Tonkin & Taylor

T&T Ref: 25141.003
06 October 2014

Fletcher Residential Ltd
Level 3, Fletcher House,
810 Great South Road, Penrose
Private Bag 92114, Auckland 1142
By email : bernie@fcc.co.nz

Attention: Bernie Chote

Dear Bernie

Three Kings Renewal

Response to Auckland Council Feedback on Draft Private Plan Change Application - Option H1

As requested, this letter provides our response to Auckland Council's (AC) feedback on Fletcher Residential Ltd.'s (FRL) Draft Private Plan Change Application (DPPC). Tonkin & Taylor Ltd (T&T) prepared a Geotechnical Assessment report[i] for FRL that was included with the DPPC documents. Our responses address those feedback items identified by FRL as relating to information provided in that report, or additional information requested relating to the scope of those reports.

For clarity, our responses are provided in table form, quoting the feedback from council and responding directly, with a reference to the applicable T&T report section as appropriate. Where additional information has been requested, it has been appended to this letter.

Table 1 – Responses to AC feedback

Item(s)	Auckland Council Feedback on Fletcher Residential Draft Private Plan Changes	T&T Response	Reference
80	Confirmation that it is practical to place imported fill to the engineered standard required given expected variable composition and the challenges of confirmation testing.	The detailed earthworks specifications include identification of suitable and unsuitable soils together with conditioning, placement, compaction and verification testing regimes. As part of the specification, one criteria for acceptance of fill to the site is its ability to be conditioned and compacted to achieve the required engineering performance standards. Fill placement methods and testing procedures to confirm that the fill	

Item(s)	Auckland Council Feedback on Fletcher Residential Draft Private Plan Changes	T&T Response	Reference
		meets the required performance standard are part of the specification, and further specific methods and tests may need to be adopted during the course of the filling operation to match the specific characteristics of the fill. Such approaches have been used elsewhere for residential land development sites (such as the old Mt Wellington Quarry) to ensure that the fill placed provides appropriate support to land utility for structures, while also ensuring effective use of available resources. Measures currently in place at site are consistent with the requirements of the existing consent with respect to engineering requirements for fill placement.	
81	The T&T Reports indicates that checks and analysis have been undertaken on long-term and differential settlements, however analysis has not been provided to confirm this.	The calculations referred to in the reports are appended to this letter. The calculations assume that the complete fill depth will comprise cohesive soil fill. Inclusion of other fills types, such as rock or crushed concrete would reduce the magnitude of settlement estimated in the calculations. On this basis, we consider the estimates to be conservatively based.	T&T report section 3.3.1. Calculations Attached as Appendix A
82	The reports note that the open space and parks do not have to be placed to the higher engineered standards. The last paragraph of Section 3.1 states "For Option 15H-1 (and similarly for Option 15H-2 in the other T&T report) the fill criteria for public space areas have been set to ensure the fill supports the intended land use … settlement does not disrupt surface drainage features of playing fields." No details of the criteria appear to have been provided.	The filling criteria for public space areas will require performance equivalent to an undrained shear strength of 100kPa. This could be achieved through placing the material to this specification, or to an alternative specification with allowance for surcharging to induce settlements prior to final surface formation.	T&T report section 3.1
83	The depth of fill is significant (particularly for Option 15H-1) with the side by side playing fields adjacent to future residential development (to north and possibly south, depending on levels of filling to south), the outer margins of the playing field fill will also need to support the residential area and also need to avoid drag down effects. Therefore higher fill standards would be required within	Generic fill transition details have been developed to address this potential issue. These sections are appended to this letter and demonstrate two options for how the transition could be treated to minimise differential settlement, while also ensuring adequate support for the residential land.	Generic fill transition details attached as Appendix B

Item(s)	Auckland Council Feedback on Fletcher Residential Draft Private Plan Changes	T&T Response	Reference
	these outer portions of the playing field. This may result in an increased risk of differential settlement across playing fields. The effects of varying engineered fill standards and transitioning across the area needs further consideration.	Once actual fill sources and construction timeframes have been identified, the need or otherwise to mitigate the potential for adverse differential settlements in this zone can be assessed with greater certainty. Options to mitigate the potential for adverse differential settlement could include surcharging of the playing field fill to induce settlement prior to final surface formation.	
84	Clarification is required of what the groundwater levels will be maintained at and its effects on the lower fill layers.	The engineering fill specification excludes water sensitive materials, and requires material to be placed in thin layers with compaction to limit the potential for fill to take up water if regional groundwater level rises with the intention of minimising potential inundation settlement effects to be less than minor. Refer to PDP response for confirmation of groundwater level controls for the proposed development.	Refer T&T report section 3.4, para 4.
85	Given that the remnant slopes are typically formed, it is suggested that the quantitative information regarding overall/global slope stability for the proposed fill levels be provided. In addition, indicative extents of likely localised instability and engineering measures needed to address these should be provided (e.g. extent of rock fall catch fences, systematic rock bolting etc).	The report referred to is appended to this letter. This report also provides advice for elements that were part of earlier evolutions of the proposed scheme. Areas of existing and new cut slopes that may require localised stability measures will be identified during final design and excavation. The choice of treatment measure will depend on the magnitude and extent of the identified instability, and its potential impact on development layout.	T&T report section 4.1 and 4.2. Referenced reports attached as Appendix C.
87	Depending on confirmation of the proposed finished levels, a detailed site investigation of the undeveloped areas of reserve land (west and south) would be prudent and should not be left to be addressed via a proposed Site Management Plan prior to or during development of the site (15H-1).	Agreed. Intention to undertake such study once Option H1 is confirmed.	
2.1	The application refers to the Environment Court decision ([2011] NZEnvC214) and permit for the Quarry, and cites several technical reports including letter reports on filling and slope stability throughout	Technical reports referred to in NZEnvC124 appended to this letter. These reports relate to earlier proposals for filling of the quarry to surrounding ground level and over a potentially longer timeframe.	Technical reports referred to in NZEnvC124 attached as Appendix D.

Item(s)	Auckland Council Feedback on Fletcher Residential Draft Private Plan Changes	T&T Response	Reference
	the geotechnical report presented in support of this plan change. It would be beneficial to include these reports for review and notification purposes.	Settlement calculations (specific to the Option H1 and H2 proposals) and quarry wall stability reports are appended to this letter.	Settlement calculations attached as Appendix A, Stability report as Appendix C.
2.4	Practicality of placing imported fill to the engineering standard required. Please confirm that it is practical to place imported fill to the engineered standard required given it's almost certain variable composition and the challenges of confirmation testing.	Refer item 80 above	
2.5	Long term and differential settlements. The geotechnical report indicates that checks and analysis have been undertaken on long-term and differential settlements. Please confirm that the analysis to substantiate the statements has been undertaken.	Refer item 81 above	
2.6	Fill criteria for public open spaces. The geotechnical report notes that the open space and parks do not have to be placed to the higher engineered standards. The last paragraph of Section 3.1 states "For Option 15H-1 the fill criteria for public space areas have been set to ensure the fill supports the intended land use … settlement does not disrupt surface drainage features of playing fields." Please provide details of the criteria.	Refer item 82 above.	
2.7	Effects of varying engineered fill standards and transitioning across fill areas. The depth of fill is significant and especially for Option 15H-1 with the side by side playing fields adjacent to future residential development (to north and possibly south, depending on levels of filling to south), the outer margins of the playing field fill will also need to support the residential area and also need to avoid drag down effects and therefore, higher fill standards would be required within these outer portions of the playing field. That then leads to an increased risk of differential settlement across playing fields. Please clarify the effects of varying engineered fill standards and transitioning across the area and to provide the assessment and analysis.	Refer item 83 above.	

Item(s)	Auckland Council Feedback on Fletcher Residential Draft Private Plan Changes	T&T Response	Reference
2.8	Groundwater levels and effects on lower fill layers. Please clarify what the groundwater levels will be maintained at and its effects on the lower fill layers.	Refer item 84 above.	
2.9	Overall/global slope stability for the proposed fill levels. Given that the remnant slopes are typically formed, please provide quantitative information regarding overall/global slope stability for the proposed fill levels. In addition, please provide indicative extents of likely localised instability and engineering measures needed to address these, e.g. minimum extent of proposed setbacks, extent of rockfall catch fences, systematic rock bolting etc.	Refer item 85 above.	

We hope that these responses provide additional information and clarity to assist AC in assessing the DPPC. We are happy to discuss our responses, and provide additional information as you may require or as AC may further request.

Yours sincerely

Graeme Twose
Senior Geotechnical Engineer

6-Oct-14
p:\25141\25141.003\workingmaterial\2014_10_06_ac_reponse_h1.docx

---

[i] "Fletcher Residential Ltd, Three Kings Renewal Option 15H1 – Geotechnical Assessment", July 2014, Reference 25141.003.

Appendix A

Settlement calculations

Tonkin & Taylor

Calculation Package

Project:	Three Kings Quarry	**T&T Ref:**	25141.0030
By:	Matthew Kent	**Date:**	02 September 2014
Subject:	Buried Highwall Differential Settlements and Earthwork Specification Requirements, REV 1		

Purpose:

An assessment of potential differential settlement over buried quarry highwalls has been undertaken.

The purpose of this package is to assess the consolidation and strength parameters required for a cohesive soil fill material to meet the differential settlement requirements of 1:250, 1:500 and 1:1000.

Workings:

A description of the attached calculation contents are provided in the table below. Calcs references are Charles and Skinner (Ground Engineering Magazine, February 2001) and Bowles (5th Ed., 1997).

Page	Description
i-ii	Calculation Package Summary
1-2	Typical sections around the site
3	Determine max Mv for allowable differential settlements
4	Determine fill strength requirements

The final conclusions are based on typical highwall sections around the site. It should be noted that the Section 3 case is not typical of sections elsewhere on the site. This area has a lower wall angle (less critical) and therefore the compaction criteria determined for the other sections will be sufficient to control differential settlements at this location also.

Assumptions for the fill materials:

- The fill is homogeneous, plastic earthfill materials
- Bulk density of the fill, γb = 18 kN/m3
- Poissons ratio of the fill, μ = 0.3
- General relationship for clay materials as per Bowles table 5-6, eqn's (a) and (b) are applicable
- Auckland soil generally have a plasticity index, Ip, less than 45%. Final mixed earthfill materials will almost certainly be <45% on average. This bound has been used to determine the required equivalent undrained shear strength of the compacted fill materials to meet differential settlement requirements.

Conclusions:

Tolerable differential settlement (V:H)	Required modulus of elasticity, Es [MPa]	Required undrained shear strength for low/moderately plastic silt/clay (PI<45%), su [kPa]
1:1000	180	280
1:500	90	140
1:250	45	70

Given a standard level of compaction control and a high level of control on the material quality is should be feasible to achieve a differential settlement above the buried highwalls of 1:500.

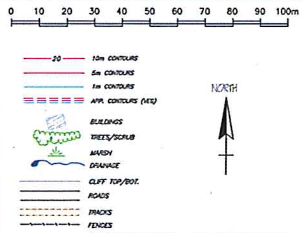
To achieve the differential settlement target of 1:1000 or better, a high level of compaction control and material selection will likely be required.

Compaction trials would be able to provide samples for Es determination via lab triaxial testing and G' determination via CPT testing to confirm the above.

Surcharging could be utilised to accelerate settlements and further minimise potential for differential settlements outside of the tolerance limits to develop.

05 September 2014
\\ttgroup.local\corporate\Auckland\Projects\25141\25141.003\WorkingMaterial\Charles&Skinner Differentials\mmk_Differentials Memo.docx

TYPICAL HIGHWALL SECTIONS FOR ASSESSMENT



WINSTONE AGGREGATES

Photogrammetry by:	PRECISION AERIAL SURVEYS
Photography Date:	5TH JANUARY 2013
Negatives Used:	R05015319 – R05015322
Photo control by:	PRECISION AERIAL SURVEYS
Co-Ordinate Circuit:	MT EDEN 2000
Datum:	AVD 1946
Contour Interval:	1m

SHEETS

DRAWING TITLE T+T ref 25141.003

THREE KINGS QUARRY

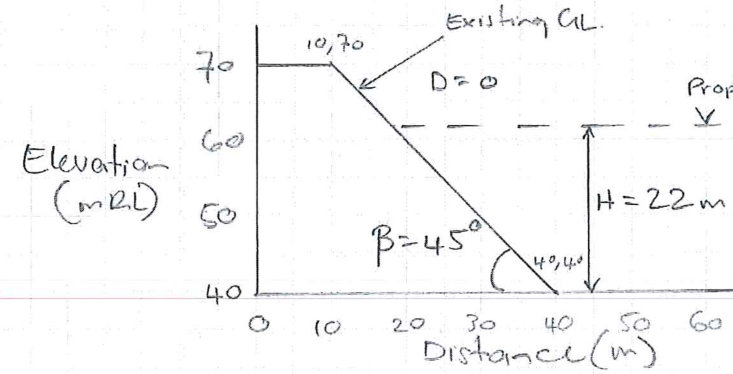
MMK 2/9/14.

TOPOGRAPHY & ORTHOPHOTO

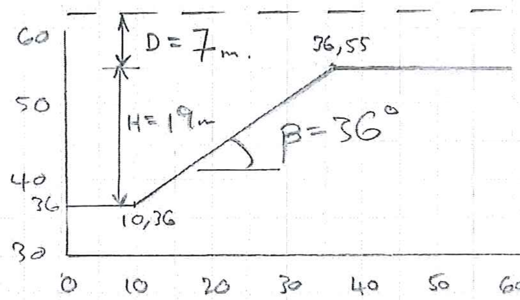
ORIGINAL DATE	SCALE @ A1	DWG REF
JANUARY 2013	1 : 1000	5846-01

P.A.S. LIMITED
BUILDING 2, 112 BUSH ROAD, ALBANY

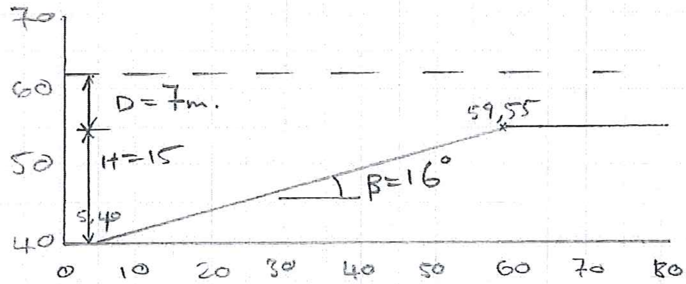
Tonkin & Taylor Project: T+T Kings Quarry	Computed: MMK 7/4/2014	Office:
	Checked: RAM 3/9/2014	Job No: 25141.003
Description: Determine range of typical slope values & fill depths	Revised: 20	File:
	Checked: 20	Sheet No. 2



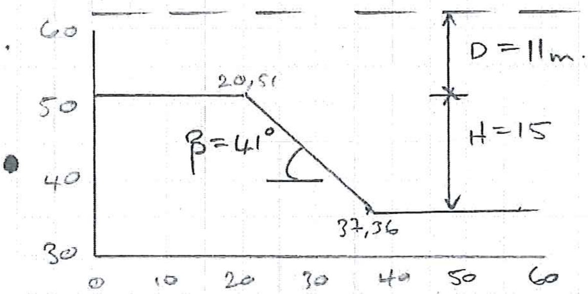
Section ①



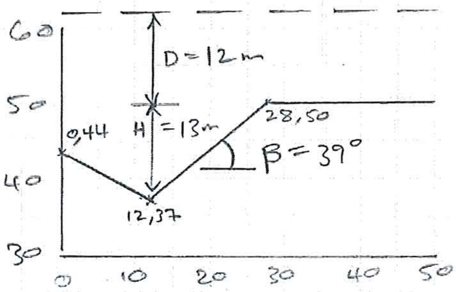
Section ②



Section ③



Section ④



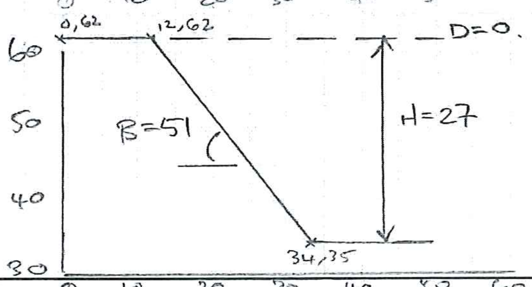
Section ⑤

Typical Ranges.

β ⇒ 15 – 50°

H ⇒ 10 – 30m

D ⇒ 0 – 15m.



Section ⑥

Tonkin & Taylor	Project:	Computed: MMK 2/9/2014	Office:
Description: Determine Max M_v for allowable differential settlements		Checked: RAM 3/9/2014	Job No:
		Revised: 20	File:
		Checked: 20	Sheet No. 3

Differential to be investigated:

1:1000 => $\alpha = 0.001$

1:500 => $\alpha = 0.002$

1:250 => $\alpha = 0.004$

From Charles + Skinner (2001) Fig 9:

if $\cot\beta > 0.5 + D_n$, then $\frac{\alpha_m}{\varepsilon_v} = \tan\beta$

if $\cot\beta < 0.5 + D_n$, then $\frac{\alpha_m}{\varepsilon_v} = \frac{2}{0.5 + D_n + \cot\beta}$

Where:

$D_n = D/H$

$\varepsilon_v = S_m/H = M_v \bar{\sigma}_v$

β	$\cot\beta$
15	3.7
20	2.7
30	1.7
40	1.2
50	0.8

Assume:

$\gamma_b = 18$ kN/m³

$\therefore \bar{\sigma}_v = 18 \times \left(\frac{H}{2} + D\right)$

Rearrange:

If $\cot\beta > 0.5 + D_n$ then $M_v = \alpha_m / \tan\beta / \left(18 \times \left(\frac{H}{2} + D\right)\right)$

If $\cot\beta < 0.5 + D_n$ then $M_v = \left(\alpha_m \times (0.5 + D_n + \cot\beta)\right) / \left(2 \times 18 \times \left(\frac{H}{2} + D\right)\right)$

Required M_v values for given α_m:

Section	β	D	H	$\cot\beta$	$0.5+D_n$	$\cot\beta > 0.5 + D_n$?	α_m 0.001 M_v	0.002 M_v (m²/MN)	0.004 M_v
1	45	0	22	1	0.5	Yes	0.005	0.01	0.02
2	36	7	19	1.4	0.9	Yes	0.005	0.009	0.019
3	16	7	15	3.5	1.0	Yes	0.013	0.027	0.053
4	41	11	15	1.15	1.23	No	0.004	0.007	0.014
5	39	12	13	1.2	1.4	No	0.004	0.008	0.016
6	51	0	27	0.8	0.5	Yes	0.003	0.007	0.013

Conclusion: To achieve no building restrictions over the whole site then min M_v values required for given differential settlement as given below. If these cannot be achieved then setbacks from high walls for each area may be reqd.

* Note: Section 3 is not really typical of the highwall profiles on the site. There should be no issue if spec is defined for the other more critical profiles on the site.

Allowable differential settlement	Average M_v (m²/MN)
1:1000	0.004
1:500	0.008
1:250	0.016

Description: Determine fill strength requirements.

From previous page:

Differential Settlement (V:H)	M_v (m^2/MN)
1:1000	0.004
1:500	0.008
1:250	0.016

Youngs Modulus =

$$M_v = \frac{(1+\nu)(1-2\nu)}{(1-\nu)E_s}$$

Assume: $\nu = 0.3$ for typical earth fill

$$E_s = 0.743 / M_v$$

Differential Settlement	E_s (MPa)	round for reporting
1:1000	186	180
1:500	93	90
1:250	46	45

Determine required Su for cohesive fill:

Ref: Bowles (5th Ed. 1997) Table 5-6 General Eqn. for clays.

(a) $E_s = k S_u$

(b) $k = 4200 - 142.54 I_p + 1.73 I_p^2 - 0.0071 I_p^3$

where: I_p = Plasticity Index, $20\% \leq I_p \leq 80\%$

Tolerable Differential	E_s (MPa)	Su for given plasticity (kPa): 20	30	40	50	60	70	80
		low,	Moderate,	High plasticity.				
1:1000	186	94	144	229	364	544	705	796
1:500	93	47	72	115	182	271	352	398
1:250	46	23	36	57	90	135	174	196

Note: [dashed box] Considered achieveable by good earthworks practice

[dotted box] Considered achieveable by high spec earthworks practice

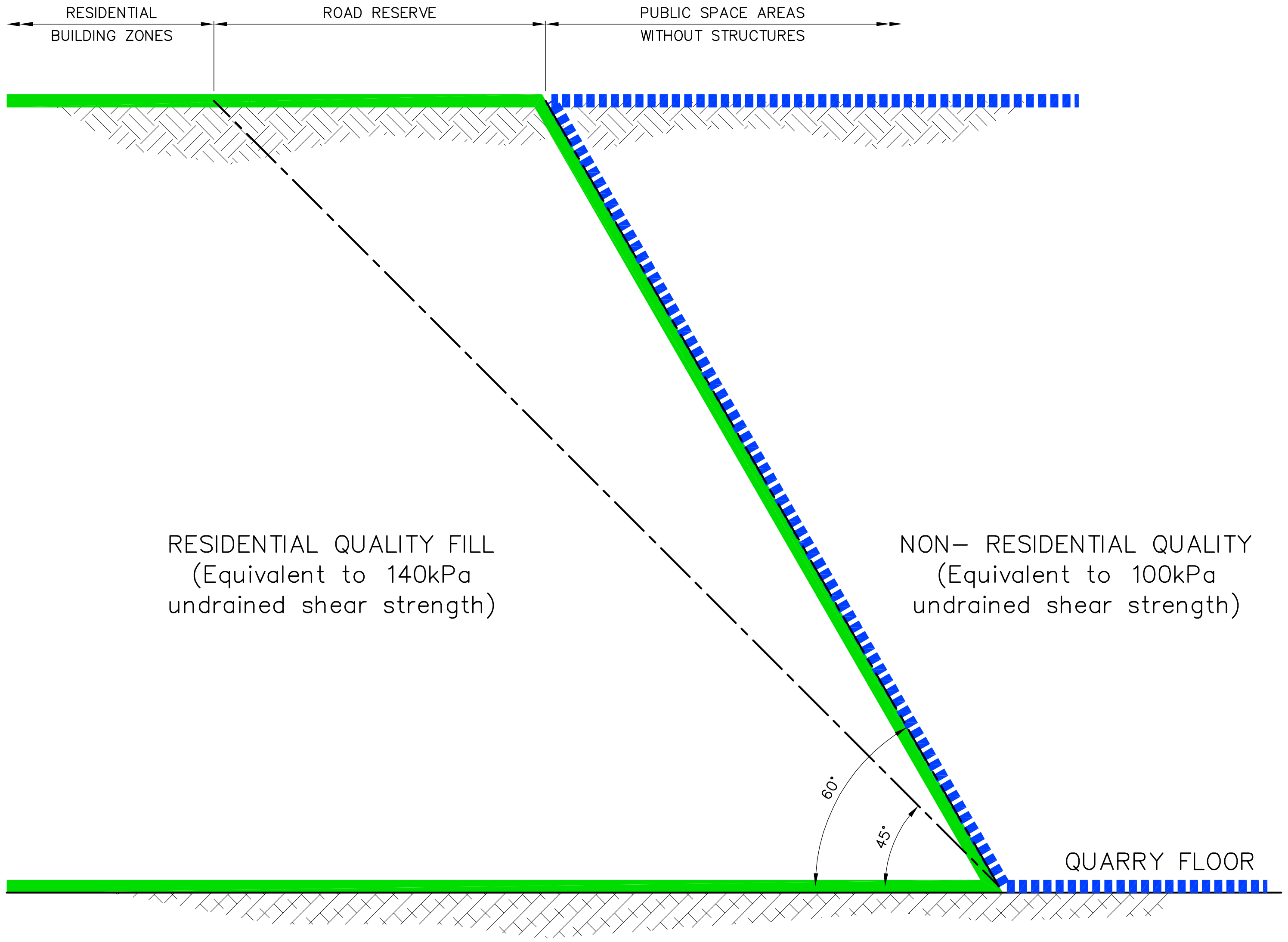
Auckland soils tend to have an I_p < 45%. Final mixed fill materials will almost certainly be < 45% use this as rough upper bound for reqd. Su values.

Conclusion: To achieve differential settlements reqd. equivalent Su.

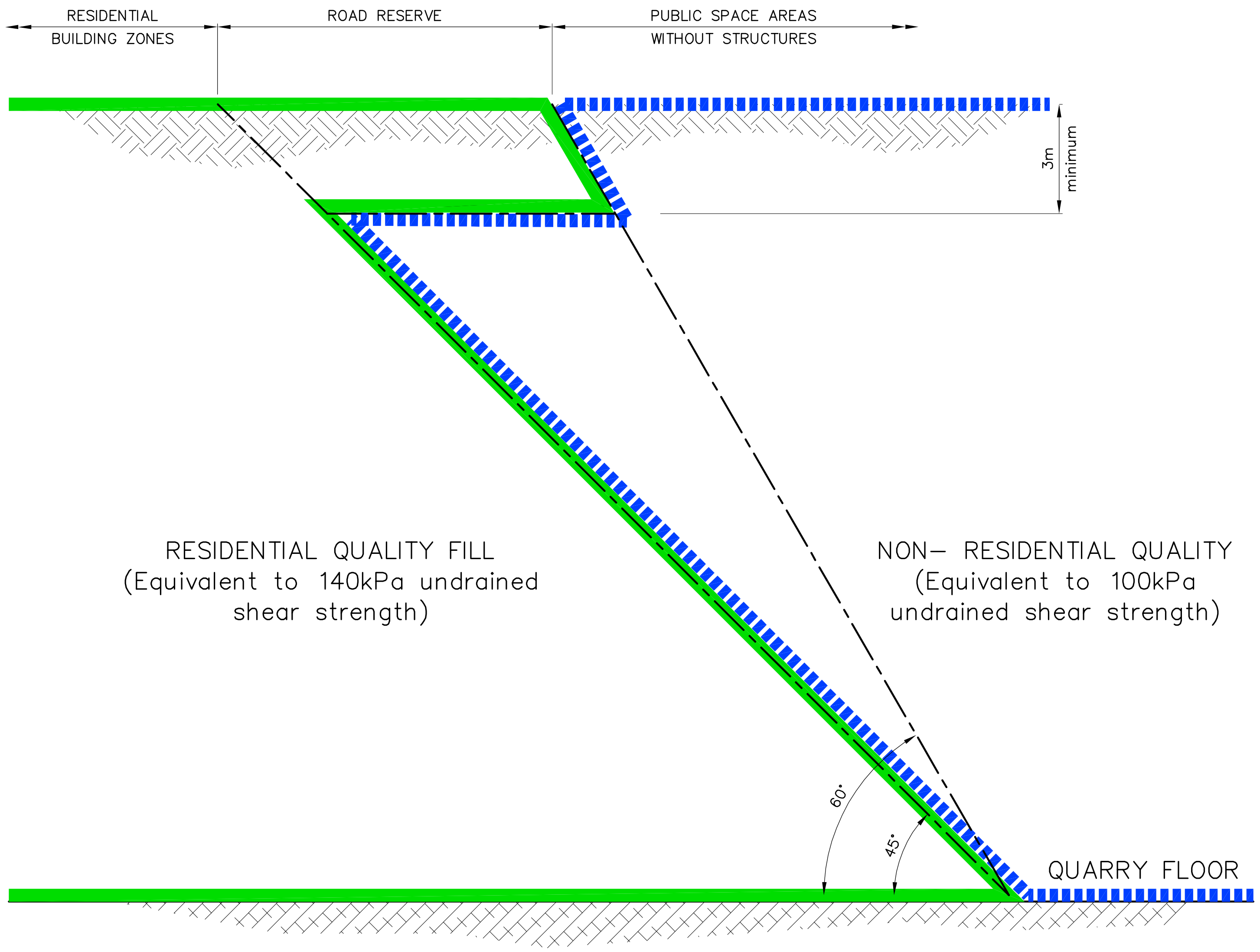
Differential	Required Equivalent Su (kPa)	Comment
1:1000	280	V. high spec reqd.
1:500	140	Typical Earthworks
1:250	70	Moderate Spec.

Appendix **B**

Fill transitions – generic sections



GENERIC FILL TRANSITION CROSS SECTION – OPTION 1
NOT TO SCALE



GENERIC FILL TRANSITION CROSS SECTION – OPTION 2
NOT TO SCALE

Tonkin & Taylor
Environmental and Engineering Consultants
105 Carlton Gore Road, Newmarket, Auckland
www.tonkin.co.nz

DRAWN	AGI	Sep. 14
DRAFTING CHECKED		
APPROVED		
CADFILE : \\25 14 1.003–F5.dwg		
SCALES (AT A3 SIZE) NTS		
PROJECT No. 25 14 1.003		

WINSTONE AGGREGATES
THREE KINGS QUARRY REDEVELOPMENT
THREE KINGS, AUCKLAND
Generic Fill Cross Section – Option 1 & 2

FIG. No. Figure 5
REV. 0

L:\25141\25141.003\WorkingMaterial\CAD\Figure\25141.003-F5.dwg, F5, 5/09/2014 12:38:32 p.m., agi, 1:1

Appendix C

Quarry slope stability report

Tonkin & Taylor

T&T Ref: 25141.003
06 November 2013

Winstone Aggregates
PO Box 17195
Penrose
Auckland

Attention: Michael Harris

Dear Mike

Three Kings Quarry - Slope Optimisation for future development - Mt Eden Road cut

1 Introduction

Winstone Aggregates (Winstones) are in the process of developing concepts for the redevelopment of the Three Kings Quarry upon completion of extraction of aggregate. The re-development concepts for the site includes filling of various parts of the quarry void, development of lakes, and re-profiling existing cut batters. Winstones are working closely with Fletcher Apartments (Bernie Chote) on this project.

The current concepts include a series of apartments, to be accessed from Mt Eden Road, but with each apartment founded on a bench within the quarry, at about RL 60m.

To assist in developing the early concept layout of these apartments, Winstones has requested that Tonkin & Taylor Ltd (T&T) provide a preliminary assessment of the quarry slopes adjacent to Mt Eden Road (Figure 1) to provide indicative guidance on cut slope profiles suitable for the proposed residential apartment end use.

Our scope of works included:

- Review existing quarry slope design reporting previously provided to Winstones by T&T.
- Visit the site to map the existing cut slopes and to develop a representative topographic section.
- Update slope height/slope angle database to provide a slope performance context.
- Undertake an assessment of the stability of an optimised Mt Eden Road cut, and provide preliminary guidance on a suitable cut slope angle.
- Reporting.

Figure 1: Site Location Plan.

2 Development Proposal

We have considered the development proposal to broadly include, (based on our discussions with Winstones and on Option 8 of the concept layout for the development provided by Bernie Chote):

- Apartment blocks up to 8 storeys high.
- 3 floors above Mt Eden Road and 5 below.
- Apartments to be founded on a cut bench within the quarry wall at approx RL 60m.
- An access road on or around RL 60m.

3 Observed Geological Conditions

The quarry has been developed within the scoria cones of the Three Kings volcanic centre, with only the "Big King "cone remaining of the original three. Quarry slopes have been cut in scoria with a large part of the southeastern corner of the pit developed within a substantial basalt dyke or sill.

The scoria is variable in composition (grain size and ash content for example) welding and interlocking and in the degree of vesicularity. The large changes visible within the pit walls are expected to reflect variation in rock mass strength throughout the pit.

Structure is largely absent from the rock mass but is well developed as coarse bedding and cross stratification within and between different scoria units found in the southern wall, which could be indicative of conditions that may exist behind the eastern wall. However, this bedding between scoria units is typically welded and is not expected to provide preferential zones of weakness.

The eastern slopes where the Apartments are proposed is made up of scoria with the exception of the southeastern corner, where a large basalt dyke/sill is present. The basalt is largely grey, very strong, with very rough concentric cooling joints that have a wide spacing. Low on the slope these joints dip into the quarry excavation, but a high degree of roughness and limited persistence, means that they present only a localised instability issue (slabs of basalt up to 1m^3 have dropped out during excavation).

Annotated photographs of the eastern wall are presented in Figures 2 & 3.

4 Current slope design and operational implementation

Previous slope design at Three Kings Quarry (by T&T in 1996[1] and reviewed in March 2009[2]) was developed for an operational quarry and considered both operational slopes and whole slope stability, including providing adequate support to adjacent land beyond the property boundary.

Our 2009 slope optimisation study[2] provided the following general design guidelines:

- Cut batters at 70° for cut slopes not exceeding 20m in height.
- Overall slope angles not to exceed 60° for slope heights not exceeding 45m.

Since 2009 additional excavation has occurred at the site and as part of this study we mapped current rock faces and updated our slope height/slope angle database with information from the east and south walls.

Measured inter-bench cut angles have not varied substantially since our 2009 study and lie typically between 45°and 70° for heights of between 12m and 19m. The RL 60m bench width on the eastern wall has been measured in a number of locations at approximately 5m. Overall slope angles vary between 40° and 50° for slope heights between 35m to 46m. An updated slope height to slope angle relationship is graphically represented in Figure 3.

Observations within the quarry indicate the cut slopes continue to perform well. The exception is the upper portion of a cut slope on the western wall which was described in our 2009 report. Additionally, one localised dropout of 1-2 cubic meters was observed from a section of the eastern wall, but this did not unduly influence the stability of the overall slope from RL 60m to the crest of the slope at about RL 80m.

[1] Tonkin and Taylor report: Winstone Aggregates – Three Kings Quarry Cut Slope Stability Assessment, 1996, ref: 13941.
[2] Tonkin and Taylor report: Winstone Aggregates – Three Kings Quarry – Slope Optimisation Study, 11 March 2009, ref: 25141.001

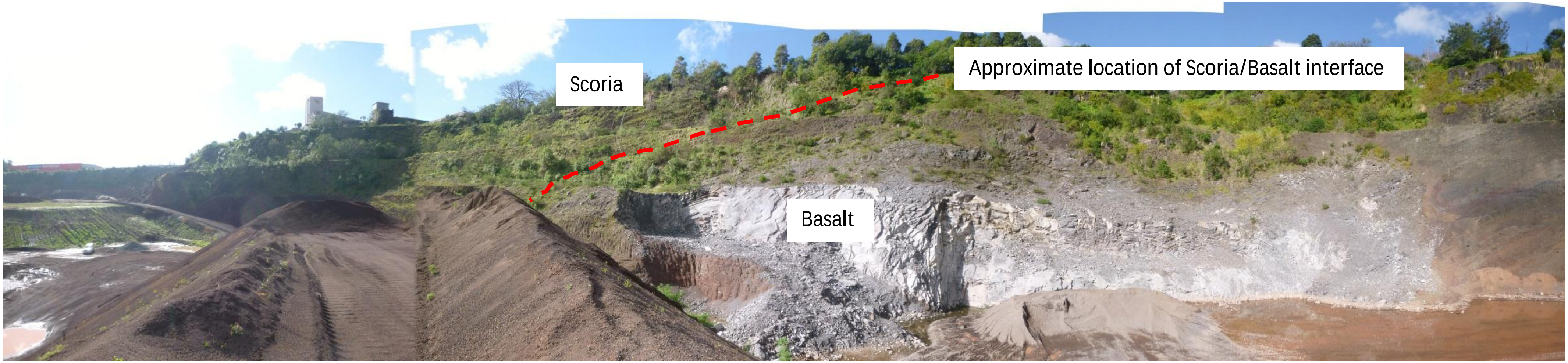


Figure 1: Panorama image of the basalt/scoria quarry face from the south eastern extent of the Three Kings Quarry, Mt Eden. The red dashed line represents the approximate location of the scoria/basalt interface based on field observations.

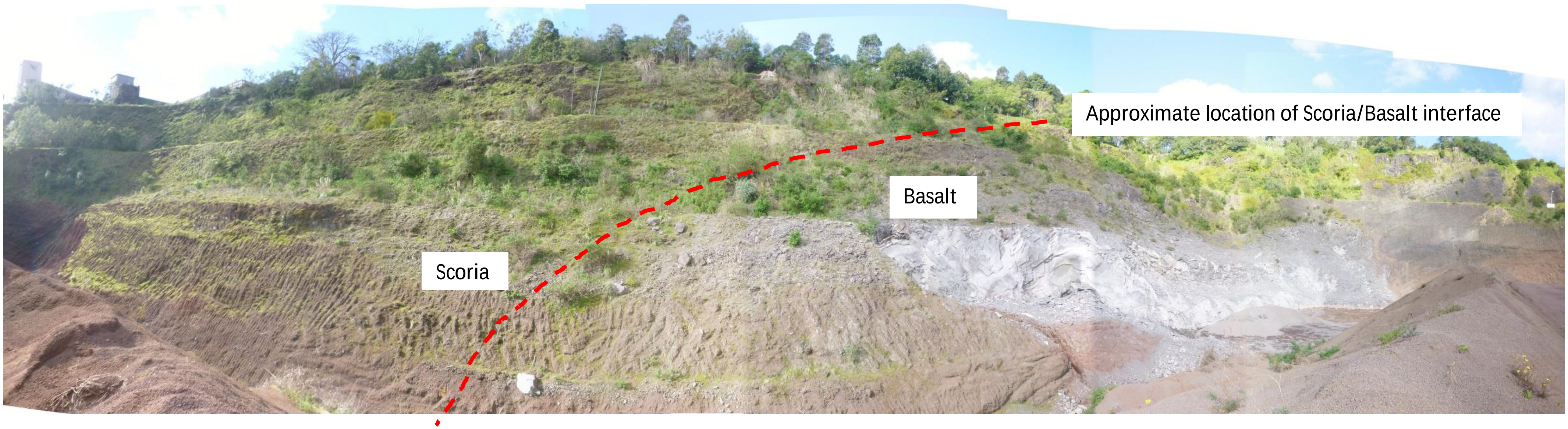


Figure 2: Panorama image of the basalt/scoria quarry face from the central eastern extent of the Three Kings Quarry, Mt Eden. The red dashed line represents the approximate location of the scoria/basalt interface based on field observations.

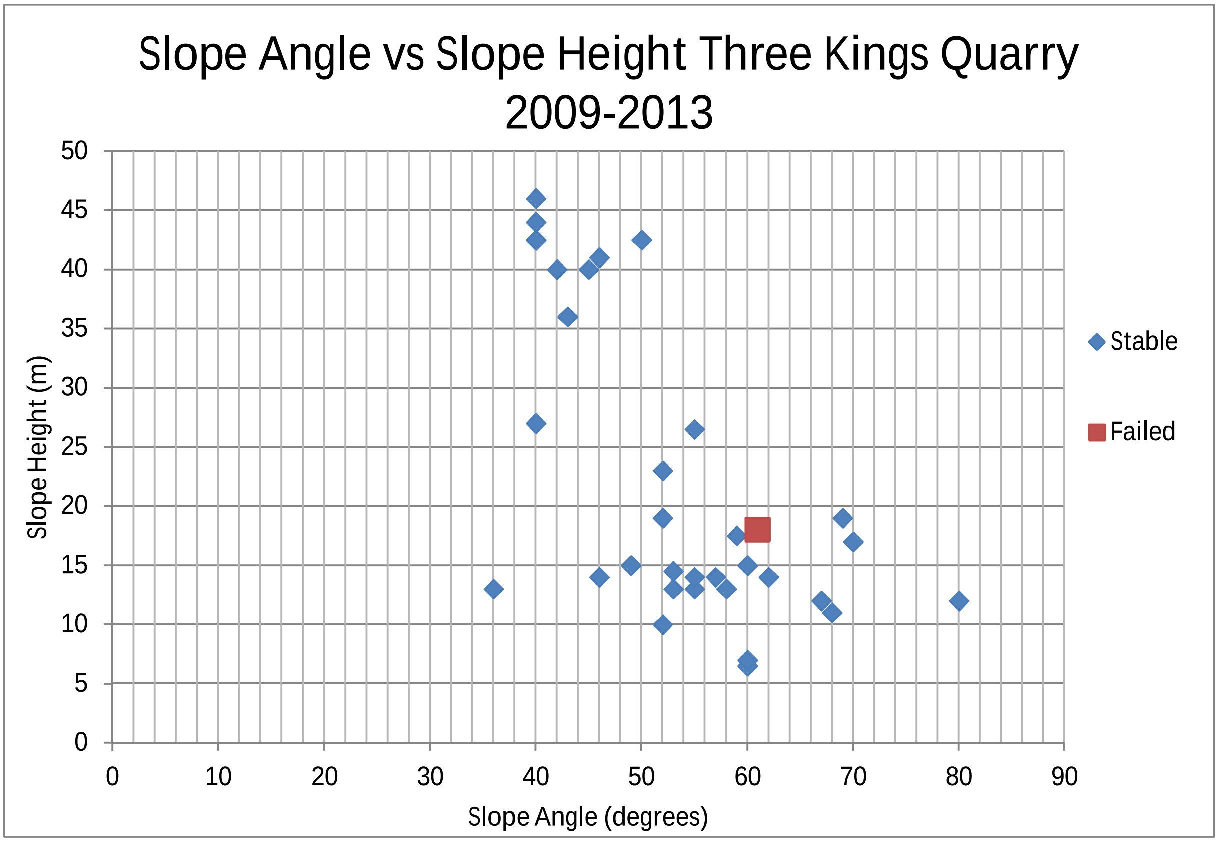


Figure 3: Slope Height vs Slope Angle for cut slopes at Three Kings Quarry.

5 Slope Stability Assessment

5.1 General

Slope stability analyses have been carried out on the basis of the scoria material strengths developed in our 2009 report. The analyses were undertaken utilising Slope W, a limit equilibrium software package, which compares driving and resisting forces within a slope and determines a ratio (or Factor of Safety) where values greater than 1 are increasingly more stable.

Analyses have been undertaken on a representative cross section through the eastern wall, which was developed from site contours supplied to us supplemented with topographic profiles measured in the field with a hand held laser rangefinder.

Groundwater monitoring in and about the quarry indicates that regional groundwater is drawn down to the level of the quarry floor[3&4], and hence low groundwater pressures are expected in the walls above this level. For the purposes of design Ru =0.1 (ratio of pore pressure to overburden stress) has been adopted as a typical case to represent seepage pressures within the scoria. For long term design cases we have assumed the regional groundwater profile will re-establish at the proposed lake level (RL 57m).

[3] Tonkin & Taylor report (ref 18670) Three Kings Quarry Assessment of Supplementary Investigations of April 2003 – June 2003.

[4] Tonkin & Taylor report (ref 18670) Three Kings Quarry Dewatering – Review of Settlement Predictions – Sept 2002.

5.2 Slope Design Criteria

For the purposes of the proposed development in the eastern wall at Three Kings, design criteria for civil construction would be required for both static and seismic design cases. We have adopted the following general design criteria when using expected mean rock mass parameters:

- Static Factor of Safety (FoS) = 1.5.
- FoS ≥ 1.0 under seismic load (0.17g)[5]

5.2.1 Design Analyses

Analysis cases included

- Back analysis of the existing slope configuration.
- A proposed cut slope at RL 60m that maximised the horizontal width of a bench at this elevation.
- A global stability case for placement of an eight storey apartment structure on the developed RL 60m bench (for which a provisional surcharge load of 10kpa per floor has been adopted).

The analyses indicate levels of global stability that meet or exceed the slope design criteria for a cut slope of 70° positioned directly adjacent to the boundary with Mt Eden Road and extending from RL 78m down to RL 60m. The result is a 22m wide platform developed at RL 60m. Global stability for this configuration is limited by the geometry of the slope below the proposed founding level at RL 60m. For this lower slope analysis indicate that the stability design criteria can be achieved for slope angles up to 56 degrees. Slope stability models are presented in Appendix A

6 Feasibility Cut Slope Design for the development proposal

On the basis of our site assessment and our analyses we make the following recommendations for feasibility cut slope designs for the eastern wall to incorporate into preliminary design for the proposed development.

- Cut slope angles not to exceed 70° for the cut batter between RL 60m and Mt Eden Road.

The recommended inter-bench slope angles are plotted on Figure 4 along with the measures slope to height information (same data as Figure 3). By inspection, acceptable performance should be achieved as slopes of this configuration are performing acceptably already (under static conditions).

We note that previous overall slope design angles of up to 60° degrees for slope heights up to 45m had been provided for overall slopes. However, given the nature and uncertainty of the proposed development, these have been scaled back to better reflect the consequence of failure. We anticipate that steeper cuts below RL 60m may be possible once more detail is provided around the nature of the development i.e. layout, expected loading etc.

[5] Derived from ASNZ1170:0 & ASNZ1170:5 and based on a Level 2 importance category.

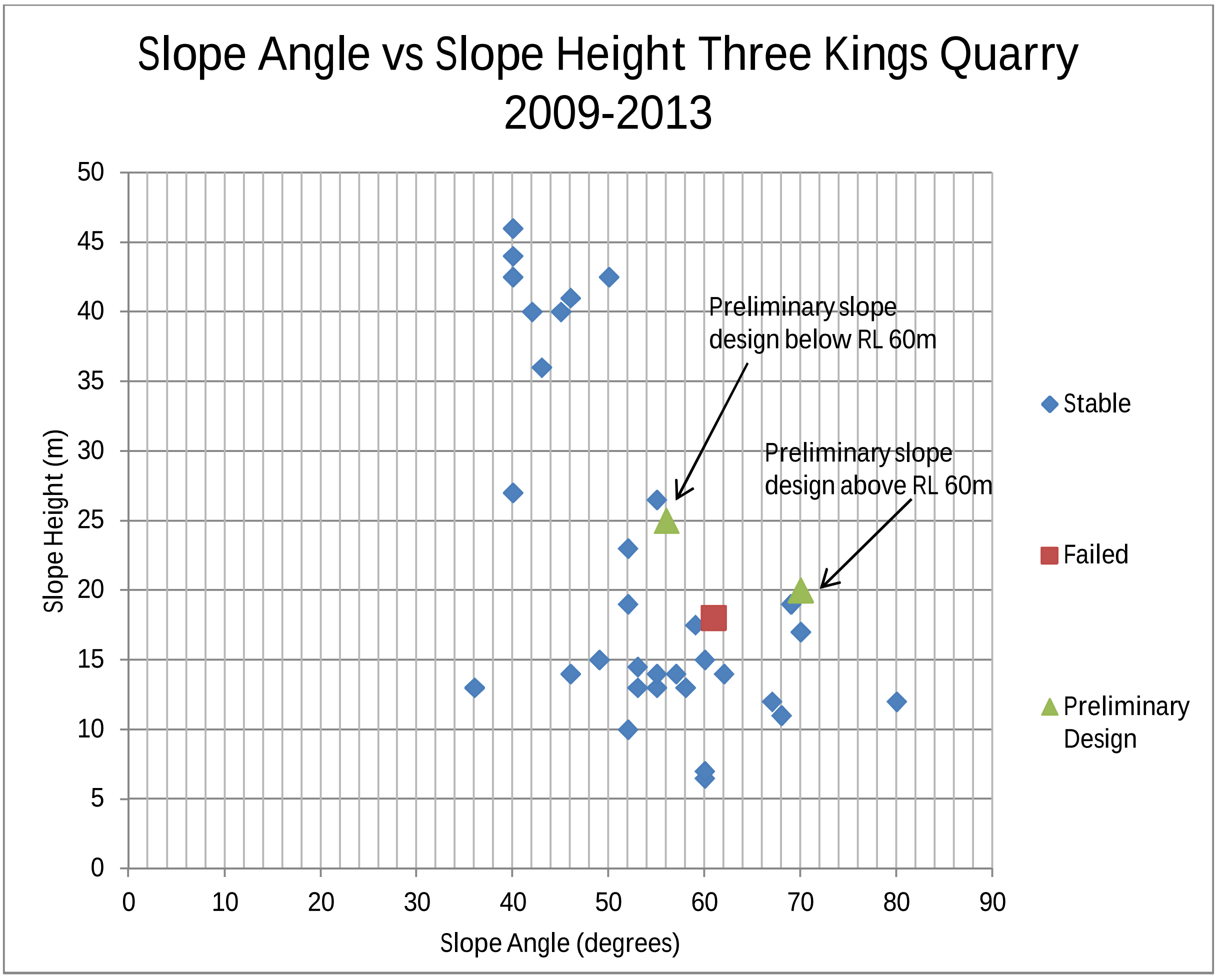


Figure 4: Slope Height vs Slope Angle for cut slopes and proposed slopes at Three Kings Quarry.

7 Support for localised face failure above RL 60m

Assessment of slope stability does not adequately address the local performance of the immediate face, including weathering and strength loss over time. In the slopes above RL 60m, this could result in small sections of the cut face fretting and failing onto the RL 60m bench. While we anticipate that volumes would be small the impact on the proposed development could be significant and would present an unacceptable risk to the structure itself and the occupants.

We consider that as part of the feasibility design allowance should be made to treat the cut slope between RL 60m and Mt Eden Road in order to provide support to the immediate exposed face and reduce the risk of local block dropouts or failure of a veneer of scoria affected by weathering.

Measures to provide this local face support could include application of shotcrete or mesh to the face or incorporating local face support as an integral part of the apartment design.

8 Recommendations

We have provided some feasibility level design guidance that can be incorporated into Winstone's ongoing and overall development design process. However, uncertainty remains around the range of material strengths and composition, and the variation in applied loadings. These will need to be addressed on a location specific basis as the proposal proceeds towards a consent level design and eventually final design. The impact on the proposed scheme of any local variation from the above general advice should be considered when identifying the most appropriate time to undertake detailed investigation works to address these uncertainties.

We make the following recommendations:

- Site specific investigation at the specific locations of the apartment blocks once these are determined. This would incorporate drilling of boreholes from the crest of the slope to assess variability in material types and potential for unfavourable rock structure. (We note that we have provided a preliminary scope and estimate of these works to Bernie Chote for consideration)
- Laboratory testing of materials to provide more detail on material strengths.
- Review of rock mass strengths and slope stability analysis results based on site specific investigation and expected design loads and layouts.

9 Applicability

This report has been prepared for the benefit of Winstone Aggregates with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
....	....
Cameron Lines	Robert Hillier
Senior Engineering Geologist	Geotechnical Group Manager

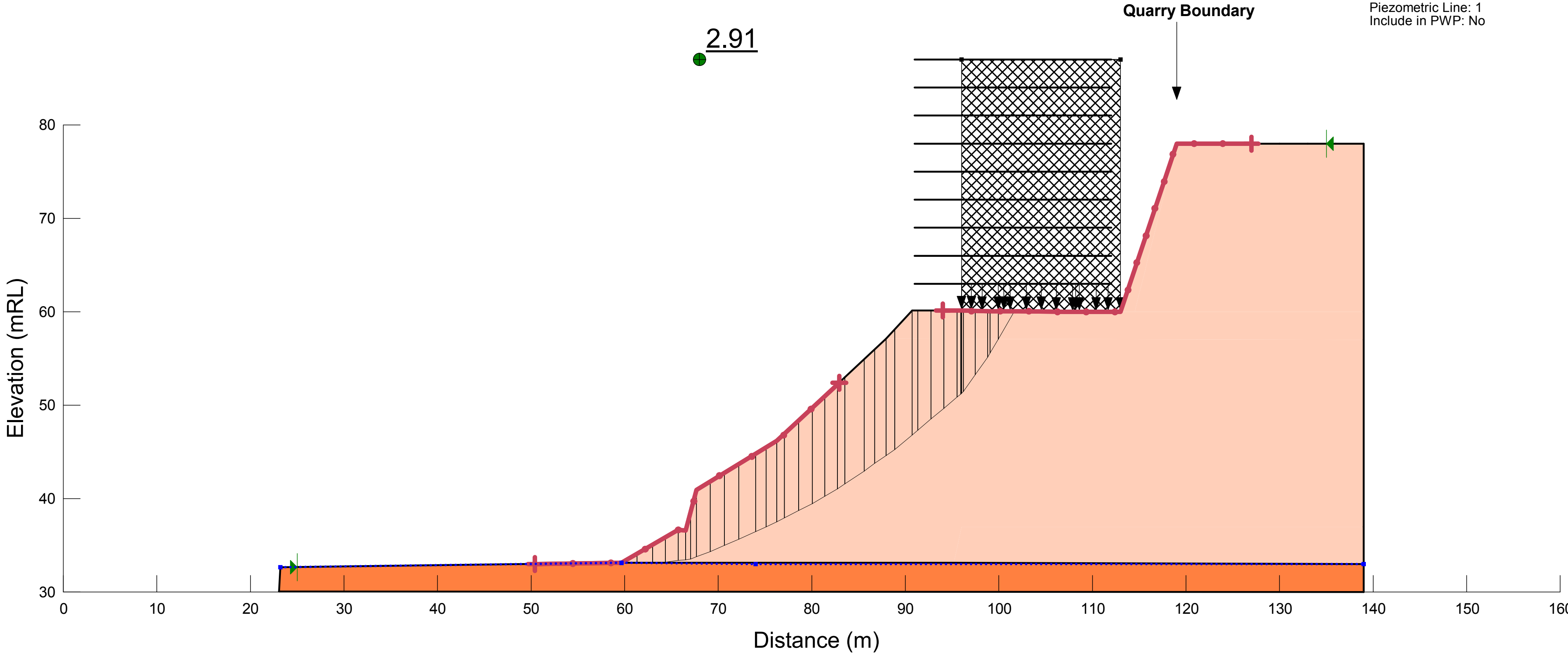
8-Nov-13
\\peke.ttgroup.local\projects\25141\25141.003\workingmaterial\2013_11_04_mt_eden_rd_cut_slopes.docx

Appendix A: Selected Slope Stability Analyses

Analysis Notes:
1. Method: Morgenstern-Price
2. Direction of movement: Right to Left
3. Optimize Critical Slip Surface Location: Yes
4. Soil Strength Models: Mohr-Coulomb
5. PWP Conditions Source: Piezometric Line with Ru
6. Tension Crack Option: Search for Tension Crack
7. Horz Seismic Load: 0g
8. Directory: P:\25141\25141.003\WorkingMaterial\August 2013 Slope Analysis\
9. File Name: Section Whole Slope CJL.gsz

Name: Scoria Shear Normal
Model: Shear/Normal Fn.
Unit Weight: 14 kN/m³
Strength Function: RocLab
Phi-B: 0 °
Ru: 0.1
Include in PWP: Yes

Name: Scoria Shear Normal - Below RGL
Model: Shear/Normal Fn.
Unit Weight: 14 kN/m³
Strength Function: RocLab
Phi-B: 0 °
Piezometric Line: 1
Include in PWP: No



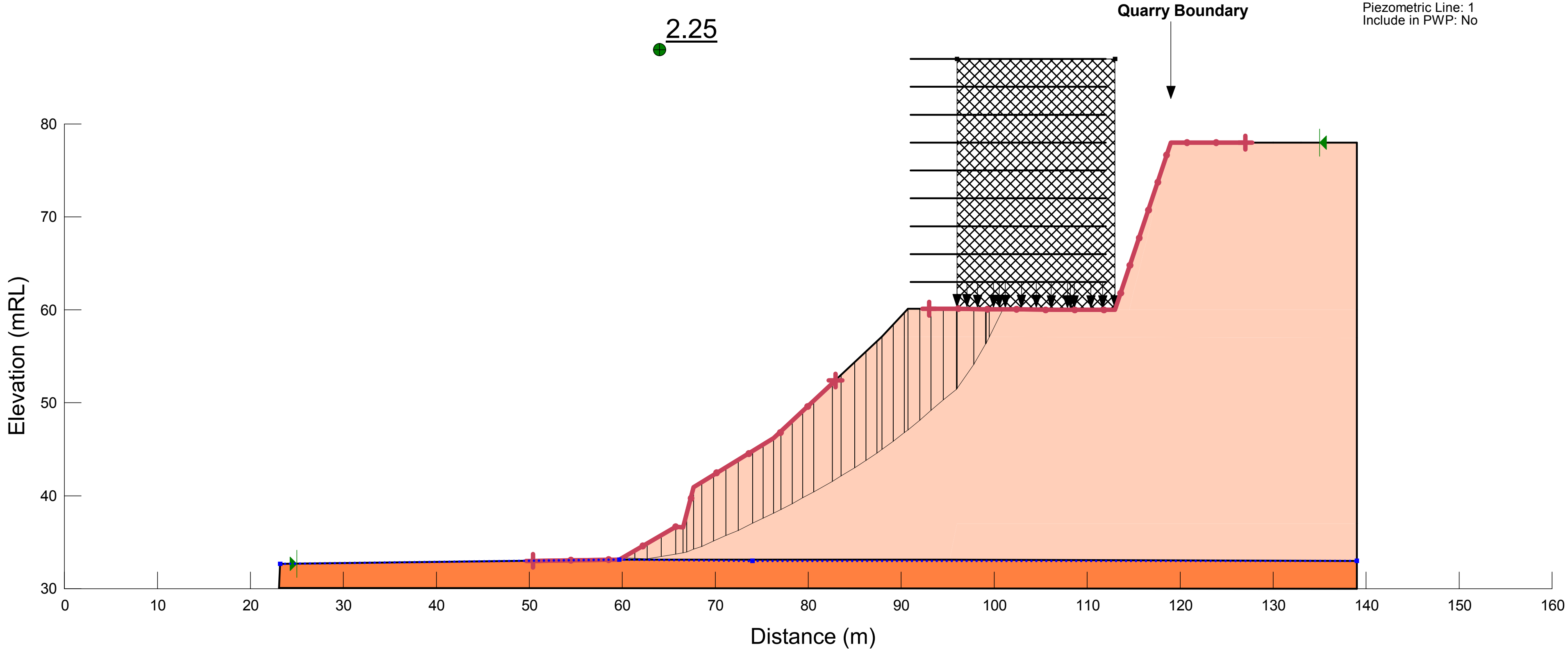
70 degree upper Slope, existing lower slope

Tonkin & Taylor	Scale 1:500 @ A3 Analysed by: CJL August 2013	**Winstone Aggregates** **Three Kings Quarry - East Wall Development**

Analysis Notes:
1. Method: Morgenstern-Price
2. Direction of movement: Right to Left
3. Optimize Critical Slip Surface Location: Yes
4. Soil Strength Models: Mohr-Coulomb
5. PWP Conditions Source: Piezometric Line with Ru
6. Tension Crack Option: Search for Tension Crack
7. Horz Seismic Load: 0.17g
8. Directory: P:\25141\25141.003\WorkingMaterial\August 2013 Slope Analysis\
9. File Name: Section Whole Slope CJL.gsz

Name: Scoria Shear Normal
Model: Shear/Normal Fn.
Unit Weight: 14 kN/m³
Strength Function: RocLab
Phi-B: 0 °
Ru: 0.1
Include in PWP: Yes

Name: Scoria Shear Normal - Below RGL
Model: Shear/Normal Fn.
Unit Weight: 14 kN/m³
Strength Function: RocLab
Phi-B: 0 °
Piezometric Line: 1
Include in PWP: No



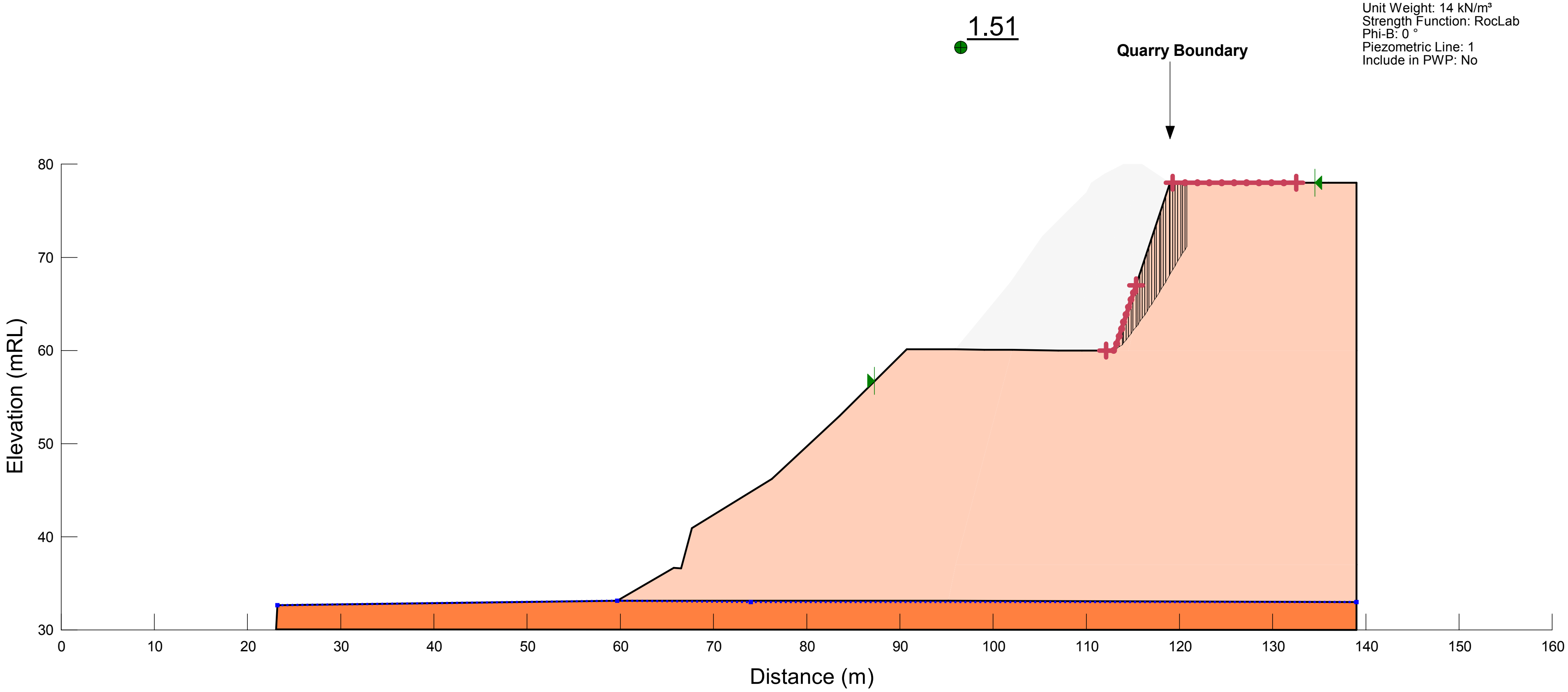
70 degree upper Slope, existing lower slope, seismic

Tonkin & Taylor	Scale 1:500 @ A3 Analysed by: CJL August 2013	**Winstone Aggregates** **Three Kings Quarry - East Wall Development**	

Analysis Notes:
1. Method: Morgenstern-Price
2. Direction of movement: Right to Left
3. Optimize Critical Slip Surface Location: Yes
4. Soil Strength Models: Mohr-Coulomb
5. PWP Conditions Source: Piezometric Line with Ru
6. Tension Crack Option: Search for Tension Crack
7. Horz Seismic Load: 0g
8. Directory: P:\25141\25141.003\WorkingMaterial\30-07-13 Quarry site visit\August 2013 Slope Analysis\
9. File Name: Section AA CJL.gsz

Name: Scoria Shear Normal
Model: Shear/Normal Fn.
Unit Weight: 14 kN/m³
Strength Function: RocLab
Phi-B: 0 °
Ru: 0.1
Include in PWP: Yes

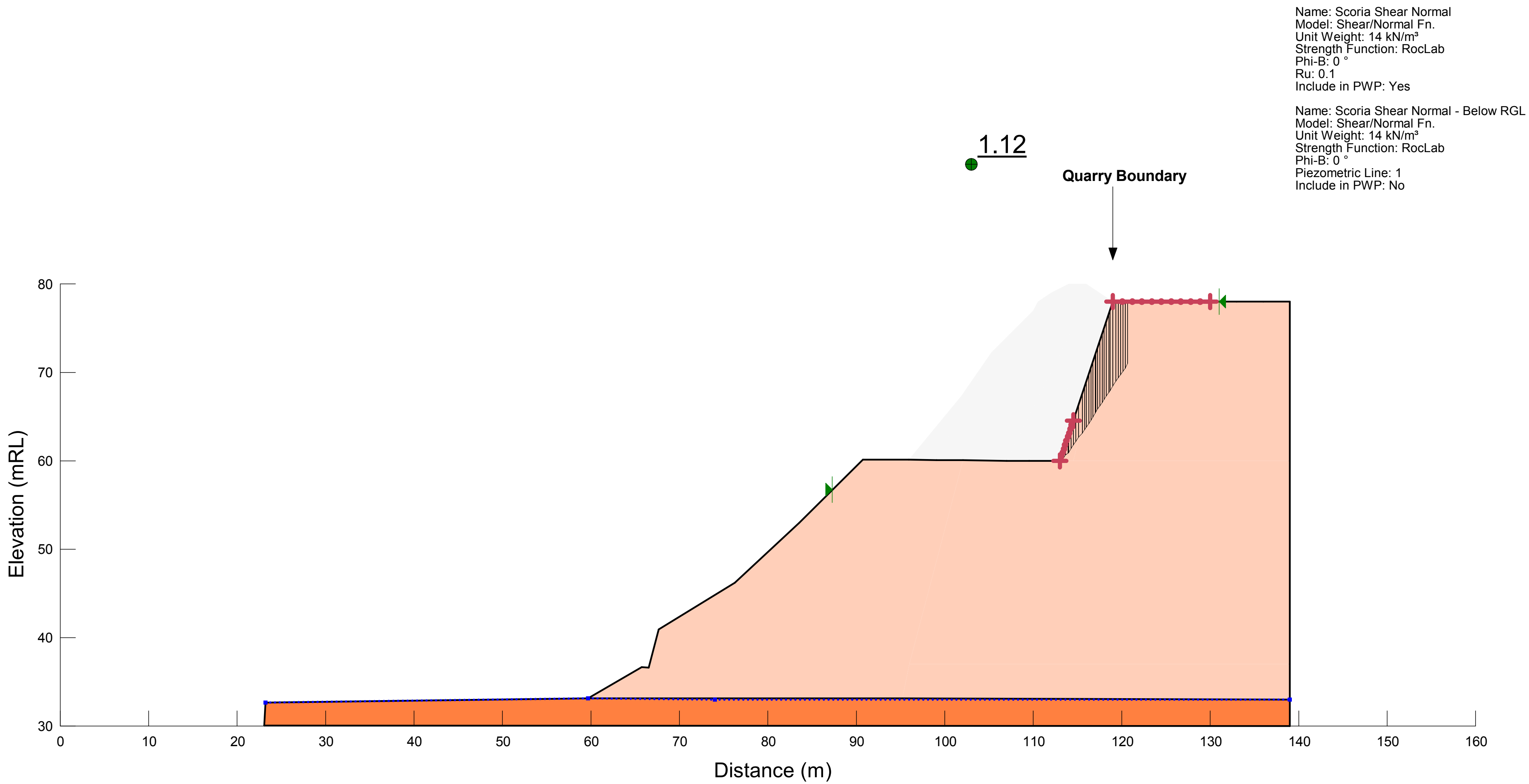
Name: Scoria Shear Normal - Below RGL
Model: Shear/Normal Fn.
Unit Weight: 14 kN/m³
Strength Function: RocLab
Phi-B: 0 °
Piezometric Line: 1
Include in PWP: No



70 degree upper Slope, existing lower slope, Static

Tonkin & Taylor	Scale 1:500 @ A3 Analysed by: CJL August 2013	**Winstone Aggregates** **Three Kings Quarry - East Wall Development**	

Analysis Notes:
1. Method: Morgenstern-Price
2. Direction of movement: Right to Left
3. Optimize Critical Slip Surface Location: Yes
4. Soil Strength Models: Mohr-Coulomb
5. PWP Conditions Source: Piezometric Line with Ru
6. Tension Crack Option: Search for Tension Crack
7. Horz Seismic Load: 0.17g
8. Directory: P:\25141\25141.003\WorkingMaterial\August 2013 Slope Analysis\
9. File Name: Section AA CJL.gsz



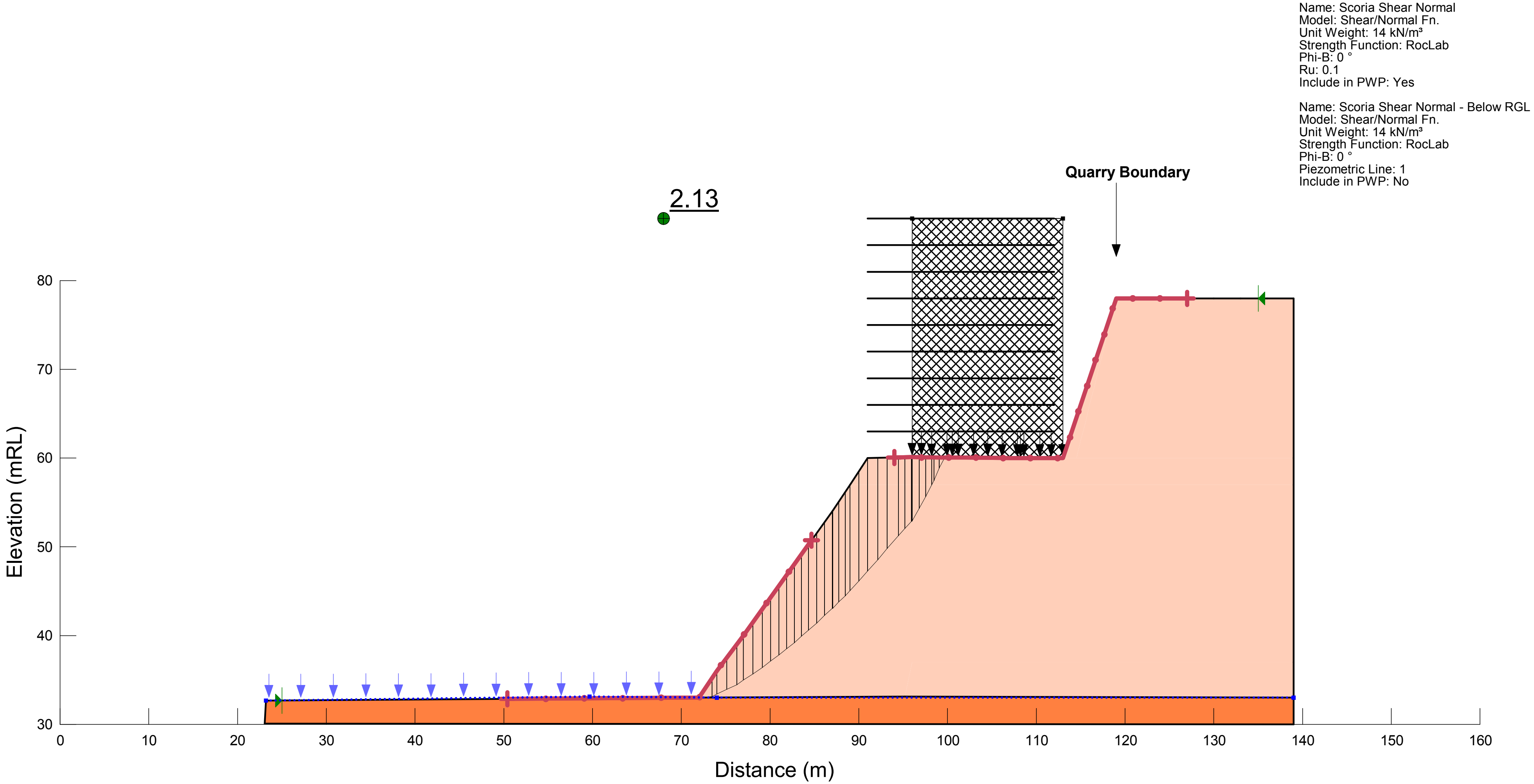
70 degree upper Slope, existing lower slope, seismic

Tonkin & Taylor

Scale 1:500 @ A3
Analysed by: CJL
August 2013

Winstone Aggregates
Three Kings Quarry - East Wall Development

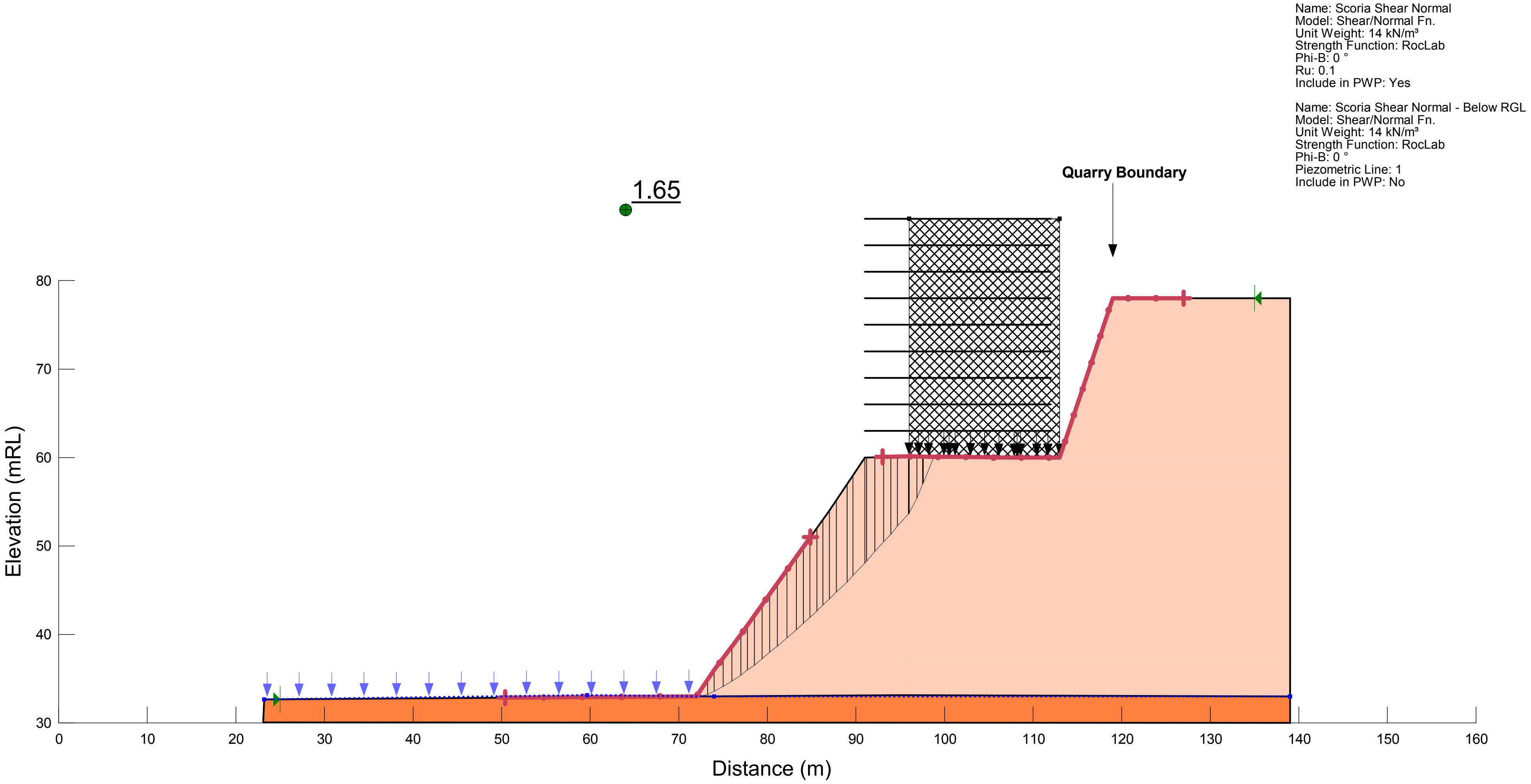
Analysis Notes:
1. Method: Morgenstern-Price
2. Direction of movement: Right to Left
3. Optimize Critical Slip Surface Location: Yes
4. Soil Strength Models: Mohr-Coulomb
5. PWP Conditions Source: Piezometric Line with Ru
6. Tension Crack Option: Search for Tension Crack
7. Horz Seismic Load: 0g
8. Directory: P:\25141\25141.003\WorkingMaterial\August 2013 Slope Analysis\
9. File Name: Section Whole Slope 56deg CJL.gsz



70 degree upper Slope, 56 degree lower slope,

Tonkin & Taylor	Scale 1:500 @ A3 Analysed by: CJL August 2013	**Winstone Aggregates** **Three Kings Quarry - East Wall Development**

Analysis Notes:
1. Method: Morgenstern-Price
2. Direction of movement: Right to Left
3. Optimize Critical Slip Surface Location: Yes
4. Soil Strength Models: Mohr-Coulomb
5. PWP Conditions Source: Piezometric Line with Ru
6. Tension Crack Option: Search for Tension Crack
7. Horz Seismic Load: 0.17g
8. Directory: P:\25141\25141.003\WorkingMaterial\August 2013 Slope Analysis\
9. File Name: Section Whole Slope 56deg CJL.gsz



70 degree upper Slope, 56 degree lower slope, seismic

Tonkin & Taylor	Scale 1:500 @ A3 Analysed by: CJL August 2013	**Winstone Aggregates** **Three Kings Quarry - East Wall Development**	

Appendix **D**

Technical reports referred to in NZEnvC124

Tonkin & Taylor

T&T Ref : 25141
08 July 2008

Winstone Aggregates
P.O. Box 17195
Greenlane
Auckland 1546

Attention: Richard Compton

Dear Richard

Managed Fill at Three Kings
Fill operations and development option assessment

1 Introduction

The feasibility of operating the Three Kings Quarry as a managed fill commencing before, and continuing after, quarrying operations have ceased is being investigated by Winstone Aggregates. Provided consent to fill the site is obtained within 12-18 months, quarry operations would be expected to cease in the next 5-10 years.

Three Kings Quarry is an open pit quarry operation recovering scoria from an ancient volcanic vent in the predominantly residential area of Three Kings, Auckland. At its current depth, (quarry base at RL34, with quarry rim at RL60-RL80 approx), resources are being extracted from below regional groundwater level. Groundwater within the quarry is depressed to below the quarry floor by pumping from a well within the quarry property.

In summary, a range of options from open space (parks) to residential, commercial or industrial development could be considered once the quarry is backfilled. Provided an engineered fill cap (last 5-10m of fill) completes the backfill where structures might be built (or specific foundation design is undertaken) these development options are feasible. Confirmation that fill settlement has reduced to a rate tolerable to the structures would be necessary prior to development.

It is expected that if effort is put into conditioning and compacting fill material to a suitable standard, building developments may be possible within a few years of fill completion.

2 Background

Tonkin & Taylor Ltd has previously provided Winstone with advice relating to the operation of the completed quarry pit as a clean fill. The advice consisted of preliminary estimates of the potential magnitude of long term surface settlement associated with backfilling of the pit.

Tonkin & Taylor Ltd - Environmental and Engineering Consultants, 105 Carlton Gore Road, Newmarket, Auckland, New Zealand
PO Box 5271, Wellesley St, Auckland 1141, Ph: 64-9-355 6000, Fax: 64-9-307 0265, Email: auck@tonkin.co.nz, Website: www.tonkin.co.nz

Fill options of end tipped, un-compacted clean fill to fully engineered fill were considered in the advice.

The preliminary estimates were based on a number of key simplifying assumptions.

1 fill would be brought up in uniform layers across the entire quarry floor,

2 regional groundwater would be allowed to rise in step with the filling.

More recent planning envisages zoned filling of the quarry, and a range of potential groundwater control scenarios during the filling period and post filling.

The zoned filling sequence is presented here, along with associated updated estimates of residual surface settlement magnitude. Settlement estimates are presented for filling by uncontrolled end tipping without specific compaction (bulk clean fill operation) to a fully engineered fill using selected materials and utilising controlled compaction, (an earthworks operation). The potential effect of different groundwater control scenarios on the estimates is discussed. The filling operation options are described below along with the assumptions inherent in the settlement estimates associated with them. Finally, comment is made on the implications the estimated range of settlements have on development of the filled site.

3 Issues for development

Zoning and consent requirements aside the settlement behaviour of the fill will strongly control the options and timing of any development following completion of filling.

After filling the suitability of the site for development other than as open space/recreational (residential, commercial or industrial) will depend on the magnitude of settlement remaining (residual settlement) at the time a development is constructed. Residual settlements (and differential settlement) will need to be of an order consistent with the tolerances of the structures and infrastructure required for the development.

3.1 Development options

The tolerances to surface settlement for areas developed as open space would be expected to be much higher than those associated with residential, commercial or industrial buildings.

Guidance on settlement tolerances for buildings in general is provided in the NZ building code. Appendix B B1/VM4, clause B1.0.2,

"Foundation design should limit the probable maximum differential settlement over a horizontal distance of 6m to no more than 25mm under serviceability limit state load combinations of NZS 4203:1992[updated in 2004], unless the structure is specifically designed to prevent damage under a greater settlement."

This clause effectively sets a guidance limit of approximately 1:240 differential settlement.

Further guidance on the tolerance of specific building types and/or uses to differential settlement is provided by Bjerrum, 1963 as summarised below.

Table 1 - Differential settlements and buildings

#	Description	Limit
1	Limit for typical settlement sensitive machinery	1/750
2	Potential damage to frames with diagonals	1/600
3	Potential limit for cracking	1/500
4	Tilting of high buildings becomes noticeable	1/250
5	Structural damage likely, considerable cracking	1/150

The need to protect against aesthetic damage to residential developments, and to ensure functionality of machinery in an industrial situation is likely to require residual differential settlements to be limited to 1/500 – 1/750 rather than the more relaxed criteria in the building code.

On this basis, the criteria for building development suitability adopted here is set at approximately half that of the building code – 10mm and a differential of 1:500. This is considered a conservative criterion, appropriate to this early stage assessment. It is not intended to reflect the level at which a settlement trigger should be set in any consent for the filling. With information relating to individual building requirements, specific design may provide for more relaxed criteria.

For development of open space and park areas higher total settlements could typically be tolerated, depending on final use.

3.2 Fill operation options

Residual and differential settlement is likely to be strongly controlled by the type of operation utilised for the clean fill. Operations with limited control over

1. the quality of fill placed
2. the uniformity of the fill
3. the level of compaction of the fill

would be expected to result in large residual settlement and differentials across the site for many years after completion of the backfill.

Operations where the quality of the fill placed is controlled, materials are spread and compacted in thin uniform layers and to an acceptable standard will reduce the potential for significant residual settlement and differential settlement.

Filling operations ranging from a basic clean fill operation to a controlled earthworks operation are being considered by Winstones for the fill operation. These options are discussed in further detail in the following sections

3.2.1 Basic clean fill operation

For this type of operation, it is assumed that the filling proceeds to a filling plan, but that there is little or no control over the state of fill when it is placed, and that no specific compaction effort is put into the materials. Very wet, clayey materials may be included in the fill.

It is likely that the material would be end tipped in piles, with little spreading out in layers. As such, there is potential for significant non-uniformity in the fill, with resulting non-uniformity in surface settlements on closure of the filling operation.

Parameters used in estimation of consolidation and residual settlement for this option reflect the potential for very soft materials with slow consolidation characteristics.

3.2.2 Controlled clean fill

This operation is essentially similar to a clean fill operation. More effort is put in to spreading materials out into thin layers, and some degree of compactive effort would be put into the materials. The compactive effort is likely to consist of tracking of fill using clean fill plant rather than dedicated compaction plant.

The extra effort put into spreading fill out into thin layers increases the uniformity of the fill, reducing the potential for higher than necessary settlement differentials.

3.2.3 Controlled, engineered earthworks operation

For this type of operation, it is assumed that the filling proceeds to a specific filling plan with significant selection and control of the fill materials.

Very wet materials may be excluded from the site, or conditioned prior to placement in the main filling area. All materials would be conditioned to optimum moisture content for compaction, and fill materials would be spread out in thin uniform layers for compaction. Wet materials would be mixed with dryer materials. Quality control testing may be carried out to ensure the fills meet the required level of compaction.

Care would be taken to ensure that pockets of granular fill are not encapsulated in low permeability cohesive materials, and the fill layers shaped to ensure good drainage.

Specific consideration will need to be given to any fill placed below water level. If not well designed, this part of the filling process could result in long term consolidation settlements despite the high quality of fill placed above the water level. Options include the use of granular fill where placed below water, temporary dewatering for cohesive fill placement, or specific settlement rate enhancing options such as the installation of wick drains and the application of surcharges.

3.2.4 Fill cap

No matter what type of operation forms the bulk of the filling, it would be an advantage for the final few metres (5-10m) of fill to be to engineered fill standard. It would provide suitable foundation material in areas where building development is likely, and will serve to raft out, (mask) differentials associated with non-uniformity in fill.

For developments resulting in high ground loadings, additional localised treatments such as temporary surcharging may be required to ensure load induced settlement is within acceptable limits, particularly for basic clean fill or controlled clean fill type operations.

4 Filling regime

Figures 1 to 5 attached summarise the filling sequence on which the settlement estimates here are based. The sequence reflects Winstones broad intentions for filling at the site, but is necessarily preliminary in nature.

In summary, the filling sequence is as follows

1. Construction of a southern access from Mt Eden Rd against the southern wall of the quarry, to provide a second site entry.

2. Overfilling of the access embankment to form a stockpile area adjacent to Mt Eden Road (at RL 55m approximate).

3. Filling of the northern pit area

4. Filling of the quarry to final grades.

Table 2 presents a yearly summary of the expected filling rate (rate of fill importation) for an expected seven year life of the operation. The rate of fill will depend on many factors that can only be estimated – e.g. availability of fill is generally a function of development and hence economic activity. Winstone has estimated seven years as the absolute minimum time frame for filling the site, but expects it more likely to be of the order of 10 years to 12 years. The minimum time frame produces the most conservative, (highest residuals) settlement scenarios. Table 3 provides a summary of how the fill is advanced year by year for the life of the fill based on the import rates and filling sequence.

The fill import rates were provided by Winstones Aggregates, and are necessarily preliminary in nature. Actual import rates will likely vary considerably from those in the table, and will depend in part on the Consent under which the operation will be controlled and by demand for disposal of fill while the fill is in operation.

Table 2 – Assumed incoming fill volumes year 1 to 8

Year	Incoming fill volume (m^3)[1]
1	410,000
2	385,000
3	400,000
4	465,000
5	465,000
6	465,000
7	465,000
8	150,000

1 – Fill volumes supplied by Winstones Aggregates Ltd, email of 23 April 2008

Table 3 – Fill sequence year by year

Year	Fill sequence and levels[1]
1	Accessway construction – complete
2	Stage 1 fill – complete
3	Stage 2 fill to RL 45m
4	Stage 2 fill to RL 55m
5	Stage 2 fill to RL 65m
6	Stage 2 fill to RL 70m Stage 3 fill to RL 62m
7	Stage 3 fill complete

1 - Approximate levels only

5 Fill consolidation and residual settlement modelling

A simplified numerical model of the quarry and backfill sequence has been developed. The model includes;

1. The basic shape of the quarry as it relates to fill depth at any point
2. The basic filling sequence combined with the estimated fill import rate, modelled on a year by year time scale.
3. Fill parameters (settlement magnitude and rate parameters) that reflect the broad scale behaviour of the fill mass. The parameters are applied uniformly in the fill - allowance is not made for spatial variability.

The model is necessarily a gross simplification of a complex reality. Simplified models of residual pore pressure and consolidation rate are utilised to allow simple calculations to determine the settlement estimates.

The use of sophisticated modelling is not considered appropriate for the estimates owing to the preliminary nature of the work, and due to the high degree of uncertainty in key parameters, (i.e. – fill import rates, fill type, filling sequence). Further the fact that actual rates of settlement can be monitored and used to revise the settlement model prior to any building development occurring, i.e. Building consent represents future control.

5.1 Parameters

Soil parameters have been selected to represent the varying states of fill in each of the options. Reference has been made to test data from Winstone's Puketutu clean filling operation in selection of parameters for the basic clean fill case (data supplied by Winstone). For the clean fill and controlled clean fill cases, the material is assumed to be placed at well above optimum water content.

For the engineered fill case typical values used to control engineered fills have been used to develop the required parameters using generally accepted correlations. The engineered fill is assumed to be placed at or very near to optimum water content.

Table 4 summarises the parameters selected.

Table 4 - Consolidation parameters

	Option		
	Basic clean fill	**Controlled clean fill**	**Engineered fill**
Coefficient of volume compressibility, m_v	0.2 m^2/MN	0.16 m^2/ MN	0.06 m^2/ MN
Coefficient of consolidation - c_v	15 m^2/year	40 m^2/year	150 m^2/year

6 Residual settlements

The quarry has been divided into three zones for the reporting of estimated settlement. The zones are identified on Figure 5.

The reported settlements (Table 5 and Table 6) have been calculated using a simplified model and are best seen as comparative, (providing an indication of potential differences between filling options) rather than absolute. Specific monitoring of actual surface settlement as it develops will provide the opportunity for modelling parameters to be calibrated and predictions refined for future development.

Table 5 - Estimated residual settlements on closure (seven year fill time)

	Clean fill		Clean fill - controlled		Engineered fill	
	total	diff	total	diff	total	diff
South west quarry	75-150	>1:250	25-75	>1:250	5-10	< 1:250
North quarry	100-200	>1:250	50-100	>1:250	10-20	~1:250
South east quarry	200-300	>1:250	100-200	>1:250	30-50	> 1:250

Table 6 - Estimated time for residuals to reduce to acceptable level for building[1]

Location	Clean fill	Clean fill - controlled	Engineered fill
South west quarry	5-15 years	1-5 years	~1 year
North quarry	20-30 years	5-10 years	1-2years
South east quarry	20-30 years	10-15 years	1-2 years

1 – Acceptable level for building development – 10mm magnitude, 1:500 differentials.

6.1 Monitoring

Prior to any future development of the filled site it will be necessary to confirm residual settlement projected over the development life has reduced to a satisfactory level.

It is recommended that settlement monitoring marks be installed across areas of proposed or potential development. Commencement of future development can then be contingent on settlement rates being such that projected settlements over the life of any proposed structure are tolerable.

It is recommended that data from the monitoring marks would be supplemented by data from a number of piezometers confirming that excess pore pressures had also reduced to satisfactory levels at various depths within the fill. Remaining excess pore pressure is an indicator of remaining residual settlement.

7 Discussion

7.1 Future Development and settlement

The immediate residuals predicted are considered too high and time constrained for any realistic building development programme for all cases except under full engineered fill in the SW quarry zone.

The estimated time for residuals to reduce to acceptable levels for development is high for the clean fill option (in the order of 20-30 years for much of the quarry), but becomes more acceptable for parts of the quarry (SW and N zones) under controlled clean fill scenario.

Engineered fill operations provide the most satisfactory outcome in terms of limiting delays to future building development.

Assuming relatively uniform fill materials, the factor to most influence settlement differential is the variable fill depth. The areas of highest variability occur adjacent to the quarry faces, where fill depth rapidly reduces from approximately 40m to as little as 5-10m. Without particular attention to fill management and monitoring in these areas, they would potentially be high risk for, and possibly need to be excluded from, future building development. Consequently, extra effort in fill management and compaction and subsequent settlement monitoring is recommended for these areas to minimise this effect. The density of the settlement monitoring network should reflect the potential rapid change (spatially) in settlement magnitude.

It is an option to work the quarry out to approximately RL 29-32m. If this occurs with the ground water level held at its present level of RL34m, the base of the quarry backfill will be placed below water. To minimise the time between completion of fill and future development specific attention will also need to be paid to the placement of this fill. Significant long term settlement could be generated from this material if care is not taken.

Options to place granular fill in this area, or to temporarily dewater the quarry for placement should be considered. Alternatively, consolidation rate enhancing measures could be taken to ensure the settlement generated in poorly compacted, saturated material is suitably accelerated. Measures such as the installation of wick or chimney drains could provide this function.

7.2 Groundwater control scenarios

Winstone is considering a range of options for long term groundwater control at Three Kings. The options range from

- indefinite pumping (to maintain groundwater within the quarry walls and floor at RL34m) to
- allowing regional groundwater to recover as the fill is placed
- allowing regional groundwater to recover soon after fill completion.

For the clean fill and controlled clean fill operations considered here, estimated surface settlement would not be expected to vary significantly between these groundwater options. It is most likely that the fill materials placed would be at the wettest and softest state when placed, and groundwater rising within the fill would not be expected to further soften the material. These materials would be expected to commence consolidating as soon as buried by further fill. This is the basis for the settlement estimates in Table 5.

These groundwater control scenarios have more substantial impact on settlement estimates if a significant quantity of dry cohesive material is included in the backfill. When initially placed the dry material is likely to be high in air voids (even under controlled clean fill conditions) and quite stiff and resistant to consolidation. When water enters this material however it has the potential to soften substantially initiating consolidation and associated surface settlement.

If groundwater is held permanently below the base of the fill, then the dry material will wet up only through percolation of surface water into the quarry backfill from the surface. This process is likely to take many years to tens of years and hence consolidation of the initially dry material would be delayed leading to a greater residual settlement magnitude and extending the period over which settlements would be experienced at the site.

If groundwater is allowed to rise within the fill on completion, then softening and commencement of settlement associated with the dry components of the fill will be delayed by only a short period, and the magnitude of residual settlement manifest at ground surface long term would be increased by a margin, depending on the proportion of dry material making up the backfill.

7.3 Other potential options to minimise time lag between completion of fill and future use

7.3.1 Piled foundations

The south west quarry zone is considered a possibility for future development of structures supported on piles. The piles would extend through the fill to the quarry floor at approximately 15-20m depth. In other parts of the quarry, piles would need to extend some 30-40m depth and would therefore probably be uneconomic.

The type of fill placed in this area would also determine the practicality of piled foundations. If construction debris such as broken concrete or rubble was placed within the fill, piling operations would become more difficult. Driving or drilling piles would be hindered by obstructions within the fill.

7.3.2 Dynamic Compaction

Winstone asked Tonkin & Taylor to comment on the possibility of utilising Dynamic Compaction methods to assist in compaction.

Dynamic compaction (D-C) involves densification of loose soil by repeatedly dropping a large steel or concrete weight onto the ground surface. High energies are generated, and soils are typically densified to depths significantly in excess of those possible by standard compaction plant, (rollers). The method is commonly used to successfully densify loose sands, old refuse landfills, and less commonly to densify cohesive materials.

D-C may provide a means of partially densifying material placed in clean fill or controlled clean fill conditions without the need for continuous compaction, (compaction plant on site). D-C is effective up to 5m depth. The energy applied in the D-C process is directly related to the depth of treatment. To treat a 5m thick layer the energy required is likely to be of the order of 100ton metres at 2.5m centres.

Therefore if D-C were to be applied, on completion of up to 5m deep lifts D-C equipment could be brought to site and the fill layer treated (over a period of days), before further material was placed. The amount of D-C appropriate to each fill layer would be determined on site by compactive effort trials.

The D-C would be expected to reduce the residual settlement associated with clean filling by improving fill density. The degree to which the density is improved, and to which final settlement residuals would be reduced would depend heavily of the fill composition, layer depth, and energy applied. Large improvements could be expected for un-compacted clean fill, particularly loose granular materials. Moderate improvements could be expected for unsaturated cohesive materials.

D-C is not generally suitable for compacting saturated cohesive (clayey) materials. As such it would not be appropriate for compacting cohesive fill placed in the base of the quarry below water level.

D-C generates ground vibrations potentially damaging to buildings. Within the Three Kings Quarry however, the vibrations would not be expected to significantly affect surrounding properties. The fill would be contained within quarry faces that would be expected to significantly attenuate the low frequency vibrations. Vibrations would only be expected to be noticeable if the compaction weight struck hard objects or basalt intrusions in direct and continuous contact with the quarry floor or faces.

In summary, D-C would be an option to partially compact end tipped materials, however the level of densification achieved is likely to be variable and difficult to quantify. The material would not be expected to achieve density or settlement performance of an engineered fill, but would be expected to exhibit improved performance compared to clean fill or controlled clean fill operations.

8 Conclusions and Recommendations

1. The magnitude of settlement, and the time period over which it occurs following completion of filling, is dependant on the type of operation and fill used.

2. Any future building development will require consents. The consents would be expected to require that ongoing settlement over the life of the structure(s) comply with the provisions of the Building Code (refer Section 3.1 of this report) or for specific design to accommodate greater settlement. Similarly future consents could, if necessary identify building exclusion zones in areas where there are rapid changes from deep to shallow fill (such as above the quarry faces).

3. Settlement and fill pore pressure monitoring should be implemented in accordance with a Site Fill Management Plan. The monitoring data will provide the basis for confirming compliance with future consent requirements or set the basis for specific design at the time of development.

9 Applicability

This report has been prepared for the benefit of Winstone Aggregates with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

TONKIN & TAYLOR LTD

Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor by:
....	....
Graeme Twose	J. Doug Johnson
Geotechnical Engineer	Group Manager - Geotechnical

16-Jul-08
p:\25141\workingmaterial\grt080708letcombined.doc

Figures

NOTE:

AREAS AND BOUNDARIES SHOWN ARE SUBJECT TO SURVEY.

FINAL FLOOR CONTOURS. 9/05

REV	AMENDMENT	BY	DATE

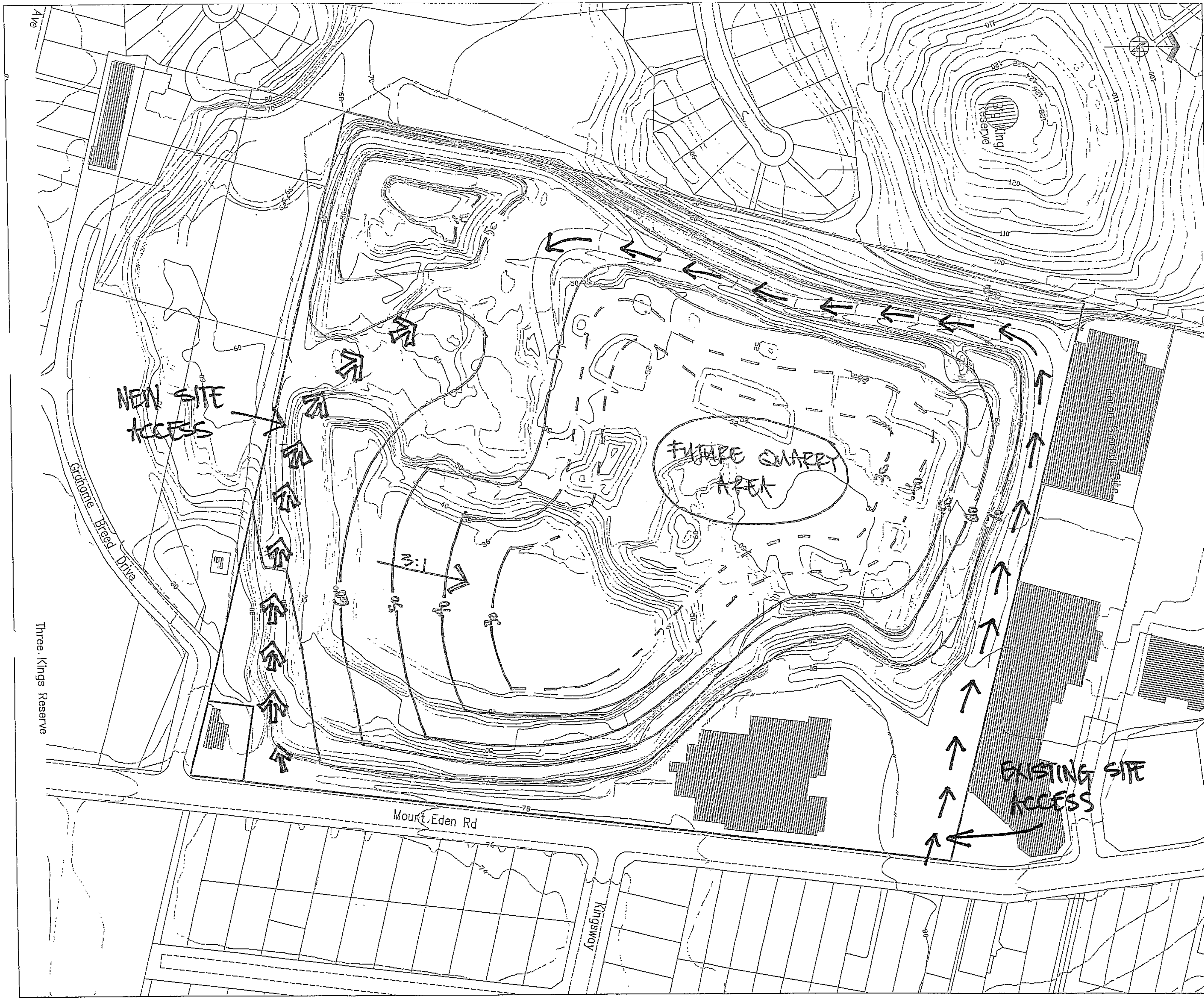
PROJECT:

WINSTONE AGGREGATES LTD.
THREE KINGS QUARRY
THREE KINGS

TITLE:

EXISTING SITE PLAN

DESIGNED:	DATE:	SIGNATURE:	PLOT DATE:
DRAWN:	DATE:	SIGNATURE:	CAD REF:
			CAD XREF:
CHECKED:	DATE:	SIGNATURE:	SURVEY BY:
APPROVED:	DATE: SEPT 07	SIGNATURE:	SURVEY DATE:
			SDR REF:
PLOT STATUS:			
HC REF:	SCALES: 1:1000 1:2000 (A3)		A1
DRAWING No: FIGURE 1			REV



NOTE:
AREAS AND BOUNDARIES SHOWN ARE SUBJECT TO SURVEY.

ACCESSWAY FORMATION 9/05

REV	AMENDMENT	BY	DATE

PROJECT:
WINSTONE AGGREGATES LTD.
THREE KINGS QUARRY
THREE KINGS

TITLE:
EXISTING SITE PLAN

DESIGNED: DATE:	SIGNATURE:	PLOT DATE:	
DRAWN: DATE: 10.09.07	SIGNATURE:	CAD REF:	
CHECKED: DATE: SEPT 07	SIGNATURE:	CAD XREF:	
APPROVED: DATE: SEPT 07	SIGNATURE:	SURVEY BY:	
PLOT STATUS:		SURVEY DATE:	
		SDR REF:	

SCALES: 1:1000 1:2000 (A3) | A1
DRAWING No: | REV

FIGURE 2

NOTE:
AREAS AND BOUNDARIES SHOWN ARE SUBJECT TO SURVEY.

STAGE 1 FILL
9/05
FILL STAGE FOOTPRINT

REV	AMENDMENT	BY	DATE

PROJECT:
WINSTONE AGGREGATES LTD.
THREE KINGS QUARRY
THREE KINGS

TITLE:
EXISTING SITE PLAN

DESIGNED:	DATE:	SIGNATURE:	PLOT DATE:
			CAD REF:
DRAWN:	DATE: 10.09.07	SIGNATURE:	CAD XREF:
CHECKED:	DATE: SEPT 07	SIGNATURE:	SURVEY BY:
			SURVEY DATE:
APPROVED:	DATE: SEPT 07	SIGNATURE:	SDR REF:
PLOT STATUS:			

NC REF:	SCALES: 1:1000 1:2000 (A3)	A1
DRAWING No: FIGURE 3		REV

NOTE:
AREAS AND BOUNDARIES SHOWN ARE SUBJECT TO SURVEY.

STAGE 2 FILL

9/05 FILL STAGE FOOTPRINT

REV	AMENDMENT	BY	DATE

PROJECT:
WINSTONE AGGREGATES LTD.
THREE KINGS QUARRY
THREE KINGS

TITLE:
EXISTING SITE PLAN

DESIGNED: DATE:	SIGNATURE:	PLOT DATE: 28.09.07	
DRAWN: DATE: 10.09.07	SIGNATURE:	CAD REF:	
CHECKED: DATE: SEPT 07	SIGNATURE:	CAD XREF:	
APPROVED: DATE: SEPT 07	SIGNATURE:	SURVEY BY:	
PLOT STATUS:		SURVEY DATE:	
		SDR REF:	
HG REF:	SCALES: 1:1000 1:2000 (A3)	A1	
DRAWING No: FIGURE 4		REV	

NOTE:
AREAS AND BOUNDARIES SHOWN ARE SUBJECT TO SURVEY.

END OF FILLING.
APPROX FINAL 9/05 SURFACE LEVEL.

REV	AMENDMENT	BY	DATE

PROJECT:
WINSTONE AGGREGATES LTD.
THREE KINGS QUARRY
THREE KINGS

TITLE:
EXISTING SITE PLAN

DESIGNED:	DATE:	SIGNATURE:	PLOT DATE:
DRAWN:	DATE: 10.09.07	SIGNATURE:	CAD REF: / CAD XREF:
CHECKED:	DATE: SEPT 07	SIGNATURE:	SURVEY BY: / SURVEY DATE:
APPROVED:	DATE: SEPT 07	SIGNATURE:	SDR REF:
PLOT STATUS:			
HG REF:	SCALES: 1:1000 1:2000 (A3)		A1
DRAWING No: FIGURE 5			REV

Tonkin & Taylor

1959 - 2009 50 YEARS

T&T Ref : 25141
15 May 2009

Winstone Aggregates
PO Box 17195
Greenlane
Auckland 1546

Attention: Richard Compton

Dear Richard

Three Kings Quarry - Consent to Fill
Geotechnical response to Section 92 queries from ACC

1 Introduction

Winstone Aggregates lodged an application for consent to operate a clean fill at the Three Kings Quarry, Mt Eden in February 2009. Following submission, Auckland City Council Development Engineering requested further information from Winstone Aggregates, in a Section 92 request. The further information related specifically to a report from Tonkin & Taylor Ltd - "Clean Fill at Three Kings, Fill operations and development option assessment" (8 July 2008) that was included in Winstone Aggregate's submission document.

2 Response to Section 92 Queries

2.1 General

Auckland City Council Development Engineering sent Winstone Aggregates and email on 7 April 2009 containing a number of queries regarding the geotechnical aspects of the application for consent to operate a clean fill at Three Kings Quarry, Mt Eden, described in Tonkin & Taylors report..

Auckland City Council Development Engineering commented that;

"The geotechnical report by T & T Consultant is considered preliminary and not sufficient for the purpose of assessing the stability of the site after completion of filling works."

They identified a number of areas which they considered should be investigated further by Tonkin & Taylor.

The Tonkin & Taylor Limited report was prepared to explore the range of ways Winstone Aggregates might operate the clean fill (from a simple clean fill site to a fully controlled engineered fill operation) and how that could impact land use and development potential immediately after completion of filling, and at some time in the future. A range of possible future uses for the land was considered by the report; from open space or parklands/recreational space to residential or commercial/ industrial subdivision. In this context, the report was necessarily general and covered a range of options, rather than specific to the requirements for a particular end use.

A key conclusion of the report was that ground surface settlement could be expected to occur for some period of time following completion of clean filling, irrespective of the filling regime and groundwater control regime utilised by Winstone Aggregates. The magnitude and period over which settlement would be expected to occur could, however, be controlled by the degree of engineering effort employed by the filling operation; being selective about the type of fill accepted by the clean fill, by conditioning the fill and employing specific compactive effort to control fill density and by the way ground water is controlled.

Should the land be set aside purely as open space (recreational space without significant structures), then very little specific engineering intervention is likely to be required during the filling. If it is intended the land be developed soon after completion of the filling as a residential subdivision, then carefully planned engineered filling operations would be required to ensure the final landform and its performance was suitable.

Irrespective of Winstone Aggregate's decisions in this regard, any future development on this land will require further consents. It is these consents that will address much of the specific detail required to ensure successful development, (be it a park or a commercial/industrial subdivision) in the context of the way the clean fill was operated.

The following sections respond to each of the specific comments made by Auckland City Council Development Engineering in the Section 92 request, in the context of the discussion above. In each case the comments from the email are reproduced in full and are indentified by quotations in italics. Our response to the query follows in plain text.

2.2 Queries and responses

"The report presented three ground water control scenarios and the most critical option in terms of ground stability after completion of filling [has] not been assessed. I would recommend the applicant to proceed further to identify which is the most critical option."

Ground surface settlement (ground stability?) is expected to occur for some period of time following completion of clean filling, irrespective of the filling regime and groundwater control regime utilised. By employing suitable controls on fill placement and compaction matched to the land's intended end use, and with performance confirmed by monitoring, then there is no critical option.

For engineered filling options, specifications would ensure that materials were placed such that they are not significantly affected by changes in the groundwater regime. With less controlled filling, it is most likely that fill would be placed wet to significantly wet of optimum, and hence would also be unlikely to soften as a result of changes in the groundwater regime.

Our report of 8 July, Section 7.2 discusses the broad implications of three possible groundwater control scenarios and concludes that they differ primarily in the length of time surface settlement might be expected to occur after clean fill completion

"For deep fill, can you ask the applicant's engineer to comment or provide an evaluation relating to collapse settlement due to inundation if groundwater is allowed to recover after the filling work is completed[?]."

Collapse settlement is the onset of additional consolidation following inundation of groundwater in fill material that has been placed without systematic compaction. The inundation of groundwater (either from surface infiltration or through a rise in groundwater level through the fill) softens the material, and additional consolidation is induced. For appropriately engineered fill it is extremely unlikely.

At Three Kings the possibility of such additional settlement would only relate to the clean fill operated as a "Basic clean fill operation" (Section 3.2.1 of T&T's letter) and to a lesser extent a "Controlled clean fill" (Section 3.2.2) and only if significant dry material was included in the fill. As noted in response to the earlier query, this is not considered likely.

A basic clean fill operation would only become a likely fill scenario if the quarry was to become an open space or park, or if it was intended that the land lie undeveloped for decades while consolidation settlement abates.

For the open space scenario, surface settlement or additional surface settlement on groundwater inundation would not be expected to be a significant constraint on the land use. For a delayed development scenario, any additional settlement arising from the potential effects of groundwater inundation would be expected to be complete, and confirmed by survey monitoring prior to consent for development being approved.

In the unlikely event that a building development scenario that included a basic clean fill operation was progressed by Winstones, and significant dry material was placed, the land would necessarily lie undeveloped for decades (T&T letter, Section 7.1), while consolidation settlement was ongoing. During this period, groundwater would be expected to inundate the fill through surface infiltration, initiating any additional (collapse) settlement resulting from softening of dry fill well before background consolidation settlement had abated and a development was commenced.

If regional groundwater control was subsequently changed (i.e. pumping ceased and regional groundwater allowed to rise) at a later date still, this would not be expected to initiate a further period of collapse settlement.

"Specific soil properties to be achieved for the cleanfill to minimise settlement including mitigation against collapse settlement." "Specific compaction method suitable for the cleanfill, degree of compaction required and how it can be achieved."

Section 3.2 of our report discusses the impact of clean fill soil properties on settlement in general terms. Specific soil properties to be achieved are directly related to the level to which settlement is required to be minimised to suit a particular future land use. Clean fill operations that control the quality of the fill, the uniformity of the fill, and the density of the fill would be expected to minimise post filling surface settlement residuals, and the potential for collapse settlement.

The level to which these controls should be employed depends on the intended future uses of the land and an acceptable stand down period on completion of filling (to allow settlement to abate). Section 3.2 of our report discusses the impact of clean fill soil properties on settlement in general terms.

Even with appropriately targeted fill properties, it will be essential that the performance of the completed fill is confirmed via monitoring prior to development. We expect that monitoring would consist of survey levelling on settlement markers placed cross the fill surface, and possibly with settlement plates within the fill itself. Refer also Section 8 of our report, item 2.

"Is there any requirement for preloading of the site prior to its use for development?"

We would expect that a foundation report/geotechnical report would be a requirement of any consent to develop this land in the future. Any requirement for preloading or any other foundation treatment will be specific to the proposed development, and would be addressed at that time. Refer also to T&T report Section 8, item 2.

"Any recommended method to improve the compaction of the site."

Refer T&T report Section 3.2.3. The compaction methods eventually employed would depend on the type of fill materials used.

"Recommended foundation designs and parameters for future development."

Foundation designs and parameters would depend (among other things) on;

- The nature of the development and its use, the loads to be sustained, the type of foundation proposed, the tolerances of the structures to differential settlement and on the design codes current at the time development is proposed (it may be 20 – 50 years in the future)
- The type of fill placed beneath the specific area of the proposed development (it is possible the quarry could be zoned for different levels of fill engineering depending on intended end use.
- The location within the Three Kings Quarry, and the depth to original quarry floor

All of these variables are undefined at present. It is not appropriate for design recommendations and parameters to be supplied at this time.

3 Applicability

This report has been prepared for the benefit of Winstone Aggregates with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

TONKIN & TAYLOR LTD

Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor by:
....	....
Graeme Twose	J. Doug Johnson
Geotechnical Engineer	Group Manager, Geotechnical

15-May-09
p:\25141\workingmaterial\s92responsegrtfinal.doc