as water levels rise within the surrounding lake and raise groundwater levels in the batters. It would be expected, in the first instance, that the batter faces would

slump along a shear failure plane thereby removing support to the structural filling present up to the cut face line shown on 20533-02. If this form of failure does take place the analyses show that, for stability factors of safety to exceed 1.5 at building positions, future buildings should be set back by 12 m from the horizontal extent of the undercut area as shown on 20533-02.

Drawing 20533-02 shows, in red, the boundary of Lot 105 DP 436316 within which the new lots shown on DP 472593 (in Appendix 1) are located. As the boundaries of Lot 105 were close to the extent of the undercut line, the building set backs from the undercut line, were taken to be parallel to and 12 m from the eastern boundaries of Lot 105. Where the boundary line is beyond the undercut limit line on the western side of Lot 105, the set back distance is increased to 15 m.

The building restriction lines are shown on DP 472593 to define areas P to Z for which buildings are to be generally excluded when supported on surface foundations. These restriction lines are located in accordance with the set backs from the original boundaries with lot 105 as described above.

It is possible to cantilever floor slabs beyond the building restriction lines into areas P to Z on DP 472593 with the cantilevered span being determined by the structural strength of the slab beyond the building restriction line. The structural designer, who would be a chartered professional engineer, shall assume a fulcrum line for the cantilever at the building restriction line. The exception is at the western restriction line on Lot 436 where the restriction line has been determined to set buildings back from the inground piles as described in the paragraph below, and buildings should not be cantilevered forward of that restriction line.

The locations of future buildings on **lot 436** along the western boundary of the lot above the slopes leading down to the reserve of lot 1002 were researched. Subsequent analyses recommended the installation of inground "palisade" piles to stabilize the upper sections of the 2.5 m slopes that lead down from Lot 436 into lot 1002. These recommendations were contained in the report dated 25 February 2014 from S & L Consultants Ltd to The Lakes (2012) Ltd which is contained in Appendix 5. The details of the piles are shown on drawings 20533-08 and 20533-09 which are appended to this report.

The inground wall was constructed on 20 to 27 March 2014 under the observation of S & L Consultants Ltd to the details shown on 20533-08 and 20533-09. On DP 472593 the recommended building restriction line is 2.5 m from the inground wall alignment and 4.5 m from the western boundary of lot 436. This line is to ensure that buildings will not be affected if, for any reason, instability of the slopes to the west takes place and the ground on the western side of the inground wall is displaced while providing support to the building site to the east of the wall. The building restriction line referred to above is shown on DP 472593.

Since the construction of the inground palisade wall on lot 436 the owner of the lot has placed non supervised filling over the sloping ground in the building restriction area west of the palisade wall alignment and also to the south of area V on DP 472593. The stability of the

building area to the east of this filling is maintained at acceptable levels by the presence of the inground piles and the limit on building to the south by the building restriction line. The suitability of this filling to support any building foundation should be checked at actual proposed building position.

6.3 Liquefaction Potential

Liquefaction can occur in saturated sands or low plasticity silts during intense cyclic seismic loadings when porewater pressures reduce effective strengths and drainage takes place so that soil particles are resorted to a more dense state with subsequent reductions in soil volumes. The main effects of liquefaction are that ground settlement can occur with some settlement being differential. Where slopes or watercourses are present lateral spread may also take place.

The potential for liquefaction to take place at the building platform levels and subsequent effects of vertical and horizontal displacements were analyzed using the CPT data obtained in June 2013 and contained in Appendix 3.

The liquefaction assessment methodology adopted is that described by the New Zealand Geotechnical Society, July 2010 "Geotechnical Earthquake Engineering Practice – Module 1, Guidelines for the Identification, Assessment and Mitigation of Liquefaction Hazards".

NZS 1170.0:2004 "Structural Design Actions" requires that two seismic events be considered namely

- In the ultimate limit state (ULS) with a 1 in 500 year return period event whereby buildings should not collapse but may be beyond economic repair, and
- In the serviceability limit state (SLS) with a 1 in 25 year return period event whereby buildings should remain functional and not require significant repair

As liquefaction only occurs in saturated soils at or below groundwater levels, analyses undertaken in the ULS included the groundwater levels recorded in the CPT holes. Such levels were controlled by the ambient lake level present at that time. To consider an elevated lake level at the time of a 1 in 500 year seismic event would lower the probability of such a combined event from taking place.

Specific liquefaction analyses have been undertaken using the software package Cliq (Geologismiki 2011). The factors input into this software were

- an earthquake magnitude of 7.5 on the Richter scale
- class D – Deep Soil – subsoil class condition as described in NZS 1170.5:2004
- a site response factor of 1.12 (class D soil)
- a return period factor of 1.0 for the ULS and 0.25 for SLS
- a base peak ground acceleration of 0.2g (Tauranga)
- an importance level of 2 applicable to domestic buildings

From this data the design peak ground accelerations are:

- in the ULS, 0.22g
- in the SLS, 0.06g

The results of the analysis are shown on the summary sheets in Appendix 5.

As illustrated on the summary sheets, significant liquefaction is not predicted at any of the CPT positions, either in the areas improved by filling or in the unimproved areas. Minor liquefaction is indicated at all positions at a depth of 10.0 to 11.0 m and the results of this liquefaction will cause vertical and lateral ground movements as indicated on the plots.

The plots at CPTs 2A, 2B, 4A and 7 show some liquefaction potential immediately below the groundwater level and this has some influence in increasing the possible vertical and lateral displacements at those locations.

The influence of the level of groundwater is further illustrated on the plots at CPT positions 2B and 3B in a SLS seismic event and the raised lake and groundwater levels being 0.75 m below the ground level (the 1 in 50 year flood level). In these cases a minor liquefaction potential is indicated immediately below the groundwater level and in the case of CPT 2B, down to a depth of 4.7 m, with associated vertical and lateral displacement being possible.

Vertical settlements in the ULS were derived to be (in mm)

CPT position	ULS	SLS and elevated groundwater level
1A	3	
1B (filled)	0.45	
2A	5	
2B (filled)	12	42
3A	3.5	
3B (filled)	3.5	26
4A	3.2	
4B (filled)	3.5	
5(filled	Zero	
6 (filled)	4	
7 (filled)	17	

where (filled) refers to the presence of filled ground.

As future building will take place on the filled ground where the underlying peat had been replaced, only the estimated settlements at CPT positions 1B, 2B, 32B, 4B, 5 and 6 are applicable. The total settlements at these locations range from zero at CPT position 5 to 12 mm at CPT position 2B. As there is a consistent raft of subdivision filling present it is probable that differential settlements would be minimal.

Lateral spreading may occur where horizontal constraint is reduced at the batters leading down to the lake to the east west and south, and from the accessway at CPT 5 down to the grassed reserve to the north.

Lateral spreading magnitudes were derived to be (in mm)

CPT position	ULS	SLS and elevated groundwater level
1A	30	
1B (filled)	6	
2A	65	
2B (filled)	200	150-210
3A	25	
3B (filled)	25	111
4A	400	
4B (filled)	Zero	
5(filled	1	
6 (filled)	61	
7 (filled)	Zero	

where (filled) refers to the presence of the filled improved ground.

The larger lateral spreads at 2B and 4A would be due to liquefaction occurring immediately below the ground water levels plotted in the analysis sheets. The possible lateral spread at CPT position 2B was reassessed at the set back of 12 m recommended for stability purposes in 5.2 above. The magnitude of lateral spread reduced to 150 mm. The differences in lateral spread between positions 2A and 2B of 135 mm and 4A and 4B of 400 mm also indicates the situation where the organic soils and non supervised filling in the batter slope down to the adjacent lake may be displaced away from the more competent ground in the filling that replaced the organic soils.

Consideration of the effects of vertical and horizontal deformations may be based on work undertaken by the Ministry of Business, Innovation & Employment (MBIE) in Christchurch as there are no current guidelines for building on land that could be subject to liquefaction elsewhere in New Zealand. The magnitudes of deformations derived would place the Stage 2H area in the Christchurch post earthquake TC1 zone in terms of vertical settlements and generally in terms of TC2 in terms of lateral spread. It is recommended that foundations for future houses in the Stage 2H area be constructed as **enhanced foundation slabs** as described in the MBIE publication "Repairing and Rebuilding Houses Affected by the Canterbury Earthquakes." On all sites the ultimate bearing capacity is in excess of 200 kPa and therefore MBIE guidelines for option 3 or 4 would be appropriate. Such a construction for option 4 is available as a Firth RibRaftEQ or similar. The construction requires a specific design to take into account the number of storeys and the wall and roof cladding on the buildings. The use of a tied slab system will be more resistant to any effects of seismically induced differential settlements or lateral

movements. This recommendation should be reconsidered if the MBIE guidelines for the remainder of New Zealand before building details are prepared for the development of lots in Stage 2H.

Alternatively, the use of a **timber framed subfloor on shallow piles** can be adopted as described for Types A and B for TC2 applications in the MBIE guidelines.

The analyses at CPT positions 5 and 6 show the responses to ULS seismic conditions at the filled causeway from Double Bay Road onto the Stage 2H area. Minor vertical and lateral displacements are possible which would be unlikely to seriously damage any road formation and the roadway should remain serviceable after such an event, albeit possibly requiring some minor repair work to kerbing and/or sealed surfaces. Installed services such as wastewater or water supply lines are unlikely to be damaged.

6.4 Stormwater Disposal

As the subsoils present on the building areas comprise stiff natural soils or well compacted filling using cohesive soils, the disposal of stormwater runoff from roofs and hard stand areas by on site ground soakage methods is unlikely to be successful. Reticulation to capture stormwater on individual lots is therefore to be run to stormwater service outfalls provided for each lot.

7.0 Summary

Records and observations during the earthworks that were undertaken in 2007 have determined the extent by which a level area had been established for Stage 2H of The Lakes development. A subsequent review of that data and the analysis of the results of additional tests in June 2013 have determined that

(a) The filling placed where the underlying peat was removed, is suitable for the support of residential structures with shallow foundations. For the sizing of these foundations an ultimate bearing capacity in the limit state of 300 kPa may be adopted.

(b) The areas of natural ground, where an original hill was reduced by up to 6 m, are also suitable for the support of residential structures with shallow foundations.

(c) The batters leading down to the inundation levels of the adjacent lake are of low stability in comprising nonstructural inorganic filling overlaying the natural peats and organic silts. It is possible that slumping of lateral movement of those batters may take place in the future. Such movement may remove lateral support to the extremities of the structural filling that had replaced the peat. Buildings should not be located in the restriction areas P to Z shown on DP 472993 except in the circumstances described in (e) below, to ensure that stability factors of safety at those building positions exceed conventionally accepted values.

(d) Building development on lot 436 is to take place within the areas defined by the building restriction lines shown on DP 472593 and also back from the western boundary by distances shown on drawing 20533-08 in Appendix 5 and also on DP 472993.

(e) Buildings may extend into restriction areas P to Z except over the western restriction line on lot 436, provided that the structure is cantilevered beyond the building restriction lines. The design of the structure is to be undertaken by a chartered professional structural engineer.

(f) Assessments of the effects of liquefaction have determined that, in the ultimate limit state event, vertical seismically induced settlements are likely to be low and within tolerable limits for conventional house construction. Lateral spreading in such seismic conditions is also likely to be within tolerable limits. Because of the possibility that subsoil conditions could differ away from the test positions described in this report, it is recommended that all future buildings in the Stage 2H area be constructed on an enhanced foundation slab as described in section 6.3 above.

(g) In the ULS seismic event minor damage may occur to the roadway into the Stage 2H development but the formation should remain serviceable to traffic.

8.0 Topsoil Thickness

During the subdivision earthworks areas of cut or fill were initially stripped of topsoil and this was then replaced to target depths of up to 200mm. No guarantee is implied or given that the topsoil on any part of any lot is 200mm deep or less and it is recommended that future owners or builders check topsoil depths when preparing site development plans, cost schedules or contracts for site works.

9.0 Alterations to Council Land Information System Data

At the time of the preparation of this report, land information shown on the Council web site comprised

- A 4:1 runout zone on the eastern and western sides
- 1:2 and 1:3 projections from the bases of the slopes

These zones are now incorrectly plotted as they refer to the original Land Form shown on attached drawing 20533-01 before the subdivision earthworks.

It is recommended that the "natural hazards" plots be removed as they are not now applicable. Future advice given to future property owners should be based on this report which would be advised to those owners through the consent notices on the property titles.

10.0 Professional Opinion

A statement in the format of Councils Infrastructure Development Code (Form G2) that all lots are suitable for building is contained in Appendix 2. This statement is accompanied by Form G3 which summarises the information and recommendations within this report.

In accordance with subdivision consent condition 8, it is recommended that the content of this report is advised to future owners of the 11 lots within the Stage 2H development at The Lakes by a consent notice on the certificates of title for all lots.

11.0 Applicability

Recommendations contained in this report are based on data from pre and post subdivision boreholes, observations of soil exposures during earthworks, and the results of tests in filling placed. Inferences about the nature and continuity of subsoils away from these locations are made but cannot be guaranteed.

In all circumstances, if variations in the subsoils occur which differ from those described or are assumed to exist, the site should be inspected by an engineer suitably qualified to make an informed judgment and provide advice on appropriate improvement measures.

This report has been prepared specifically for the proposed subdivision development in Stage 2H of The Lakes Development and no responsibility is accepted by S & L Consultants Ltd for the use of any part of this report for other development sites without their written approval.

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