SHRIMPTON & LIPINSKI

THE LAKES DEVELOPMENT
STAGES 2D, 2F, 2G, 2J, 2K, 2L and 2M
INCLUSIVE
PYES PA, TAURANGA

Report on Earthworks and
Recommendations for Development

Volume 1 of 2

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Contents

1.0 Introduction

This report refers to the site development earthworks completed for Stages 2D (part), 2F, 2G, 2J, 2K, 2L and 2M of The Lakes residential subdivision development at Pyes Pa.

The locations of each of these stages are shown on plans 124511-site-01 and DP 408042, both prepared by Harrison Grierson Consultants. Copies of these plans are included in Appendix 1 of this report. These plans show the following proposed residential developments.

Stage 2D (part)
: Comprising five lots numbered 471 to 475 inclusive in which single dwelling developments can occur. This part of Stage 2D is in the Western Bay of Plenty District Council area. That part of Stage 2D in the Tauranga City Council area is referred to in the summary geotechnical report for stages 2A to 2F inclusive of S&L Consultants Ltd, reference 18264, and dated 17 March 2008.

Stage 2F
: Comprising large lot 499 in which medium density residential development will require resubdivision into smaller lots or designated building areas. The stage 2F area is currently divided by the district boundary between the Tauranga City Council and the Western Bay of Plenty District Council. Recommendations for the future development of the total area of stage 2F were given to the geotechnical summary report for stages 2A to 2F dated 17 March 2008. The section relating to Stage 2F of that report is included in section 6.0 of this report

Stage 2G
: Comprising large lots 515 and 520 on which medium density residential development will require resubdivision into smaller lots or designated building areas.

Stages 2J and 2L
: Located on elevated ground adjacent to Kennedy Road, these stages comprise 71 lots numbered 549 to 596, and 675 to 697 on which single dwelling development can occur.

Stages 2K and 2M
: These stages comprise one large lot on each stage on which future residential development will require resubdivision into smaller lots or designated building sites.

Construction of the roading and reticulation to service these stages of The Lakes development has been completed by the developer, Grasshopper Farms Ltd.

Approval for the Lakes Development was initially granted jointly by the Tauranga City Council and Western Bay of Plenty District Council on 24 May 2004 based on subdivision plan 16916 dated 20 April 2004 prepared by S&L Consultants Ltd.

A variation was approved by the Tauranga City Council on 18 September 2007 for the proposed development on the area known as Stage 2 at The Lakes. The basis of the Stage 2 development was subdivision scheme plan 124825-2-RC04 prepared by Harrison Grierson.

Stages 2D, 2F, and 2G are located on the lower lying areas within the development. Parts of these stages are within the former flood plain of the Kopurererua stream which flows past The Lakes development to the west.

Access to Stages 2D, 2F and 2G is by Lakes Boulevard from the subdivision entrance at Takitimu Drive. Access to the elevated stages of 2J, 2K, 2L and 2M will be initially from an extension of Kennedy Road. When future stages to the east are constructed, a link will be formed from upper Kennedy Road to Lakes Boulevard

This composite report has been prepared for the Section 224C Certificate application for DP 408042 and describes the earthworks undertaken in the formation of Stages 2D, 2F, 2G, 2J, 2K, 2L and 2M of the subdivision and summarises the suitability of the prepared ground in cut and fill for future urban housing development. The report states the relevant standards adopted for the placement of filling to support residential buildings and recommendations for developing future building sites.

During the report references are made to as built drawings prepared for each stage. These drawings are reference plans which show the positions of compaction tests undertaken during the earthworks, pre and post construction borehole positions and post construction settlement control markers. The second of the as built drawings show the depths of the filling that was placed and depths of cut that were made.

The following drawings are referred to in this composite report:

Stage No:	**Reference Plan:**	**Cut/Fill Plan:**
2D (part)	AB12	AB15
2F	AB7	AB8
2G	AB12 and AB13	AB15 and AB16
2J	AB11 and AB12	AB14 and AB15
2K	AB11 and AB12	AB14 and AB15
2L	AB12	AB15
2M	AB11and AB12	AB14 and AB15

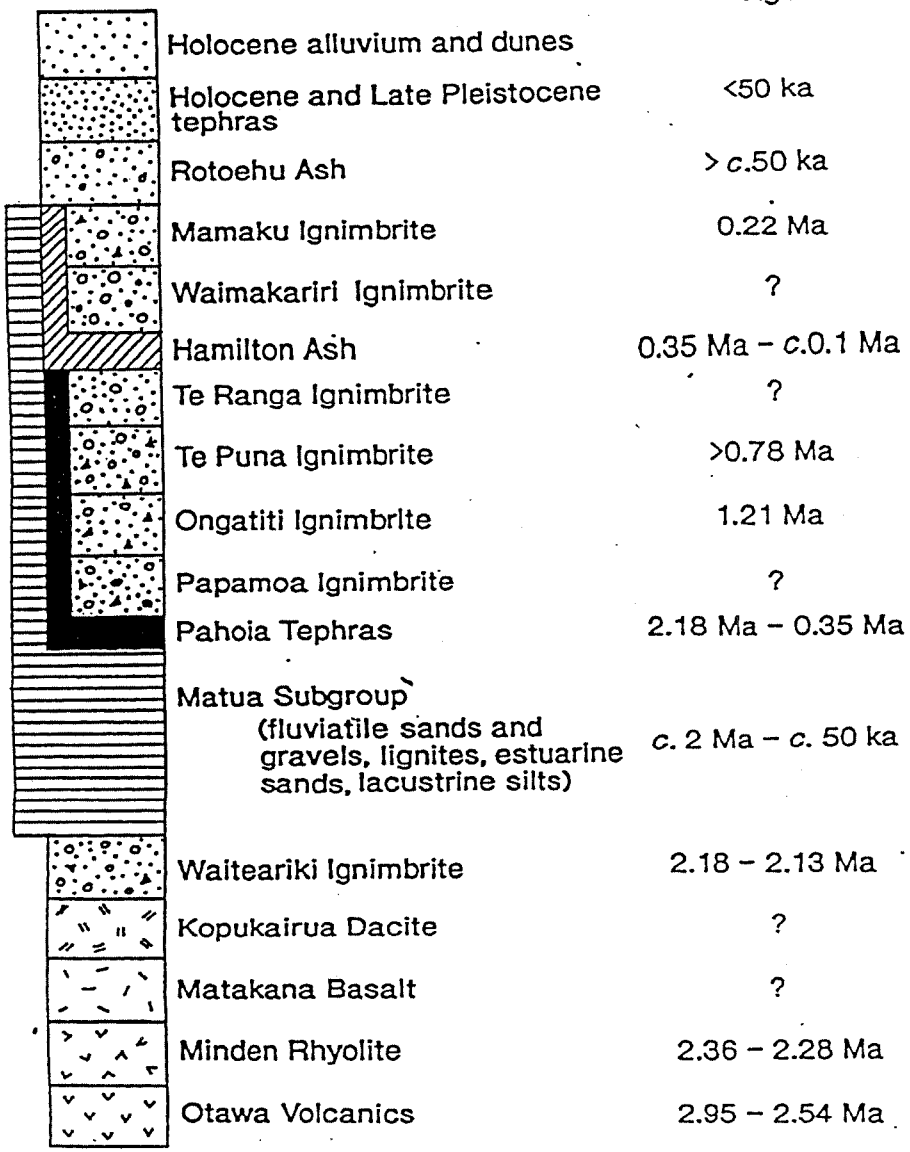
These drawings are contained in Appendix 1.

2.0 Original Landform and Geology

The landform prior to the commencement of the subdivision construction 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 has 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



TAURANGA RELIC SLIP VERIFICATION STUDY
Figure 2: Generalised stratigraphy of the Tauranga area

DESCRIPTION OF ASH SEQUENCE MATERIALS AND MATUA SUBGROUP

YOUNGER ASH
The Post-Rotoehu Ash Tephras consist of a number of ashfall tephra deposits, most of which are sourced from the Taupo Volcanic Zone. The thickness of the individual tephra layers varies from 0.1 to 3m.

ROTOEHU ASH
The Rotoehu Ash is a distinctive sequence of shower-bedded tephras derived from the Taupo Volcanic Zone. Individual beds within the 0.3 to 2.4m thick sequence vary from 0.5 to 20 cms in thickness and are typically white to greyish yellow and fine to coarse sandy texture.

HAMILTON ASH
The Hamilton Ash Formation consists of strongly weathered clay-textured tephra beds and palaeosols. It consists of up to eight units. The sequence ranges in thickness from <0.5m to about 6m in areas of ponding.

TAURANGA GROUP
The Pahoia Tephras comprise all the tephras older than the Hamilton Ash Formation and are intercalated with fluvial and other sediments of the Matua Subgroup. They are a sequence of clay-rich rhyolitic tephras which consist of a wide range of grain sizes and structures, including clay, silts, silty sands and pebbles.
The presence of an intermediate aquifer layer gives rise to seepage and erosion problems in outcrop.

MATUA SUBGROUP

The Matua Subgroup includes a wide range of lithologies from fluvial pumiceous and rhyolitic silts, sands and gravels, lacustrine to estuarine muds, lignites and peats intercalated with airfall tephras and thin distal ignimbrites. The sediments display a number of sedimentary structures such as cross-bedding, planar stratified and massive units, and post-depositional slump and water escape structures. Most of these sediments were derived from reworked ignmibrites, lava domes and flows, and tephras from the Tauranga region and the TVZ.

Adapted from Oliver 1997 and Briggs et al 1996

The geology within the Stages 2D to 2M areas can be described as:

(i) On the steep sided hills to the east (stages 2J, 2K, 2L and 2M)
- Taupo volcanic zone tephras comprising Rotoehu ash (light grey sand) overlaid by brown or yellow post Rotoehu ash being coarse grained silts, sandy silts and sands. These are collectively referred to as "younger ashes" and overlay.
- "Older" ash derivative strongly weathered clay textured tephra beds and palaesols (Hamilton ash) overlaying.
- Older terrestrial and estuarine sediments deposits of the Matua subgroup of the Tauranga formation. These may comprise a wide variety of lithologies.
- Te Ranga ignimbrite being white-grey pumiceous sands and coarse silts.

A summary of this stratigraphy is shown on the diagram on page 5.

(ii) At the lower areas to the west below the transition slopes and adjacent to the Kopurererua Stream (stages 2D, 2F and 2G)
- Alluvial silts, sands and gravels transported by the stream.
- Organic peat at the existing ground surfaces or overlaid by alluvial soils at depth.
- Eroded sections of the more elevated Taupo volcanic zone tephra that have been reduced to the levels of the stream plain or rise above these levels as mounds or ridges that extend in to the stream plain area.

3.0 Presubdivision Investigations

Prior to obtaining approval for the original development on 24 May 2004 a comprehensive geotechnical assessment was undertaken by S&L Consultants Ltd. The subsequent report that accompanied the consent application was titled "Pyes Pa West Urbanisation Development, Geotechnical Assessment Report, reference 16944" and was dated October 2003.

Fifty two machine drilled boreholes and twenty six excavated pits were used to identify the subsoils that are present on the development area. Relevant test positions for each stage were:

Stage No.	Reference Plan.	Machine Bores:	Test Pits:
2D	AB12	47, 50	25
2F	AB7	20, 49, 50	24
2G	AB12 and AB13	14,15	25
2J,2K, 2L, 2M	AB12	47	

Each of these boreholes and test pits showed the presence on the lower areas of Stage 2 to be:

- Peat (organic silt) ranging from depths of 1.2m (borehole 50) to 4.5m (boreholes 14 and 15) adjacent to Stage 2G

- Grey sandy silts and sands underlying the surface peat. These inorganic soils were found to be of varying densities and strengths with uncorrected SPT N values in the range of 1 to 6. The investigation borehole depths ranged from 6m to 18.5m. No further organic soils were encountered in that depth apart from the surface cover of peat.

Machine drilled borehole 47 was located on the former Grant plateau (now stages 2J, 2K, 2L and 2M) adjacent to Kennedy Road and showed the subsoils present within the slope profiles down to the Stage 2D and 2G areas. This borehole showed the presence of the "younger" and "older" ashes, the underlying Matua subgroup soils and Te Ranga Ignimbrite at a depth of 9m. The borehole was 27m deep

The presubdivision investigations concluded that:

- The soils to be obtained in areas of cut on the higher ground would be suitable for placement as filling to support future houses although some conditioning may be required so that placement would be near optimum moisture contents.
- Areas of higher ground away from the areas of peat and not to be disturbed by construction earthworks would be suitable for the support of future houses in accordance with NZS3604.
- As the volcanic ash stratigraphy varies in type and relative strength foundation bearing conditions may vary across building sites formed in areas of cut.
- Similar variations in soil type may be encountered in road subgrades and insitu testing would be required to determine pavement depths applicable to the subgrade conditions present.
- The peat soils can be removed to depths governed by the capability of the earthmoving machinery on the site and the cost effectiveness of removing the peat and undertaking its replacement with filling obtained from elsewhere within the subdivision development area.

4.0 Scope of Subdivision Earthworks

The general earthworks undertaken in Stage 2D, 2F 2G, 2K, 2L and 2M areas inclusive were:

(a) The removal of the surface peats and the replacement of the peat with filling obtained from borrow areas within The Lakes development in Stages 2D, 2F, and 2G. Prior to placement of the filling over the stripped areas, extensive subsoil drainage systems were constructed. The positions of these drains and their outfalls are shown on the reference plans in this report for each stage. The drains mainly originated at the bases of shallow gullies that extended southwards into the peat areas from the steep hillsides to the north and south to south east. The points of seepage that are serviced by the drains were identified when removal of the peat commenced.

(b) The reduction of the areas within stages 2J to 2M by excavations of up to 11m to form uniform near flat sloping ground in a northerly direction. The soils taken in the areas of cut were placed as the replacement filling in the areas where surface peats were removed in Stages 2D, 2F and 2G and the subgrade of Lakes Boulevard adjacent to Stages 2D, 2F,and 2G.

(c) The placement of filling at the south eastern corner of Stages 2K and 2M as

shown on 18264–AB11 and AB14 to ease slopes from the adjacent Kennedy Road formation down to the areas of cut within Stages 2J and 2K as described in (b) above

(d) The trimming of the steep slopes that existed between the upper areas of Stages 2J to 2M and the lower stages of 2D and 2G to form more stable gradients. Associated with this work, which was mainly in cut, filling was placed within a motorscraper haul route that existed down these slopes between upper lots 575 and 675 in Stages 2J and 2L and lower lots 475 and 515 in Stages 2D and 2G and to infill an old landslip scarp and seepage gully below lots 682 to 685 in the previously completed section of Stage 2D.

(e) The stabilising of the reformed slopes between stages 2J and 2L above and stages 2D and 2G below with the extensive planting of revegetation plant species and the placement of mulch over the total faces of the batters to encourage plant growth.

The depths of cut and filling shown on drawings 18264-AB14, AB15, and AB16 were derived from surveyed contours of the finished surface taken on completion of the earthworks compared with topographical surveys undertaken by S&L Consultants Ltd and Grasshopper Farms Ltd prior to the subdivision construction and also after the removal of the unsuitable surface soils and prior to the placement of the replacement filling.

The earthworks were undertaken by Hick Bros Earthmoving. The areas of Stages 2J to 2M were reduced for filling elsewhere in the 2006–2007 earthworks season. The recontouring of the slopes between upper level stages 2J and 2L and lower level stages 2D and 2G and the replacement filling in Stages 2F and 2G was undertaken in the 2007– 2008 earthworks season

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

5.0 Earthworks Standards

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 150kPa (any 10 tests)
- Minimum single value 100kPa

Where the filling placed was clearly pumiceous sand obtained from borrow pits in the Te Ranga ignimbrite Scala penetrometer tests were specified with blow counts of 4 or more per 100mm of penetration being required.

The calculation of air voids percentages was dependant on the determination of the solid densities of the soils used in the filling. These soils mainly comprised mixed silts, clayey silts, sandy silts and sands depending on the depths below the original ground surfaces that the cuts were made for obtaining fill materials. For cohesive silt/clay soil mixtures a value of solid density of 2.65t/m^3 was used in the calculation of air voids. Where the sample taken for laboratory determination of insitu water content comprised pumiceous sands and was indicative of the soils in which the nuclear densometer test was undertaken a lower value of 2.56t/m^3 was used in the calculations.

The earthworks were supervised by site project engineers employed by Grasshopper Farms Ltd and observed by engineering staff from S&L Consultants Ltd during specific site inspections.

Compaction and strength control testing was undertaken by IANZ accredited Opus International Consultants Ltd both on site and in their Tauranga laboratory.

The following numbers of complying compaction tests were undertaken:

Stage No.	No. Tests
2D (lots 472-425)	13
2F	29
2G	45
2J	13
2K	10
2L	37 including the slopes below
2M	6

The test results are listed in Appendix 3.

6.0 Recommendations for Development of Stage 2D (lots 471 to 475) and 2G (lot 515)

The Stage 2D and 2G (lot 515) areas are located on the eastern side of Lakes Boulevard. The relative lot positions are shown on DP 408042 and 18264-AB12 and AB13.in Appendix 1

The original topography within these two areas comprised transitional near flat ground between rising ground to the east to the Grant Plateau (now Stages 2J and 2L) and the low lying ground to the north west where Stage 2F and the western part of Stage 2G are located. The low lying land formed part of the flood plain of the Kopurererua Stream. The current alignment of Lakes Boulevard is along the edge of the areas of peat that were within the flood plain area

Prior to construction of the roading and services in the Stage 2D and 2G areas substantial earthworks were undertaken to:

(a) Reduce the upper Grant Plateau levels to provide near flat building areas in the future Stage 2J to 2M development areas and to obtain filling for the development of Stages 2F and 2G where replacement of the peat soils was undertaken with this filling. The haul routes from the

Grant Plateau that were down a gully which existed above lot 475 in Stage D and the reserve area between lots 495 and 515 were reshaped to be part of the pedestrian and cycleway system that traverses the slopes between Stages 2D and 2G and upper Stages of 2J to 2M.

(b) Establish a route for the realignment of the natural gas pipeline behind lots 472 to 475 and 515. Initial earthworks were undertaken mostly in cut as the pipeline easement 6m wide was created as a near level berm on the sloping ground. Where groundwater was encountered in the cut faces along the gas pipeline route subsoil drainage was installed some of which was located in a trench below the gas pipeline invert. These drains are shown on drawing 18264-AB12 and AB13.

(c) Reduce the original steep slope face angles present on the rising ground above Stages 2D and 2G and up to Stages 2J and 2L. This required the easing back of the original slopes to be not steeper than 1 on 2 (26 degrees) with an intermediate maintenance berm at midslope. This berm will be utilised as part of the walkway system. The scope of the earthworks undertaken on the steep slopes above 2D and 2G was derived from the stability analyses described in Section 6.4 of this report. The lower limits of resulting slopes were defined by the gas main easement

In the areas of filling shown on 18264-AB15 and AB16, as well as in the subgrade of Lakes Boulevard, the underlying peat was first removed down to the underlying inorganic soils. Subsoil drains were constructed where required following an inspection of the excavated levels and the identification of points of incoming seepage. Structural filling was then undertaken to the standards listed in Section 5.0.

6.1 Subdivision Construction Filling

Supervised structural filling, as shown on drawings 18264-AB15 and AB16, was placed in accordance with the methods and standards quoted in NZS4431 under the observation of S&L Consultants Ltd. Compaction testing on site confirmed that a high and uniform degree of compaction has been achieved suitable for the support of buildings.

After placement of the filling in Stages 2D and 2G (Lot 520) settlement markers numbered 11, 12 and 13 were monitored at locations shown on 18264-AB11 and AB12. The levels on these markers have been surveyed at regular intervals and the surveys were continued during the construction of the roading and services. The results of these surveys to the date of this report are within Appendix 3.

The degrees of settlement have fluctuated over the monitoring period with variations up or down probably due to the expected accuracy of the survey.

The trends during the monitoring period indicate that any future settlement will be within tolerable limits for future buildings constructed on surface foundations.

For all of the lots which will be located in the areas of fill the ultimate ground bearing capacity in the limit state may be taken at 300kPa and this capacity

meets the definition of "good ground" as defined in NZS3604. Future buildings may therefore be detailed in accordance with NZS3604.

Within areas of structural filling on which buildings may be erected, however, the possibility of variation of soil type and strength may exist away from observation or compaction test locations. The normal inspection of foundation conditions during construction of buildings by competent tradesmen as described in NZS3604 and by building inspectors would still be undertaken. If for any reason areas of low soil strength are found professional geotechnical advice should then be sought.

6.2 Stability of Sloping Ground Above Stages 2D (lots 472 to 475) and 2G (lot 515)

To assess the finished profiles that were formed on the steep sloping ground that rose above Stages 2D and 2G to the Stage 2J and 2L areas to the south east investigation boreholes were put down under the supervision of S&L Consultants Ltd by Perry Drilling Ltd during April 2007. These boreholes supplemented the original subsurface data that was available from machine borehole MB47 drilled in September 2003 that was located above Lot 471 in Stage 2D.

The summary log for MB47 is contained in Appendix 5. The soils that made up the slopes above Stage 2D and as described in MB47 down to a depth of about 9.5m were removed in the subdivision earthworks in the 2006-2007 earthworks season and prior to the earthworks to form the finished slopes above the Stages 2D and 2G areas, that took place in November – December 2007. This initial borehole showed that below a depth of 9.0m the subsoils comprised medium to coarse grained pumiceous sand being Te Ranga ignimbrite. The borehole indicated that the ignimbrite extended to and beyond the depth of the borehole of 27m. Standard penetration tests (SPT) in the rock showed that densities increased with depth.

The boreholes put down in April 2007 were located at the crests of the original slopes below stages 2J and 2L and at intermediate lifts on the slope faces on the haul tracks for the bulk earthmoving equipment. From this borehole data and the existing slope geometry it was deduced, by analysis, that the sloping ground between the upper and lower stages and had to be reduced in slope to not more than 26 degrees (1 on 2) to provide acceptable factors of safety against slope failure. In plotting these slope angles and for providing for an intermediate berm for slope maintenance and also as an extension of the cycle and walkway through the subdivision, it was found that the surface ash soils would be removed by the recontouring earthworks leaving the Te Ranga ignimbrite to be mostly exposed on the cut faces.

6.2.1 Stability Analyses

For the sloping ground above the Stage 2D and 2G areas the stability of three cross sections were analysed. These cross sections (numbered 5, 7 and 8) are shown in position on 18264-AB12.

The investigation borehole positions from which the data was obtained to undertake the stability analysis are also shown on this drawing.

As a reference in Appendix 1 drawings 18264–20 and 21 show the slope contours before and after the excavations were made to re contour the slope faces.

Each of these cross sections and intermediate cross section 6 has differing profiles and constituents. The finished sloping ground at each of the cross sections was formed in the following manner.

Cross Section 5 (above the western end of lot 515)

- Constructed in cut, the maximum depth being 9m slightly to the east of the immediate berm
- The lower section of the slope above the gas pipeline follows the original slope of 25 degrees before reductions occurred as the slope angles steepened at about the western edge of the intermediate berm
- After the earth works were completed the exposed soils on the slope faces were stiff brown ash derivative silts at the lower levels overlaying Te Ranga ignimbrite at 1.0m deep. The ignimbrite was exposed on the upper trimmed slopes above the intermediate berm
- Finished slope angles at 24 to 26 degrees.

Cross section 6 (above the eastern end of lot 515)

- Constructed in areas of cut and filling
- On the lower slope of 25 degrees minor subdivision filling is present up to 1.5m deep as a transition between the upper steeper slopes and the flatter areas on the lot
- At and above the intermediate berm areas of cut up to 7.0m deep have exposed the Te Ranga ignimbrite being present as coarse silty sands
- At the upper level, minor depths of subdivision filling to 2.0m as part of the replacement filling to the old haul route from the upper plateau to the stage 2J area
- Finished slope angles are at 25 degrees

Cross Section 7 (above lot 473)

- This section mainly followed the original slope face up to the intermediate berm
- Above the berm a cut depth of up to 6.0. took place to create the 25 degree slopes above the berm
- Te Ranga ignimbrite was exposed in the cut faces above the intermediate berm. The surface soils in the lower slopes are stiff as derivative sandy silts
- Finished slope angles are at 25 to 26 degrees

Cross Section 8 (adjacent to lot 471)

- Constructed and mostly in cut with the maximum cut depth being 8.0m at the intermediate berm
- Minor structural filling at the toe of the slopes up to 2.0m deep
- Finished slope angles at 24 degrees

The borehole data and also inspections of the exposed soils and rock derivatives on the finished slope faces were used to determine effective strength parameters that were used in the stability analyses for each cross section.

Each slope profile was analysed in the fully drained (ambient) state and also when soil porewater pressures are raised by the assignment of a pore pressure ratio Ru.

The soil strength parameters adopted were:

Soil Type	Effective Cohesion kPa	Effective Friction Angle Degrees	Density kN/m³	Maximum Ru
Structural filling (sandy)	3	32	16	0.15
Surface sandy silt	2	32	14	0.15
Silt (Matua subgroup)	2	30	14	0.15
Ignimbrite	2	40	14	0.15

The value of effective angle of internal friction of 40 degrees for the Te Ranga ignimbrite was derived from SPT values in the investigation boreholes and the back analysis of original slopes which stood at angles of up to 45 degrees where the ignimbrite was present in the slope faces.

Analyses were undertaken using the program X-Slope where the input was the slope geometry established by survey and the soil strength parameters listed above.

Computed factors of safety were:

Cross Section	Lower Slope		Upper Slope		Total Slope	
	Fully Drained	Raised Ru	Fully Drained	Raised Ru	Fully Drained	Raised Ru
5	1.60	1.21	1.88	1.45	2.15	1.66
7	1.64	1.37	1.61	1.36	1.99	1.67
8	1.54	1.30	1.74	1.50	>1.61	>1.30

The analyses show that, for slope profiles 5, 7 and 8, which are typical of the slope profiles above Stages D and G, stability factors of safety are in excess of the conventionally acceptable factors of safety of:

1.5 For ambient or fully drained slopes which is the expected condition for the slopes as formed.

1.2 For transient conditions whereby porewater pressures may be raised for a short period of time and dissipation occurring after the storm even which raised the porewater levels.

Therefore, lots 471 to 475 within Stage D and lot 515 within Stage 2G are unlikely to be subject to the effects of any natural hazards due to presence of the formed slopes above these lots

7.0 Recommendations for Development on Stage 2F

7.1 Subdivision Construction Filling

Supervised structural filling, as shown on drawings 18264-AB7 and AB8, was placed in accordance with the methods and standards quoted in NZS 4431 under the management of S & L Consultants Ltd. Compaction testing on site confirmed that a high and uniform degree of compaction has been achieved suitable for the support of buildings.

After placement of the filling in Stage 2F six settlement markers numbered 9, 10, 11, 47, 48 and 49 were installed at locations shown on 18264-AB7 in or adjacent to the Stage 2F area. The levels on these markers were surveyed at regular intervals. The results of these surveys to the date of this report over the previous period of up to 180 days are within Appendix 3.

The degrees of settlement have fluctuated over the monitoring period with variations up or down probably due to the accuracies of the surveys. Recorded monthly settlements up to the preparation of this report were in the range of 1 to 3mm. The trends during the monitoring period indicate that any future settlement will be within tolerable limits for future buildings constructed on surface foundations. These limits are stated in Appendix B of compliance document B1/VM4 for the New Zealand Building Code prepared by the Department of Building and Housing.

The future development of Stage F would include the construction of the subdivision roading which would be set below the levels of adjacent lots. The same high degree of compaction of the filling occurred in the areas for future roads, as for the likely building areas. A stable road subgrade would therefore be present. It is recommended that the road pavements be detailed for a subgrade CBR of 7.

For all of the lots which will be located on the areas of fill the ultimate ground bearing capacity in the limit state may be taken at 300kPa and this capacity meets the definition of "good ground" as defined in NZS3604. Future buildings may therefore be detailed in accordance with NZS3604.

A statement in support of the suitability of the filled areas for subdivision is contained in Appendix 2 of this report.

Within areas of structural filling on which buildings may be erected, however, the possibility of variation of soil type and strength may exist away from observation or compaction tests locations. The normal inspection of foundation conditions during construction of buildings by competent tradesmen as described in NZS 3604 and by building inspectors would still be undertaken. If for any reason areas of low soil strength are found professional geotechnical advice should then be sought.

7.2 Stability of Replacement Filling

The extent of the structural filling shown on 18264-AB8 along the northern, southern and western margins of Stage 2F was determined by the practical limits to which the surface peat soils could be removed. The extent of the filling shown was surveyed as being at the base of the excavation. For stability purposes during construction the excavations were battered into the remaining peat before the controlled backfilling took place. Additional filling was placed over the peat beyond the replacement filling areas to raise ground levels.

A building restriction line is applicable to limit future buildings to be located on the structural filling where reliable ground will be present to support conventional buildings with surface foundations. Beyond the restriction lines filling will be present which may not be suitable to support buildings and ground settlement may occur where this filling has been placed over organic soils which were not removed during the subdivision earthworks.

To confirm that the building restriction line identified from the survey during the earthworks is in the correct position additional boreholes were machine drilled along the building restriction line in February 2008. The test positions are shown on 18264-AB7 and summary logs are in Appendix 4. Each borehole showed the depth of the filling that is present and also the absence of any former peat indicating that the correctly filled ground extends beyond the building restriction lines.

The building restriction lines are shown on 18264-AB8 and the survey plan DP 408042

8.0 Recommendations for Development on Stage 2G (Lot 520)

8.1 Subdivision Construction Filling

Supervised structural filling, as shown on drawings 18264-AB13 and AB16, was placed in accordance with the methods and standards quoted in NZS 4431 under the management of S & L Consultants Ltd. Compaction testing on site confirmed that a high and uniform degree of compaction has been achieved suitable for the support of buildings.

After placement of the filling in lot 520 and two areas to the west in future stages, settlement markers numbered 5 and 13 installed close to Stage 2G at locations shown on 18264-AB13. The levels on these markers were surveyed at regular intervals. The results of these surveys to the date of this report over the previous period of up to 180 days are within Appendix 3

The degrees of settlement have fluctuated over the monitoring period with variations up or down probably due to the accuracies of the surveys. Recorded monthly settlements up to the preparation of this report were in the range of 1 to 3mm. The trends during the monitoring period indicate that any future settlement will be within tolerable limits for future buildings constructed on surface foundations. These limits are stated in Appendix B of compliance document B1/VM4 for the New Zealand Building Code prepared by the Department of Building and Housing.

The future development of Lot 520 would include the construction of the subdivision roading which would be set below the levels of adjacent lots. The same high degree of compaction of the filling occurred in the areas for future roads, as for the likely building areas. A stable road subgrade would therefore be present. It is recommended that the road pavements be detailed for a subgrade CBR of 7.

For all of the lots which will be located on the areas of fill the ultimate ground bearing capacity in the limit state may be taken at 300kPa and this capacity meets the definition of "good ground" as defined in NZS3604. Future buildings may therefore be detailed in accordance with NZS3604.

A statement in support of the suitability of the filled areas for subdivision is contained in Appendix 2 of this report.

Within areas of structural filling on which buildings may be erected, however, the possibility of variation of soil type and strength may exist away from

observation or compaction tests locations. The normal inspection of foundation conditions during construction of buildings by competent tradesmen as described in NZS 3604 and by building inspectors would still be undertaken. If for any reason areas of low soil strength are found professional geotechnical advice should then be sought.

8.2 Stability of Replacement Filling

The extent of the structural filling shown on 18264-AB16 along the northern, western margins of Lot 520 was determined by the practical limits to which the surface peat soils could be removed. The extent of the filling shown was determined surveyed as being at the base of the excavations. For stability purposes during construction the excavations were battered into the remaining peat before the controlled backfilling took place. Additional filling was placed over the peat beyond the replacement filling areas to raise ground levels.

A building restriction line is applicable to limit future buildings to be located on the structural filling where reliable ground will be present to support conventional buildings with surface foundations. Beyond the restriction line filling will be present which may not be suitable to support buildings and ground settlement may occur where this filling has been placed over organic soils which were not removed during the subdivision earthworks.

To confirm that the building restriction line identified from the survey during the earthworks is in the correct position, seven additional boreholes were machine drilled along the building restriction line in March 2008. The test positions are shown on 18264-AB13 and summary logs are in Appendix 4. Each borehole showed the depth of the filling that is present ant also the absence of any former peat indicating that the correctly filled ground extends beyond the building restriction lines

The building restriction lines are shown on 18264-AB12 and AB13 and the survey plan DP 408042.

9.0 Recommendations for Development on Stages 2J, 2K, 2L and 2M

The areas of Stages 2J, 2K, 2L and 2M originally comprised undulating farmland at the end of Kennedy Road. Steep slopes existed between the upper levels and those to the west that have been developed as Stages 2D and 2G of The Lakes development

As shown on appended drawings 18264-AB14 and AB15 the depths of cut undertaken over most of the areas within these stages vary from zero at the south eastern corners of Stages 2K and 2M and within lots 590 to 592, to 11m within lots 562 to 564 and 566 to 569 within Stage 2J. In stage 2L, further to the east, cut depths were up to 9.0m in lots 675 and 691. Structural filling was placed to elevate original ground levels at the south eastern corner of stages 2K and 2M

9.1 Post constructing Testing

Post construction machine drilled or handaugered boreholes were put down on every lot that did not contain supervised filling, at locations shown on appended drawings 18264-AB11 and AB12. These boreholes were generally 1.0m deep and were intended to show soil types and continuity and to confirm the ground bearing conditions for shallow building foundations. Deeper boreholes were put down at some locations as part of the investigations to obtain data from slope stability analysis (refer to section 5.2).

As the boreholes were being drilled undrained shear strengths were recorded with a hand held shear vane pushed in advance of the auger. Where sandy soils were encountered a Scala penetrometer was also driven from the finished ground surface.

Summary logs of the soils found in the boreholes are in Appendix 4. The soils found in the boreholes in areas of cut and their strengths determined in the boreholes are summarised on tables 2, 3 and 4 on pages 18, and 19. The boreholes indicated the varying soil types that may be present at building foundation levels in the areas of subdivision cut

In each post investigation borehole the undrained shear strengths were variable but were mainly very high. For any building foundation to be detailed to NZS 3604:1999 and subsequent amendments, an undrained shear strength of at least 60kPa should be present at the foundation level. At this strength the ultimate ground bearing capacity in the limit state may be taken at 300kPa and therefore the bearing conditions can be taken as "good ground" in terms of NZS 3604.

All test positions on the lots on which post construction boreholes were put down the undrained shear strengths at likely foundation levels were in excess of 60kPa and therefore "good "ground" can be considered to be present at the test position

The boreholes also confirmed that some additional filling had been placed over the previously cut areas to level surfaces once the bulk earthworks had been completed. Depths of filling of up to 1.0m were present at borehole positions 549, 553, 555, 561, 562, 564, 565, 567, 568, 569, 572, 574, 575, 576, 582, 584, 586, 592, 596, 675, to 682, 686, 689, 690, 699, 700, 702 and 706. The filling has been placed to the standards listed in section 4.0 as indicated by the strengths recorded.

Table 2

A Summary of Exposed Subsoil Types in Areas of Cut As Determined from Post Construction Boreholes Stage 2J

Lot No.	Depth of Cut (m)	Soil Type	Shear Strength at Foundation Depths (kPa) or Scala Penetrometer blows per 100mm
549	0-1	fill over clayey silt	200+
550	2-5	clayey silt	161
551	3-7	clayey silt	149
552	6-7	clayey silt	200+
553	7	fill over clayey silt	200+
554	7	clayey silt	136
555	7	fill over clayey silt	174
556	7-8	clayey silt	190
557	7-8	sandy silt	180
558	8-11	clayey silt	101
559	7-10	sandy silt	149
560	5-9	clayey, sandy silt	165
561	5-8	fill being clayey silt	200+
562	8-10	fill over sandy silt	161
563	10-11	sandy, clayey silt	200+
564	10-12	fill being clayey silt	174
565	4-8	fill over clayey silt	200+
566	4-7	fill over clayey silt	200+
567	4-7	Fill over clayey silt	200+
568	4-7	fill over clayey silt	200+
569	5-7	fill over silty sand	200+
570	6-8	sandy silt	200+
571	7-9	silty sand	8/100 blows
572	9-10	fill over silty sand	8/100 blows
573	10-11	silty sand	8/100 blows
574	10	fill being clayey silt	200+
575	5-9	fill being clayey silt	200+
576	8-11	fill over clayey silt	200+
577	8-11	clayey silt	200+
578	8-11	clayey silt, sand	196
579	8-11	silty sand	3/100 blows
580	8-10	sandy, clayey silt	127
581	7-10	clayey silt, sand	200+
582	7-9	fill over silty sand	4/100 blows
583	6-7	clayey silt	79
584	6	fill over clayey silt	200+
585	5-6	clayey silt	89
586	5-6	fill over clayey silt	161
587	5-6	clayey silt	149
588	4-6	sandy silt	5/100 blows
592	0-1	fill	
596	7-8	fill over ignimbrite	

Table 3
Summary of Exposed Subsoil Types in Areas of Cut As Determined from Post Construction Boreholes
Stage 2L

Lot No.	Depth of Cut (m)	Soil Type	Shear Strength at Foundation Depths (kPa)
675	0-7	fill over clayey silt	200+
676	7-8	fill over ignimbrite	174
677	6-8	fill over sandy silt	200+
678	5-8	fill over ignimbrite	200+
679	3-7	fill	200+
680	2-6	fill	200+
681	1-3	clayey silt	142
682	1-3	silty sand	200+
683	1-2	clayey sand	200+
684	1-2	clayey silt	174
685	1-2	clayey silt	150+
685	1-3	Clayey silt	150+
686	1-4	fill over sandy silt	200+
687	1-4	fill over clayey silt	200+
688	1-4	clayey silt	200+
689	4-5	clayey silt	82
690	5-7	fill over clayey silt	168
691	6-8	clayey silt, silty sand	200+
692	5-7	clayey silt	100
693	3-5	clayey silt	155
695	6-10	sandy silt	183
696	5-9	clayey silt	200+
697	2-6	clayey silt	200+

Table 4
Summary of Exposed Subsoil types in Areas of Cut as Determined from Post Construction Boreholes
Stages 2K and 2M

Bore No.	Depth of Cut (m)	Soil Type	Shear Strength at foundation depth (kPa) or Scala Penetrometer blows per 100mm
639	9		
642	7-8		
646	1-4		
653	6		
657	4-5		
694		clayey silt	171
698	1-4	clayey silt	184
699	1-2	fill over clayey silt	117
700	1-3	fill over sandy silt	200+
701	3-4	clayey silt	120
702	4	fill over clayey silt	190
703	2-4	clayey silt	200+
704	1-4	clayey silt	196
705	1-3	silty sand	6/100 blows
706	0-2	fill over clayey silt	200+

9.2 Subdivision Construction Filling

Supervised structural filling as shown on drawings 18264-AB11 and AB14 was placed in accordance with the methods and standards quoted in NZS 4431 under the observation of S & L Consultants Ltd. Compaction testing on site confirmed that a high and uniform degree of compaction has been achieved suitable for the support of buildings. Some post construction boreholes that encountered the filling also confirmed this suitability.

A statement in support of the suitability of the filled areas for the erection of building in terms of NZS 3604 is appended in Appendix 2 of this report. Within areas of structural filing on which buildings may be erected, however, the possibility of variation of soil type and strength may exist away from observation or compaction tests locations. The normal inspection of foundation conditions during construction of buildings by competent tradesmen as described in NZS 3604 and by building inspections should therefore be undertaken. If for any reason areas of low soil strength are found professional geotechnical advice should be sought.

9.3 Areas of Cut

As shown on 18264-AB13 and AB14 and described on tables 2, 3 and 4 the varying depths of cut have exposed a variety of different soil types and strengths immediately below the topsoil overlay.

The recorded undrained shear strengths show, however, that the soils at likely foundation depths in the areas of cut are of high strength. Where sandy soils were present the Scala penetrometer tests also indicate high densities and therefore good ground bearing capacity.

For all lots located in the areas of cut the ultimate ground bearing capacity in the limit state may be taken at 300kPa and this capacity meets the definition of "good ground' as defined in NZS 3604.

However the possibility of variation of soil type and strength may exist away from observation or post construction borehole locations. The subsoils at foundation excavation levels are found to be of lower strength or have been disturbed by earthworks machinery during further site development, foundations detailed in accordance with NZS 3604 may have to be deepened or widened under engineering advice. This may require additional on site testing specific to the building that is to be erected and the calculation of actual ground contact pressures under foundations by a structural engineer

9.4 Land Stability

Most of the areas on the lots on stages 2J, 2K, 2L and 2M comprise near flat or gently sloping ground as a result of the subdivision earthworks. In these areas no global stability issues exist that may restrict or prevent buildings from being erected.

The steep slopes that lead down to lower stages 2D and 2G are present along the north western boundaries of residential lots 560, 561, 562, 565 to 575 and 675 to 681 inclusive.

Analyses, as described in section 6.2.1, determined the stability of the formed slopes above Stages 2D and 2G that are located on the eastern side of Lakes Boulevard. Concurrent with these analyses cross sections 1 to 4, as shown on 18264-AB13,

were also plotted based on the topographical plan 18264-20 in Appendix 1. After the earthworks to reduce the original ground levels on stages 2J, 2K, 2L and 2M had been completed early in 2007, additional boreholes were put down on these cross sections under the subdivision of S&L Consultants Ltd by Perry Drilling during April 2007. These boreholes supplemented the original subsurface data that was available from machine borehole MB47 of September 2003.

The boreholes put down in April 2007 were located at the crests of the original slopes below Stage 2J and at intermediate lifts on the slope faces on the haul tracks for the bulk earthmoving equipment. From this borehole data and the existing slope geometry it was deduced, by analysis, that the sloping ground between the upper stages and the lower stages had to be reduced in slope to not more than 26 degrees (1 on 2) to provide acceptable factors of safety against slope failure. In plotting these slope angles and in providing for an intermediate berm for slope maintenance and also as an extension of the cycle and walkway through the subdivision, it was found that the surface ash soils would be mostly removed by the recontouring earthworks leaving the Te Ranga ignimbrite to be exposed on the cut faces of the four cross sections, Cross section 1 was seen as representative and subsequently analyses in the manner described in section 6.2.1 of this report. The computed factors of safety were

Lower Slope		Upper Slope		Total Slope	
Fully Drained	Raised Ru	Fully Drained	Raised Ru	Fully Drained	Raised Ru
1.83	1.43	1.78	1.34	1.94	1.50

These stability factors of safety are in excess of the conventionally accepted values and therefore the properties above the batters within Stage 2J are unlikely to be subject to the effects of natural hazards due to the presence of the slopes

9.5 Building restrictions

While the stability analyses have shown that acceptable degrees of stability are present on and above the battered slopes below lots 560, 561, 562, 565, to 575 and 675 to 681, the crests of these slopes are vulnerable to erosion. Temporary low bunds have been constructed along the crests of the batters on these lots to prevent concentrated discharge of surface water over the slope faces and these bunds should be kept in place wherever possible

Stormwater and wastewater services have been constructed along the crests of the batters on lots 565 to 575 and 675 to 579. The presence of these services effectively imposes a building restriction line on those lots which will set back buildings from the slope crests as the close proximity rules for building foundations to these services, as described in the Council Code of Practice for Development, are to be observed. It is recommended that similar set backs from the slope crests be observed on lots 560, 561, 562, 680 and 681 where the stormwater and wastewater lines are not present. A set back as a building restriction line of 5m from the north western boundaries of these lots is shown on drawings 18264-AB11 and AB12 and also on DP 408042.

Furthermore, it is recommended that

- Within the building restriction lines and also over the Council services no additional filling is placed even if retained behind walls. Retaining walls may be constructed up to the building restriction line or close to the eastern side of the underground services as defined in the Code of Practice on Council drawing WW15.

- The slope faces are maintained with a dense grass and plant cover. No garden refuse should be cast over the slope faces

- The properties are developed so that no surface water flows can occur over the slope faces. Surface water should be collected and be piped to the stormwater outfalls on each lot that were installed as part of the subdivision development

- Even though permeable soils may be present ground soakage is not to be used as a means of disposing of stormwater runoff on the site.

10.0 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 300mm. No guarantee is implied or given that the topsoil on any part of any lot is 300mm deep or less and it is recommended that future owners or builders check topsoil depths when preparing site development plans and cost schedules

11.0 Professional Opinion

A statement in the format of Councils Code of Practice for Development (Form G2) that all lots are suitable for building is contained in Appendix 2. This statement is accompanied by Form G2A which summarises the information and recommendations within this report

12.0 Applicability

Recommendations contained in this document 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 judgement and provide advice on appropriate improvement measures.

This report has been prepared specifically for the proposed subdivision development on Stages 2D(part), 2F, 2G, 2J, 2K, 2L and 2M of The Lakes development as shown on DP 408042 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.

S & L Consultants Ltd
Consulting Engineers, Surveyors, Planners

M W Hughes CPEng
Geotechnical Engineer

11 August 2008

Appendix One

Drawings

Subdivision Plan by Harrison Grierson 124511- site -01

Reference Plans
- 18264-AB7
  – Stage 2F

- 18264-AB11,AB12,AB13
  – Stages 2D (part), 2G, 2J, 2K, 2L, and 2N (3 sheets)

- 18264-20
  – Slope Contours Before Earthworks, Stages 2D, 2G

- 18264-21
  - Completed Slope Contours to Stages 2D, 2G

- DP 408042

Cut – Fill Plans
- 18264- AB8
  - Stage 2F

- 18264-AB14, AB15, AB16
  - Stages 2D (Part), 2G, 2J, 2K, 2L and 2M