20 January 2025

KINGS QUARRY STAGE 2

PEBBLE BROOK ROAD, WAINUI

GEOTECHNICAL REPORT

Kings Quarry Limited

AKL2023-0190AB Rev. 1

AKL2023-0190AB		
Date	**Revision**	**Comments**
10 October 2023	A	Initial draft for internal review
18 October 2023	B	Issue for client review
17 November 2023	0	Final issue
20 January 2025	1	Updated reference to Fast-track Approvals Act 2024

	Name	Signature	Position
Prepared by	Henry Nagel		Project Engineering Geologist
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Appendices

1 INTRODUCTION

CMW Geosciences (CMW) was engaged by Kings Quarry Limited to carry out a geotechnical assessment and reporting of a site located at Pebble Brook Road, Wainui, which is the subject of an application to expand the existing quarry operations.

This report is to support Kings Quarry Limited's resource consent application under the Fast-track Approvals Act 2024.

The purpose of this report is to present a conceptual geotechnical model to support an assessment of the key geohazards associated with the final quarry landform, in particular the global pit and spoil disposal area stability, based on site mapping and desktop study information. This report **excludes** any testing or determination of the quality of the rock as an aggregate resource or opinion, assessment or interpretation of the suitability of the rock for such purpose, as well as localised geohazards associated with the quarrying process. Our stability assessments and cross sections shown in this report and its attachments have been undertaken for stability assessment purposes only and should not be taken to be used for resource prospecting.

2 SITE DETAILS

The site is located adjacent to 162 Pebble Brook Road, Wainui as shown on ***Figure 1***.

Details of the site are as follows:

- The site is defined by its steep topography and deeply incised gullies rising from a ground level at the base of the quarry at RL45m (Auckland 1946 Datum) to RL250m at the highest point at the northern extent of the property.
- The eastern boundary of the property is bound by a shallow tributary of the Waitoki Stream, which runs immediately south-east of the existing Stage 1 pit. Several overland drainage features feed into this stream from the northern hills, including a prominent gully running west to east some 250m north of the Stage 1 pit.
- Most of the site is heavily vegetated with regenerated native bush. The neighbouring property along the eastern boundary of the site is also heavily vegetated, but the surrounding properties to the north, east and south are predominately flatter-gradient farmland.
- The existing Stage 1 pit is approximately 70m deep and as wide as 150m at the base.

3 PROPOSED DEVELOPMENT

Brief details for the development are as follows:

- Based on discussion with the client and supplied summary letters, the Stage 2 operations are to span over the next 45 years, comprising two main excavation areas named "A-Pit" and "B-Pit".
- A-Pit is to be excavated first to the north of the existing Stage 1 pit, with total volumes of 960,000m^3 proposed. A-Pit will be gradually filled as B-Pit is excavated, with overall fill batters not exceeding 20°. We understand that compaction will be required for the fill to achieve net volumes. Total excavation volumes for B-Pit are 9,300,000m^3, 87% of which is stated to be product.
- Access to A-Pit will be via an existing haul road accessed from the existing Stage 1 pit, which is to be widened.

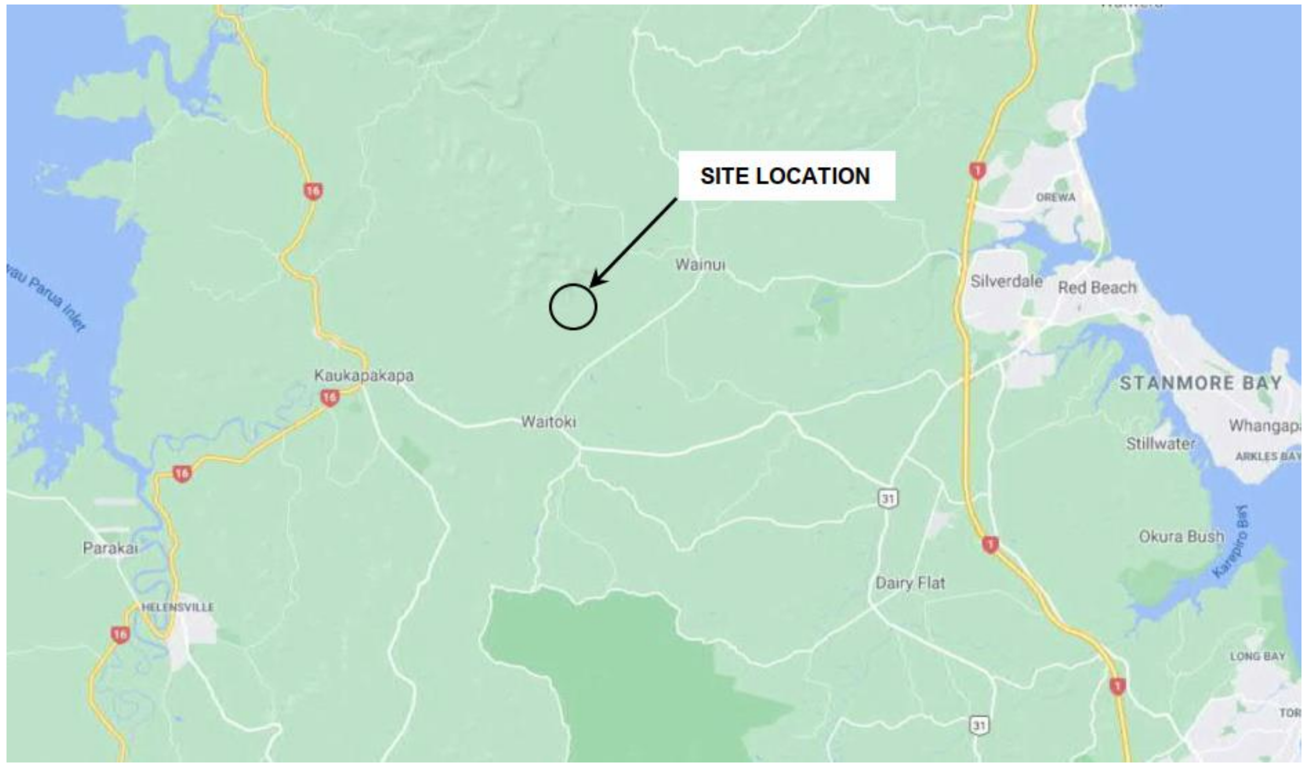

Figure 1: Site Location Plan (Auckland Council GeoMaps)

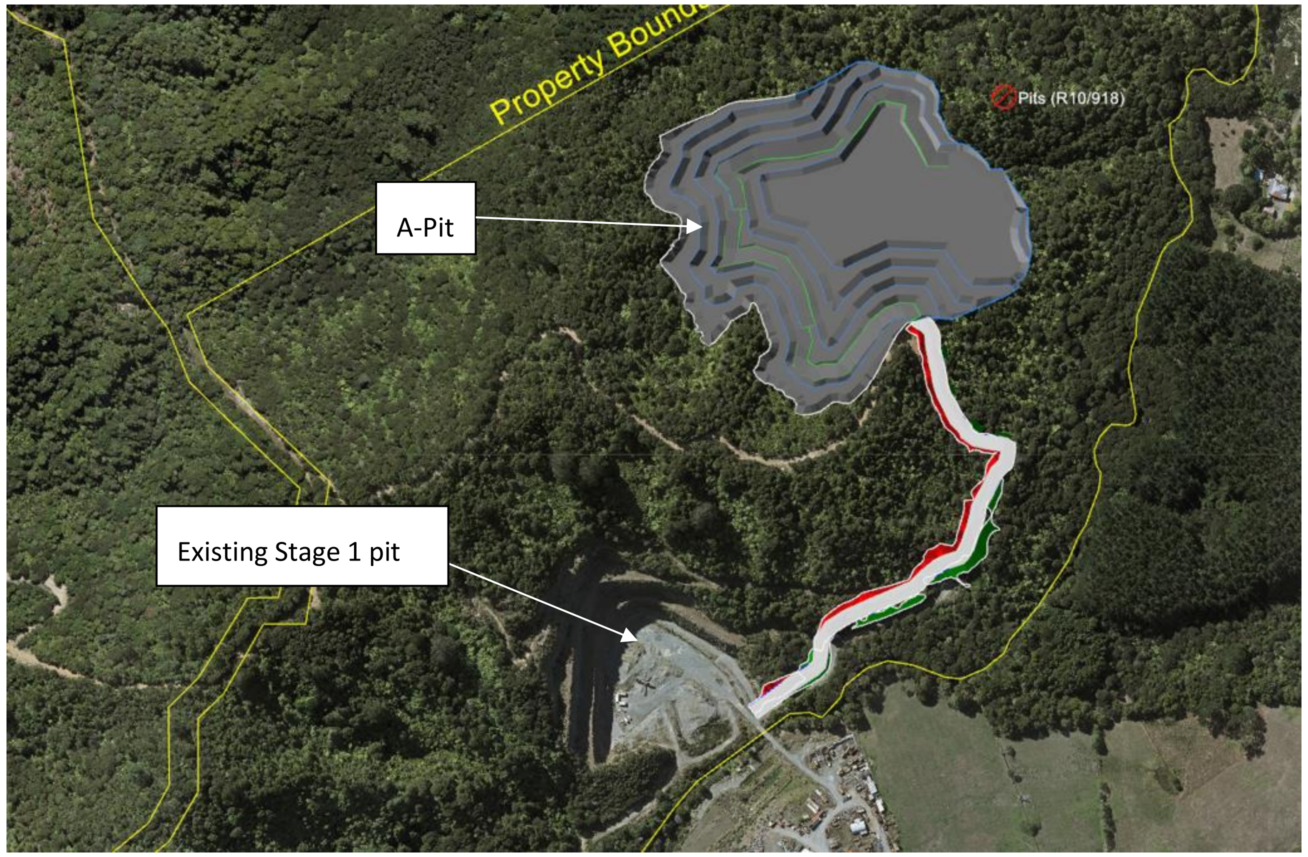

Figure 2: A-Pit Location

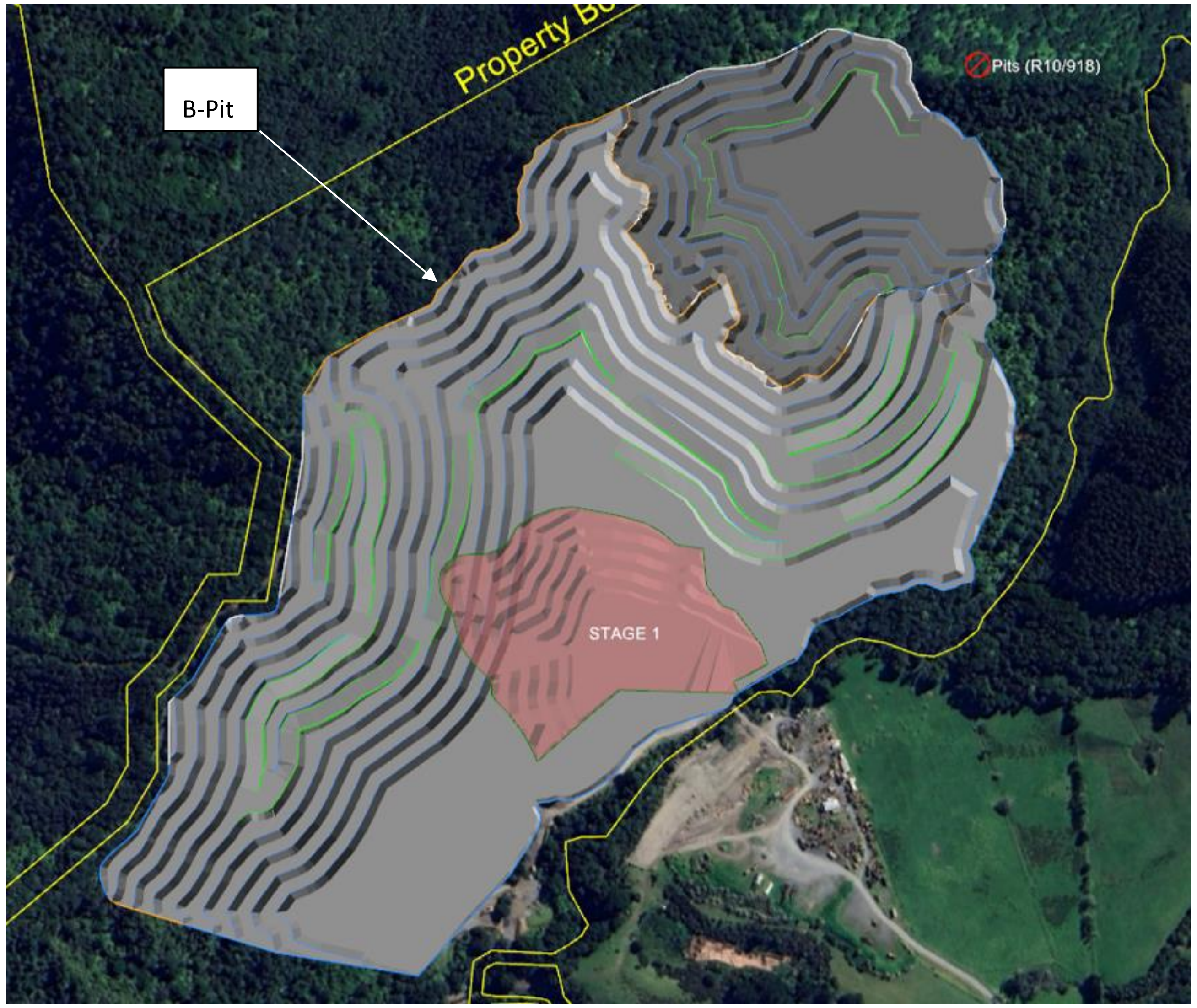

Figure 3: B-Pit Location

4 DESKTOP STUDY

The following documents were reviewed during preparation of this report:

- Geological Resources Report prepared by Grant Fisher Industrial Geology, referenced WAL08/1, dated April 2009.
- Resource Estimation Report prepared by Tonkin & Taylor Limited, referenced 1002085.v4, dated May 2017.
- Geotechnical Investigation Report prepared by CMW Geosciences, referenced AKL2020-0254AB Rev. 1, dated 1 December 2021.
- Factual Technical Report prepared by Williamson Water & Land Advisory Limited (WWLA), refenced WWLA0931 Rev. 1, dated 30 October 2023.

5 FIELD MAPPING

Given the extremely difficult access to the gully fill area and the presence of native bush, intrusive investigations were not feasible. Field mapping was undertaken on 14 September 2023 during mostly dry weather conditions. The scope of the mapping is as follows:

- Undertake a walkover within the proposed gully fill area (A-Pit) to map rock outcrops.
- Four localities were mapped as depicted in ***Figure 5*** below. Geological observations were undertaken at each of these localities to infer the regional geology. Reports of each locality are presented in ***Appendix C***.

5.1 Groundwater

For the purpose of our stability analysis for this report, we have based groundwater levels on the information provided in the WWLA report referenced in Section 4.

6 GEOLOGY

6.1 Published Geology

Published geological maps[1] for the area depict the regional geology for the area as comprising predominantly interbedded sands and gravels of the Albany Conglomerate (Waitemata Group), contacted with sheared Hukerenui Mudstone (Northland Allochthon) and sandstone of the East Coast Bays Formation (Waitemata Group) in the eastern portion of the subject area, as illustrated in ***Figure 4***. Measurements along bedding suggest regional dip to the south-east.

The rockmass of the published geology is typically overlain by a mantle of residual soil derived from its weathering, which is generally described as silt and sandy silt within Waitemata Group geology and clay and clayey silt within Hukerenui geology.

The main geohazards associated with these geological units are presented below:

Published Geology Summary			
Geological Unit	**Location**	**Behaviour**	**Principal Potential Geohazards**
Waitemata Group	Predominant geology and source of quarry product	Silty/sandy soil mantle prone to translational slides over less weathered rock mass Structural features (refer to Section 6.2 below)	Landslips
Hukerenui Mudstone	Contact to the east	High plasticity clays prone to debris sliding and deep-seated creep, even on gentle slopes	Landslips

[1] GNS Web Map <https://data.gns.cri.nz/geology/>.

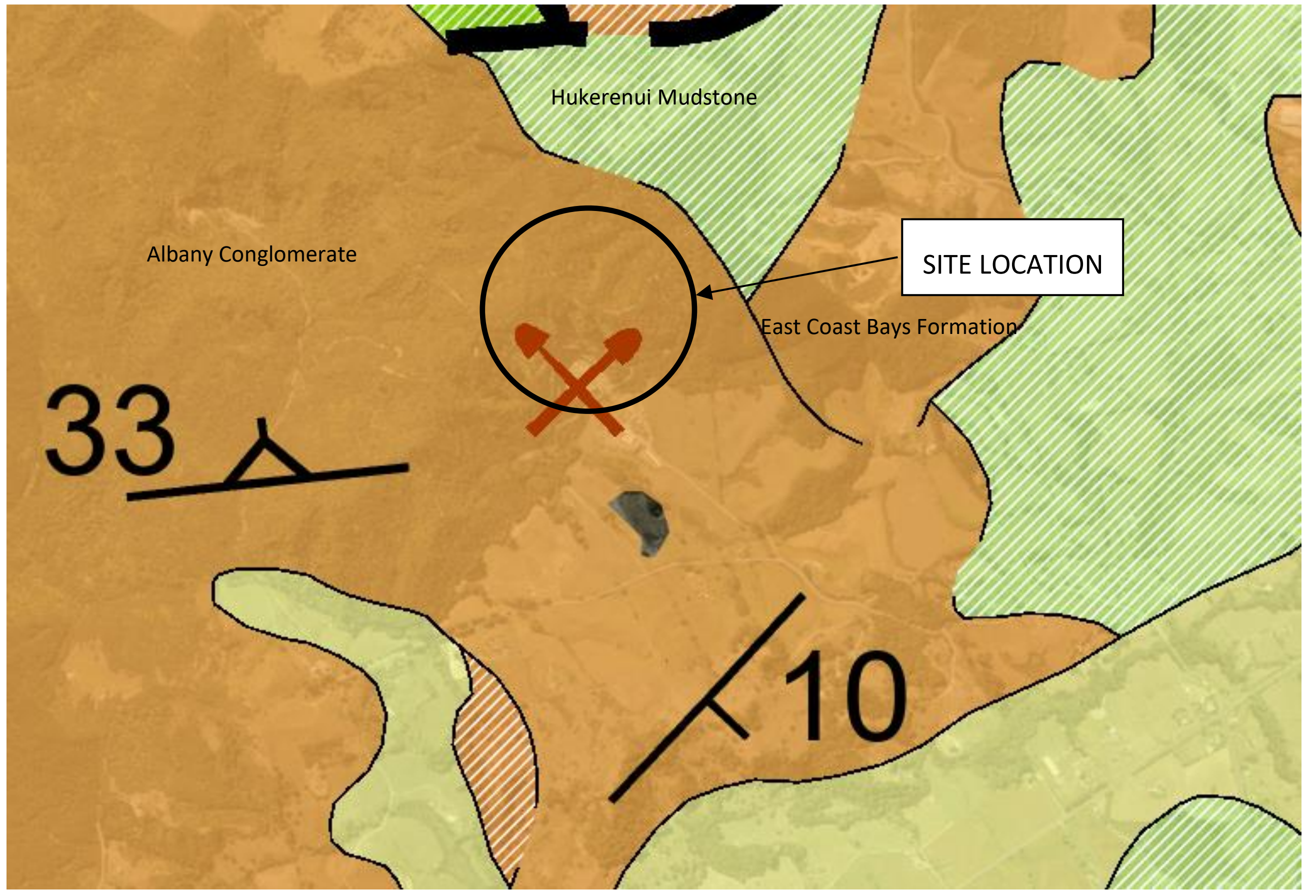

Figure 4: Regional Geology (GNS Science Web Geology Map)

INTERPRETIVE

7 GROUND MODEL

7.1 Geological Units

Our assessment of the distribution of the regional geology is illustrated on ***Figure 5*** below, which is based on our site mapping described in Section 5 above, and our review of available information. We have included in our ground model a mantle of residual soil over the rock, with thicknesses of approximately 5m (localised deeper variations of up to 15m depending on ground profile).

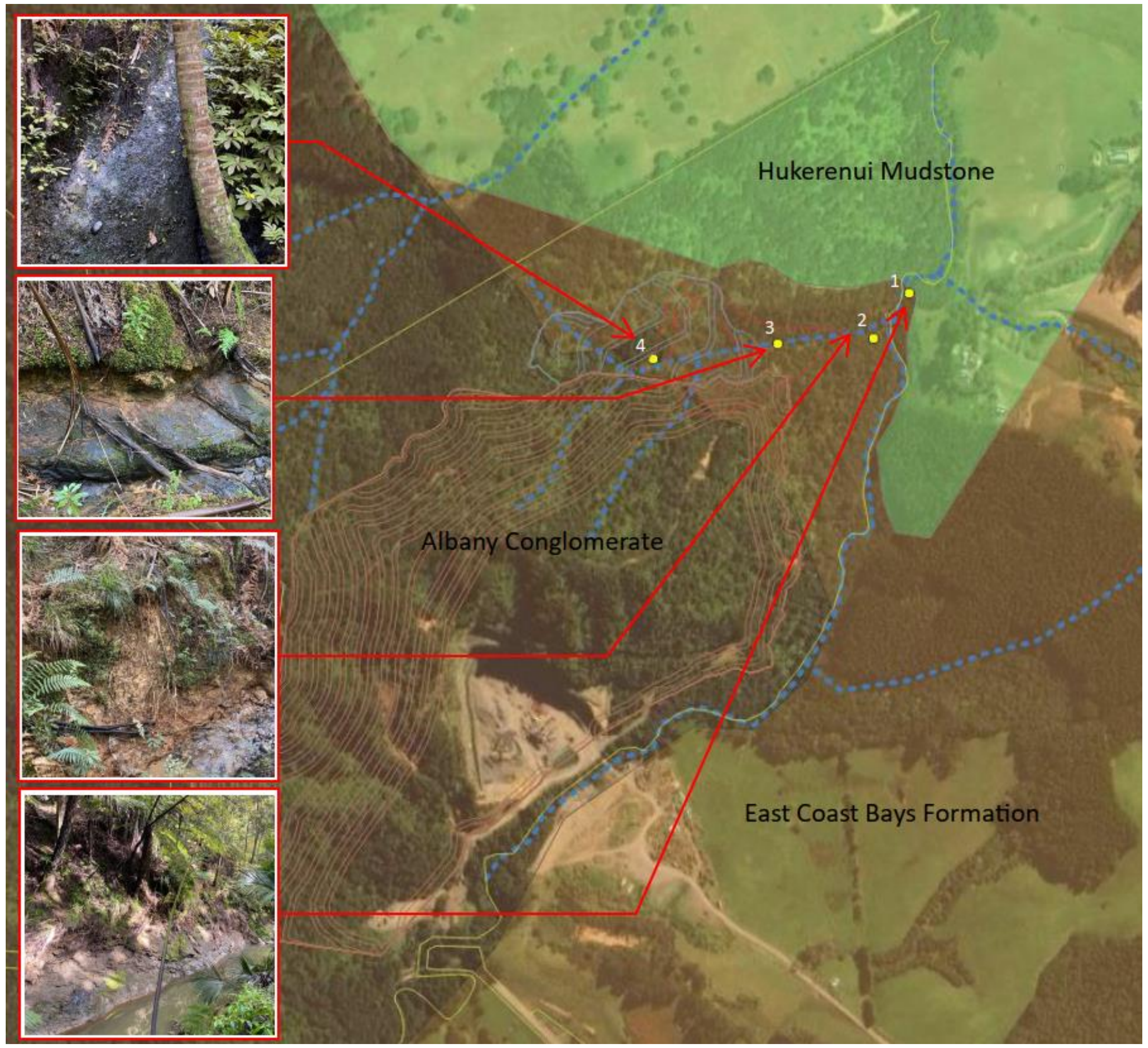

Figure 5: Geological Map

Descriptions of the outcrops encountered at each locality are provided below.

Localities 1 to 3*:* East Coast Bays Formation – massive siltstone and sandstone rock exposures overlain by thin (<1m) gravelly alluvial/outwash deposits.

Locality 4: Albany Conglomerate – gravels (generally up to cobble sized) suspended in a cemented sand/mud matrix.

7.2 Quarry Structural Mapping

CMW undertook a structural geology assessment of the Albany Conglomerate exposed in the existing pit for the Stage 1 report referenced above. This is summarised below:

- Bedding not well defined. Changes in clast size and quantity are the defining feature of the bedding.
- Where bedding measurements achievable, generally dipping at 10° in various directions due to folding.
- Two faults were observed inferred to have formed during deposition prior to consolidation of the sediment.
- Predominant structural defects within quarry walls inferred to be shallow face fallouts due to weathering/erosion of less weathering-resistant rock material.

7.3 Groundwater

Groundwater levels are inferred to be generally 40m below ridgelines, with perched levels of 20 to 30m below existing ground level (BGL). In low-lying areas (i.e., base of pit), groundwater levels are likely similar level to Waitoki Stream levels (approximately 5m below pit floor).

7.4 Recommended Geotechnical Parameters

Geotechnical Design Parameters					
Unit Description	Typical Thickness (m)	γ (kN/m³)	c´ (kPa)	ϕ´ (deg)	S_u (kPa)
Engineered Fill	50-60m	19	5	30	140
Residual Soils/Overburden	5-15m	18.5	5	40	80
Albany Conglomerate	-	23	200	40	2000

The distribution of the geological layers are presented in the slope stability printouts in ***Appendix B***.

8 GEOHAZARDS ASSESSMENT

A full Geotechnical Risk Register including geohazards assessment is presented in ***Appendix A*** and contains references for the assessment methods used. The table below is a summary of critical geohazards to this project and is based on information available to date. The Geotechnical Risk Register is a live document that will be updated as the project progresses. Where relevant, specific assessment details can be found in the respective design calculation packages in the appendices as noted.

Geohazard Assessment Summary

Item	Geotechnical Hazard	Description	Area Affected	Assessment Outcome	Existing Risk of Damage to Land / Structures			Mitigation Measure	Residual Risk of Damage to Land / Structures		
					Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
1	Earthquake	Seismicity	Entire Site	For a design life of >100yrs (IL1): ULS PGA = 0.14g M = 5.9				Not applicable			
		Fault Rupture	Entire Site	Nearest active fault = Waikopua Fault, approximately 60km from the site. Focal depth = ~25km.	1	4	4	No mitigation required	1	4	4
2	Slope Instability / Landslide	Global Instability	Quarry	Target Min. FOS = 1.2, 1.1 and 1.0 for prevailing, worst credible and seismic conditions (low risk parks, bush). Results show that the proposed quarry excavations meet this criteria within the rock excavations. Within the overburden mantle at the very top of the proposed excavations, FOS do not meet this criteria.	4	2	8	Overburden soils should be battered at 45° or shallower.	2	2	4
		Cut / Fill Batter Stability	Quarry fill slopes and cut benches	Refer to target criteria above. For the seismic case in Section C, FOS achieved based on the Newmark Sliding Block approach (a maximum total horizontal displacement of 200mm is considered allowable for low risk scenarios according to Table 6.1 in the Bridge Manual). Static conditions for the fill meet FOS criteria. Proposed cut batters (in rock) 63° or less (and overall wall angle of 45° or less) meet FOS criteria.	1	5	5	To satisfy our assumptions, drainage will be required both underfill and mid-fill as well as bench drains. In addition, the fill must be compacted to engineered standards. Overall fill batter slopes must not exceed 20°. Further details are provided in Section 9.1 below and within the appended Slope Stability memo. Detailed investigation, design and monitoring of the fill site should be carried out as part of quarry works and form part of the resource consent conditions.	1	5	5
4	Settlement	Compressible Soils	Fill areas	Pit fill areas are proposed to be re-forested and no structures on or near these areas.	5	1	5	No mitigation required	5	1	5
		Effects of Dewatering	Entire site	Groundwater drawdown assessment has been carried out by Williamson Water and Land Advisory (WWLA). The outcome of their assessment indicated that the calculated drawdown outside of the excavation area is not enough to cause land settlement in the non-compressible Albany Conglomerate. Given the lack of settlement sensitive receptors (i.e. buildings and infrastructure) the effect of this settlement is classified as negligible.	5	1	5	No mitigation required	5	1	5

Geohazard Assessment Summary											
Item	Geotechnical Hazard	Description	Area Affected	Assessment Outcome	Existing Risk of Damage to Land / Structures			Mitigation Measure	Residual Risk of Damage to Land / Structures		
					Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
5	Erosion	Cut Batters	Quarry	Minimal erosion expected due to rock strength.	2	1	2	Crest drain should be considered to intercept water before entering the quarry, to be located at least 10m back from the crest.	1	1	1
		Fill Batters	Quarry fill batters	Engineered fill batters of up to 20°.	5	1	5	Fill batters will be planted out during re-forestation. Preferential flowpaths must be re-established.	2	1	2
6	Groundwater	Groundwater Impacts	Entire site	Refer to Item 4 above.				Not applicable			
8	Sedimentation	Rockfall, Debris Inundation	Quarry	Generally, localised rock fallouts anticipated to occur at quarry benches due to weathering processes, ranging from gravel-sized to blocks up to 1m^3.	4	3	12	Minimum bench width of 8m required to contain anticipated rockfall. A safety windrow on the quarry floor at least 8m back from the face is required to safeguard the lowest bench level. Quarry faces should be mapped and monitored by a suitability qualified geo-professional such that worker health and safety is not comprised. This may comprise the use of rock bolting / mesh / scaling or other similar rock slope treatment. It is anticipated that the final quarry face should be made safe by the quarry process noted above.	4	2	8
9	Construction Risks	Stockpile locations	Entire site	Stockpiles of unsuitable material/topsoil and/or rubbish may excessively load slopes.	3	4	12	The location of all temporary stockpiles must be approved by the Geotechnical Engineer prior to placement. Where stockpiles cannot be avoided above sloping ground they should be placed over a wide area with the height restricted under the direction of the Geotechnical Engineer.	2	4	8
		Land Instability as a Result of General Works	Entire site	Construction sequencing may lead to unnecessary instability.	3	4	12	Sequencing must be undertaken so that the design limits discussed in Section 9 of the report are not exceeded.	2	4	8
		Winter works	Fill areas	Wetter winter months will reduce fill quality and engineered fill specification may be unable to be achieved.	5	3	15	Fill must be placed to engineered fill specification. If material is too wet to achieve this specification, the use of lime/cement drying techniques could be considered.	3	3	9

9 RECOMMENDATIONS

9.1 Quarry Design Recommendations

The following recommendations are based on the results of our slope stability analysis and the observations made of existing pit performance within our Stage 1 GIR.

9.1.1 Stage 2 Pit Excavations

In order to ensure that the quarry face is left in acceptable safe condition at its end of life, the following should be considered.

- Cut batters in rock should not exceed 63°.
- Cut batters in the residual soil mantle should not exceed 45°.
- Bench height should be no greater than 16m (vertically), and should be at least 8m wide.
- Benches should be designed to drain freely to reduce risk of water infiltration into the rock mass from benches.
- Overall wall angle should not exceed 45°.
- A crest drain at least 10m back from the crest should be constructed to intercept water before entering the quarry.
- A safety windrow (bund) should be constructed on the quarry floor 8m back from the face to safeguard against rockfalls occurring below the lowest bench level.

We anticipate that localised batter instability will be treated as part of quarrying operations. A geo-professional should be engaged to map, analyses and monitor the pit face during quarry works, suitable rockfall protection measures should be carried out where necessary (i.e. rock bolting, mesh, fencing).

9.1.2 Pit Backfill and Spoil Disposal Site

As outlined in the appended stability memo, for the fill batter in the seismic case, it is unfeasible to design out to allow zero seismic displacement. It has been calculated that a seismic displacement of up to 50mm will occur during a UCS seismic event which is considered acceptable displacements for embankments in the NZ Bridge Manual.

To satisfy ongoing stability conditions, the following must be integrated into the design:

- Backfill must be placed in accordance with Section 9.2 below.
- Overall finished slopes should not exceed 20°.
- Drainage must be installed within the fill. These would likely comprise underfill drainage, bench drains, and lateral drains/blankets at specific intervals as the fill is brought up.
- The finished surface should be planted out as soon as practicably possible to reduce risk of erosion. Overland flows should be reinstated in a controlled manner (e.g., designing preferential drainage paths) to limit surface infiltration.
- Due to the anticipated displacement during a seismic event, it is recommended that an assessment be made after such events to ensure that any induced cracking that may lead to water infiltration is remediated suitably.
- The spoil disposal site should be investigated following bulk excavation prior to fill placement to carry out a detailed design of the fill site. Suitable instrumentation and monitoring should be carried out during the fill placement, including groundwater pressures and slope monitoring.
- The investigation, design and monitoring of the fill disposal area should form part of the Resource Consent requirements.

9.2 Earthworks

All earthwork activities must be carried out in general accordance with the requirements of NZS 4431:2022[2] under the guidance of a Chartered Professional Geotechnical Engineer. Given the steep nature of the proposed fill disposal area, this fill will need to be placed as a very stiff/dense engineered fill.

A summary of the key project specific construction risks, as presented in the Project Risk Register in ***Appendix A***, are as follows:

Key Construction Risks	
Item	**Mitigation Measures**
Stockpile Locations	Locations of any stockpiles must be approved by the Geotechnical Engineer prior to placement
Subgrade Preparation	Any uncontrolled fills, loose material, topsoil/organics should be removed/undercut prior to placement of fills
Land Instability During Works	Refer to Item 9 of Project Risk Register

The temporary stability of the works is the responsibility of the main contractor. All works are to be completed in accordance with the requirements of current safety legislation and WorkSafe NZ.

Earthfill must be placed, spread, and compacted in controlled 250mm to 300mm thick (loose) lifts under the direction of a geotechnical engineer. The fill may comprise either granular or cohesive material subject to being free of any organic material and having no particles greater than 150mm diameter.

Most of the proposed cut material, including the natural and existing fill materials should be suitable for reuse as Engineer Certified Fill. Soil textures and moisture contents will however vary widely, and careful management, conditioning and compaction control will be required.

All earth fill must be placed to ensure adequate knitting of successive fill lifts by ripping any natural subgrade or fill surfaces that have become dry prior to placing the following fill lift.

We consider the following specification appropriate to verify engineered fill placement. Achieving this standard will require the fills to be placed to standards normally used for subdivision purposes. In clay fills, moisture conditioning is critical to achieving these standards and typically such fills are not able to be placed outside the normal earthworks season limits (October to May), or sometimes not even within these dates without the use of lime/cement drying techniques, depending on weather conditions and the skill of the contractors.

INTERPRETIVE

[2] Standards New Zealand (2022) Engineered fill construction for lightweight structures, NZS 4431:2022

Summary of Earthfill Testing Requirements			
Fill Type	**Test Method**	**Frequency***	**Compliance Criteria**
Granular	Maximum Dry Density Scala Penetrometer	New material type 1 x 1m test/1,500m³	95% MDD 4 blows per 100mm
Cohesive	Vane Shear Strength	4 tests/1,500m³	Min. average 140kPa over 10 tests, min. single value 110kPa
	Air Voids	1 test/1,500m³	Min. average 10% over 10 tests, max. single value 12%

9.3 Haul Road

It is anticipated that re-construction of the haul road from Stage 1 pit to A-Pit will involve cuts and fills. These earthworks should be undertaken in accordance with Section 9.2 above. If proposed fill depths are greater than 1m thickness, a specific slope stability assessment may be required.

10 FURTHER WORK

The following further work is recommended to be undertaken:

- Detailed investigations and design of the fill disposal area.
- Detailed rock mass mapping and analysis of pit exposures during excavation. Design of rock fall protection measures if required.
- Earthworks monitoring, testing and instrumentation of the fill disposal area.

This further work is reflected in the conditions (conditions 16-18) proffered by the Applicant requiring a specific geotechnical investigation of A-Pit including detailed design of the fill disposal area prior to fill disposal activities commencing for A-Pit.

Based on the recommendations as set out in Section 9 of our report, global stability factors of safety should be targeted to confirm compliance, including assessment of the different stages of filling throughout its lifetime.

11 CLOSURE

Additional important information regarding the use of your CMW report is provided in the '*Using your CMW Report*' document attached to this report.

This report has been prepared for use by Kings Quarry Limited in relation to the Kings Quarry Stage 2, Pebble Brook Road, Wainui project in accordance with the scope, proposed uses and limitations described in the report. Should you have further questions relating to the use of your report please do not hesitate to contact us.

Where a party other than Kings Quarry Limited seeks to rely upon or otherwise use this report, the consent of CMW should be sought prior to any such use. CMW can then advise whether the report and its contents are suitable for the intended use by the other party.

USING YOUR CMW GEOTECHNICAL REPORT

Geotechnical reporting relies on interpretation of facts and collected information using experience, professional judgement, and opinion. As such it generally has a level of uncertainty attached to it, which is often far less exact than other engineering design disciplines. The notes below provide general advice on what can be reasonably expected from your report and the inherent limitations of a geotechnical report.

Preparation of your report

Your geotechnical report has been written for your use on your project. The contents of your report may not meet the needs of others who may have different objectives or requirements. The report has been prepared using generally accepted Geotechnical Engineering and Engineering Geology practices and procedures. The opinions and conclusions reached in your report are made in accordance with these accepted principles. Specific items of geotechnical or geological importance are highlighted in the report.

In producing your report, we have relied on the information which is referenced or summarised in the report. If further information becomes available or the nature of your project changes, then the findings in this report may no longer be appropriate. In such cases the report must be reviewed, and any necessary changes must be made by us.

Your geotechnical report is based on your project's requirements

Your geotechnical report has been developed based on your specific project requirements and only applies to the site in this report. Project requirements could include the type of works being undertaken; project locality, size and configuration; the location of any structures on or around the site; the presence of underground utilities; proposed design methodology; the duration or design life of the works; and construction method and/or sequencing.

The information or advice in your geotechnical report should not be applied to any other project given the intrinsic differences between different projects and site locations. Similarly geotechnical information, data and conclusions from other sites and projects may not be relevant or appropriate for your project.

Interpretation of geotechnical data

Site investigations identify subsurface conditions at discrete locations. Additional geotechnical information (e.g. literature and external data source review, laboratory testing etc) are interpreted by Geologists or Engineers to provide an opinion about a site specific ground models, their likely impact on the proposed development and recommended actions. Actual conditions may differ from those inferred to exist due to the variability of geological environments. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. Interpretation of factual data can be influenced by design and/or construction methods. Where these methods change review of the interpretation in the report may be required.

Subsurface conditions can change

Subsurface conditions are created by natural processes and then can be altered anthropically or over time. For example, groundwater levels can vary with time or activities adjacent to your site, fill may be placed on a site, or the consistency of near surface conditions might be susceptible to seasonal changes. The report is based on conditions which existed at the time of investigation. It is important to confirm whether conditions may have changed, particularly when large periods of time have elapsed since the investigations were performed.

Interpretation and use by other design professionals

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a geotechnical report. To help avoid misinterpretations, it is important to retain the assistance of CMW to work with other project design professionals who are affected by the contents of your report. CMW staff can explain the report implications to design professionals and then review design plans and specifications to see that they have correctly incorporated the findings of this report.

Your report's recommendations require confirmation during construction

Your report is based on site conditions as revealed through selective point sampling. Engineering judgement is then applied to assess how indicative of actual conditions throughout an area the point sampling might be. Any assumptions made cannot be substantiated until construction is complete. For this reason, you should retain geotechnical services throughout the construction stage, to identify variances from previous assumption, conduct additional tests if required and recommend solutions to problems encountered on site.

A Geotechnical Engineer, who is fully familiar with the site and the background information, can assess whether the report's recommendations remain valid and whether changes should be considered as the project develops. An unfamiliar party using this report increases the risk that the report will be misinterpreted.

Environmental Matters Are Not Covered

Unless specifically discussed in your report environmental matters are not covered by a CMW Geotechnical Report. Environmental matters might include the level of contaminants present of the site covered by this report, potential uses or treatment of contaminated materials or the disposal of contaminated materials. These matters can be complex and are often governed by specific legislation.

The personnel, equipment, and techniques used to perform an environmental study can differ significantly from those used in this report. For that reason, our report does not provide environmental recommendations. Unanticipated subsurface environmental problems can have large consequences for your site. If you have not obtained your own environmental information about the project site, ask your CMW contact about how to find environmental risk-management guidance.

Appendix A: Geotechnical Risk Register

CMW Geosciences
Great People | Practical Solutions

CLIENT:	Kings Quarry Limited	DESIGNER:	HN
PROJECT:	Kings Quarry Stage 2 Wainui	CHECKED:	CR
		JOB NO:	AKL2023-0190
TITLE:	GEOTECHNICAL RISK REGISTER	DATE:	18/10/2023
		ISSUED FOR:	AKL2023-0190AB

Item	Geotechnical Hazard	Description	Relevant Standards*/Guidance Documents	Area Affected	Assessment Outcome	Existing Risk of Damage to Land / Structures			Mitigation Measure	Residual Risk of Damage to Land / Structures		
						Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
1	Earthquake	Seismicity	NZGS and MBIE (2021) Earthquake Geotechnical Engineering Practice in New Zealand, Module 1: Overview of the Guidelines	Entire Site	For a design life of >100yrs (IL1): ULS PGA = 0.14g M = 5.9				Not applicable			
		Fault Rupture	GNS Science, New Zealand Active Faults Database, retrieved from https://data.gns.cri.nz/af/	Entire Site	Nearest active fault = Waikopua Fault, approximately 60km from the site. Focal depth = 25km.	1	4	4	No mitigation required	1	4	4
		Liquefaction	MfE and MBIE (2017), Planning and engineering guidance for potentially liquefaction-prone land NZGS and MBIE (2021) Earthquake Geotechnical Engineering Practice in NZ, Module 1: Overview of the Guidelines NZGS and MBIE (2021) Earthquake Geotechnical Engineering Practice in NZ, Module 2: Geotechnical Investigations for Earthquake Engineering NZGS and MBIE (2021) Earthquake Geotechnical Engineering Practice in NZ, Module 3: Identification, assessment and mitigation of liquefaction hazards	Entire Site	Excavations will be undertaken in rock and therefore liquefaction is considered to be of very low risk. Extensive drainage within fills is proposed.	1	5	5	No mitigation required	1	5	5
2	Slope Instability / Landslide	Global Instability	Auckland Council (2023), The Auckland Code of Practice for Land Development and Subdivision, Chapter 2: Earthworks and Geotechnical, Version 2	Quarry	Target Min. FOS = 1.2, 1.1 and 1.0 for prevailing, worst credible and seismic conditions (low risk parks, bush). Results show that the proposed quarry excavations meet this criteria within the rock excavations. Within the overburden mantle at the very top of the proposed excavations, FOS do not meet this criteria.	4	2	8	Overburden soils should be battered at 45° or shallower.	2	2	4
		Cut / Fill Batter Stability	Auckland Council (2023), The Auckland Code of Practice for Land Development and Subdivision, Chapter 2: Earthworks and Geotechnical, Version 2	Quarry fill slopes and cut benches	Refer to target criteria above. For the seismic case in Section C, FOS achieved based on the Newmark Sliding Block approach (a maximum total horizontal displacement of 200mm is considered allowable for low risk scenarios according to Table 6.1 in the Bridge Manual). Static conditions for the fill meet FOS criteria. Proposed cut batters (in rock) 63° or less (and overall wall angle of 45° or less) meet FOS criteria.	1	5	5	To satisfy our assumptions, drainage will be required both underfill and mid-fill as well as bench drains. In addition, the fill must be compacted to engineered standards. Overall fill batter slopes must not exceed 20°. Further details are provided in Section 9.1 below and within the appended Slope Stability memo. Detailed investigation, design and monitoring of the fill site should be carried out as part of quarry works and form part of the resource consent conditions.	1	5	5
		Stream bank instability and erosion	Auckland Council (2023), The Auckland Code of Practice for Land Development and Subdivision, Chapter 2: Earthworks and Geotechnical, Version 2	Slopes adjacent to Waitoki Stream	Gully fills are not proposed to be within the vicinity of the stream and therefore prevailing stability conditions are anticipated to remain unchanged.	1	3	3	No mitigation required	1	3	3
3	Problematic Soils	Rockmass Exposure	N/A	Quarry	Rock with open defects have high rates of permeabilities and are susceptible to infiltration, however, the lack of extensive defects observed during the Stage 1 structural mapping indicates this to be of low risk.	5	1	5	No mitigation required	5	1	5
		Expansive Soils	MBIE (2021) Acceptable Solutions and Verification Methods For New Zealand Building Code Clause B1 Structure, Amendment 20 NZS 3604:2011	Fills/residual soils	Although the quarry fill material will be expansive, the area will be re-forested and no structures are to be located here.	5	1	5	No mitigation required	5	1	5
4	Settlement	Compressible Soils	Mesri G, Kwan Lo D, Feng T (1994) Settlement of Embankments on Soft Clays, Chapter of Vertical and Horizontal Deformation of foundations and Embankments, A.T.Yeung & G.Y.Felio, ASCE, New York, 8-56	Fill areas	Pit fill areas are proposed to be re-forested and no structures on or near these areas.	5	1	5	No mitigation required	5	1	5
		Effects of Dewatering		Entire site	Groundwater drawdown assessment has been carried out by Williamson Water and Land Advisory (WWLA). The outcome of their assessment indicated that the calculated drawdown outside of the excavation area is not enough to cause land settlement in the non-compressible Albany Conglomerate. Given the lack of settlement sensitive receptors (i.e. buildings and infrastructure) the effect of this settlement is classified as negligible.	5	1	5	No mitigation required	5	1	5
5	Erosion	Cut Batters	N/A	Quarry	Minimal erosion expected due to rock strength.	2	1	2	Crest drain should be constructed to intercept water before entering the quarry, to be located at least 10m back from the crest.	1	1	1
		Fill Batters	N/A	Quarry fill batters	Engineered fill batters of up to 20°.	5	1	5	Fill batters will be planted out during re-forestation. Preferential flowpaths must be re-established.	2	1	2
6	Groundwater	Groundwater Impacts		Entire site	Refer to Item 4 above.				Not applicable			
7	Geothermal activity	Formation of geysers, hot springs, fumaroles, mud pools	Auckland Council GeoMaps (Geothermal overlay)	Not applicable	No geothermal zones mapped on or near area.				Not applicable			
8	Sedimentation	Rockfall, Debris Inundation	MBIE & NZGS (2016) Rockfall: Design considerations for passive protection structures	Quarry	Localised rock fallouts anticipated to occur at quarry benches due to weathering processes, ranging from gravel-sized to blocks up to 1m3.	4	3	12	Minimum bench width of 8m required to contain anticipated rockfall. A safety windrow on the quarry floor at least 8m back from the face is required to safeguard the lowest bench level. Quarry faces should be mapped and monitored by a suitability qualified geo-professional such that worker health and safety is not comprised. This may comprise the use of rock bolting / mesh / scaling or other similar rock slope treatment. It is anticipated that the final quarry face should be made safe by the quarry process noted above.	4	2	8
9	Flooding	Flooding, inundation	Auckland Council GIS	Quarry floors	Flooding risk to be assessed by others. This should consider the proximity to the stream and proposed floor levels of the quarry relative to anticipated flooding levels.				Not applicable			
9	Construction Risks	Stockpile locations	N/A	Entire site	Stockpiles of unsuitable material/topsoil and/or rubbish may excessively load slopes.	3	4	12	The location of all temporary stockpiles must be approved by the Geotechnical Engineer prior to placement. Where stockpiles cannot be avoided above sloping ground they should be placed over a wide area with the height restricted under the direction of the Geotechnical Engineer.	2	4	8
		Land Instability as a Result of General Works	Auckland Council (2023), The Auckland Code of Practice for Land Development and Subdivision, Chapter 2: Earthworks and Geotechnical, Version 2	Entire site	Construction sequencing may lead to unnecessary instability.	3	4	12	Sequencing must be undertaken so that the design limits discussed in Section 9 of the report are not exceeded.	2	4	8
		Winter works		Fill areas	Wetter winter months will reduce fill quality and engineered fill specification may be unable to be achieved.	5	3	15	Fill must be placed to engineered fill specification. If material is too wet to achieve this specification, the use of lime/cement drying techniques could be considered.	3	3	9
10	Safety in Design	Temporary batter slope	N/A	Quarry	Risk of temporary batter collapse due to inappropriate dimensions (including rock spire).	3	4	12	Design limits discussed in Section 9 of the report should not be exceeded.	2	4	8

Appendix B: Slope Stability Design Memo

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SLOPE STABILITY			
Project:	Kings Quarry Stage 2	**Job Number:**	AKL2023-0190
Site Address:	Pebble Brook Road, Wainui	**Client:**	Kings Quarry Limited
Prepared by:	Henry Nagel	**Reviewed by:**	Chris Ritchie

1 DESIGN CRITERIA

The stability of cut batters and fill embankments under a range of design conditions is expressed in terms of a factor of safety, which is defined as the ratio of forces resisting failure to the forces causing failure. The following performance standards are recommended for slope stability assessment:

Slope Stability Factor of Safety Criteria (low risk parks, bush)	
Condition	**Required Factor of Safety**
Normal Groundwater Condition	1.2
Extreme (worst credible) groundwater condition	1.1
Seismic condition for ULS PGA (calculated as 0.14g)	1.0
Note*: Factor of safety < 1.0 acceptable where displacement-based approach is adopted and displacements are acceptable.	

2 DESIGN PARAMETERS

Geotechnical Design Parameters					
Unit Description	**Typical Thickness (m)**	**γ (kN/m³)**	**c´ (kPa)**	**ϕ´ (deg)**	**S_u (kPa)**
Engineered Fill	50-60m	19	30	5	140
Residual Soils/Overburden	5-15m	18.5	5	40	80
Albany Conglomerate	-	23	200	40	2000

3 METHODOLOGY

- Slope stability analyses were undertaken using the Morgenstern-Price method of slices under translational failure mechanisms using the proprietary software SLIDE Version 6.
- Seismic displacements were estimated based on a Newmark Sliding Block approach using 50th percentile correlations published in Ambraseys & Srbulov[1], Jibson[2]/Martin & Qui[3] for non-liquefied soil conditions. For the ULS event, an earthquake Magnitude 5.9 was adopted. A 60km fault source distance and 25km focal depth (Waikopua Fault) was also adopted for the Ambraseys & Srbulov correlations.

4 INITIAL RESULTS

Slope stability analyses were undertaken on Sections A, B and C (see ***Figure 1***).

Results are appended to this memo and are summarised below for the proposed landform (including pit excavations and backfill conditions).

[1] Ambraseys, N. and Srbulov, M. (1995) Earthquake induced displacement of slopes, Journal of Soil Dynamics and Earthquake Engineering, Vol 14

[2] Jibson, R.W., (2007) Regression models for estimating coseismic landslide displacement, Journal of Engineering Geology, Vol 91

[3] Martin, G.R. and Qui, P. (1994) A comparative study of predictive methods for liquefaction induced embankment displacements, *5th U.S.-Japan Workshop on Earthquake Resistant Design of Lifeline Facilities*. NCEER-94-0026

Slope Stability Analysis Results				
Section	Slope Stability Minimum Factor of Safety			ULS Displacement (mm)
	Prevailing	Transient	Seismic	
A-A	1.8	1.5	2.3	-
B-B (Pit)	1.2	1.2	1.9	-
B-B (Fill)	1.2	1.2	1.5	-
C-C (Pit)	1.2	1.2	1.2	-
C-C (Fill)	1.5	1.3	1.0	50mm

Results show that acceptable factors of safety are achieved under the assumption that up to 50mm of seismic displacement will occur within the fill for Section C.

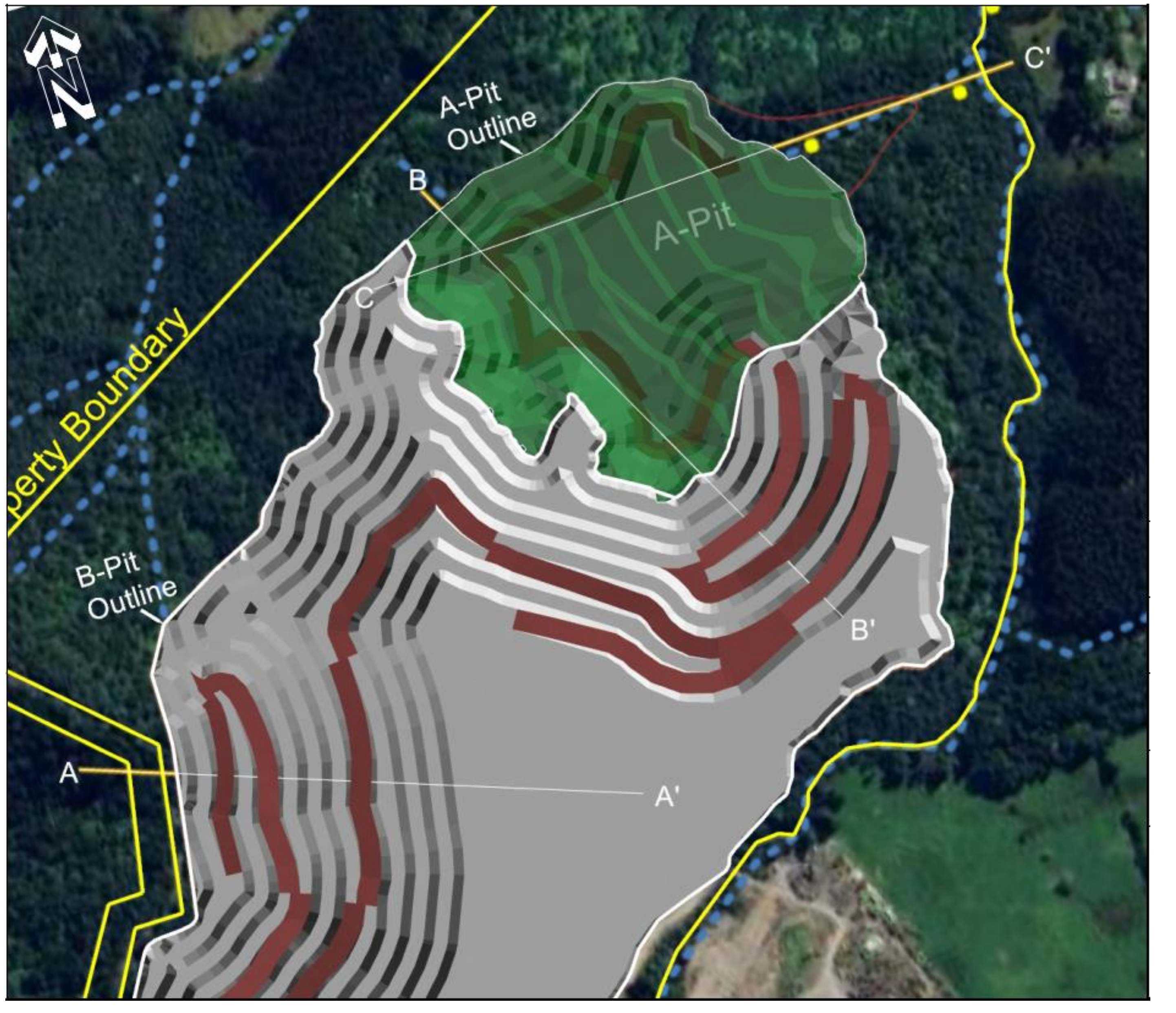
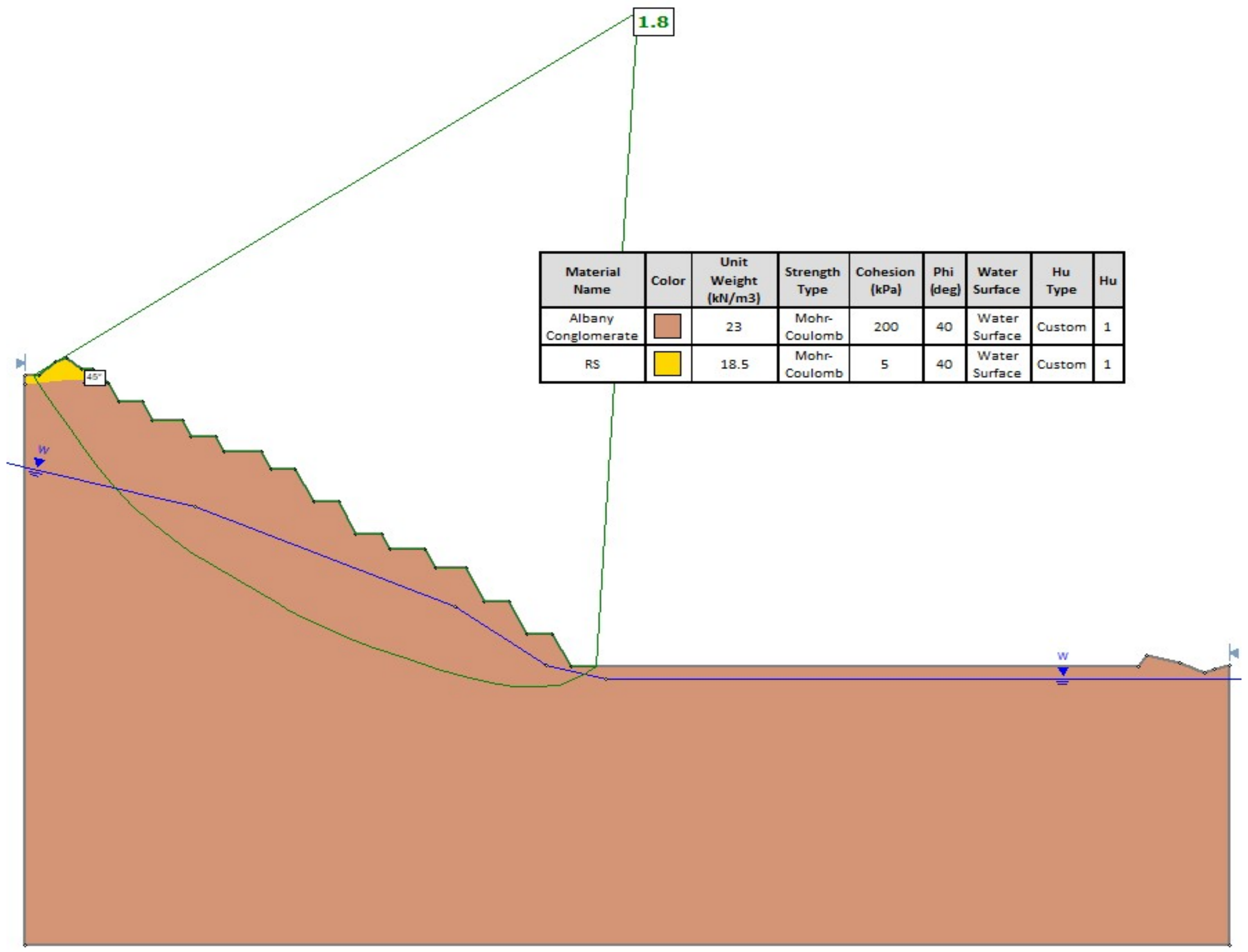
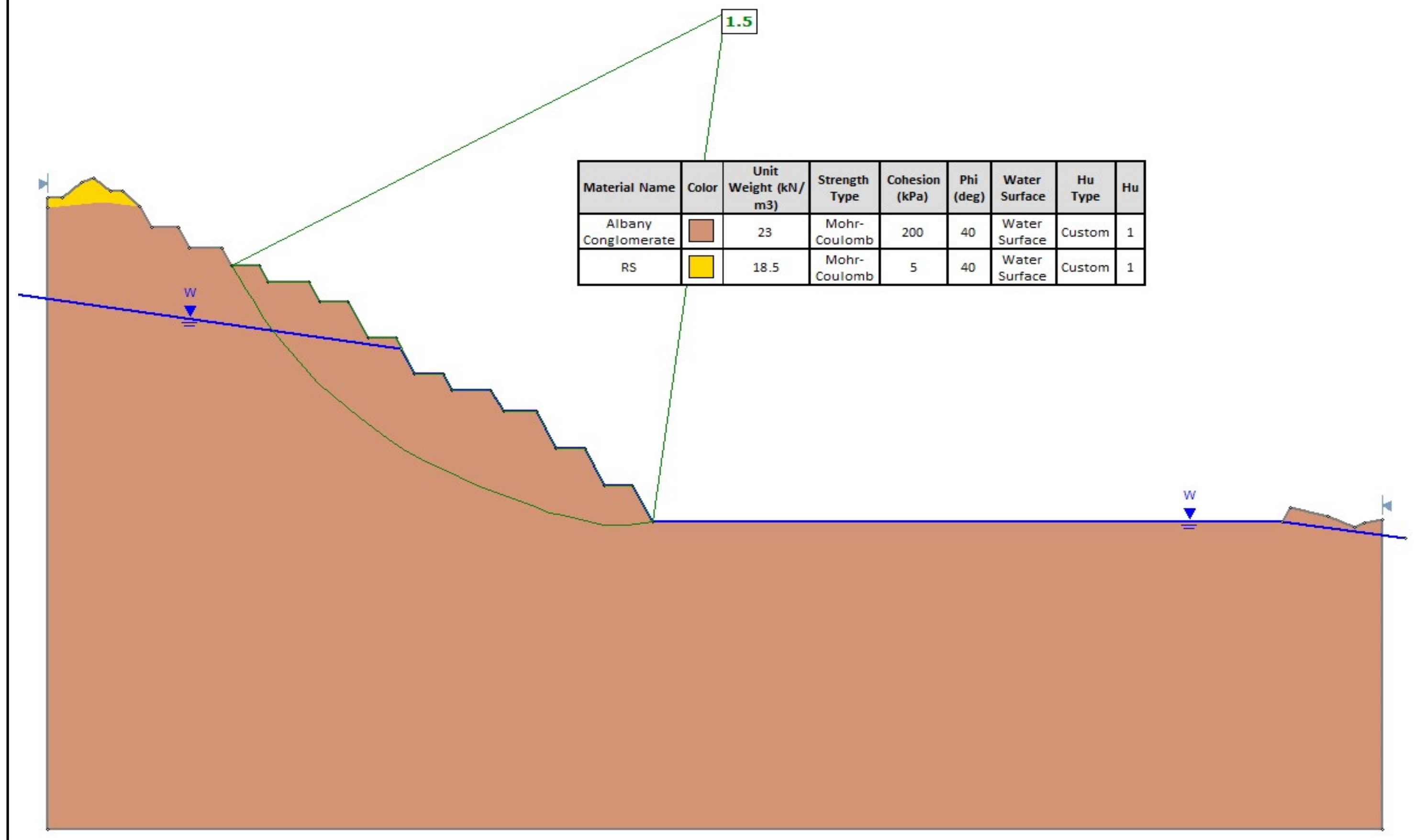


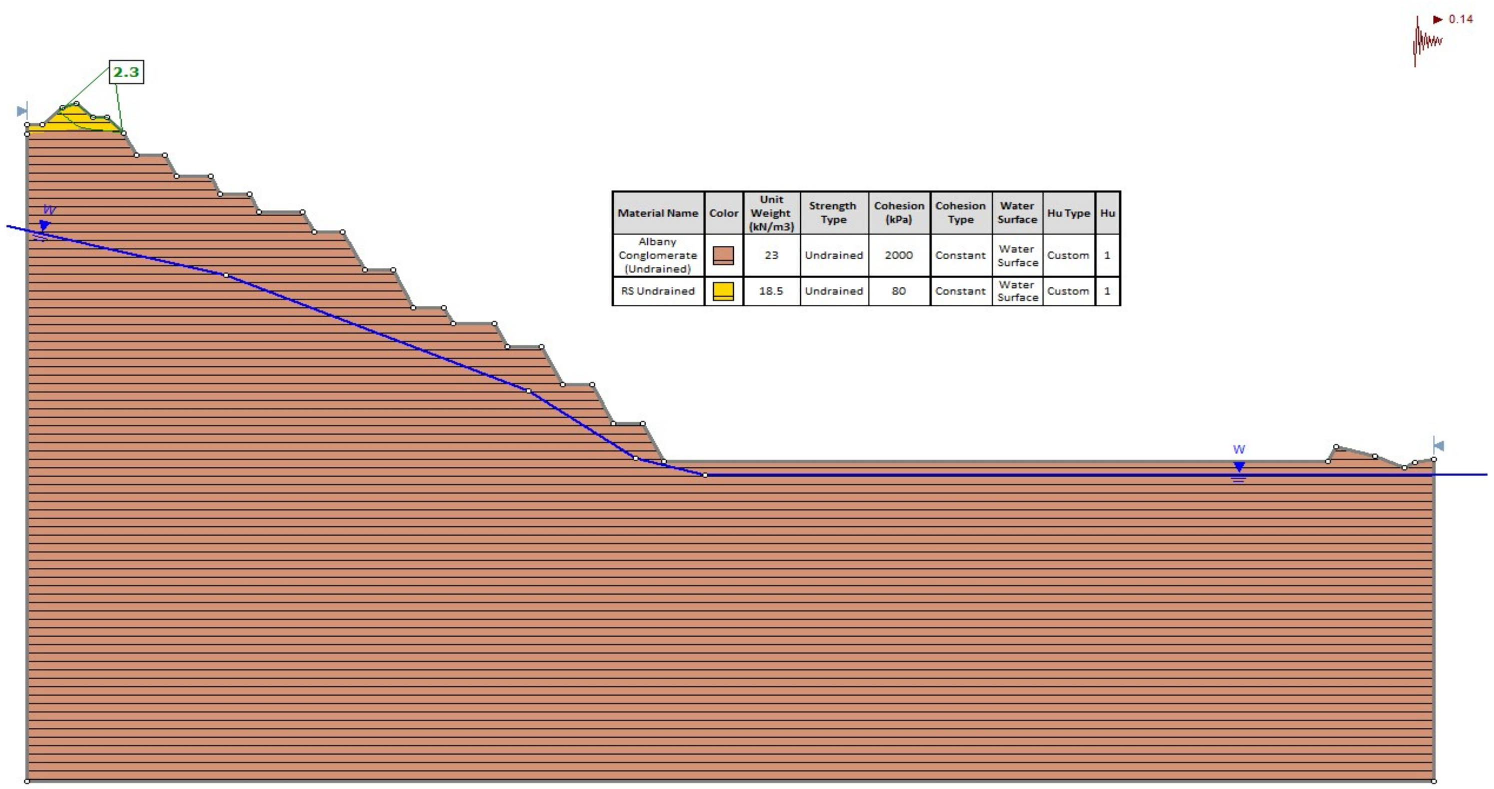
Figure 1: Slope Stability Sections



Proposed Section A - Normal Groundwater Conditions



Proposed Section A - High Groundwater Conditions



Proposed Section A - Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Albany Conglomerate		23	Mohr-Coulomb	200	40	Water Surface	Custom	1
RS		18.5	Mohr-Coulomb	5	40	Water Surface	Custom	1

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Cohesion Type	Water Surface	Hu Type	Hu
Albany Conglomerate (Undrained)		23	Undrained	2000	Constant	Water Surface	Custom	1
RS Undrained		18.5	Undrained	80	Constant	Water Surface	Custom	1

Parameters

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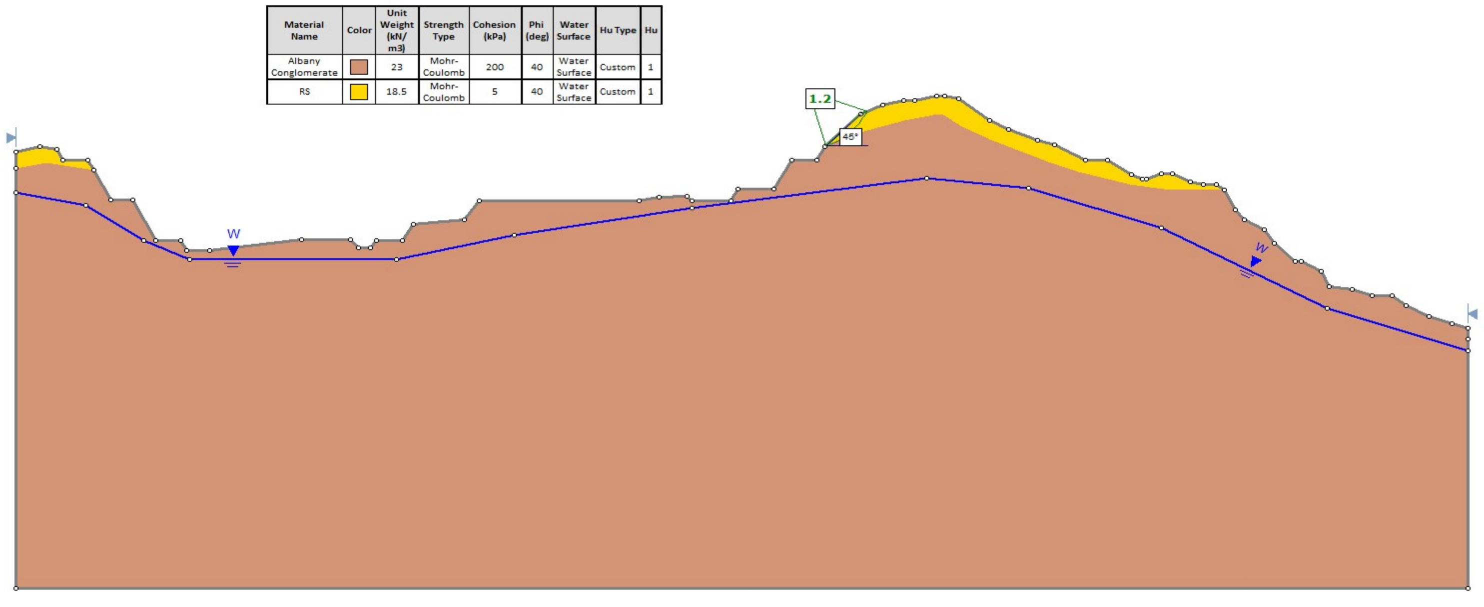
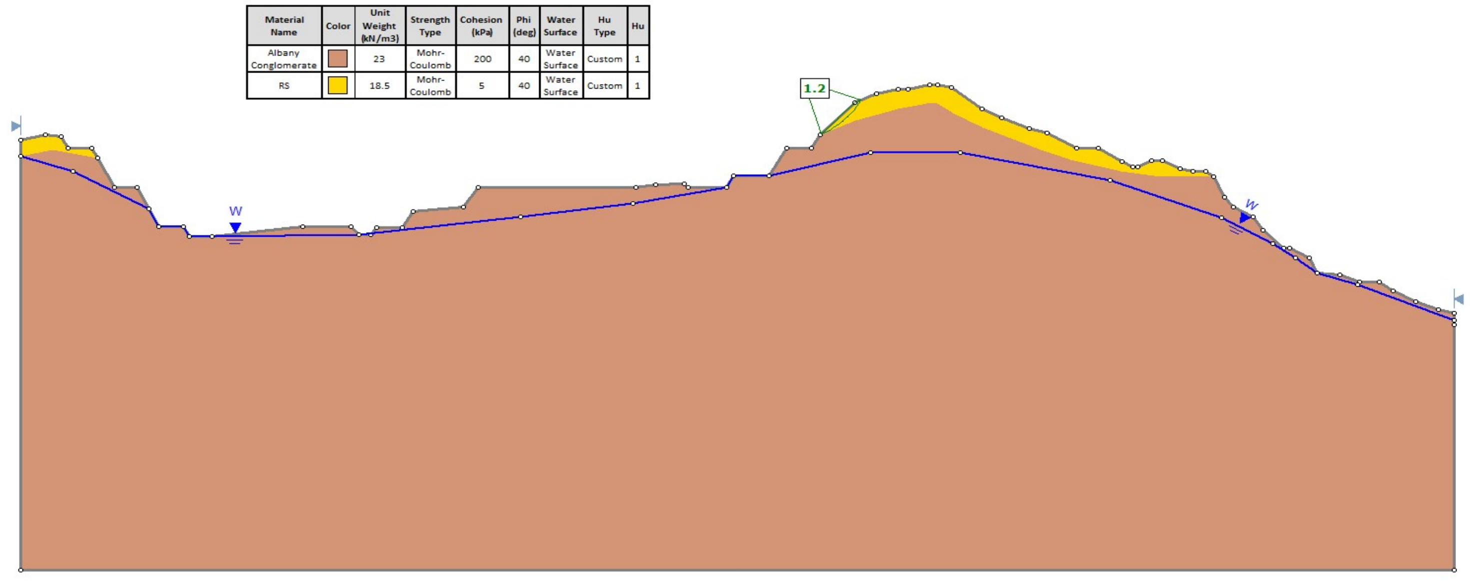
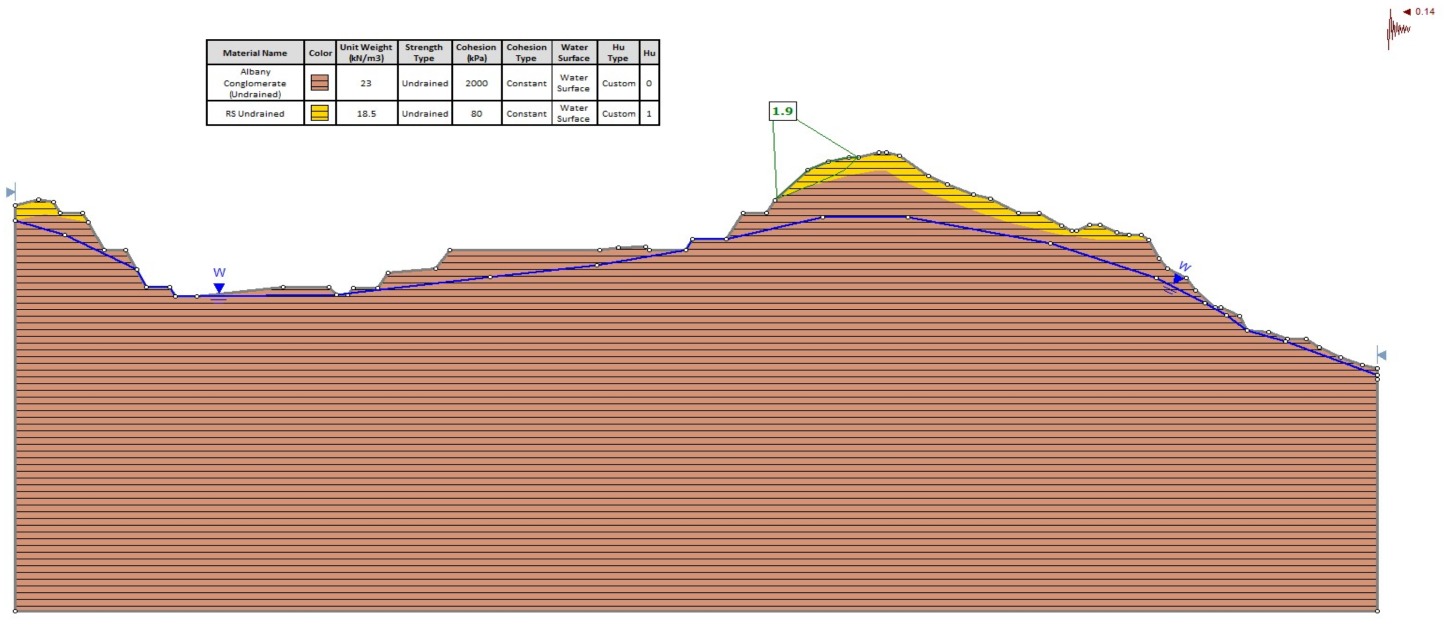
	Project Kings Quarry, Wainui	*Analysis* Cuckoo	*Project No.* AKL2023-0190
	Title Section A - Proposed	*Date* 10/10/2023	*Drawing* STAB 01



Proposed Section B (Pit) - Normal Groundwater Conditions



Proposed Section B (Pit) - High Groundwater Conditions



Proposed Section B (Pit) - Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Albany Conglomerate		23	Mohr-Coulomb	200	40	Water Surface	Custom	1
RS		18.5	Mohr-Coulomb	5	40	Water Surface	Custom	1

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Cohesion Type	Water Surface	Hu Type	Hu
Albany Conglomerate (Undrained)		23	Undrained	2000	Constant	Water Surface	Custom	1
RS Undrained		18.5	Undrained	80	Constant	Water Surface	Custom	1

Parameters

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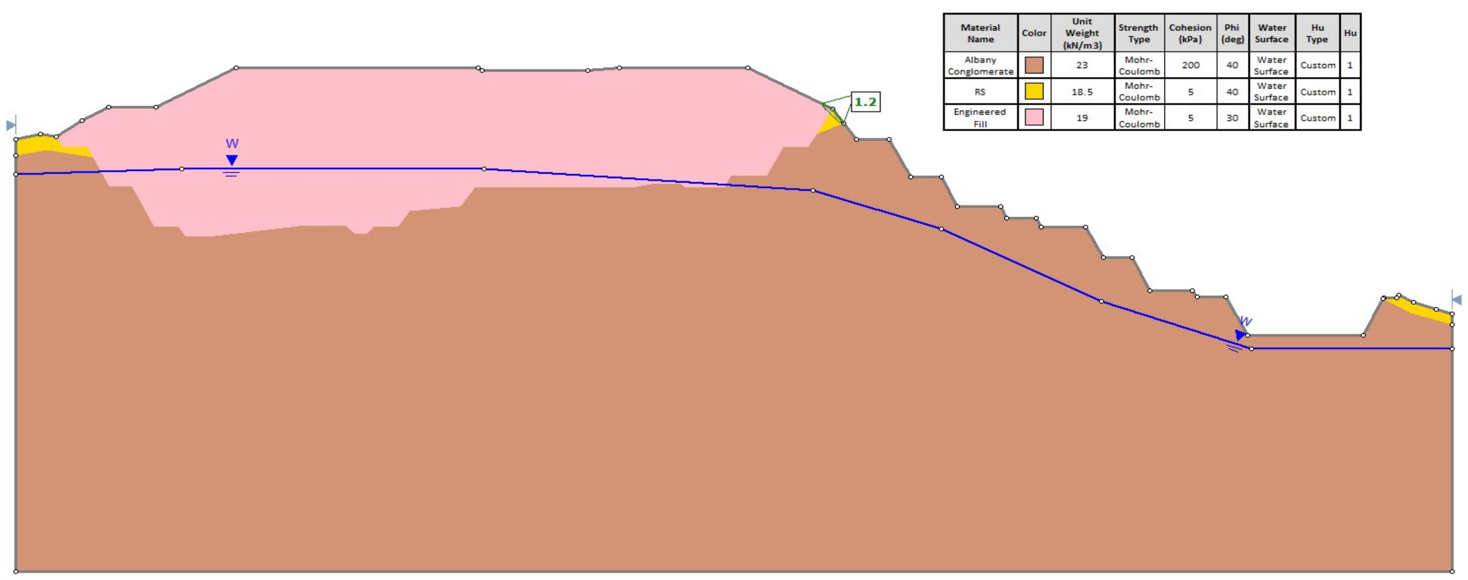
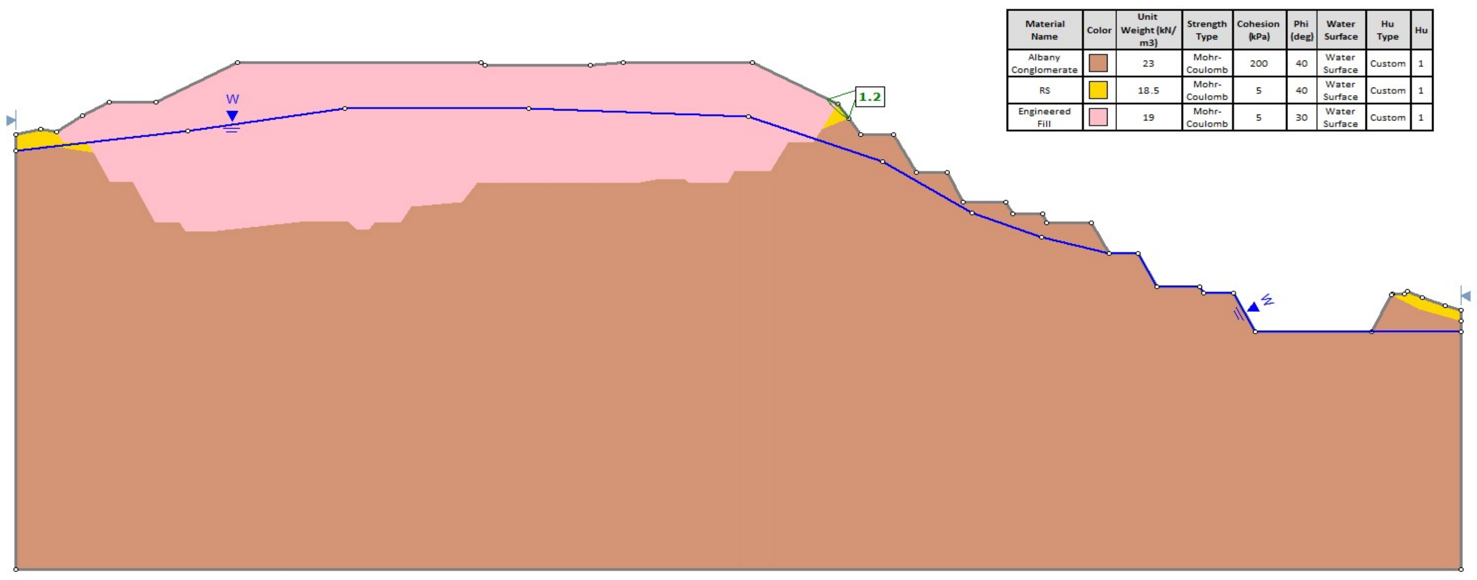
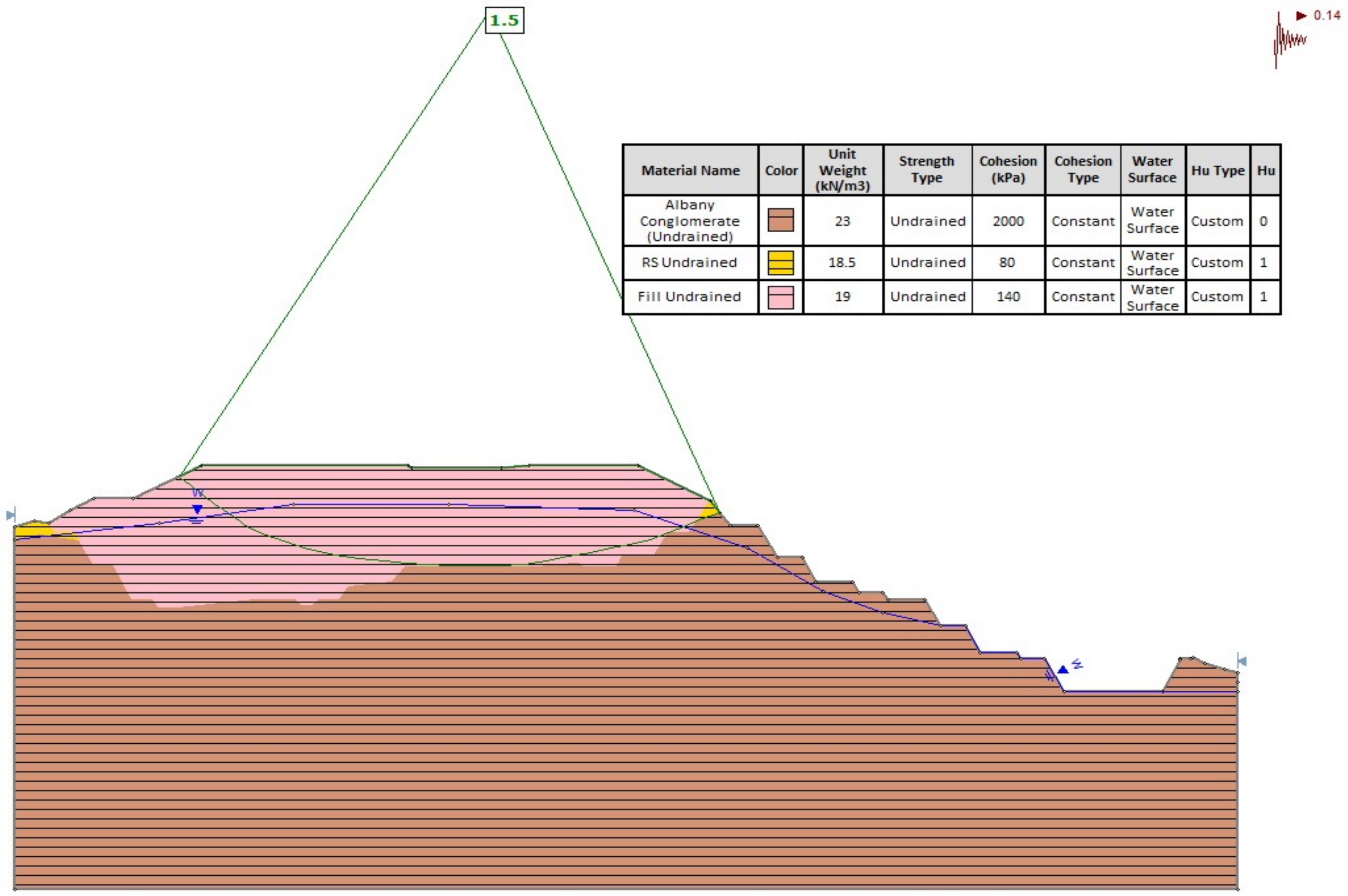
	Project Kings Quarry, Wainui	*Analysis* Cuckoo	*Project No.* AKL2023-0190
	Title Section B - Proposed (Pit Excavation)	*Date* 10/10/2023	*Drawing* STAB 02



Proposed Section B (Fill) - Normal Groundwater Conditions



Proposed Section B (Fill) - High Groundwater Conditions



Proposed Section B (Fill) - Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Albany Conglomerate		23	Mohr-Coulomb	200	40	Water Surface	Custom	1
RS		18.5	Mohr-Coulomb	5	40	Water Surface	Custom	1
Engineered Fill		19	Mohr-Coulomb	5	30	Water Surface	Custom	1

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Cohesion Type	Water Surface	Hu Type	Hu
Albany Conglomerate (Undrained)		23	Undrained	2000	Constant	Water Surface	Custom	0
RS Undrained		18.5	Undrained	80	Constant	Water Surface	Custom	1
Fill Undrained		19	Undrained	140	Constant	Water Surface	Custom	1

Parameters

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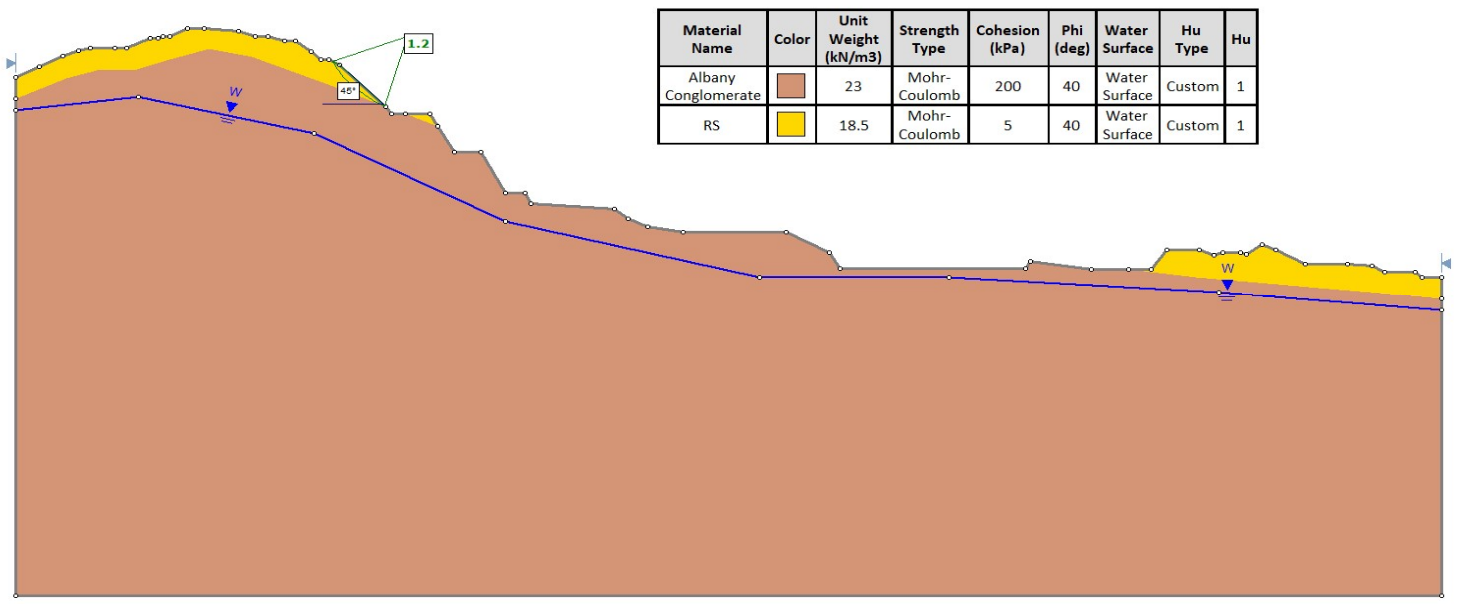
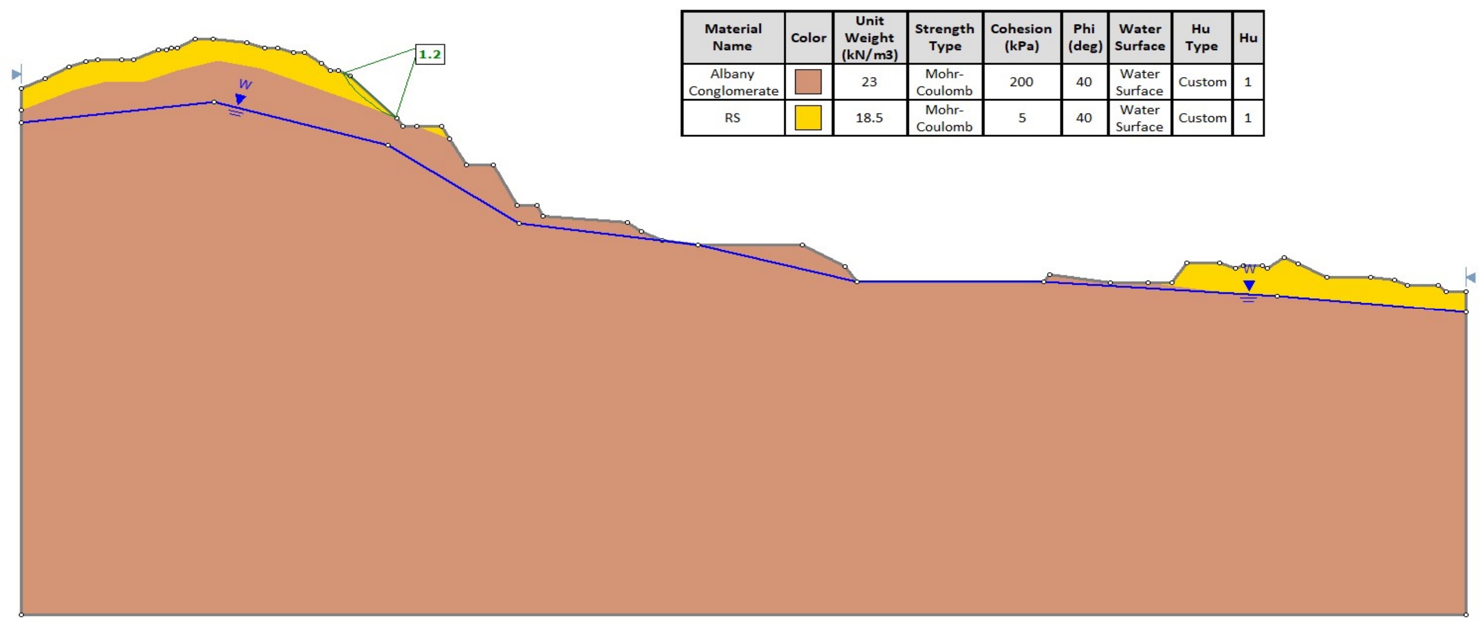
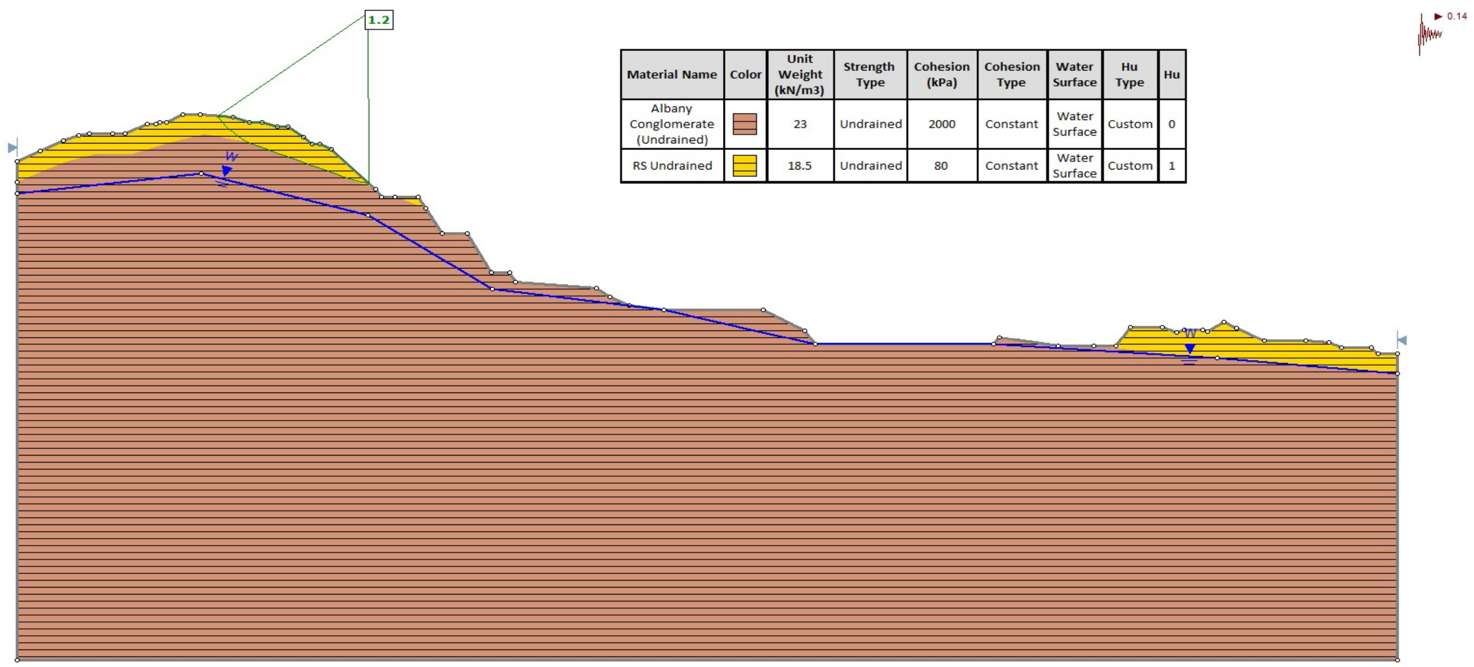
Project Kings Quarry, Wainui	*Analysis* Cuckoo	*Project No.* AKL2023-0190
Title Section B - Proposed (Pit Fill)	*Date* 10/10/2023	*Drawing* STAB 02



Proposed Section C (Pit) - Normal Groundwater Conditions



Proposed Section C (Pit) - High Groundwater Conditions



Proposed Section C (Pit) - Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Albany Conglomerate		23	Mohr-Coulomb	200	40	Water Surface	Custom	1
RS		18.5	Mohr-Coulomb	5	40	Water Surface	Custom	1

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Cohesion Type	Water Surface	Hu Type	Hu
Albany Conglomerate (Undrained)		23	Undrained	2000	Constant	Water Surface	Custom	0
RS Undrained		18.5	Undrained	80	Constant	Water Surface	Custom	1

Parameters

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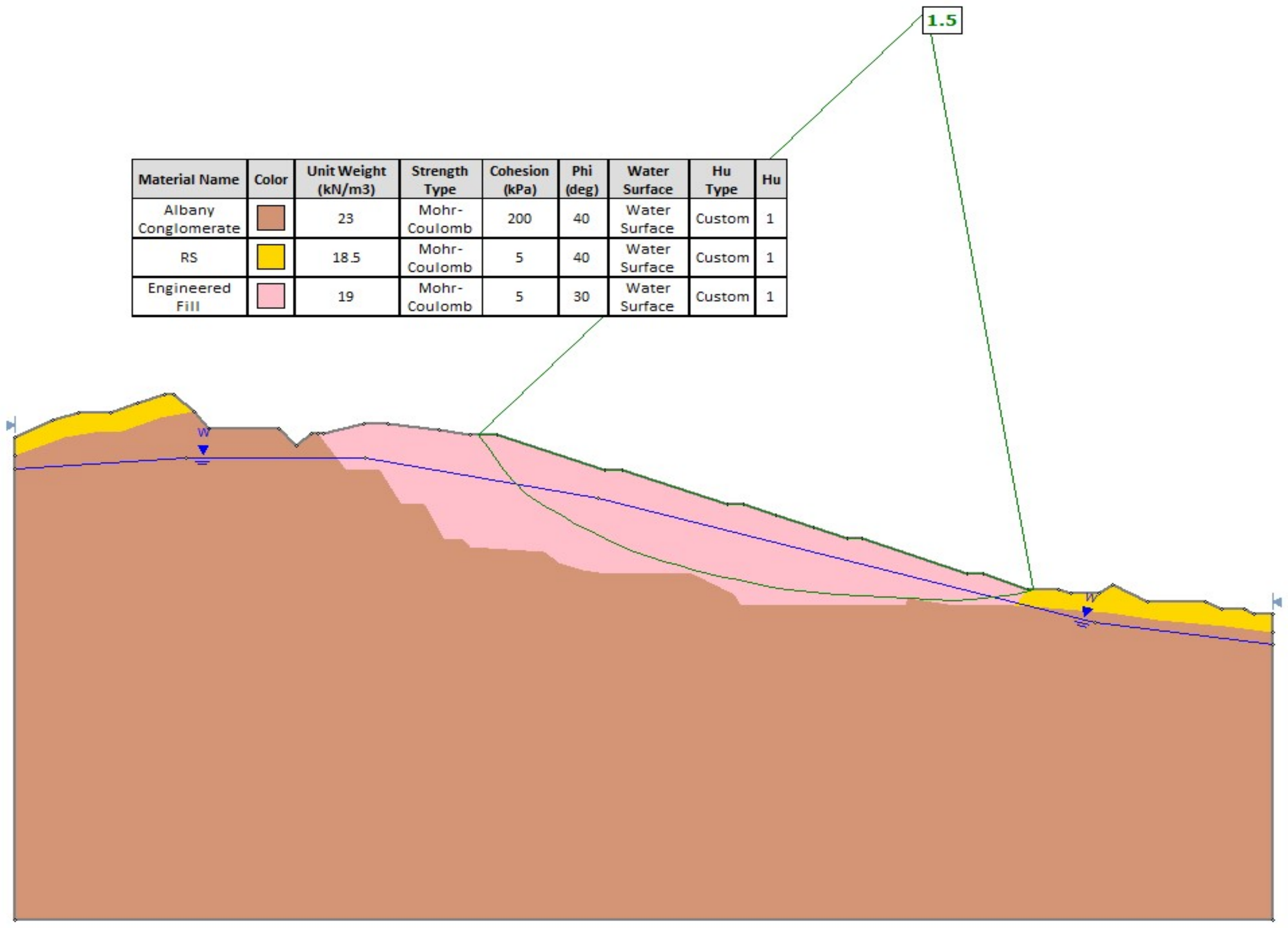
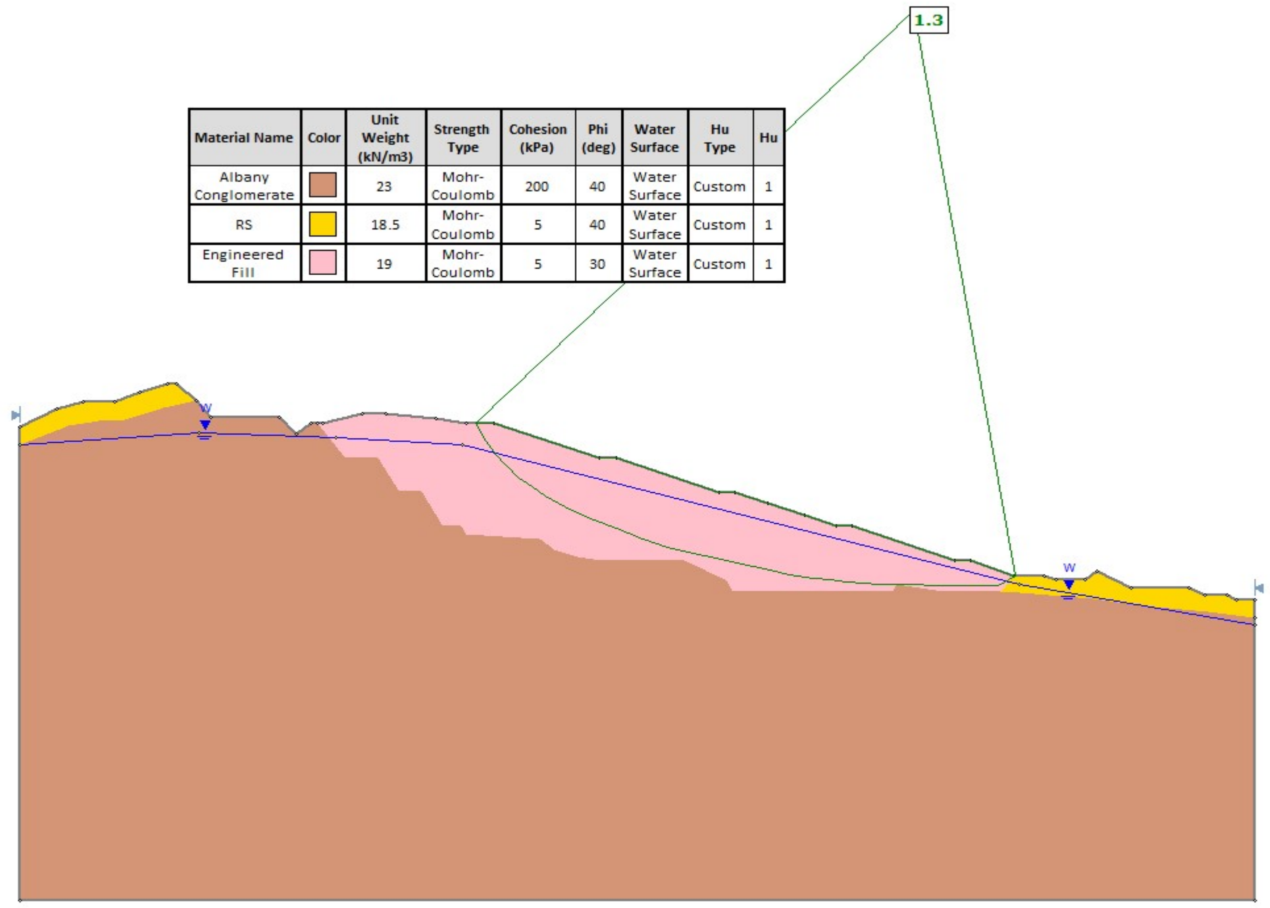
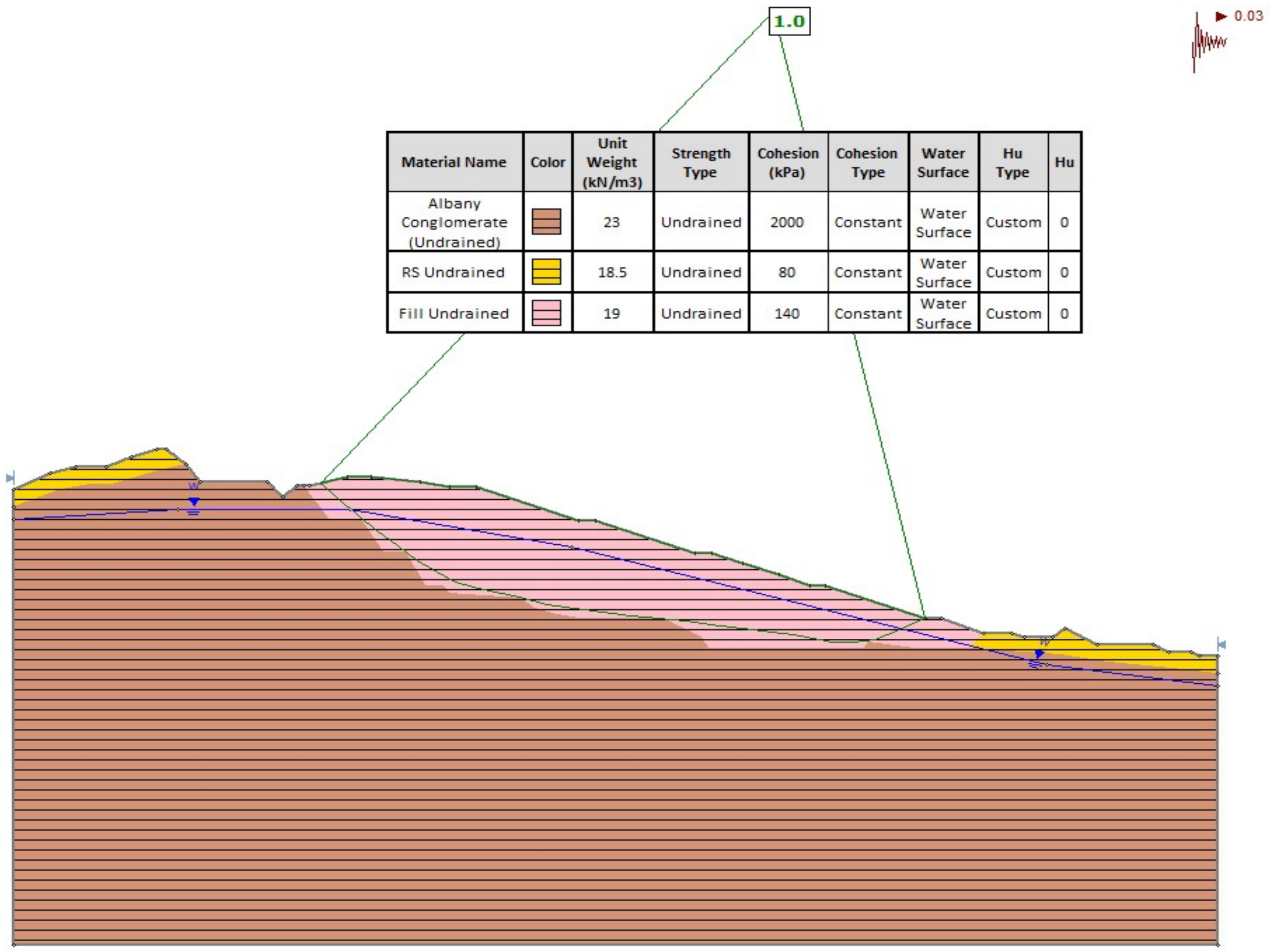
Project Kings Quarry, Wainui	*Analysis* Cuckoo	*Project No.* AKL2023-0190
Title Section C - Proposed (Pit Excavation)	*Date* 10/10/2023	*Drawing* STAB 03



Proposed Section C (Fill) - Normal Groundwater Conditions



Proposed Section C (Fill) - High Groundwater Conditions



Proposed Section C (Fill) - Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Albany Conglomerate		23	Mohr-Coulomb	200	40	Water Surface	Custom	1
RS		18.5	Mohr-Coulomb	5	40	Water Surface	Custom	1
Engineered Fill		19	Mohr-Coulomb	5	30	Water Surface	Custom	1

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Cohesion Type	Water Surface	Hu Type	Hu
Albany Conglomerate (Undrained)		23	Undrained	2000	Constant	Water Surface	Custom	0
RS Undrained		18.5	Undrained	80	Constant	Water Surface	Custom	0
Fill Undrained		19	Undrained	140	Constant	Water Surface	Custom	0

Parameters

CMW Geosciences Great People | Practical Solutions	*Project* Kings Quarry, Wainui	*Analysis* Cuckoo	*Project No.* AKL2023-0190
	Title Section C - Proposed (Pit Fill)	*Date* 10/10/2023	*Drawing* STAB 03

Appendix C: Locality Reports

SITE REPORT – LOCALITY 1

Job No:	AKL2023-0190	By:	HN	Date:	14/09/2023
Project:	Kings Quarry Stage 2	Location:	Stream		
Weather:	Sunny, passing cloud				

Remarks:

- Mapped exposed outcrops along stream close to the main gully area.
- Geology logged as massive siltstone and sandstone of the East Coast Bays Formation with localised surficial alluvial deposits (<1m) underlying narrow floodplains.

SITE REPORT – LOCALITY 2

Job No:	AKL2023-0190	By:	HN	Date:	14/09/2023
Project:	Kings Quarry Stage 2	Location:	Gully		
Weather:	Sunny, passing cloud				

Remarks:
• Mapped exposed outcrops along gully alignment. • Geology logged as massive siltstone and sandstone of the East Coast Bays Formation with localised surficial outwash deposits (<1m) deposited via overland flow.

SITE REPORT – LOCALITY 3

Job No:	AKL2023-0190	By:	HN	Date:	14/09/2023
Project:	Kings Quarry Stage 2	Location:	Gully		
Weather:	Sunny, passing cloud				

Remarks:

- Mapped exposed outcrops along gully alignment.
- Geology logged as massive siltstone and sandstone of the East Coast Bays Formation with localised surficial outwash deposits (<1m) deposited via overland flow.

SITE REPORT – LOCALITY 4

Job No:	AKL2023-0190	By:	HN	Date:	14/09/2023
Project:	Kings Quarry Stage 2	Location:	Gully		
Weather:	Sunny, passing cloud				

Remarks:

- Mapped exposed outcrops along gully alignment.
- Geology logged as gravels (generally subrounded up to cobble sized) suspended in a cemented sand/mud matrix of the Albany Conglomerate.