Slope Stability Review

Kiwi Point Quarry
Ngauranga Gorge
Wellington

Submitted to:

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1 Introduction

Geoscience Consulting (NZ) Limited was initially engaged by Holcim (NZ) Limited in 2012 to undertake a slope stability review of the quarry development at that time, and comment on the proposed expansion of the quarry. Since the initial report (September 2012), Geoscience have been subsequently engaged to carry out regular (at least quarterly) site inspections to assess ongoing quarry development and/or incidents.

The purpose of this current engagement is to provide geotechnical and geological reporting for the further development of the quarry, specifically in the areas of the North Wall, West Wall and Area H.

This report provides information on the following:

- The suitability of the proposed western batter slope to be cut in alternative directions;
- Recommendations for the extraction methodology in Area H (Southern Area); and
- Recommendations for the North Wall as follows:
  - ➢ Extraction methodology to maximize the resource yield (based on the information given in the Ormiston Associates report *"Kiwi Point Resource Review 2014"* (undated).
  - ➢ Recommendation for the remediation of the North Wall to allow buildings to be constructed at the final proposed level at the base of the slope when the quarry site is returned to Wellington City Council (WCC).

2 Scope of Work

The following scope of work was undertaken:

- Review of Ormiston Associates borehole logs of the recently drilled boreholes and recent reports;
- Geological mapping of the West Wall and Area H on 25 August 2014;
- Kinematic analysis of the results of the mapping to assess bench scale and multiple bench scale stability of the proposed western batter slopes;
- Kinematic analysis of the results of the mapping to propose safe cut batters and benches for Area H;
- Use of the available data (previous discontinuity mapping, Ormiston report, borehole logs) to produce a preferred methodology to maximise the resource at North Wall;
- Global stability assessment of the North Wall to assess appropriate remedial solutions;
- Analysis of the rock fall risk of the North Wall to give an initial indication of the potential set back distance that may be required for the construction of buildings at the base of the slope; and
- Production of this report based on our findings and data analysis.

3 Geology Overview

The geology of the Wellington area has been mapped by the Institute of Geological and Nuclear Sciences. The geology within the quarry is mapped as Triassic age Torlesse Complex grey Sandstone (“Greywacke”) and Siltstone/Mudstone (Argillite) sequences which have been repeatedly folded and faulted by a series of tectonic events.

The geological map indicates that the northern part of the quarry is overlain by Quaternary age alluvium, silt, peat and loess.

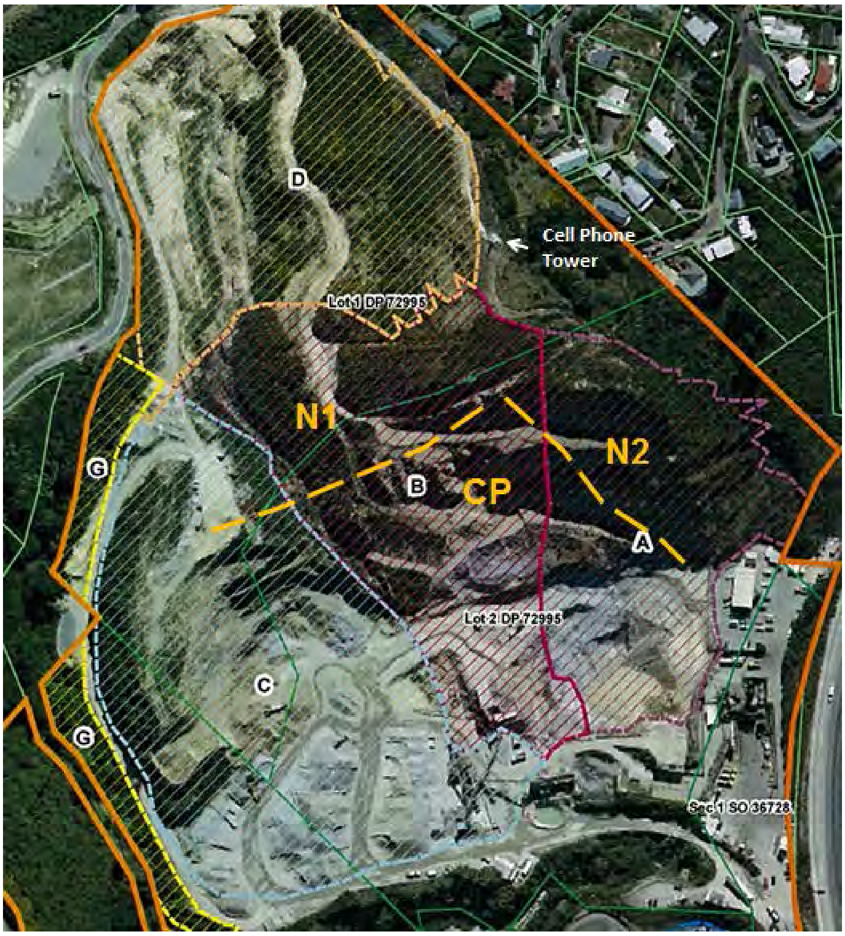
Previous reports at the Quarry indicate that the weathering profiles of the Greywacke within the quarry vary from fresh to moderately weathered. Highly weathered Greywacke is also exposed at high levels within the quarry.

Bedding is visible within the Quarry walls and, as is typical of Greywacke/Argillite in the Wellington Region, the rock in the quarry is variably jointed, with the density and continuity of the joints varying considerably.

4 Quarry Geotechnical Domains Overview

As a result of the defect mapping undertaken in 2013, the following geotechnical domains have been identified (see Figure 1 - reproduced from Figure 3 of our 2013 report).

Figure 1: Geotechnical Domains



Note: Domain CP (Central Pit) includes the north, west, south and east walls of the pit.

4.1 Domain CP

The geotechnical character of Domain CP (Central Pit) within the quarry is denoted by three defects within the rock, being the bedding planes and two joint sets.

Bedding planes (and sheared bedding) are typically at a slope angle of 70° from the horizontal and dip towards a bearing of 305°. The bedding planes are assumed to be continuous through multiple benches.

Joint Set 1 (JS1) typically dips at an angle of 75° from the horizontal towards a bearing of 220°. The assumed continuity of this joint set is less than 8 m in the lower benches (refer to section 5.2.2).

Joint Set 2 (JS2) typically dips at an angle of 45° from the horizontal towards a bearing of 090°. The assumed continuity of this joint set is less than 8 m in the lower benches.

The north, south, east and west walls all form part of this domain.

4.2 Domains N1 and N2 - Inferred Controls on Slope Stability

Domains N1 and N2 are denoted as the areas where the “greasy back” structures are observed within the east and west of the North Wall. These structures are considered to be due to stress relief within the rock mass due to down-cutting of the gullies on either side of the ridge into which the north wall is cut. They have been formed along the existing defects JS1 and JS2 which are parallel to the original ground surface. As a result the structures are more persistent than those in the unaffected rock mass beneath. It should be noted that the structures at N2 are poorly defined at this stage as access to the face in this area was considered to be too dangerous.

The eastern and western ends of the North Wall form part of this domain.

5 North Wall

This section discusses the North Wall stability, resource and remediation. The discussion includes existing stability, recommendations to improve the stability, potential maximum resource extraction and recommendations for future remediation.

The current quarry limit at the crest of the North Wall is defined by the existing land use consent. Further extraction at the crest is also restricted by the presence of a cell phone tower and associated easement as well as a 20 m buffer requirement from the residential properties to the north (see Figure 1). We understand that at the end of the quarry life, the land will be returned to WCC and the construction of commercial properties is currently proposed. In our analysis, we have allowed for the quarry to be filled to RL 92 m which is the approximate current height of the existing pit access track.

Our analysis of the North Wall includes cross sections illustrating the following scenarios:

- **Scenario 1:** The existing North Wall with batter slopes at approximately 80°;
- **Scenario 2:** The maximum resource extraction possible within the current quarry limits whilst improving current levels of stability with upper batter slopes at 55° as indicated by Ormiston and Associates drawing number 3655-2 dated 12 March 2014; and
- **Scenario 3:** Maximum resource extraction if the cell phone tower can be relocated and the wall can be extended to within 20 m from the quarry boundary (required setback).

It is noted that Scenario 2 is the most likely scenario to be chosen, as the cell tower is unlikely to be moved.

5.1 North Wall Resource

Current slope batters on the North Wall are cut at approximately 80 degrees at heights of up to 22 m with benches less than 4 m wide (typically between 2 m and 4 m wide). The overall batter slope is approximately 60 degrees.

Scenarios 2 and 3 are discussed in the following sections.

5.1.1 Resource Optimisation with Restrictions – Scenario 2

Scenario 2 maintains the current quarry limits but reduces the slope angle at the top of the existing slope to 55°. This is the commonly accepted long term maximum batter slope angle of Greywacke in the Wellington Region. This results in reduced resource extraction, but if the current restrictions remain in place, is recommended in order to maintain long term slope stability. In this scenario, the lower 3 batters have already been over excavated to more than 55°. As no access is currently available from the benches, the excavations to form this slope would need to be undertaken from the crest of the slope down.

5.1.2 Resource Optimisation without Restrictions

It would be preferable to obtain consent to extend the current limit for quarrying at the crest of the North Wall towards the property boundary. This would require the permanent relocation of the cell phone tower. We understand that a 20 m setback would be required from the boundary to safeguard the houses close to the boundary.

If this change of consent is possible, Scenario 3 would not only maximize resource yield potential, allowing a significant volume of “blue” rock to be extracted, but would also result in increased slope stability, as all of the cut batters can be cut at 55°. This is therefore the preferred final slope option.

5.2 North Wall Stability

5.2.1 Kinematic Analysis of Discontinuities

In the September 2012 Geoscience report, mapping of the North Wall was undertaken and analysis of the mapped discontinuities was detailed. This analysis is reproduced in this section for convenience.

The discontinuities in the North Wall are denoted by three defects within the rock, being the bedding planes and two joint sets.

Bedding planes (and sheared bedding) are typically at a slope angle of 70° from the horizontal and dip towards a bearing of 305°. The bedding planes are assumed to be continuous through multiple benches.

Joint Set 1 (JS1) typically dips at an angle of 75° from the horizontal towards a bearing of 220°. The assumed continuity of this joint set is less than 8m in the lower benches.

Joint Set 2 (JS2) typically dips at an angle of 45° from the horizontal towards a bearing of 090°. The assumed continuity of this joint set is less than 8m in the lower benches.

There are two main controls on slope instability on the north wall as it currently stands;

1. Planar sliding on JS1 for batter slopes above 50° (i.e. the existing condition); and
2. Wedge failures where JS1 intersects JS2.

The analysis indicates that bench scale failures may occur at slope angles over 45°, and this is observed on the North Wall. The current bench widths of approximately 2m to 4m generally contain the small scale failures that do occur, however in some cases, the debris overspills one bench and is caught by a lower bench.

As the extension of the quarry progresses, it may be required to re-align the North Wall. To assess the implications of any change in slope aspect on slope failure due to discontinuities within the rock mass, further Dips analysis has been undertaken to assess the effects of a change in slope aspect on stability. Table 1 gives an indication of the possible North Wall slope aspects, the controls on stability, and the recommended optimum slope batter angle to minimise the risk of slope failure. Note that failures may occur if slopes are cut steeper than recommended. If slopes are required to be steeper than those recommended, a risk assessment should be carried out to assess whether the consequence of failures would be acceptable (see Section 9 for further information). Benches should be maintained at a design width of no less than 5m.

Table 1: North Wall Batter Slope Design Recommendations

Possible Slope Aspects	Control on Stability			Recommended Slope Batter Angle	Comments
	Planar	Wedge	Toppling		
South facing	✓	✓	✓	40°	Planar sliding occurs on slopes steeper than 50° Wedge failure occurs on slopes steeper than 45° Toppling failure occurs on slopes steeper than 40° Bench scale failures may occur at the design slope angle of 55°
South east facing	✓	✓	✓	35°	Planar sliding occurs on slopes steeper than 35° Wedge failure occurs on slopes steeper than 40° Toppling failure occurs on slopes steeper than 35°
East facing	✓	X	✓	40°	Planar sliding occurs on slopes steeper than 40° Toppling failure occurs on slopes steeper than 50°
South west facing	✓	X	X	40°	Planar sliding occurs on slopes steeper than 40°
West facing	X	✓	X	50°	Wedge failure occurs on slopes steeper than 50°

Dips analysis for the North Wall is included in Appendix D.

5.2.2 North Wall Rockfall Risk

The main controls on North Wall stability are the discontinuities within the rock mass.

Analysis of the rock fall risk caused by the discontinuities has been completed using Rocscience Rocfall software. The model used has assumed that the proposed future filled ground surface will be at a level of RL 92 m. Note that the software is limited to single rock fall events and does not allow for multiple failures occurring instantaneously (i.e. cliff collapse events). A design rock size of 300 mm square has been used based on observed fallen rocks at the base of the quarry wall. The results for each of the three scenarios in both static and seismic conditions indicate the following:

- **Scenario 1:** When loose rock falls from the face at any height, the benches capture the falling rock before it reaches the ground (i.e. only the rock falling from beneath the bottom bench reaches the proposed ground level). However, as observed in the past, debris from wedge failures may be large enough to overtop the bench immediately below the failure and land on the bench below that.

- **Scenario 2:** Rock fall from the upper 55° batter slopes with 5 m benches is captured by the benches. The steeper batters and narrower benches towards the base of the slope are likely to be overwhelmed with rock fall debris and overtop in time. The effects of such failures will be dependent on the routine maintenance scheduled to clear fallen debris from each bench.

- **Scenario 3:** Rock fall from the slope is likely to be captured by the 5 m wide benches.

Suitable mitigation measures to minimise the risk of rock fall affecting future site users is discussed in Section 6.3. Rocfall outputs are presented in Appendix A.

5.2.3 North Wall Global Stability – Large Scale Deep Seated Landslides

The global stability of the North Wall has been modelled using Rocscience Slide software. This analysis was primarily undertaken to assess the risk of global instability for the proposed commercial end use of the quarry, however the existing North Wall was also analysed for completeness of our review. Strength parameters used in this analysis were obtained using Rocscience Roclab, which evaluates equivalent Mohr-Coulomb shear strength parameters, based on the Generalized Hoek-Brown shear-normal function, with assumed conservative bedrock strengths and characteristics. A review of relevant technical journal papers has been undertaken regarding the selection of strength parameters used in the model. There are inherent difficulties in selecting these parameters in Greywacke of the Wellington region, as the rock strength is generally controlled by the discontinuities within the rock mass, rather than the rock mass itself. The strength parameters obtained using Roclab have therefore been adjusted to accommodate the information reviewed in the papers to give more reliable parameters.

The selected parameters are given in Table 2.

Table 2: Slope Stability Parameters – North Wall

Rock Weathering	Cohesion (kPa)	Friction Angle (°)
Highly to Moderately	90	30
Slightly Weathered	470	56

The analysis was carried out under static and seismic conditions (earthquake magnitude 7.5) and the results are presented in Table 3.

Table 3: Global Slope Stability of the North Wall – Failure through Moderately Weathered Greywacke

Scenario	Factor of Safety		
	Static	1 in 50 year Earthquake (0.13g)	1 in 500 year Earthquake (0.35g)
1	1.26	1.07	0.82
2	1.35	1.11	0.82
3	1.51	1.25	0.93

In the slope stability analysis, the degree of stability of a slope is expressed as the 'factor of safety' (FOS) which is the ratio of the forces resisting failure to the driving forces causing instability.

Theoretical failure of a slope is possible when the FOS is less than 1.0, while increasing values above 1.0 indicate improving stability. A minimum FOS of 1.5 and 1.2 are commonly adopted for slopes under long term static / seismic conditions respectively.

The failure with the lowest factor of safety in each scenario is limited to the upper highly to moderately weathered Greywacke layer. Groundwater levels were added to the slope stability models for the existing condition (Scenario 1), being the highest feasible groundwater level and lower groundwater level. The high groundwater level used is shown in Appendix B. The levels were selected based on the understanding that, during and after high rainfall events, groundwater has not been observed seeping out of the slope. In both high and low groundwater cases, the effect of groundwater in the system does not affect the failure with the lowest factor of safety.

The results indicate that:

- **Static:** In all scenarios, the slope is globally stable, with a minimum FOS of 1.26.
- **SLS:** In a 1 in 50 year earthquake, in all cases the FOS is greater than 1, and therefore the global stability of the slope is expected to be maintained during an earthquake of this magnitude (0.13g). Note that this model does not allow for small scale rock failures from the rock face, which are expected in this size of event.
- **ULS:** In a 1 in 500 year earthquake, all scenarios have a FOS < 1 and therefore the likelihood of failure is high. If failure of the slope in a 1 in 500 year earthquake is not acceptable, further seismic analysis can be undertaken to assess the likely amount of displacement to be expected in such an event.

Further analysis has been undertaken to find out the factors of safety against failure of the whole face (i.e., Global Failure). A slip circle was modelled, which extends through the slightly weathered Greywacke within the lower slopes. The results are given in Table 4.

Table 4: Global Slope Stability of the North Wall – Failure through Slightly Weathered Greywacke

Scenario	Factor of Safety					
	High Groundwater			No Groundwater		
	Static	1 in 50 year Earthquake (0.13g)	1 in 500 year Earthquake (0.35g)	Static	1 in 50 year Earthquake (0.13g)	1 in 500 year Earthquake (0.35g)
1	2.02	1.57	N/A	2.67	2.16	1.42
2	2.72	1.99	N/A	2.88	2.36	1.93
3	2.86	2.35	N/A	3.82	3.10	2.66

A 1 in 500 year earthquake event with high groundwater level has not been modelled due to the low probability of these events occurring simultaneously.

The results indicate that a global failure through the slightly weathered Greywacke is unlikely. All Slide outputs are presented in Appendix B.

5.3 North Wall Slope Remediation

Table 5 details the risk reduction measures suitable for mitigation of the site from slope instability at the end of the Quarry operations.

Table 5: North Wall Risk mitigation measures

Scenario	Mitigation
1	If the slope remains at the current slope angle of around 80°, a minimum 15 m no-build zone from the base of the North Wall should be allowed for. An approximately 10 m wide catch ditch and outer bund (subject to geotechnical design) will be required at the base of the slope to catch loose material, which will need to be cleared regularly. Pedestrian access to the no build zone should be restricted. Alternatively, if regular maintenance is not considered to be possible, other remedial measures should be considered (see Section 9) Alternatively, the top part of the slope comprising completely to moderately weathered rock may be regraded to a shallower angle of no more than 55°.
2	Clearing of the upper 5 m wide benches will be required on a regular basis to prevent the build-up of rock fall debris. A no build zone of 10 m from the base of the North Wall should be allowed for. An approximately 5 m wide catch ditch and outer bund (subject to geotechnical design) will be required at the base of the slope to catch loose material, which will need to be cleared regularly. Pedestrian access to the no build zone should be restricted. Alternatively, if regular maintenance is not considered to be possible, other remedial measures should be considered (see Section 9)
3	Clearing of the benches will be required on a regular basis to prevent the build-up of rock fall debris. A no build zone of 5 m from the base of the North Wall should be allowed. Alternatively, the buildings should be designed with no windows on the wall closest to the slope, and the walls and roof designed to withstand impact loads from falling rock debris and static loads from debris accumulation. An approximately 2 m wide catch ditch and outer bund (subject to geotechnical design) will be required at the base of the slope to catch loose material, which will need to be cleared regularly. Pedestrian access to the no build zone should be restricted. Alternatively, if regular maintenance is not considered to be possible, other remedial measures should be considered (see Section 9)

6 West Wall

It is proposed to extend the West Wall further to the north. The current proposal is to form 15 m high cut batters with a south facing aspect (see proposed sketch plan presented as Figure 2). Defect mapping was undertaken on the West Wall in 2012. During our recent quarry visit on 25 August 2014, additional kinematic data was collected. All the data collected for the West Wall has been analysed using Rocscience Dips. The results of the analysis are discussed in the following section. The Dips outputs are presented in Appendix D.

A slip has occurred recently at the location of the West Wall, which is believed to be activated on a planar discontinuity as a result of steep cut batters and loading of overburden at the slope crest.

Figure 2: Sketch Plan of Proposed West Wall Batters

6.1 West Wall Stability

6.1.1 Kinematic Analysis of Discontinuities

The main control on slope instability on the West Wall currently is planar sliding on Joint Set 2, which will occur if batter slopes are cut at an angle of 45° or more with an east facing slope aspect. There is also some risk of toppling failure on bedding planes if the cut slopes are steeper than 30°.

With the proposed south facing slope aspect, wedge failures are likely to occur at cut batters steeper than 45°. As with an east facing slope, there is a risk of toppling failure on bedding planes if the cut slopes are steeper than 30°.

A suspected inactive fault is located at the intersection between the West Wall and the North Wall. However, the proposed south facing cut batters are located some metres to the west of this feature and so it is unlikely that significant deformation features will be present in the rock mass around the proposed south facing batters.

As for the North Wall, the proposed orientations for the West Wall may vary. Analysis has been undertaken of the effect of different slope aspects on slope stability on the West Wall and the results and recommendations are presented in Table 6. In all cases, benches not less than 5 m wide should be constructed to catch any small-scale failures and will need to be regularly maintained to remain effective. Note that failures may occur if slopes are cut steeper than recommended. If slopes are required to be steeper than those recommended, a risk assessment should be carried out, to assess whether the consequence of failures would be acceptable (see Section 9 for further information).

Table 6: West Wall Batter Slope Design Recommendations

Possible Slope Aspects	Control on Stability			Recommended Slope Batter Angle	Comments
	Planar	Wedge	Toppling		
South facing	X	✓	✓	50°	Wedge failure occurs on slopes steeper than 50° Low risk of toppling failure on slopes steeper than 30°
South east facing	✓	✓	X	45°	Planar failure occurs on slopes steeper than 45° Wedge failure occurs on slopes steeper than 50°
South west facing	✓	X	✓	50°	Planar failure occurs on slopes steeper than 55° Toppling failure occurs on slopes steeper than 50°
East facing	✓	✓	X	40°	Planar failure occurs on slopes steeper than 40° Wedge failure occurs on slopes steeper than 45°
North east facing	✓	✓	✓	40°	Planar failure occurs on slopes steeper than 40° Wedge failure occurs on slopes steeper than 40° Toppling failure occurs on slopes steeper than 45°
North facing	X	X	✓	45°	Toppling failure occurs on slopes steeper than 45°

6.1.2 West Wall Global Stability – Large Scale Deep Seated Landslides

The global stability of the West Wall has been modelled using Rocscience Slide software. This analysis was primarily undertaken to assess the risk of global instability for the proposed cut slope design of 40 degree slope angle with 5 m benches every 15 m vertical distance. The existing West Wall has also been analysed for completeness of our review. See Table 2 for the strength parameters used in this analysis.

The analysis was carried out under static and seismic conditions (earthquake magnitude 7.5) and the results are presented in Table 7.

Table 7: Global Slope Stability of the West Wall – Failure through Moderately Weathered Rock

Case	Factor of Safety					
	High Groundwater			No Groundwater		
	Static	1 in 50 year Earthquake (0.13g)	1 in 500 year Earthquake (0.35g)	Static	1 in 50 year Earthquake (0.13g)	1 in 500 year Earthquake (0.35g)
Existing	1.96	1.53	NA	2.13	1.67	1.20
Proposed	2.85	2.32	NA	2.88	2.34	1.74

The failure with the lowest factor of safety in both existing and proposed cases is limited to the upper highly to moderately weathered Greywacke layer. Groundwater levels were added to the slope stability models; the effect of groundwater in the system does lower the factor of safety slightly in both cases but the effect is larger in the existing case.

The results indicate that:

- **Static:** In all scenarios, the slope is globally stable, with a minimum FOS of 1.96.
- **SLS:** In a 1 in 50 year earthquake, in all cases the FOS is greater than 1, and therefore the global stability of the slope is expected to be maintained during an earthquake of this magnitude (0.13g). Note that this model does not allow for small scale rock failures from the rock face, which are expected in this size of event.
- **ULS:** In a 1 in 500 year earthquake, both cases have a FOS greater than 1 and therefore the global stability of the slope is expected to be maintained during an earthquake of this magnitude (0.35g). Note that this model does not allow for small scale rock failures from the rock face, which are expected in this size of event.

Further analysis has been undertaken to find out the factors of safety against failure of the whole face (i.e., Global Failure). A slip circle was modelled which extends through the slightly weathered Greywacke within the lower slopes. The results are given in Table 8.

Table 8: Global Slope Stability of the West Wall – Failure through Slightly Weathered Greywacke

Case	Factor of Safety					
	High Groundwater			No Groundwater		
	Static	1 in 50 year Earthquake (0.13g)	1 in 500 year Earthquake (0.35g)	Static	1 in 50 year Earthquake (0.13g)	1 in 500 year Earthquake (0.35g)
Existing	3.61	3.01	NA	4.55	3.77	2.90
Proposed	4.04	3.08	NA	4.64	4.17	2.88

A 1 in 500 year earthquake event with high groundwater level has not been modelled due to the low probability of these events occurring simultaneously.

The results indicate that a global failure through the slightly weathered Greywacke is unlikely. All Slide outputs are presented in Appendix C.

7 Area H

It is proposed to begin rock extraction from Area H to the south of the quarry (also known as the southern area). During our quarry visit on 25 August 2014, the accessible defects in this area were mapped. The Greywacke rock in this area is noticeably more fractured than in the main quarry, and the defects appear to be more randomly orientated with a wide range of dip angles.

Seven boreholes were drilled in June 2014 by McMillan Drilling Group and supervised by Ormiston associates. Defects recorded in the boreholes in this area are summarised as follows:

1. Moderately to widely spaced (0.2 m to 2 m) sub-vertical joints dipping at an angle of >80°;
2. Closely to moderately widely spaced (60 mm to 600 mm) sub-vertical joints dipping at an angle of >75°;
3. Moderately to widely spaced joints dipping at an angle of 55-70°;
4. Closely to moderately widely spaced joints dipping at an angle of 40-50°;
5. Closely to moderately widely spaced joints dipping at an angle of 20-45°; and
6. Closely to moderately widely spaced sub-horizontal joints dipping at an angle of <20°.

7.1 Controls on Stability

The mapped defects have been analysed with Rocscience Dips software. The Dips outputs are presented in Appendix D. The results indicate that the main controls on slope instability in Area H are likely to be:

- Possibility of planar failure on Joint Set E at batter angles greater than 45°;
- Possibility of wedge failure at the intersection between Joint Sets C and E which may occur at cut batter angles greater than 45°; and
- Toppling failure is possible in batter slopes steeper than 30°.

There are at least six defects logged in the boreholes drilled in Area H. Due to the rotary drilling method used, the orientations of the defects have not been determined. Defects appear to be dipping between a range of <20 to >80 which is generally consistent with the observational data collected.

7.2 Recommendations for Cut Batter Angles

Due to the wide range of dip angles and random defect orientations in this area, a conservative cut batter angle of 45° is recommended with a minimum of 5 m wide benches. The vertical interval between benches should be no more than 15m, unless specifically designed. Cut batters formed at this angle are likely to minimise the occurrence of small scale planar and wedge failures, however, these may still occur periodically. Toppling failure is expected to occur at a cut batter of 45°, however these are expected to be bench scale failures. The 5 m wide benches would be required to catch the majority of these small scale failures, and will require periodic debris clearance as part of ongoing maintenance requirements.

As excavations progress in Area H at a cut batter angle of 45°, further defect mapping and an assessment of cut slope stability should be undertaken to assess whether the cut batters could be increased to 55°. At this stage, the future scope of any required ground investigation can be determined.

8 Quarry Risk Assessment – Cut Slopes

Tables 1 and 6 and Section 7.2 give recommended cut batter angles for long term slope stability for unprotected slopes. These recommended batter angles are based on analysis using computer software and observations of the performance of existing cut slopes on site. The slope angles take into consideration both cut slope stability during quarry operations and after the quarry site has changed to commercial use.

Whilst it is clear that some of the cut slopes may be maintained and small scale failures (particularly toppling failures) be managed during regular quarry operations (i.e. ongoing bench clearance), consideration must also be given at this stage to long term maintenance requirements after quarry operations have ceased. This is likely to be more difficult to guarantee.

The Holcim Risk Assessment Matrix in Figure 3 has been used when considering the recommended slope batter angles in this report. The safety of current and future site users must be considered when planning for quarry expansion. It is considered that if the cut batter angles are steepened to angles greater than those given in this report, then the combination of Likelihood Category C – Possible and Consequence Category 5 – Disaster, results in an unacceptable “high” risk. If cut batter angles are required to be steeper than those recommended in this report, then before the quarry is handed back to WCC, slope remediation options must be considered (see Section 9).

Figure 3: Holcim Risk Assessment Matrix

ASSESSMENT MATRIX FOR USE WITH HAZARD AND INCIDENT MANAGEMENT

Category	Consequence *Hazards: How bad could it get? Incidents: How bad did it get? How bad could it have been?*				
People Safety	Fatality or multiple fatalities	Permanent Disability	Lost Time Injury	MTI	FAI
Quality	>$1 Million Recall / Stop production	$100,000 - 1M Recall / Stop production	$10,000-$100,000 Requires action	$1000-$10000 Requires action	< $1,000
Environment	Long term effect Prosecution expected	Significant Effect Prosecution Likely	Uncontrolled discharge with minor effects on the environment, moderate non-compliance.	Uncontrolled release, discharge or spill locally contained & short-term non-compliance.	Complaint, minor discharge or spill
Assets Damage	> $1 Million	$100,000 - 1M	$10,000-$100,000	$1000-$10000	< $1,000
Business Continuity	Critical interruption > 5 days	Serious interruption 2-5 days	Moderate interruption 1-2 days	Minor interruption Up to 1 day	Low interruption Up to 2 hours
Reputation	National/ international long-term. Known statutory violation, criminal offence, and possible imprisonment.	Widespread long-term local. Medium-term national. Statutory violation. Legal prosecution.	Medium-term local. Short-term national. Statutory violation. Abatement notice and fined.	Medium-term local. Reportable violation of consent. Informal warning by authority.	Short-term local. Not regulated necessarily. Regulated by an authority.
	5 Disaster	**4 Severe**	**3 Serious**	**2 Significant**	**1 Low**
A Certain	**High**	**High**	**High**	**Medium**	**Medium**
B Likely	**High**	**High**	**Medium**	**Medium**	**Low**
C Possible	**High**	**Medium**	**Medium**	**Low**	**Low**
D Unlikely	**Medium**	**Medium**	**Low**	**Low**	**Low**
E Rare	**Medium**	**Low**	**Low**	**Low**	**Low**

The commonly accepted long term maximum batter slope angle of Greywacke in the Wellington Region is 55% (without adverse defect orientation) and it is recommended that permanent slopes are not cut steeper than this within the Quarry.

9 Remedial Options

If the recommended cut slope angles in Tables 1 and 6 and Section 7.2 are required to be steepened, then short term slope maintenance during quarry operations as well as long term slope remediation to safeguard the safety of future site users will be required.

9.1 Maintenance During Quarry Operations

Benches will need to be designed to allow regular access for machinery or quarry workers to safely remove any debris accumulating from failures above. This is required to maintain the ability of the benches to catch falling debris.

9.2 Long Term Remedial Options

If regular maintenance of the slopes and any future catch ditch and bund cannot be undertaken, then slope remedial options for long term stability should be considered. Low maintenance remedial options could include:

- No build zone;
- Anchored mesh; or
- Anchored shotcrete.

10 Overburden

Overlying the moderately weathered rock in all areas there is expected to be a veneer of highly weathered rock, loess and colluvium comprising silty soil. It is recommended that this material is cut at a slope angle of no more than 1V:2H for permanent excavations. Further investigation of this material is required if higher angle slopes are required.

11 Summary

Geoscience Consulting (NZ) Limited has been engaged by Holcim (NZ) Limited to provide geotechnical and geological reporting for the further development of the quarry, specifically in the areas of the North Wall, West Wall and Area H.

The following scope of work was undertaken:

- Review of Ormiston Associates borehole logs of the recently drilled boreholes and recent reports;
- Geological mapping of the West Wall and Area H on 25 August 2014;
- Kinematic analysis of the results of the mapping undertaken in 2012 to assess bench scale and multiple bench scale stability of the North Wall batter slopes
- Kinematic analysis of the results of the mapping to assess bench scale and multiple bench scale stability of the proposed West Wall batter slopes;

- Global stability assessment of the West Wall to inform cut batter design;
- Kinematic analysis of the results of the mapping to propose safe cut batters and benches for Area H;
- Use of the available data (previous discontinuity mapping, Ormiston report, borehole logs) to produce a preferred methodology to maximise the resource at North Wall;
- Global stability assessment of the North Wall to assess appropriate remedial solutions; and
- Analysis of the rock fall risk of the North Wall to give an initial indication of the potential set back distance that may be required for the construction of buildings at the base of the slope.

Three scenarios for the design of the North Wall have been assessed with regard to global slope stability and future rock fall risk as the quarry is developed into a commercial area when quarry operations have ceased. Mitigation measures to reduce the consequence of instability have been provided.

Kinematic analysis of discontinuities on the North Wall and West Wall has been undertaken to assess the consequence of a variation in slope aspect on slope stability. Optimum batter slope angles have been recommended to minimise these failures.

Kinematic analysis of discontinuities in Area H has been undertaken to assess the optimum cut batter angle in this area.

12 References

Geoscience, 2012, *Kiwi Point Quarry Pit Slope Stability Review*, Holcim (NZ) Limited

Begg, J.G. & Mazengarb, C., 1996, *Geology of the Wellington Area, scale 1:50000. Institute of Geological and Nuclear Sciences Geological Map 22. 1 sheet + 128 p*. Lower Hutt, New Zealand: Institute of Geological and Nuclear Sciences Limited.

Hoek, E., Carranza-Torres, C and Corkum, B (2002). *Hoek-Brown Failure Criterion – 2002 Edition.* Proc. NARMS-TAC Conference, Toronto, 2002, 1, 267-273.

Ormiston Associates, undated, *Kiwi Point Resource Review 2014.*

Pender, M. J., 1980, *Friction and Cohesion Parameters for Highly and Completely Weathered Wellington Greywacke*, Aust-NZ 3rd Conference on Geomechanics.

Read, S.A.L, Richards, L., Perrin, N, 2000, *Assessment of New Zealand Greywacke Rock Masses with the Hoek-Brown Failure Criterion*, GeoEng 2000, Melbourne.

13 Limitations

i. We have prepared this report in accordance with the brief as provided. This report has been prepared for the use of our client, Holcim New Zealand Limited, their professional advisers and the relevant Territorial Authorities in relation to the specified project brief described in this report. No liability is accepted for the use of any part of the report for any other purpose or by any other person or entity.

ii. The recommendations in this report are based on the ground conditions indicated from published sources, site inspections and subsurface investigations described in this report based on accepted normal methods of site investigations. Only a limited amount of information has been collected to meet the specific financial and technical requirements of the Client's brief and this report does not purport to completely describe all the site characteristics and properties. The nature and continuity of the ground between test locations has been inferred using experience and judgement and it must be appreciated that actual conditions could vary from the assumed model.

iii. Subsurface conditions relevant to construction works should be assessed by contractors who can make their own interpretation of the factual data provided. They should perform any additional tests as necessary for their own purposes.

iv. This Limitation should be read in conjunction with the IPENZ/ACENZ Standard Terms of Engagement.

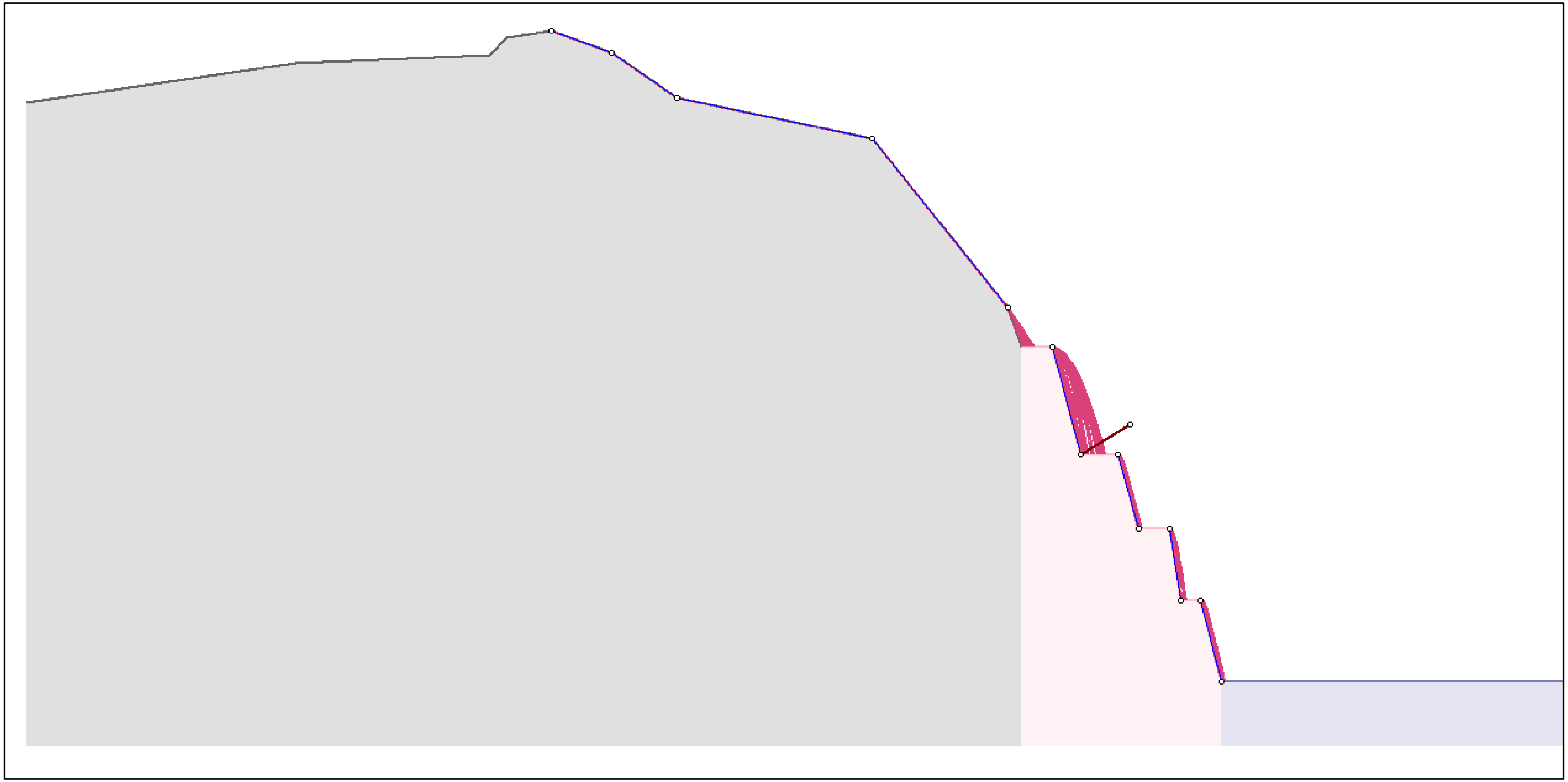
v. This report is not to be reproduced either wholly or in part without our prior written permission.

We trust that this information meets your current requirements. Please do not hesitate to contact the undersigned if you require any further information.

Report prepared by	Reviewed by
Karen Jones	**Guy Cassidy, MIPENZ, PEngGeol**
Senior Engineering Geologist	Associate Engineering Geologist

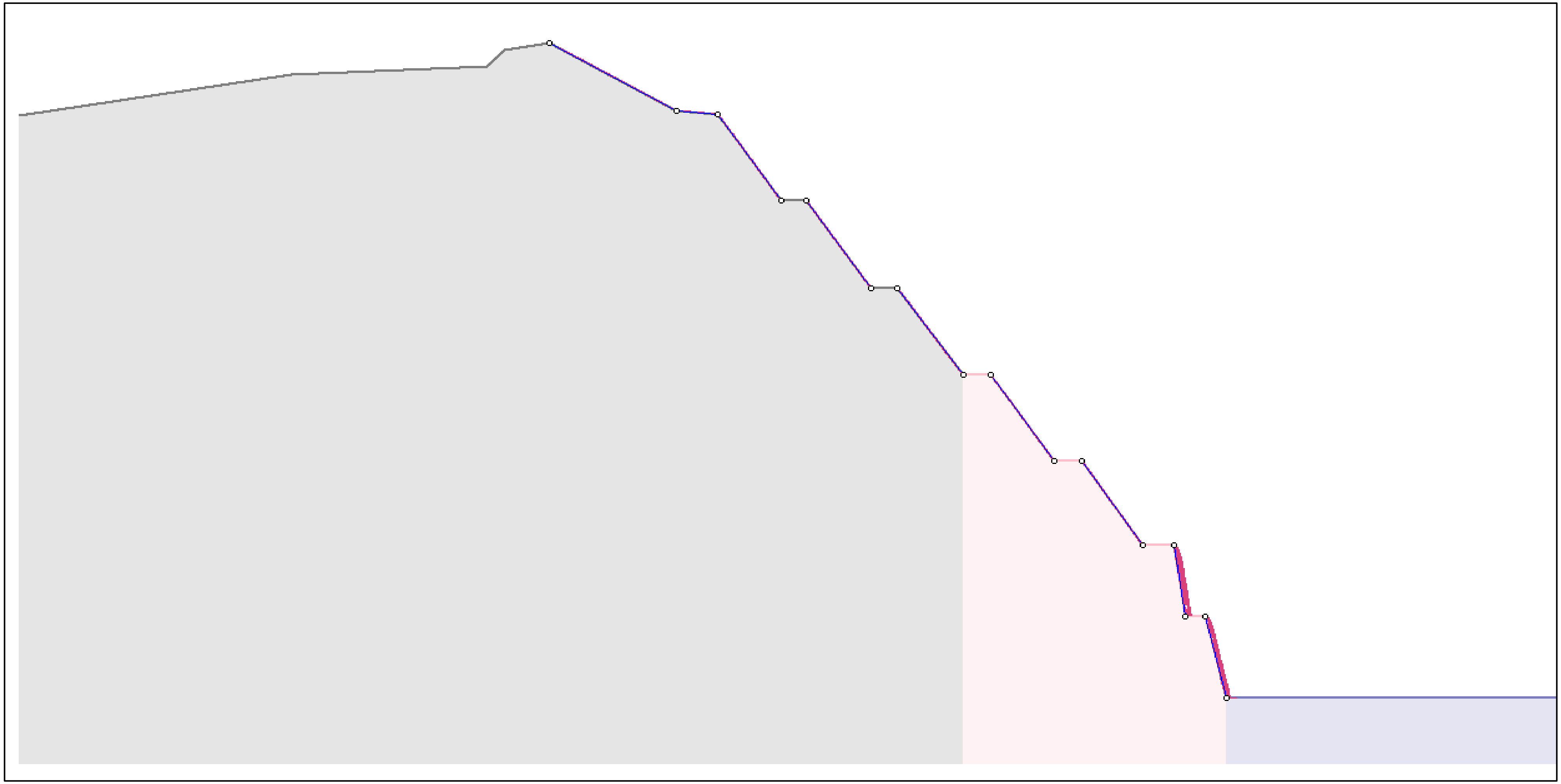
Appendix A

Rocfall Modelling

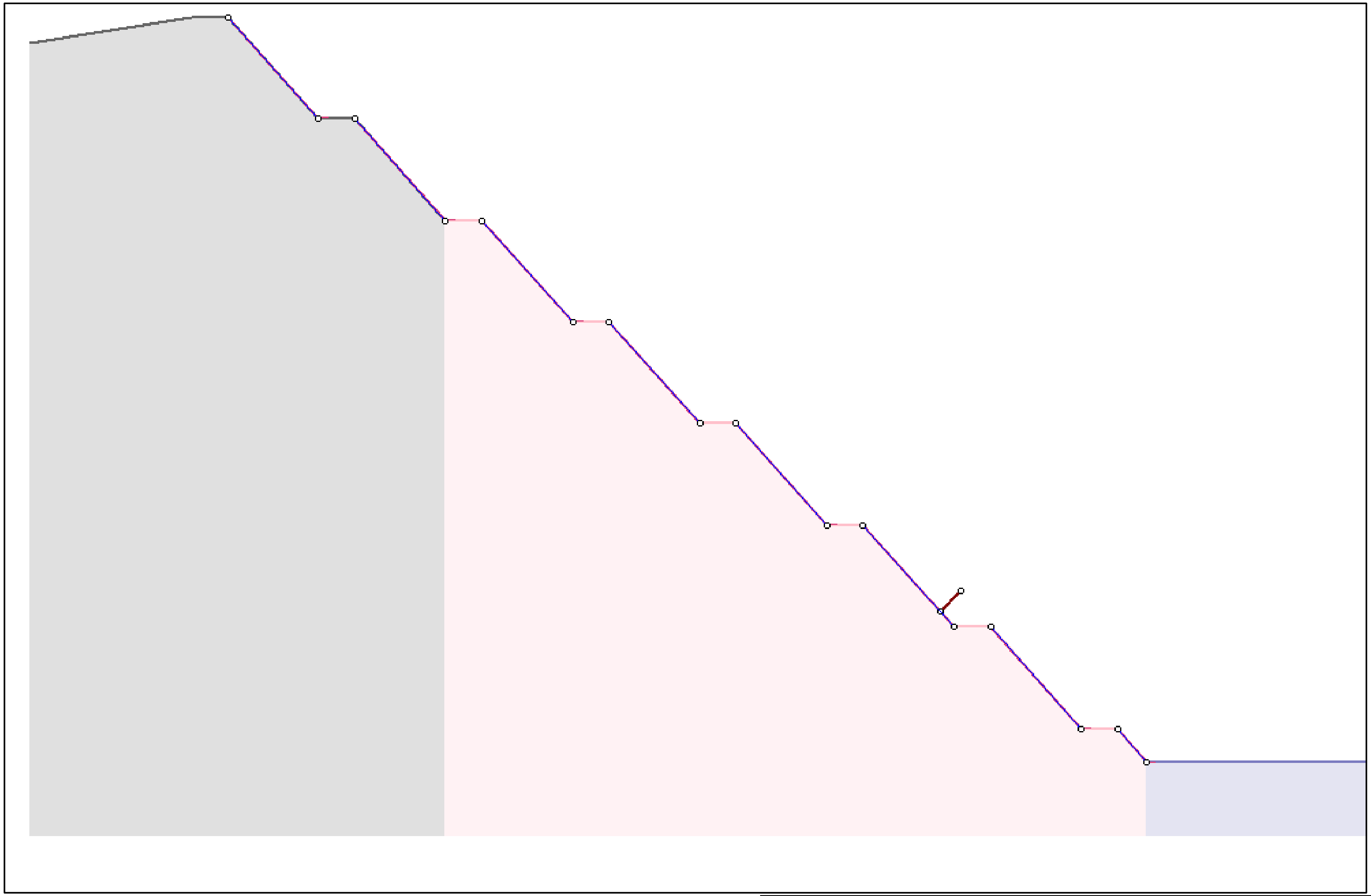


Client	Holcim (NZ) Limited
Project	KiwiPoint Quarry
Description	North Wall Rocfall Model - Scenario 1 (Seismic)

Appendix A	1	Project Number	10315



Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**North Wall Stability Model - Scenario 2 (Seismic)**		
Appendix A	2	**Project Number**	10315

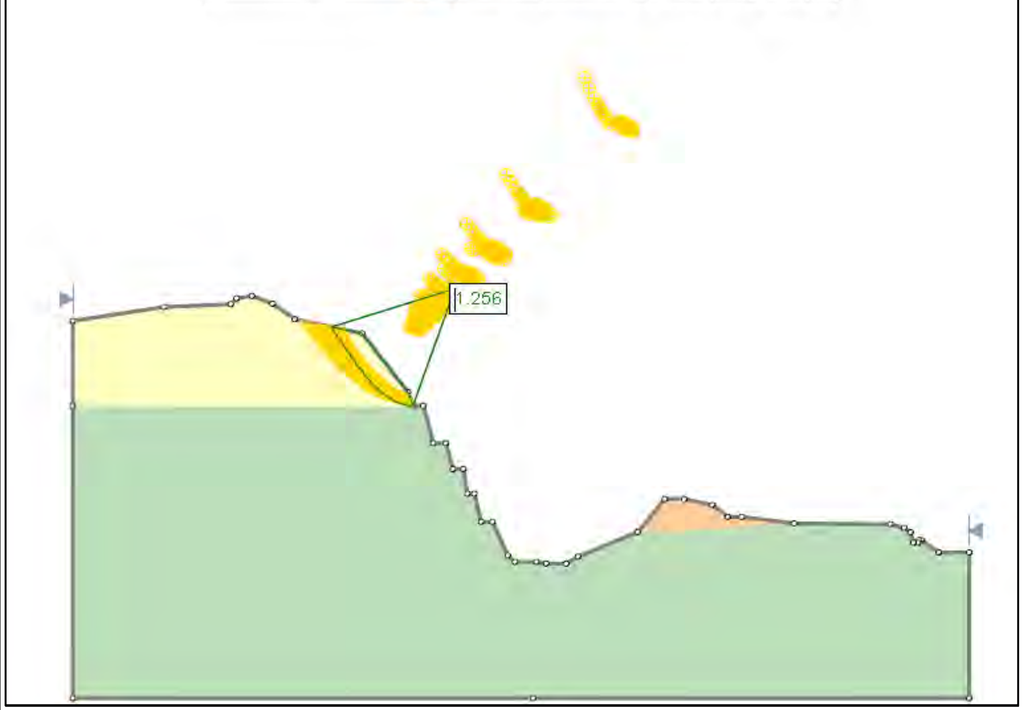


Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**North Wall Stability Model - Scenario 3 (Seismic)**		
Appendix A	3	**Project Number**	10315

Appendix B

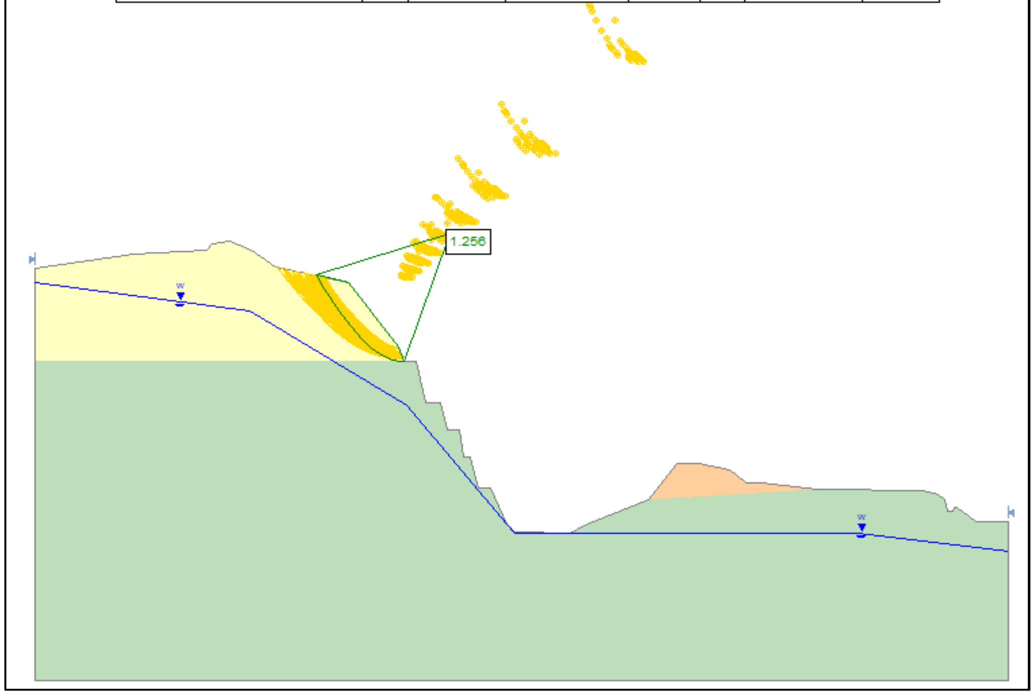
North Wall Slide Slope Stability Outputs

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Highly to moderately weathered		24	Mohr-Coulomb	91	30	None	0
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	None	0
Fill		18	Mohr-Coulomb	1	32	None	0



Static - no Groundwater

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Highly to moderately weathered		24	Mohr-Coulomb	91	30	Water Surface	Constant
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	Water Surface	Constant
Fill		18	Mohr-Coulomb	1	32	Water Surface	Constant



Static - high Groundwater

Failure surfaces with a factor of safety of less than 1.5 shown

Failure through moderately weathered Greywacke

GEOSCIENCE
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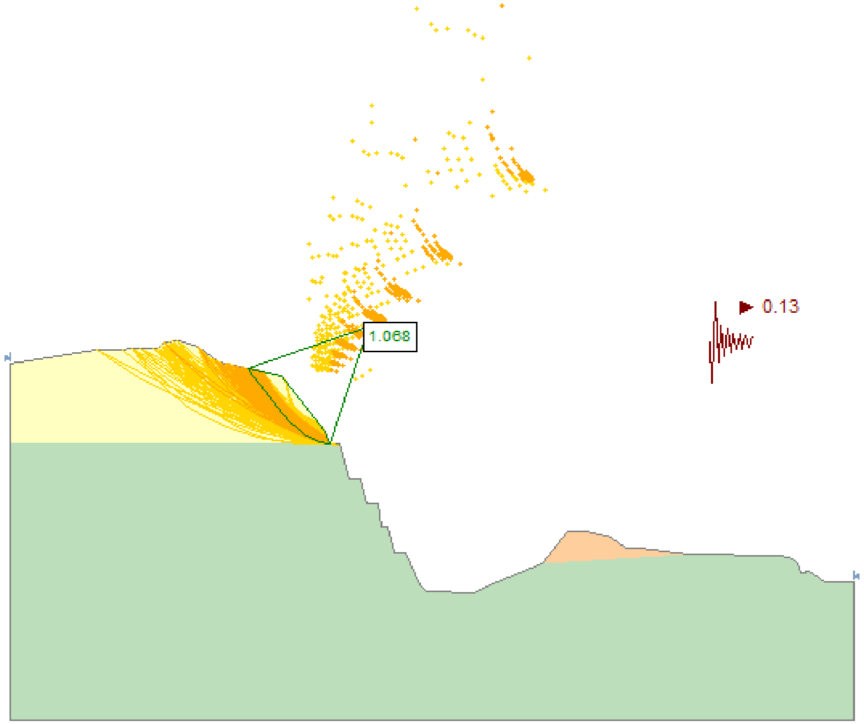
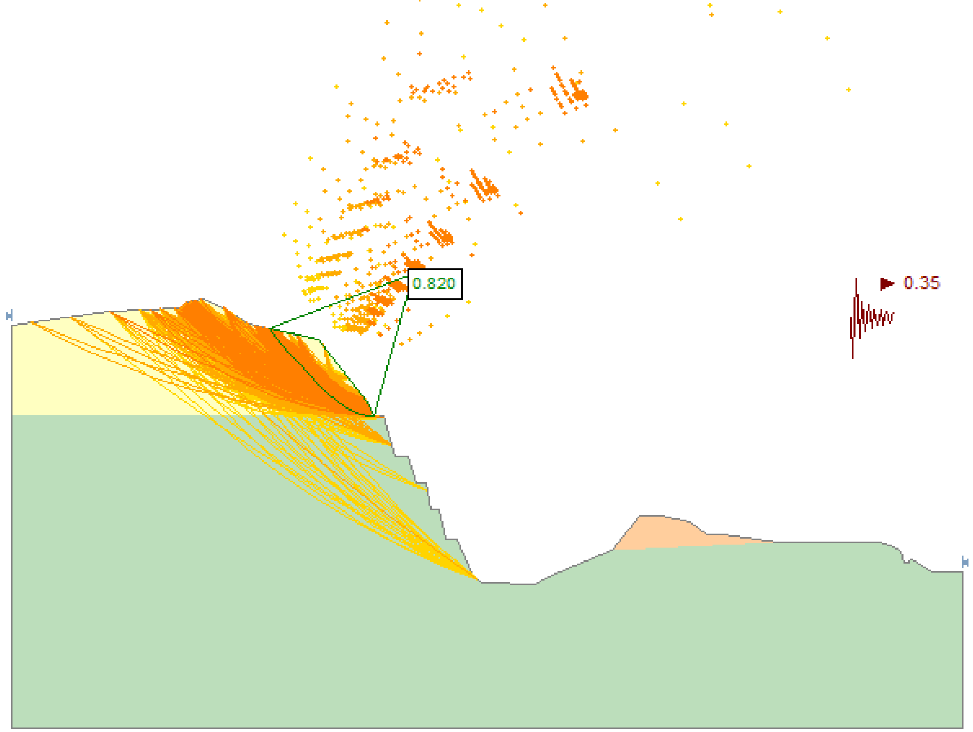
Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**North Wall Stability Model - Scenario 1 (Static)**		
Appendix B	1	**Project Number**	10315

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Highly to moderately weathered		24	Mohr-Coulomb	91	30	None	0
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	None	0
Fill		18	Mohr-Coulomb	1	32	None	0



1 in 50 year event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Highly to moderately weathered		24	Mohr-Coulomb	91	30	None	0
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	None	0
Fill		18	Mohr-Coulomb	1	32	None	0



1 in 500 year event

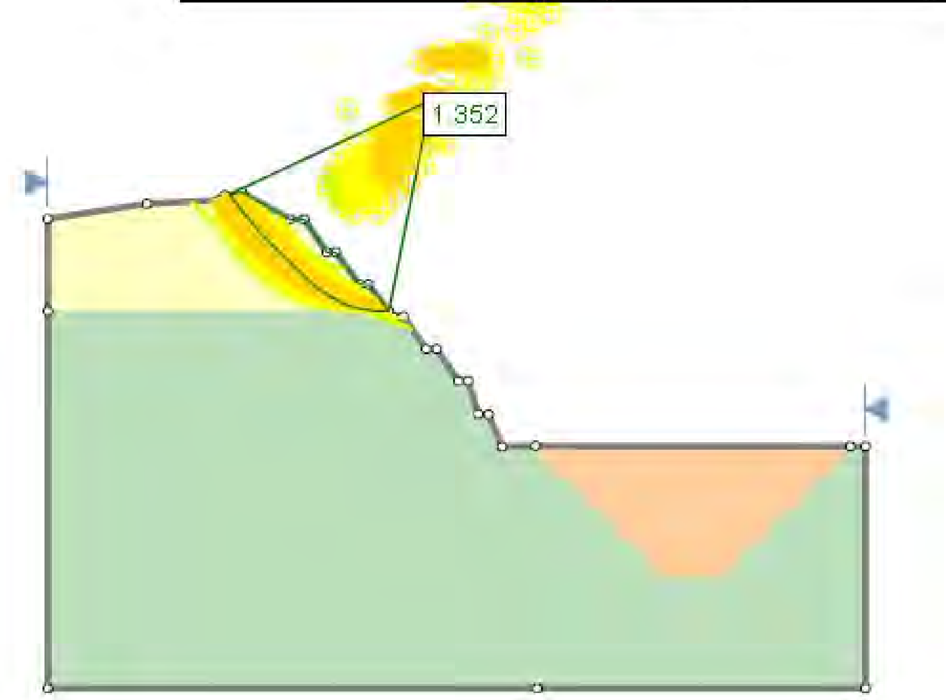
Failure surfaces with a factor of safety of less than 1.5 shown

Failure through moderately weathered Greywacke

GEOSCIENCE A proud partner of ENGEO

Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**North Wall Stability Model - Scenario 1 (Seismic)**		
Appendix B	2	**Project Number**	10315

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Highly to moderately weathered		24	Mohr-Coulomb	91	30	None	0
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	None	0
Fill		18	Mohr-Coulomb	1	32	None	0



Static - no groundwater

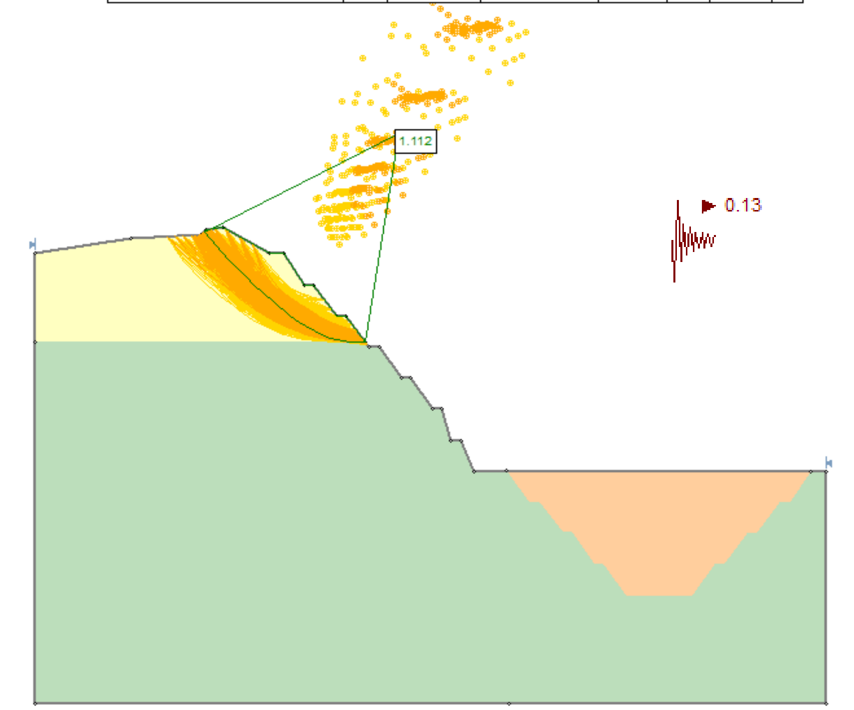
Failure surfaces with a factor of safety of less than 1.5 shown

Failure through moderately weathered Greywacke

GEOSCIENCE
A proud partner of ENGEO

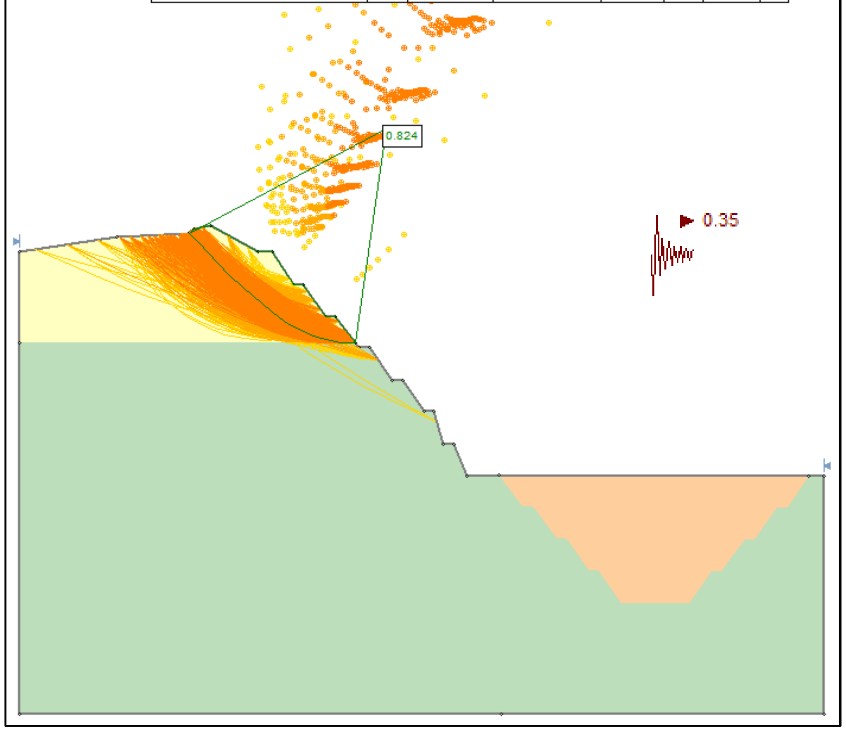
Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**North Wall Stability Model - Scenario 2 (Static)**		
Appendix B	3	**Project Number**	10315

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Highly to moderately weathered		24	Mohr-Coulomb	91	30	None	0
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	None	0
Fill		18	Mohr-Coulomb	1	32	None	0



1 in 50 year event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Highly to moderately weathered		24	Mohr-Coulomb	91	30	None	0
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	None	0
Fill		18	Mohr-Coulomb	1	32	None	0



1 in 500 year event

Failure surfaces with a factor of safety of less than 1.5 shown

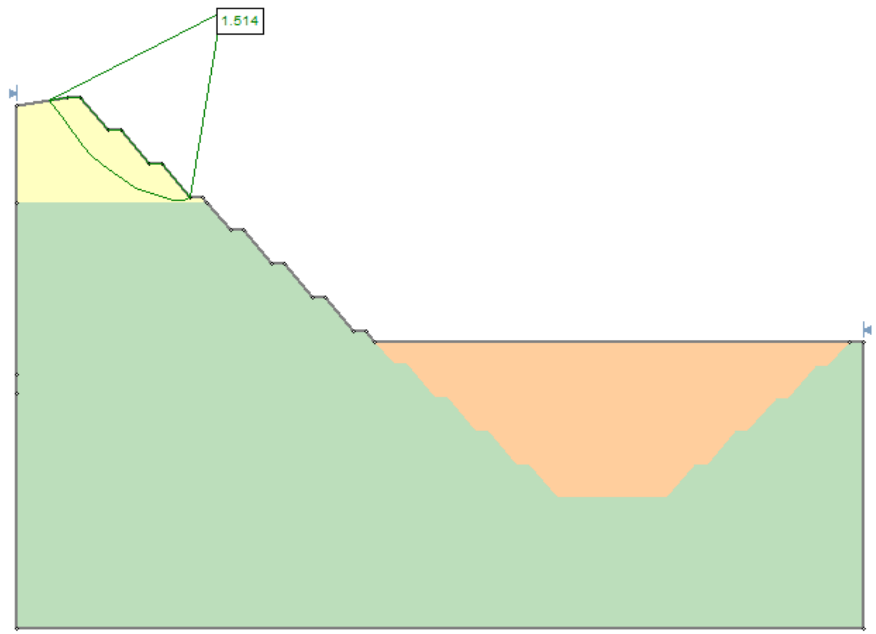
Failure through moderately weathered Greywacke

GEOSCIENCE

A proud partner of ENGEO

Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**North Wall Stability Model - Scenario 2 (Seismic)**		
Appendix B	4	**Project Number**	10315

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Highly to moderately weathered		24	Mohr-Coulomb	91	30	None	0
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	None	0
Fill		18	Mohr-Coulomb	1	32	None	0



Static - no groundwater

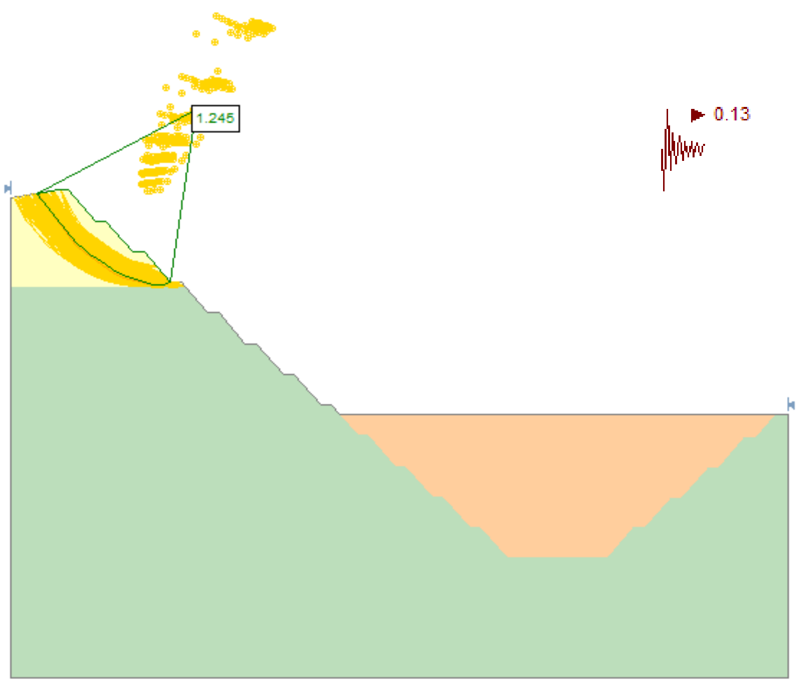
No failure surfaces with a factor of safety of less than 1.5

Failure through moderately weathered Greywacke

GEOSCIENCE
A proud partner of ENGEO

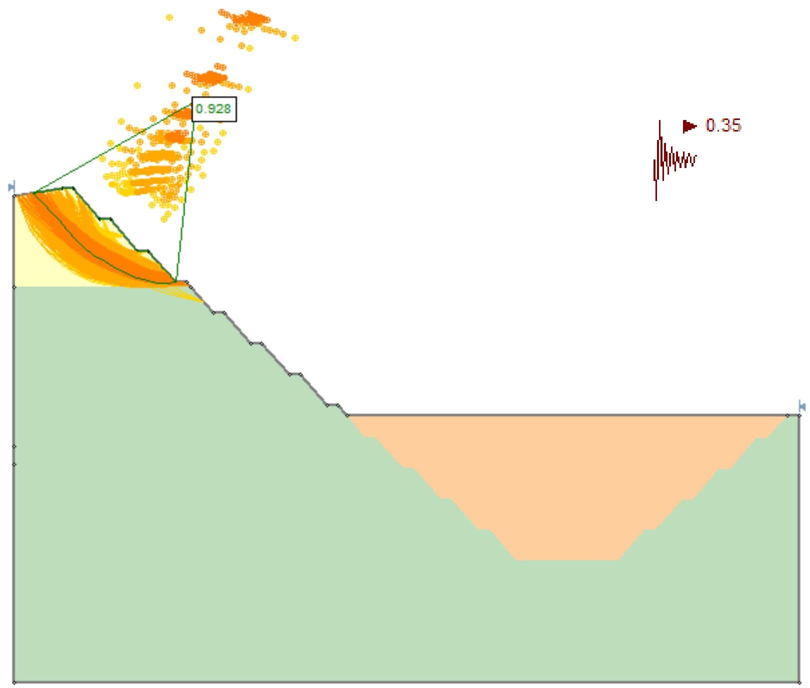
Client	Holcim (NZ) Limited		
Project	KiwiPoint Quarry		
Description	North Wall Stability Model - Scenario 3 (Static)		
Appendix B	5	Project Number	10315

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Highly to moderately weathered		24	Mohr-Coulomb	91	30	None	0
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	None	0
Fill		18	Mohr-Coulomb	1	32	None	0



1 in 50 year event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Highly to moderately weathered		24	Mohr-Coulomb	91	30	None	0
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	None	0
Fill		18	Mohr-Coulomb	1	32	None	0



1 in 500 year event

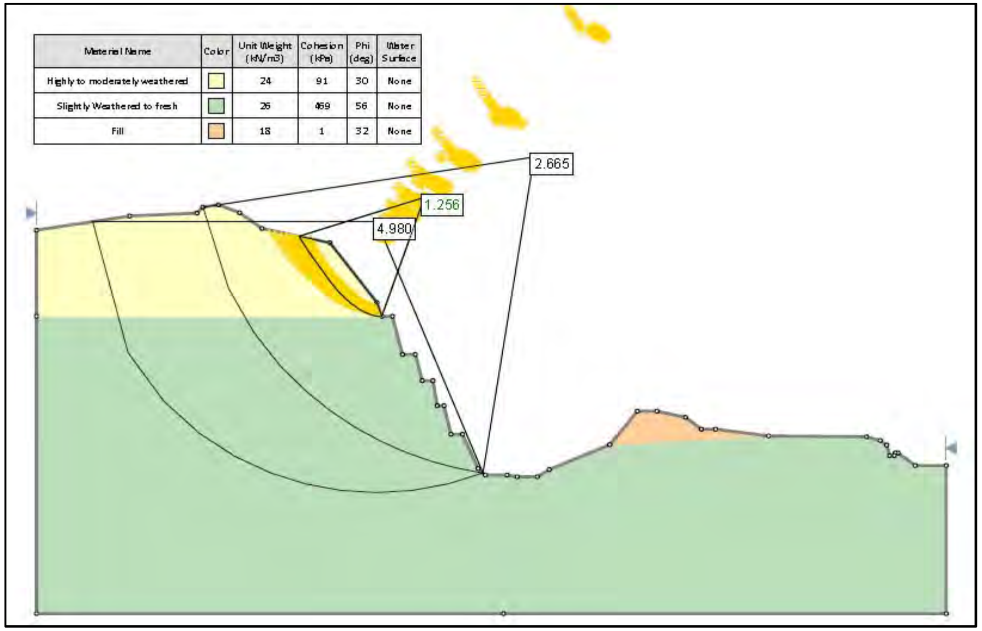
Failure surfaces with a factor of safety of less than 1.5 shown

Failure through moderately weathered Greywacke

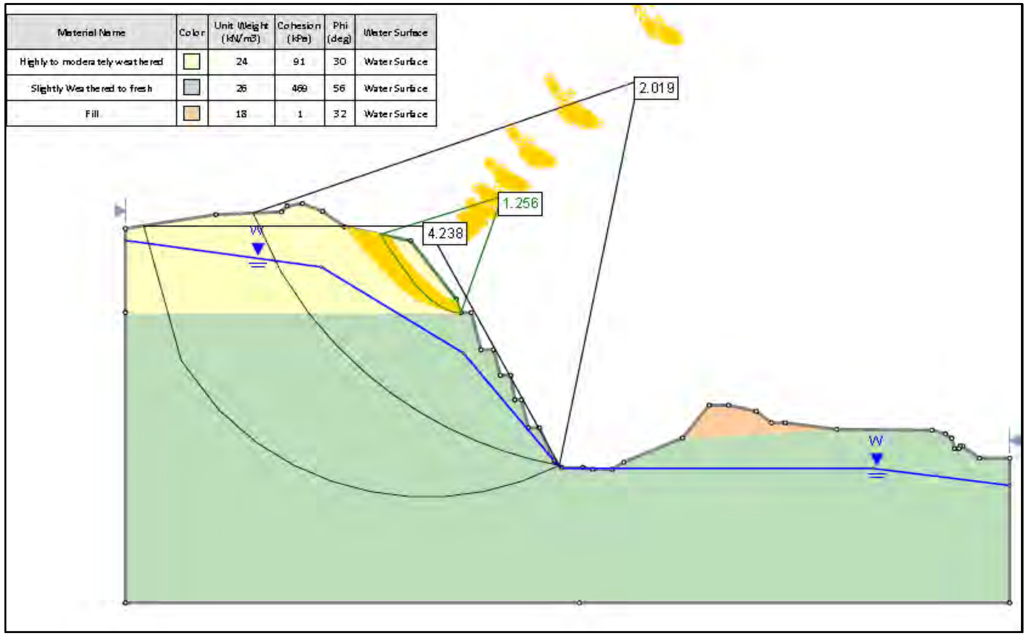
GEOSCIENCE

A proud partner of ENGEO

Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**North Wall Stability Model - Scenario 3 (Seismic)**		
Appendix B	6	**Project Number**	10315



Static - no groundwater



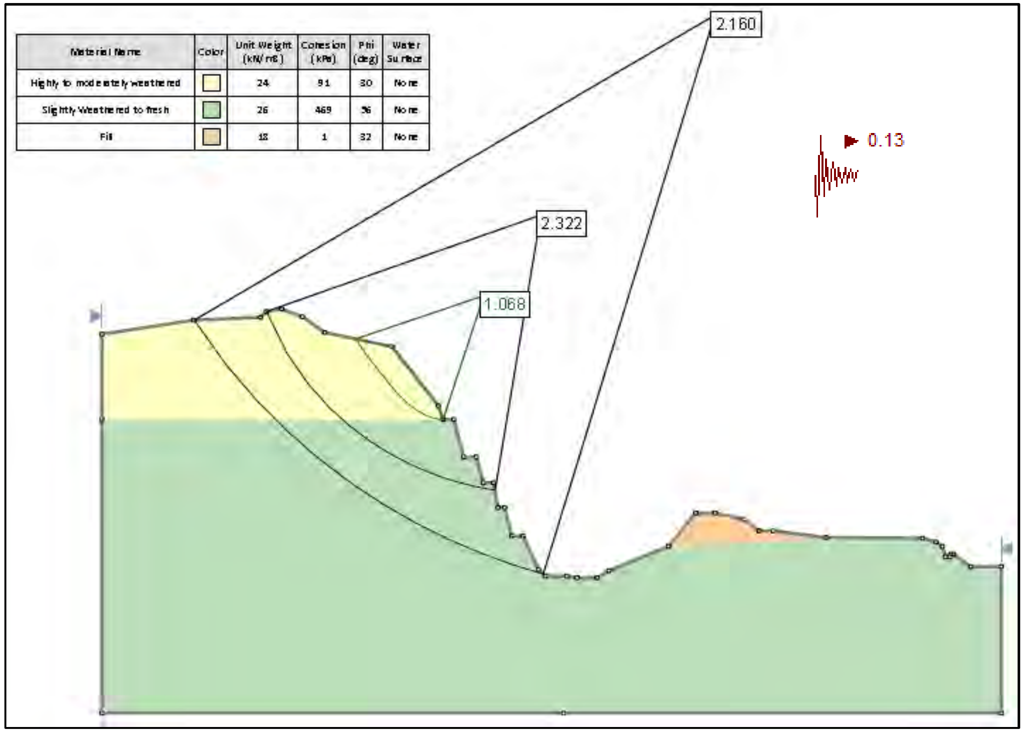
Static - high groundwater

Failure surfaces with a factor of safety of less than 1.5 shown

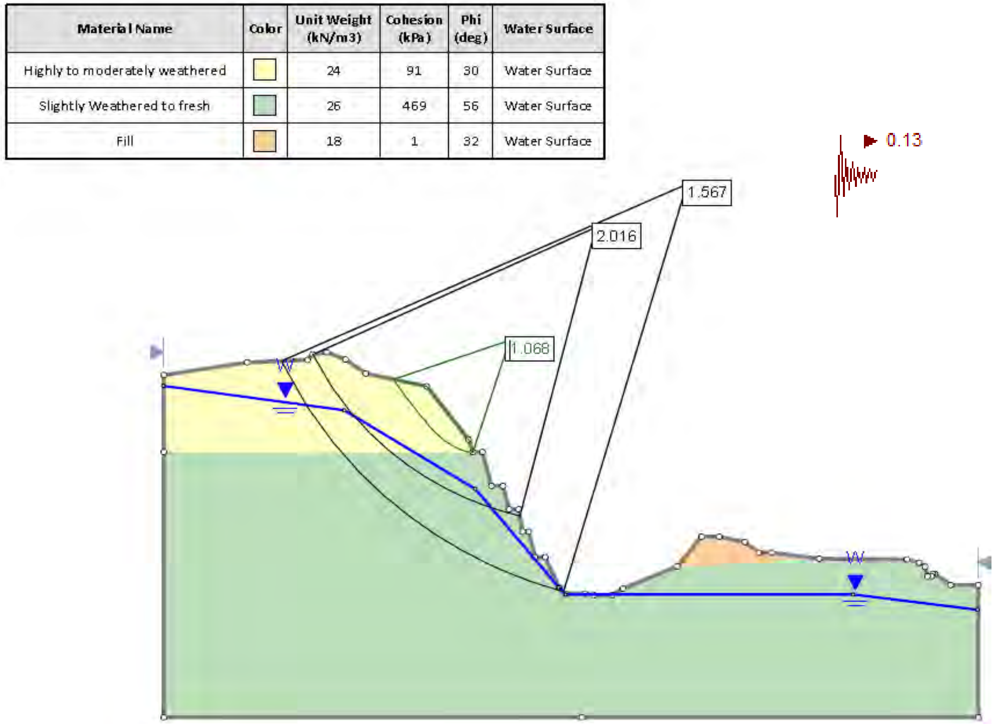
Failures through slightly weathered Greywacke

GEOSCIENCE A proud partner of ENGEO

Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**North Wall Stability Model - Scenario 1 (Static)**		
Appendix B	7	**Project Number**	10315



1 in 50 year event no groundwater



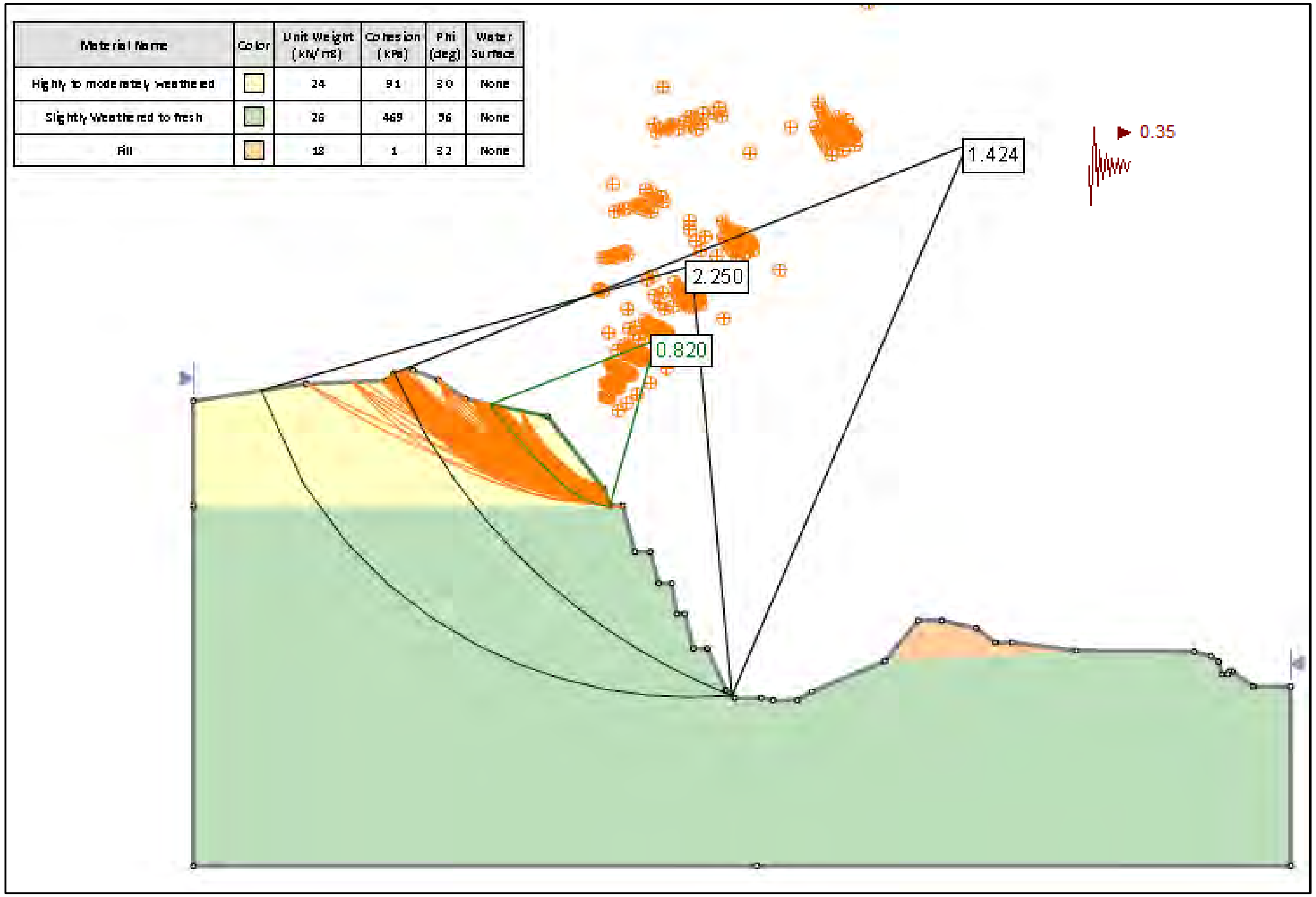
1 in 50 year event high groundwater

Failure surfaces with a factor of safety of less than 1.5 shown

Failures through slightly weathered Greywacke

GEOSCIENCE A proud partner of ENGEO

Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**lorth Wall Stability Model - Scenario 1 (Seismic SLS)**		
Appendix B	8	**Project Number**	10315



1 in 500 year event

Failure surfaces with a factor of safety of less than 1.5 shown
Failures through slightly weathered Greywacke

GEOSCIENCE
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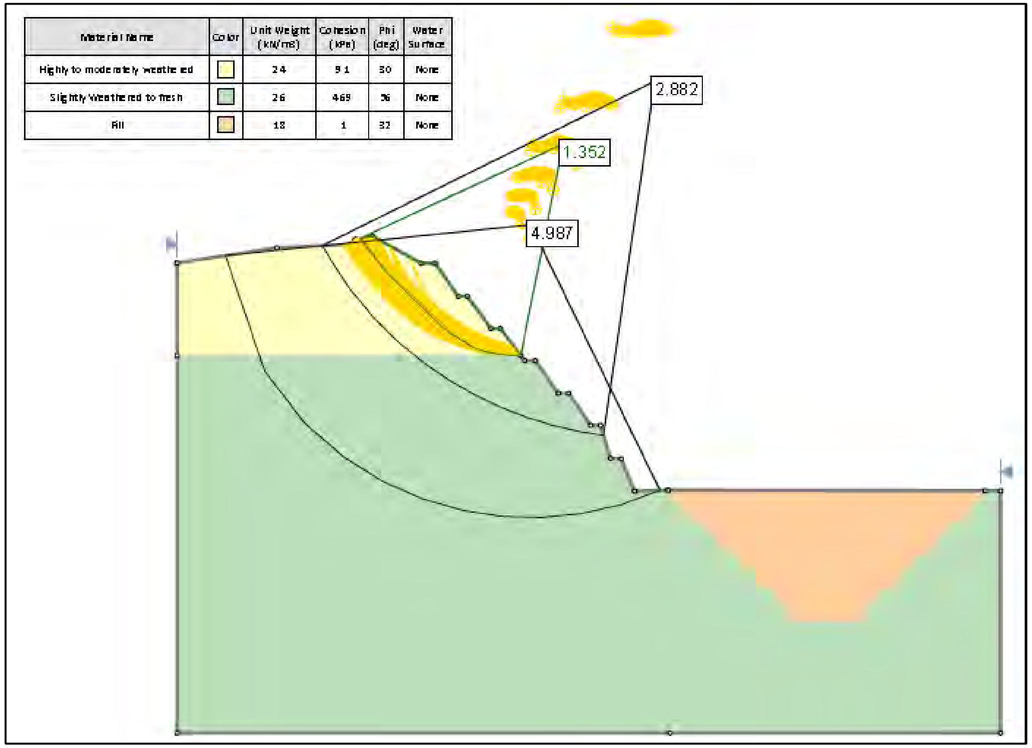
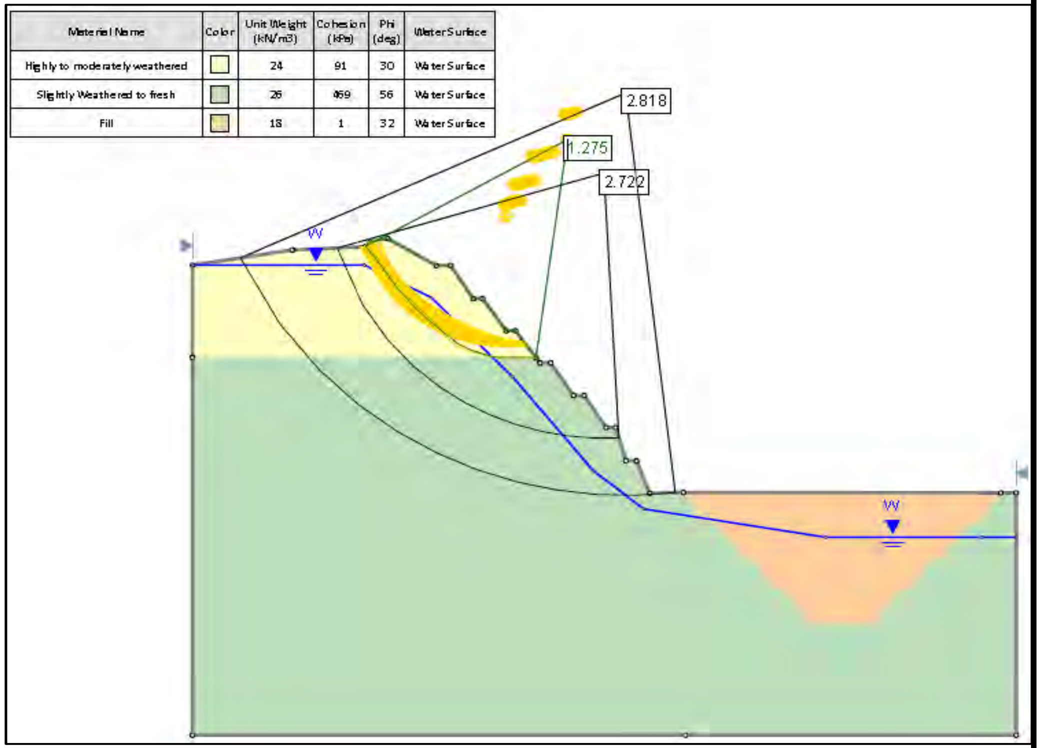
Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**lorth Wall Stability Model - Scenario 1 (Seismic ULS**		
Appendix B	9	**Project Number**	10315



Static - no groundwater

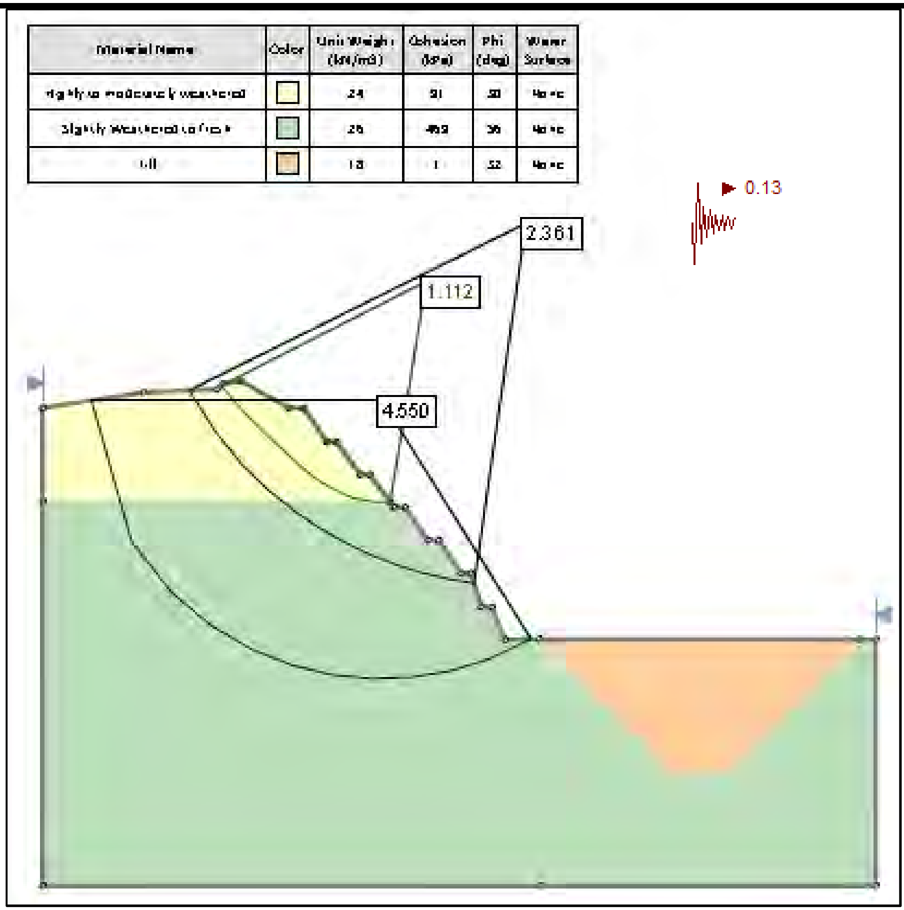


Static - high groundwater

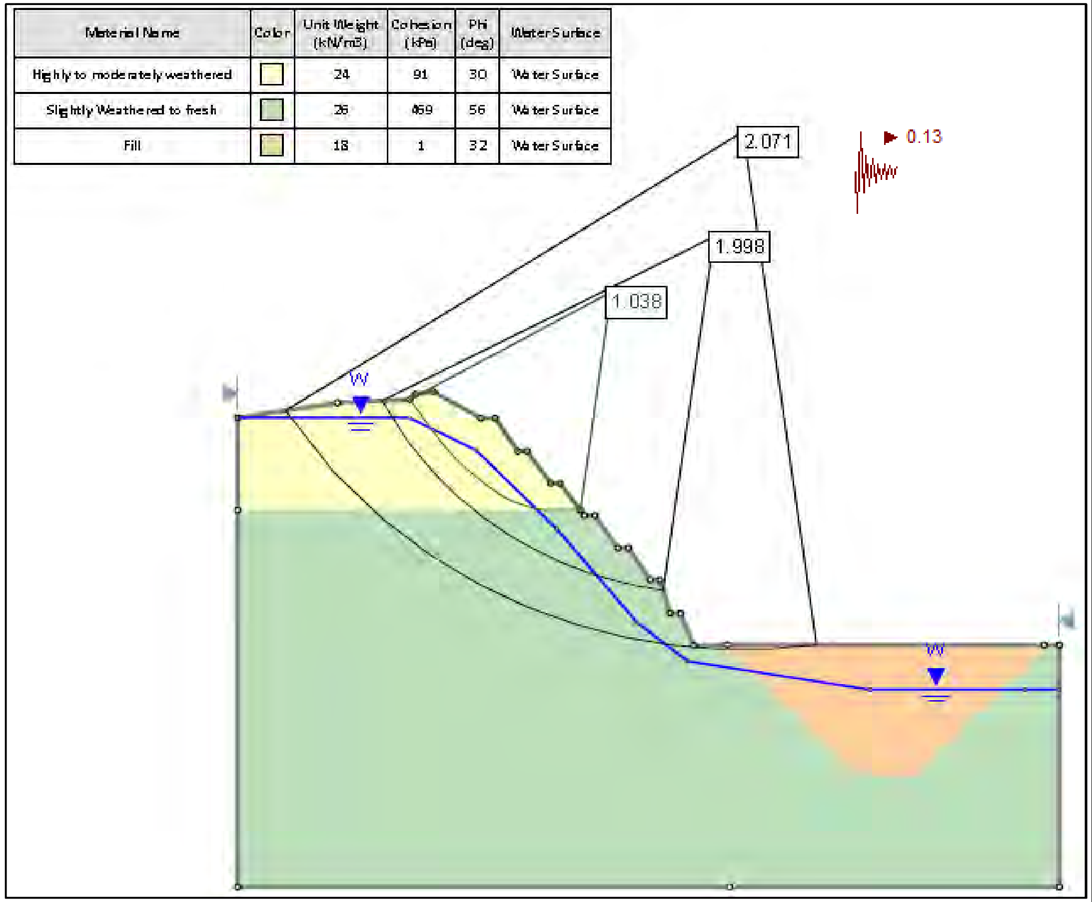
Failure surfaces with a factor of safety of less than 1.5 shown

Failures through slightly weathered Greywacke

Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**North Wall Stability Model - Scenario 2 (Static)**		
Appendix B	10	**Project Number**	10315



1 in 50 year event - low groundwater



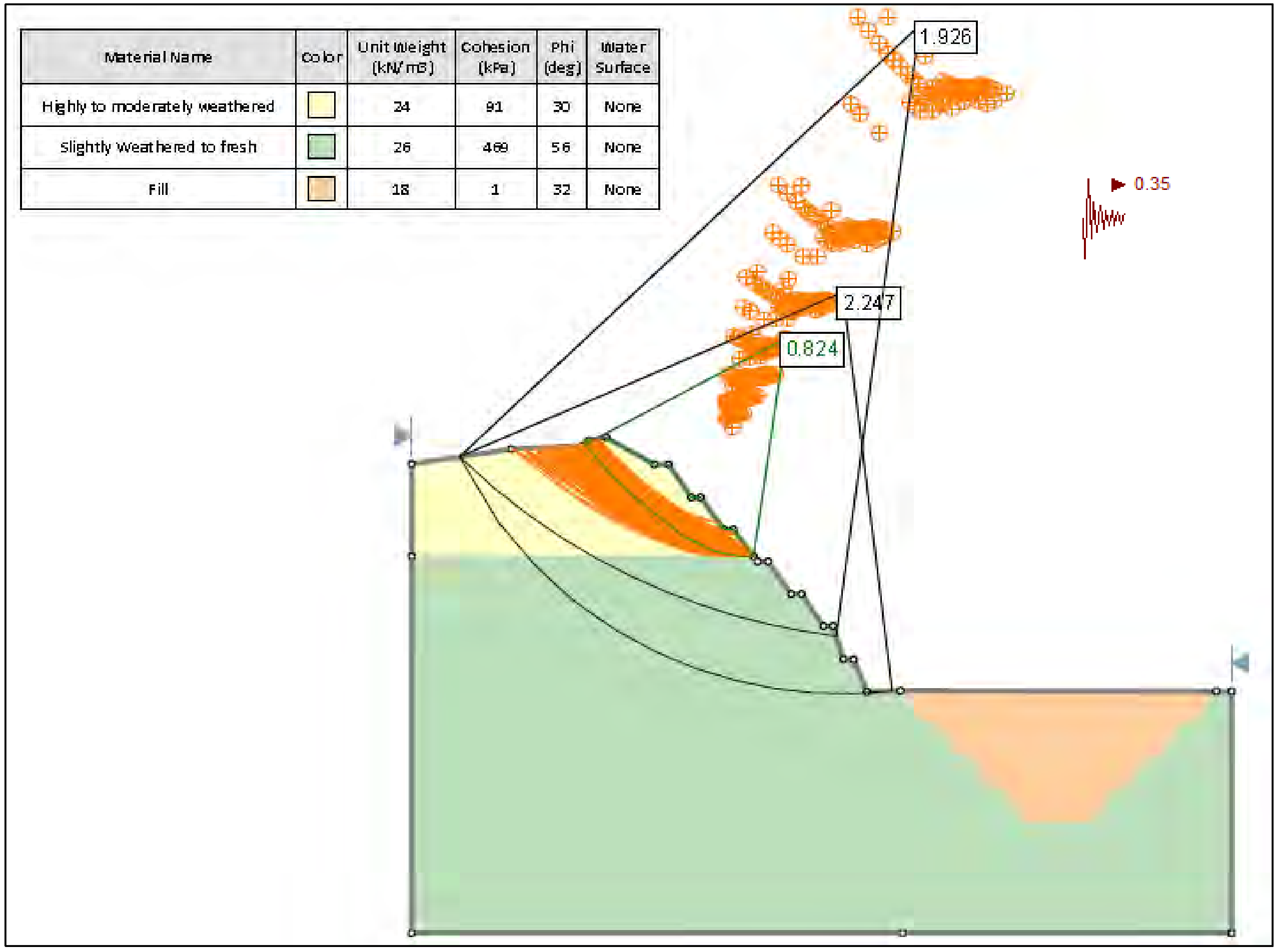
1 in 50 year event - high groundwater

Failure surfaces with a factor of safety of less than 1.5 shown

Failures through slightly weathered Greywacke

GEOSCIENCE A proud partner of ENGEO

Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**lorth Wall Stability Model - Scenario 2 (Seismic SLS)**		
Appendix B	11	**Project Number**	10315



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)	Water Surface
Highly to moderately weathered		24	91	30	None
Slightly Weathered to fresh		26	469	56	None
Fill		18	1	32	None

1 in 500 year event

Failure surfaces with a factor of safety of less than 1.5 shown

Failures through slightly weathered Greywacke

GEOSCIENCE
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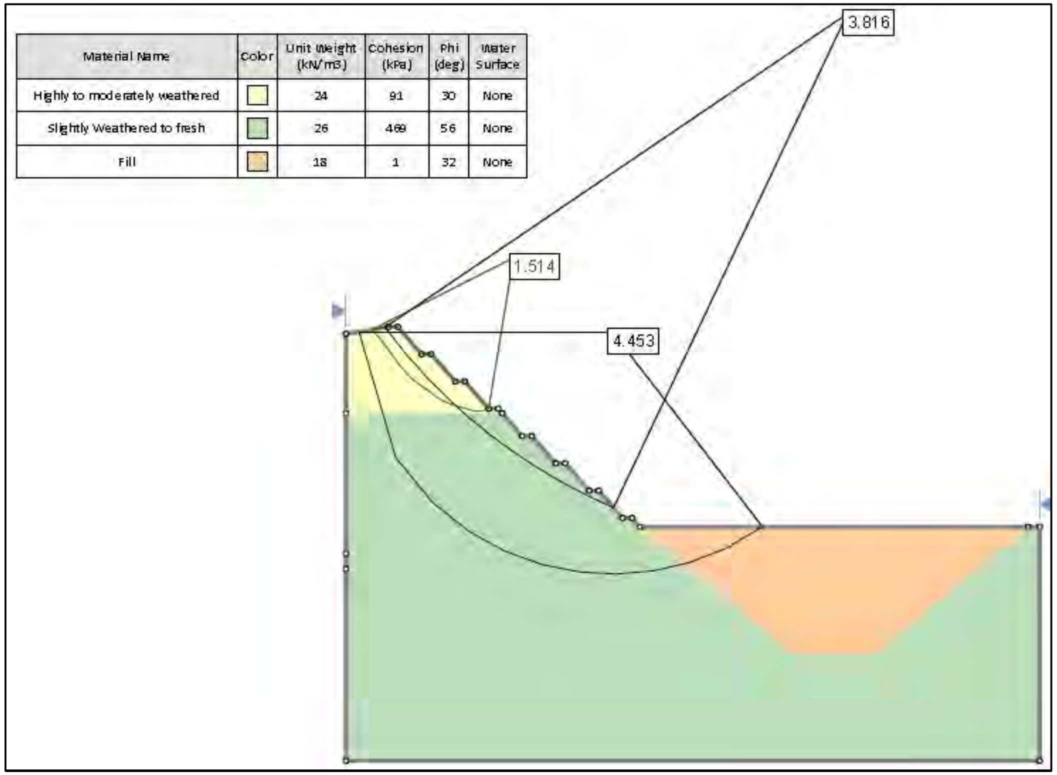
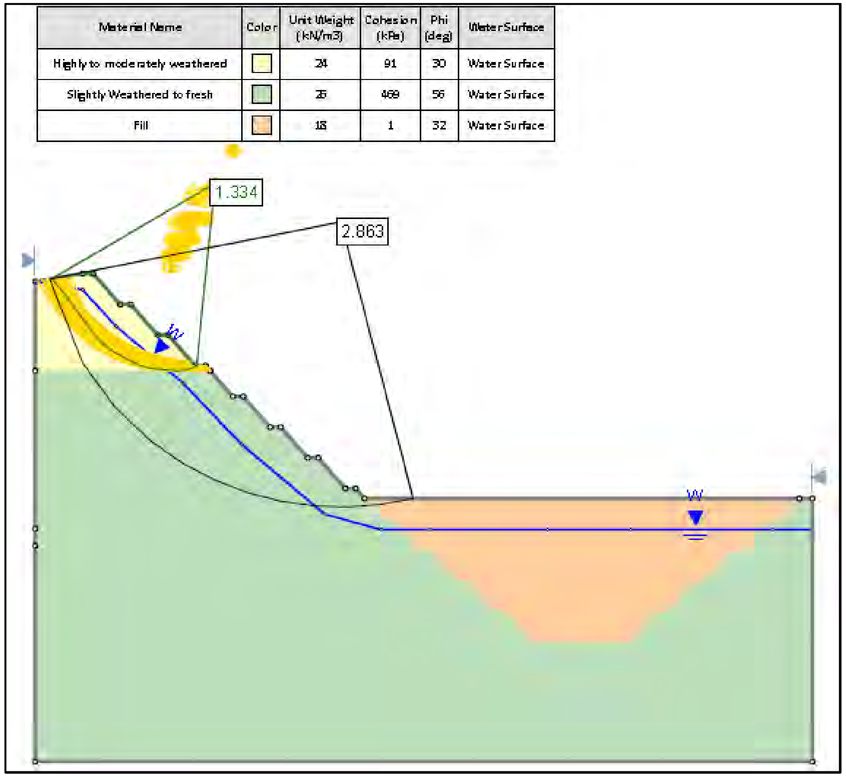
Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**lorth Wall Stability Model - Scenario 2 (Seismic ULS)**		
Appendix B	12	**Project Number**	10315



Static - no groundwater



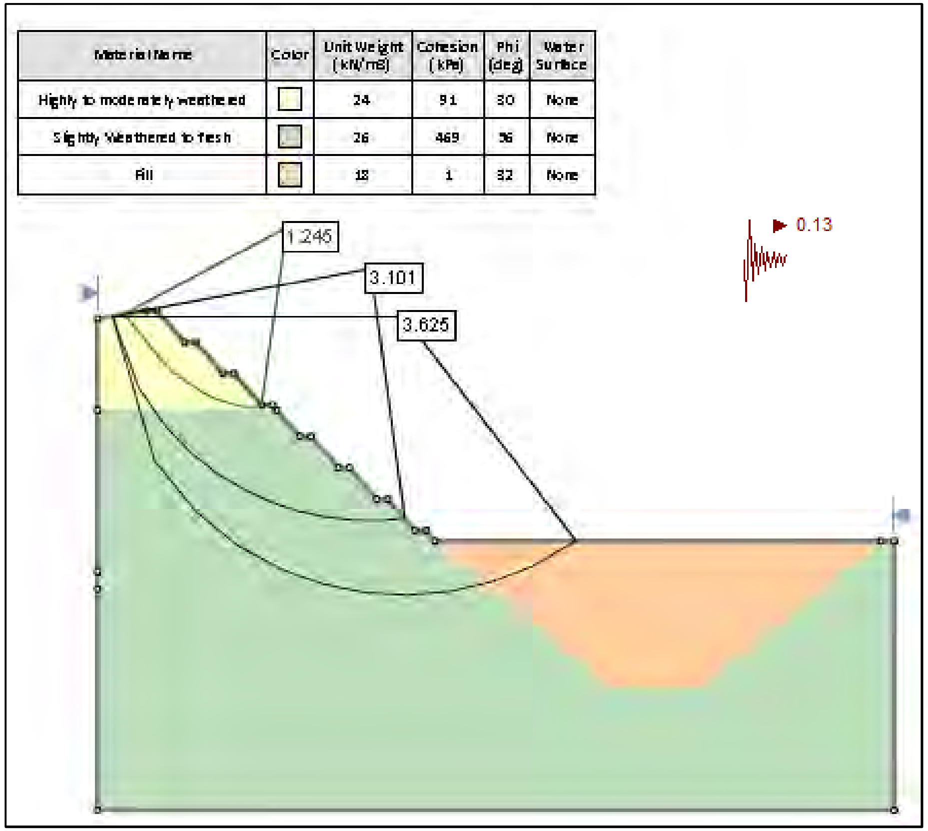
Static - high groundwater

Failure surfaces with a factor of safety of less than 1.5 shown

Failures through slightly weathered Greywacke

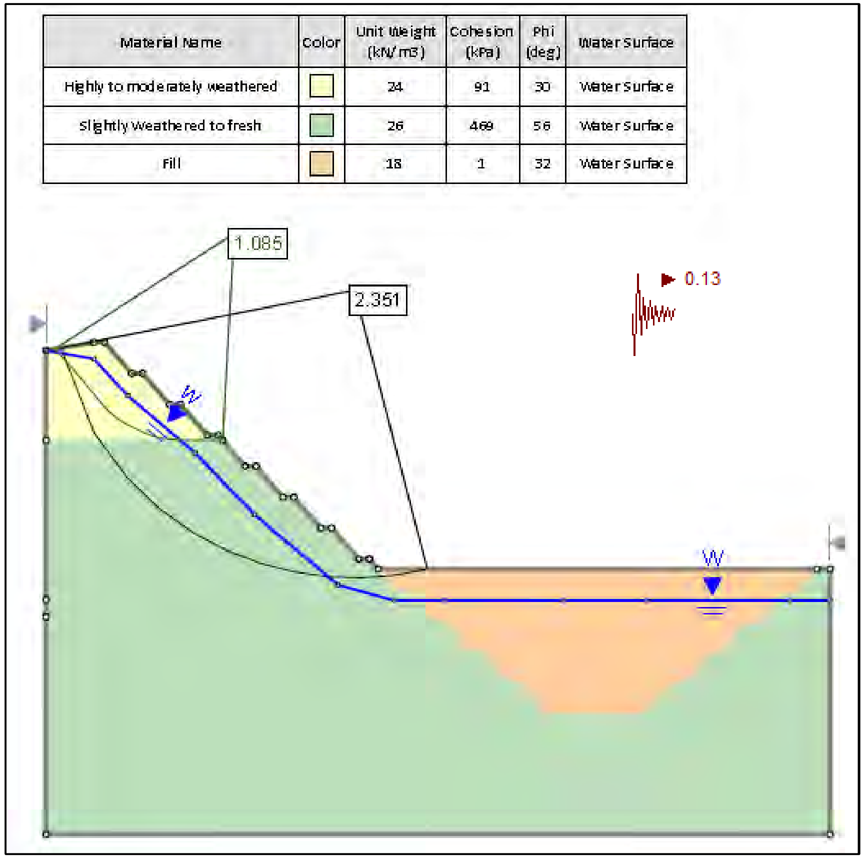
GEOSCIENCE
A proud partner of ENGEO

Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**North Wall Stability Model - Scenario 3 (Static)**		
Appendix B	13	**Project Number**	10315



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)	Water Surface
Highly to moderately weathered		24	91	30	None
Slightly Weathered to fresh		26	469	56	None
Fill		18	1	32	None

1 in 50 year event - low groundwater



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)	Water Surface
Highly to moderately weathered		24	91	30	Water Surface
Slightly Weathered to fresh		26	469	56	Water Surface
Fill		18	1	32	Water Surface

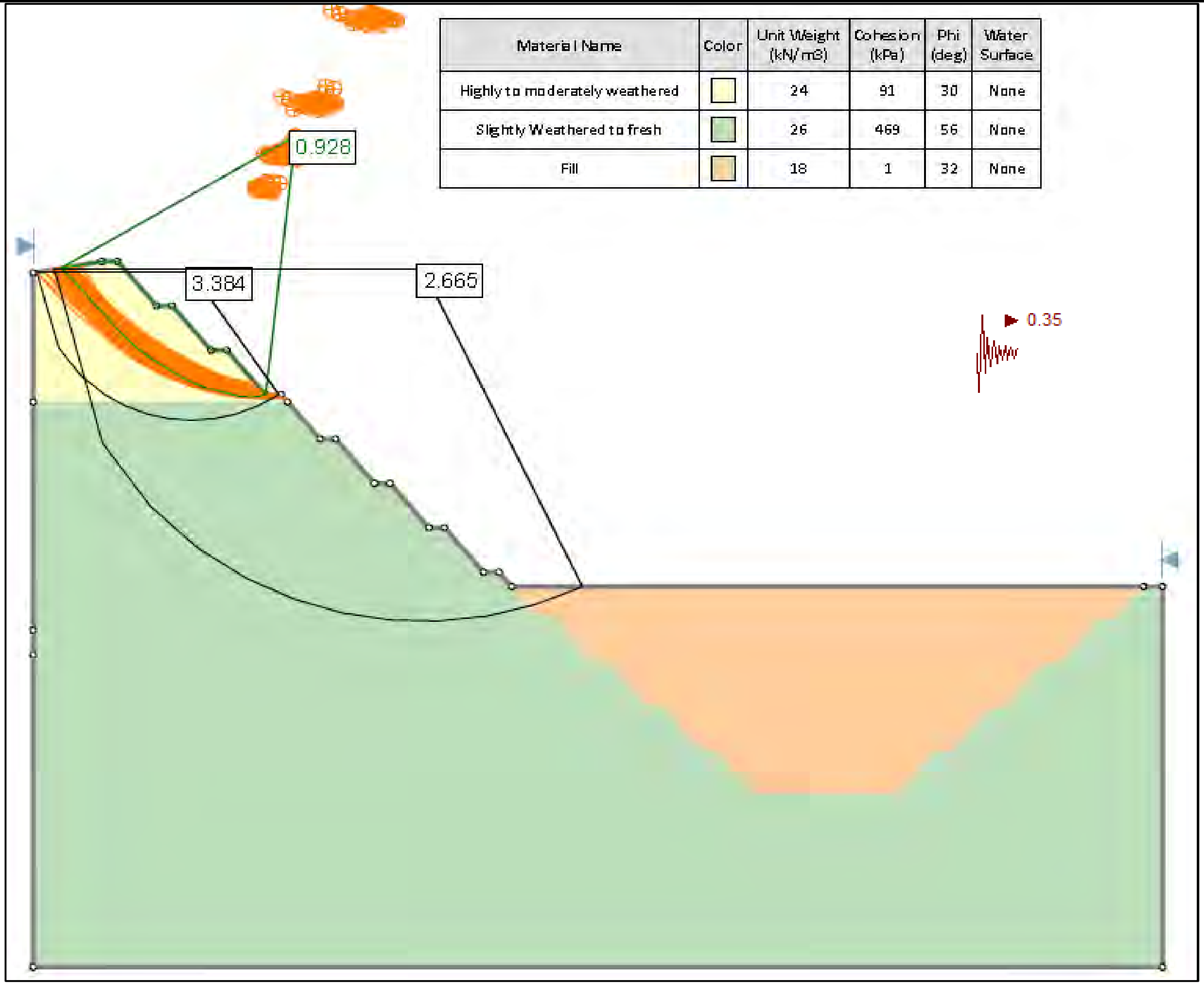
1 in 50 year event - high groundwater

Failure surfaces with a factor of safety of less than 1.5 shown

Failures through slightly weathered Greywacke

GEOSCIENCE A proud partner of ENGEO

Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**North Wall Stability Model - Scenario 3 (Seismic SLS)**		
Appendix B	14	**Project Number**	10315



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)	Water Surface
Highly to moderately weathered		24	91	30	None
Slightly Weathered to fresh		26	469	56	None
Fill		18	1	32	None

1 in 500 year event

Failure surfaces with a factor of safety of less than 1.5 shown

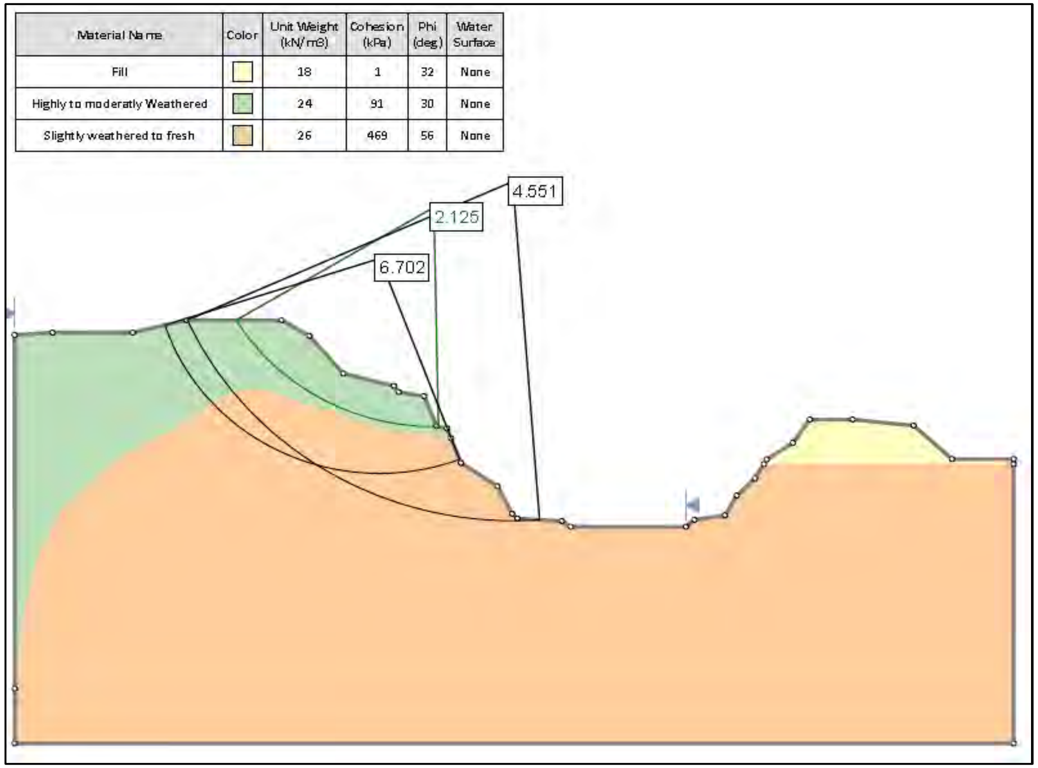
Failures through slightly weathered Greywacke

GEOSCIENCE
A proud partner of ENGEO

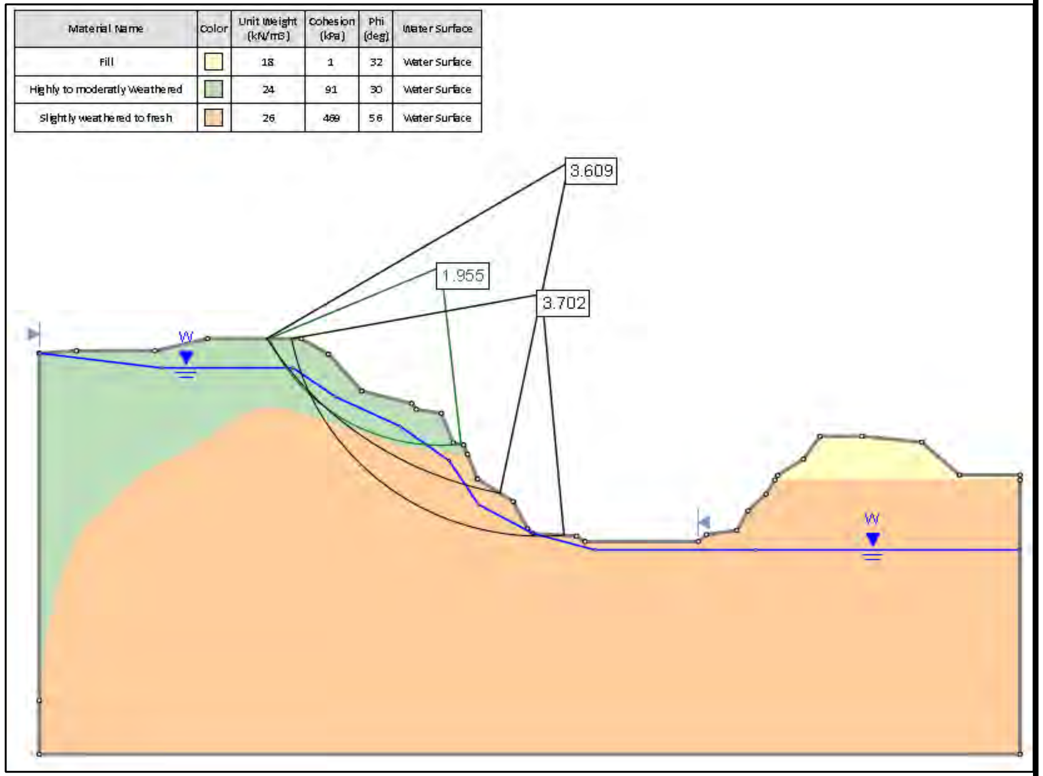
Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**lorth Wall Stability Model - Scenario 3 (Seismic ULS)**		
Appendix B	15	**Project Number**	10315

Appendix C

West Wall Slide Slope Stability Outputs



Static - no Groundwater



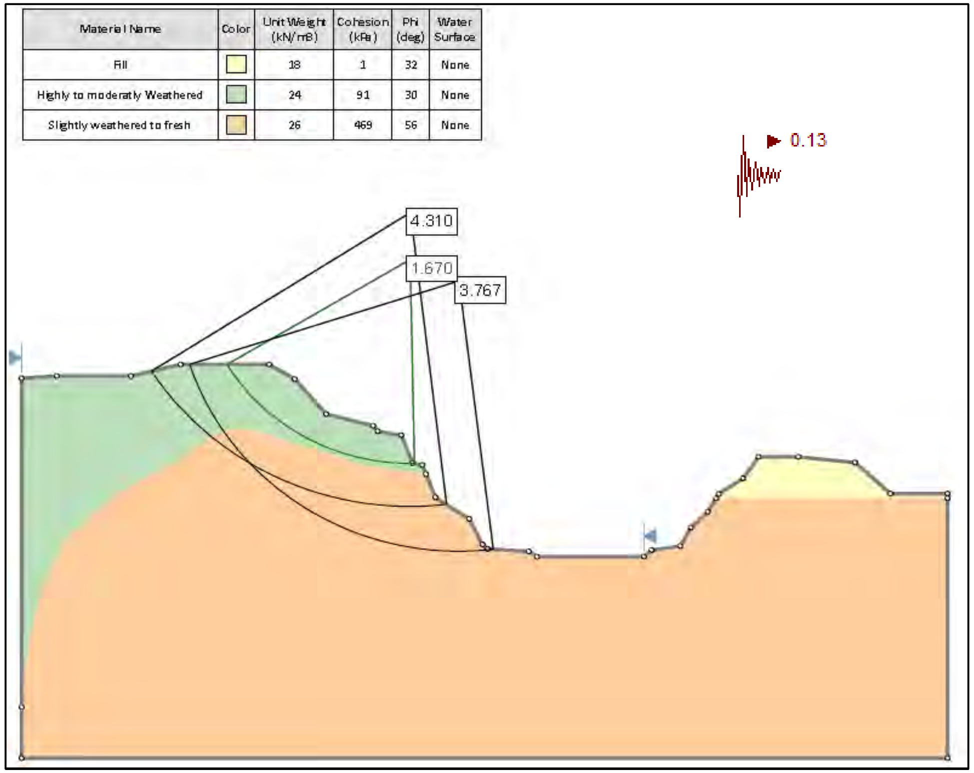
Static - high Groundwater

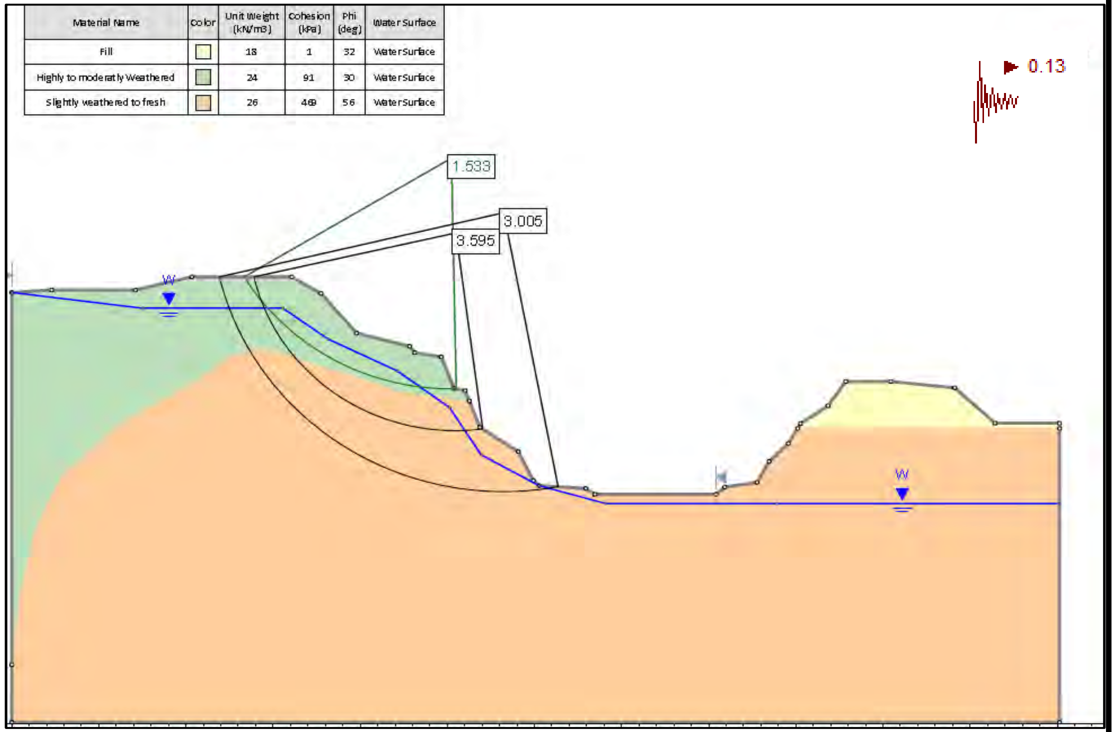
No failure surfaces with a factor of safety of less than 1.5

Failure through moderately weathered Greywacke

GEOSCIENCE A proud partner of ENGEO

Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**West Wall Stability Model - Existing (Static)**		
Appendix C	1	**Project Number**	10315





1 in 50 year event

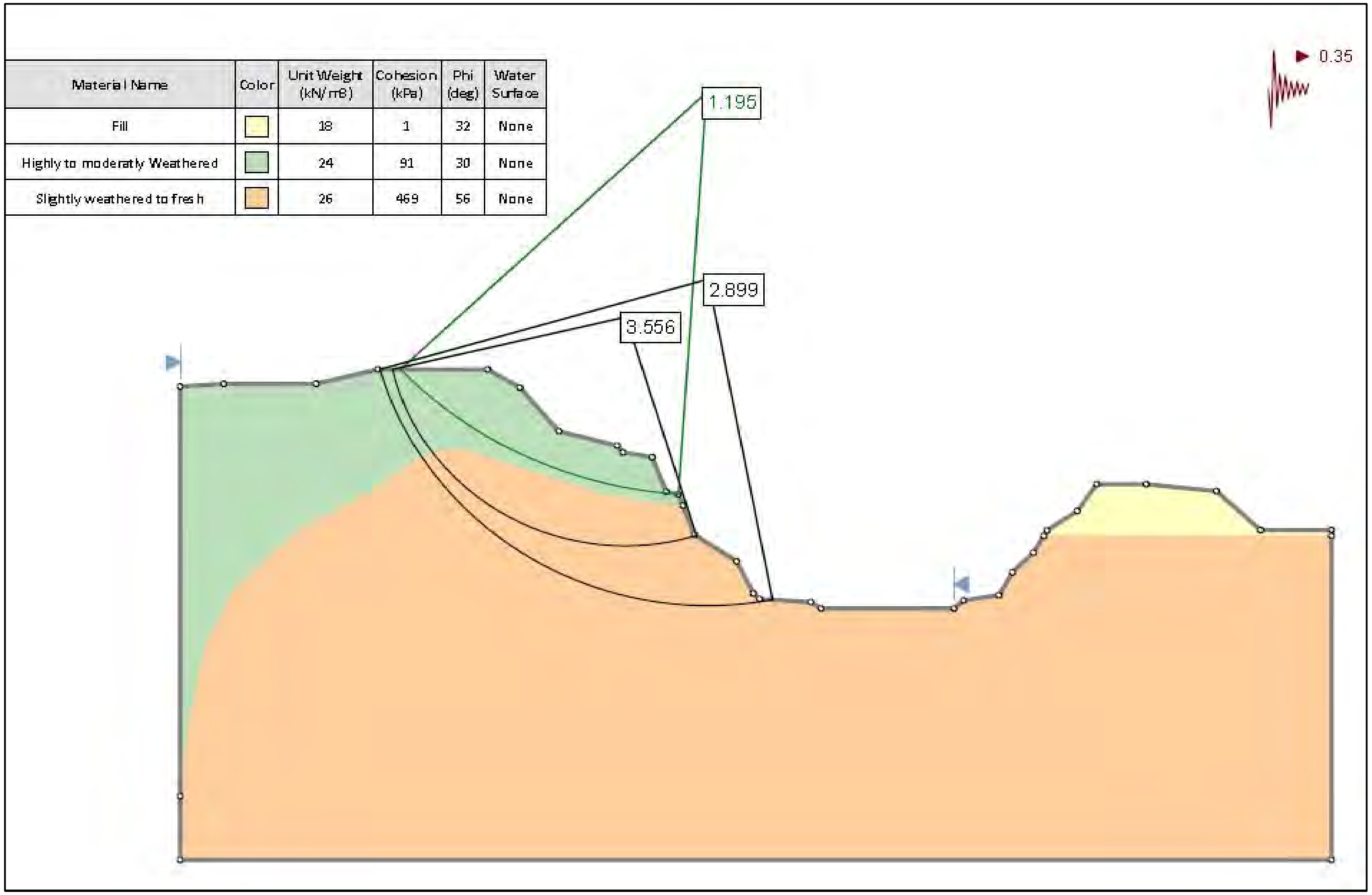
1 in 50 year event - high groundwater

No failure surfaces with a factor of safety of less than 1.5

Failure through moderately weathered Greywacke

GEOSCIENCE A proud partner of ENGEO

Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**West Wall Stability Model - Existing (Seismic SLS)**		
Appendix C	2	**Project Number**	10315



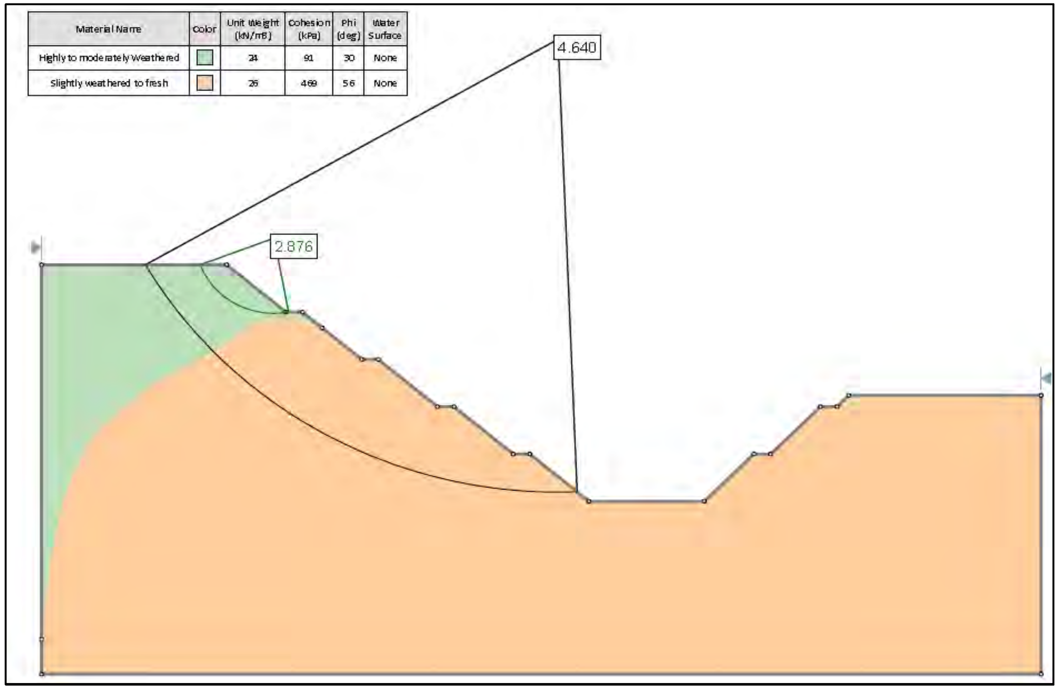
Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)	Water Surface
Fill		18	1	32	None
Highly to moderatly Weathered		24	91	30	None
Slightly weathered to fresh		26	469	56	None

1 in 500 year event

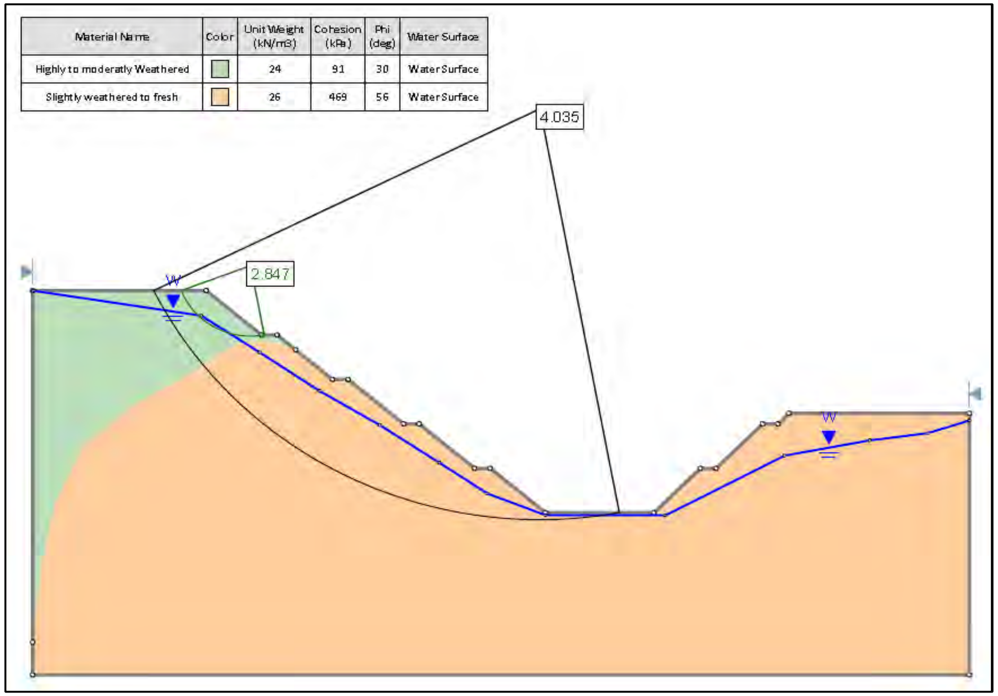
Failure through moderately weathered Greywacke

GEOSCIENCE
A proud partner of ENGEO

Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**West Wall Stability Model - Existing (Seismic ULS)**		
Appendix C	3	**Project Number**	10315



Static no groundwater



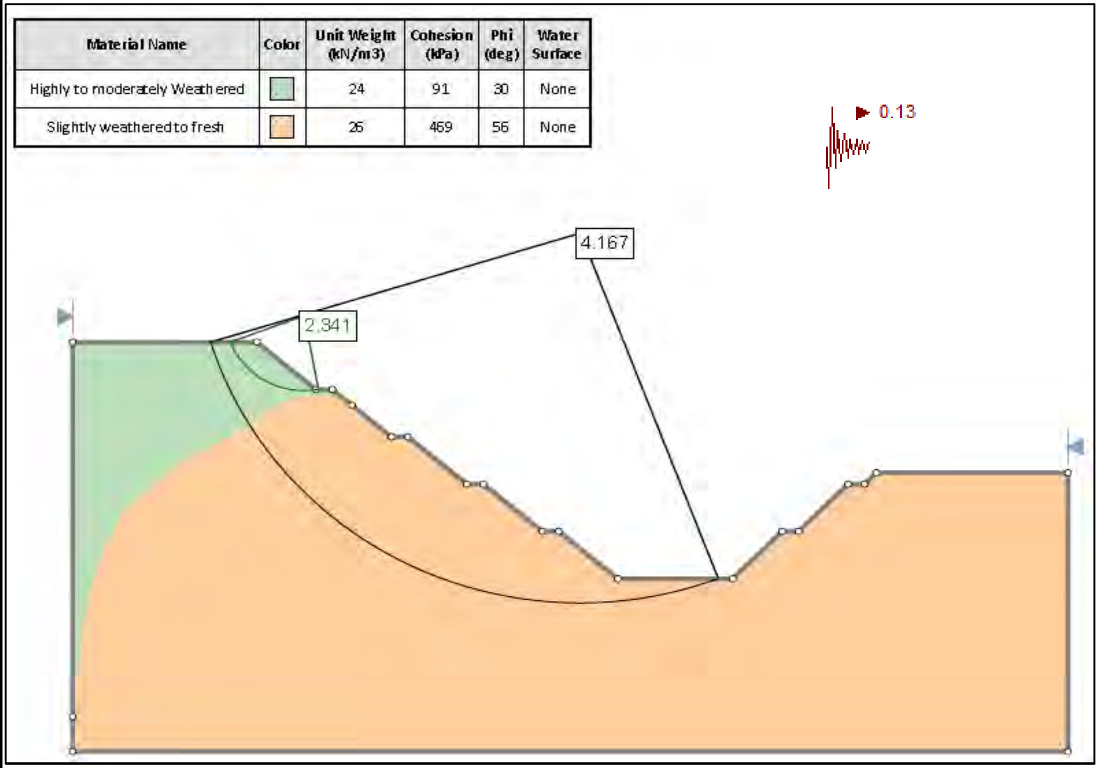
Static - high Groundwater

No failure surfaces with a factor of safety of less than 1.5

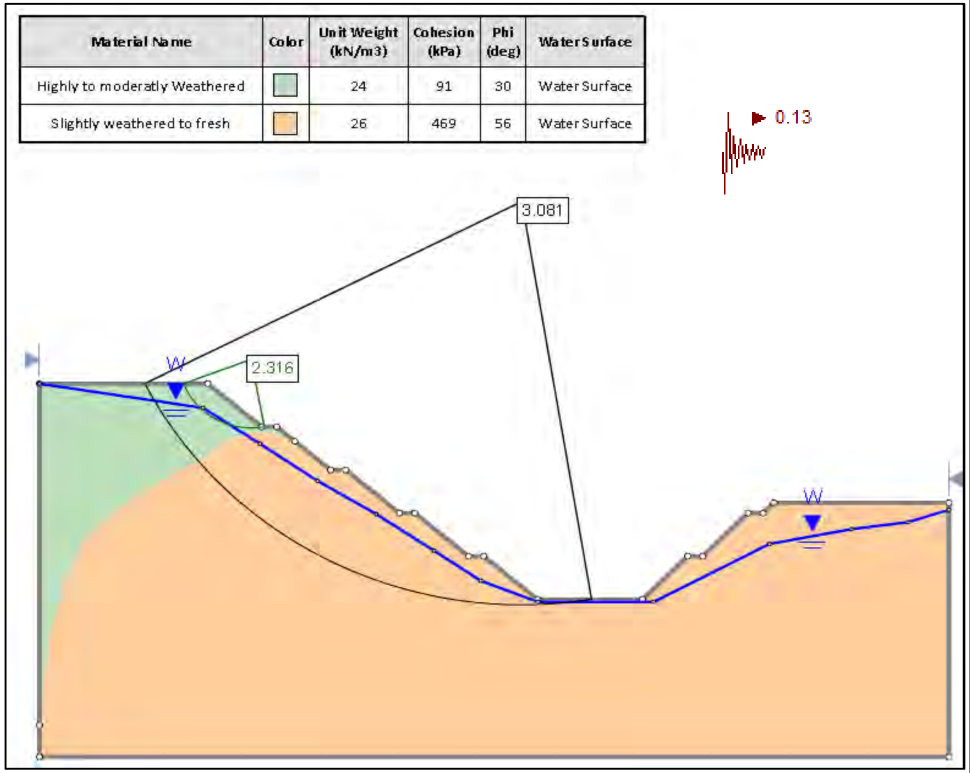
Failure through moderately weathered Greywacke

GEOSCIENCE A proud partner of ENGEO

Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**West Wall Stability Model - Proposed (Static)**		
Appendix C	4	**Project Number**	10315



1 in 50 year event



1 in 50 year event - high groundwater

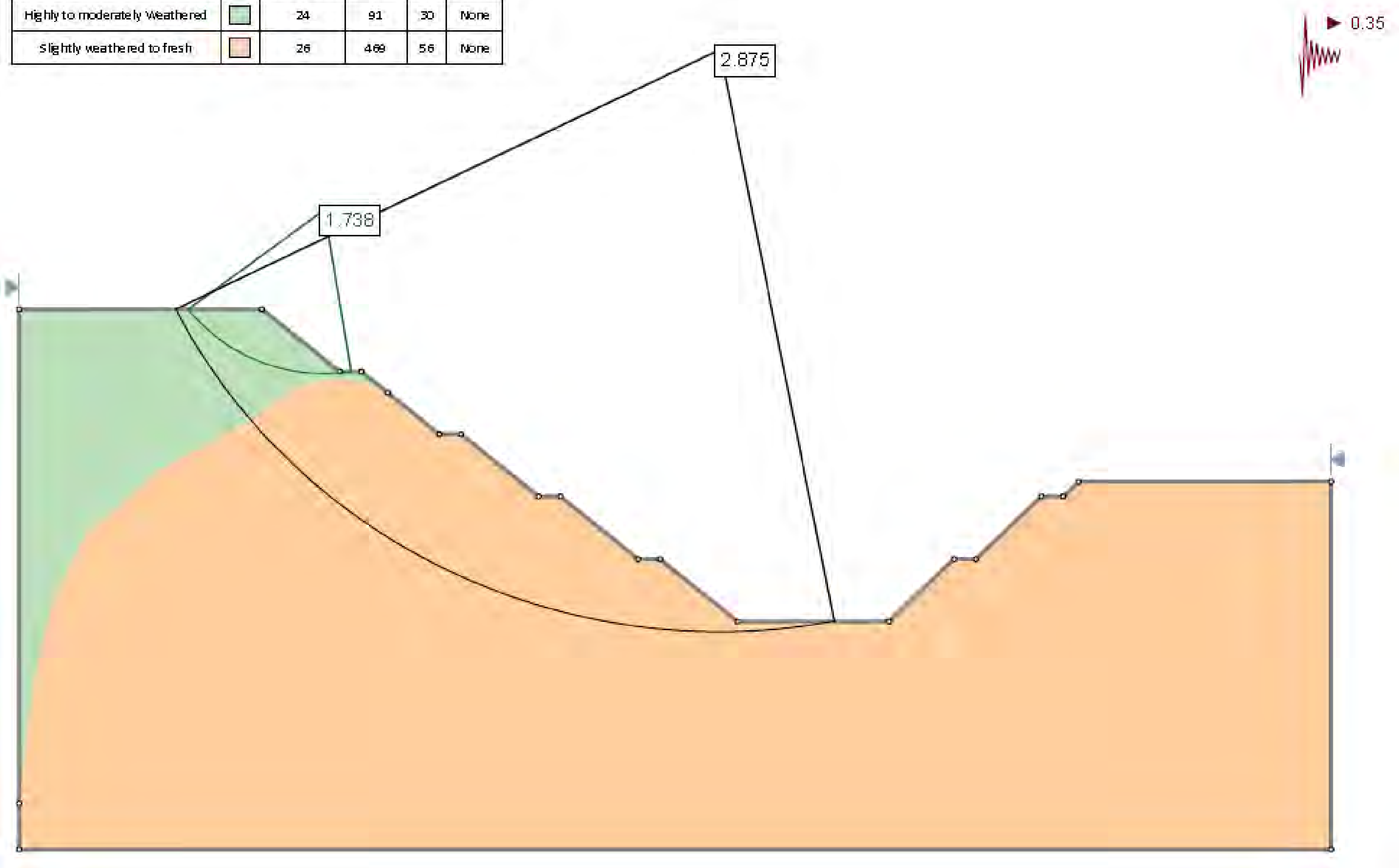
No failure surfaces with a factor of safety of less than 1.5

Failure through moderately weathered Greywacke

GEOSCIENCE A proud partner of ENGEO

Client	**Holcim (NZ) Limited**		
Project	**KiwiPoint Quarry**		
Description	**West Wall Stability Model - Proposed (Seismic SLS)**		
Appendix C	5	**Project Number**	10315

Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)	Water Surface
Highly to moderately Weathered		24	91	30	None
Slightly weathered to fresh		26	469	56	None



1 in 500 year event

No failure surfaces with a factor of safety of less than 1.5

Failure through moderately weathered Greywacke

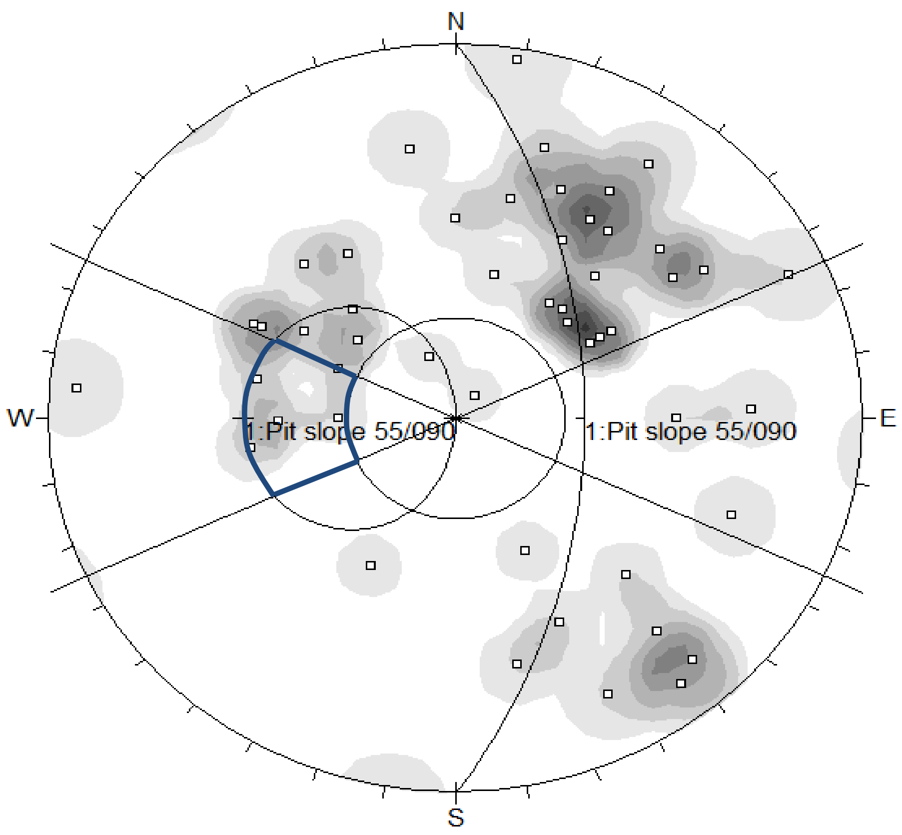
GEOSCIENCE A proud partner of ENGEO

Client	Holcim (NZ) Limited		
Project	KiwiPoint Quarry		
Description	West Wall Stability Model - Proposed (Seismic ULS)		
Appendix C	6	Project Number	10315

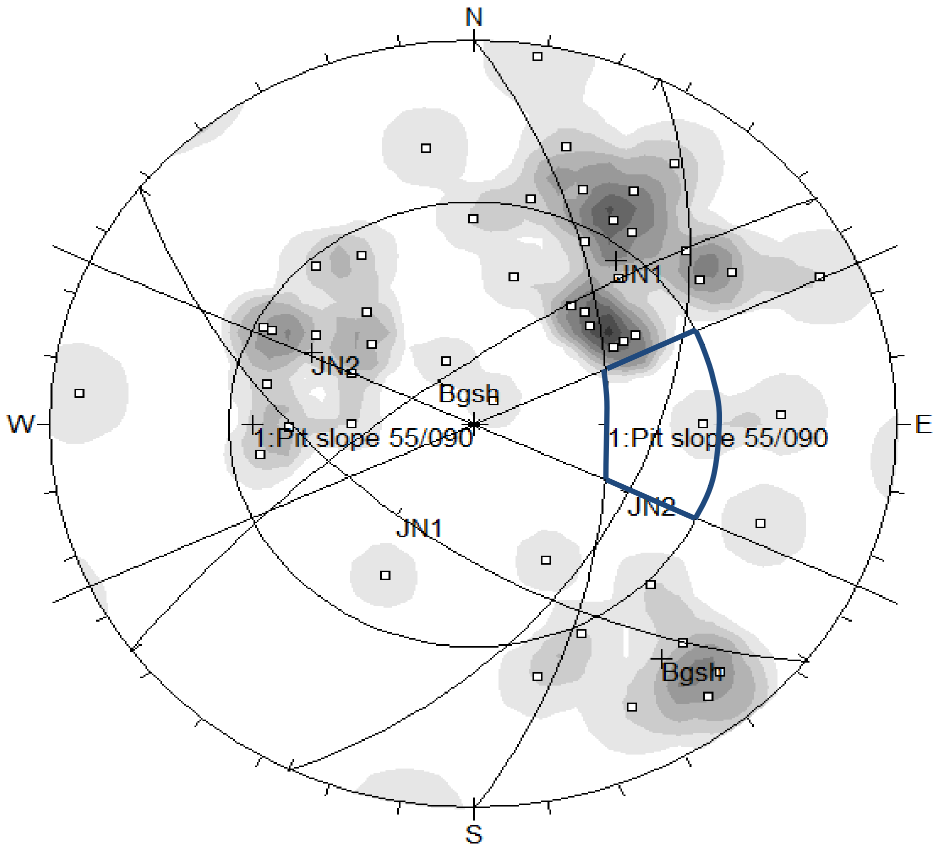
Appendix D

Dips Analysis

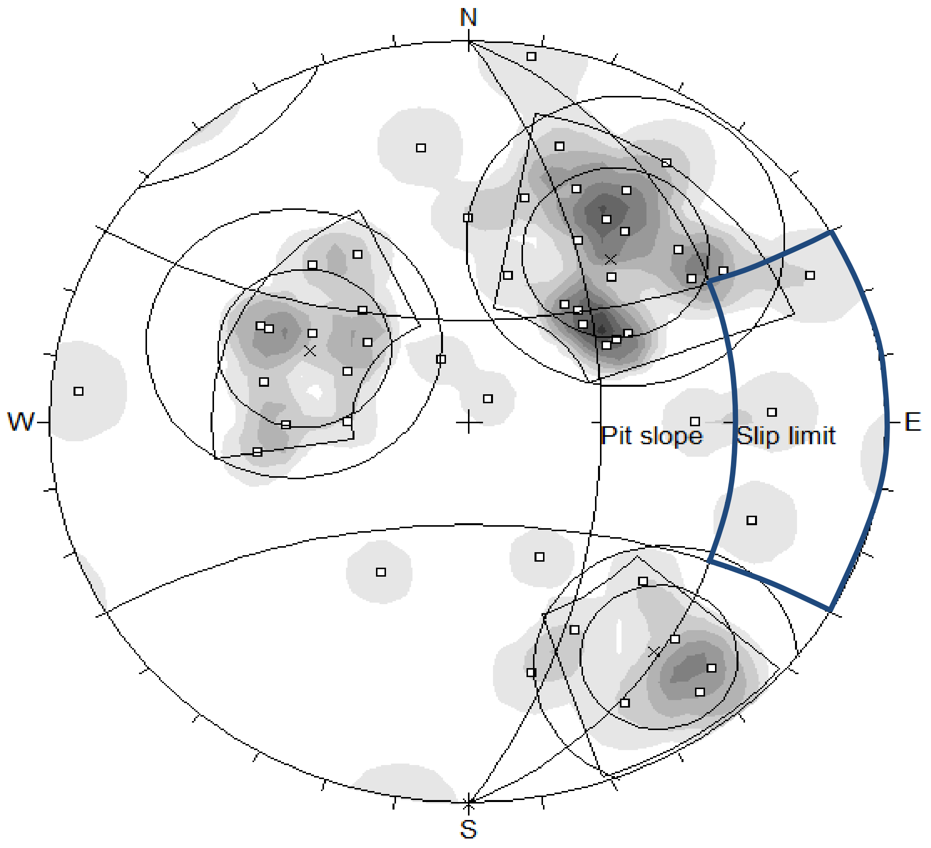
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 55° EAST FACING BATTER BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: High potential for planar failure for cut slopes with 55° batter angle and East orientation



Control on Stability: Low potential for wedge failure for cut slopes with 55° batter angle and East orientation

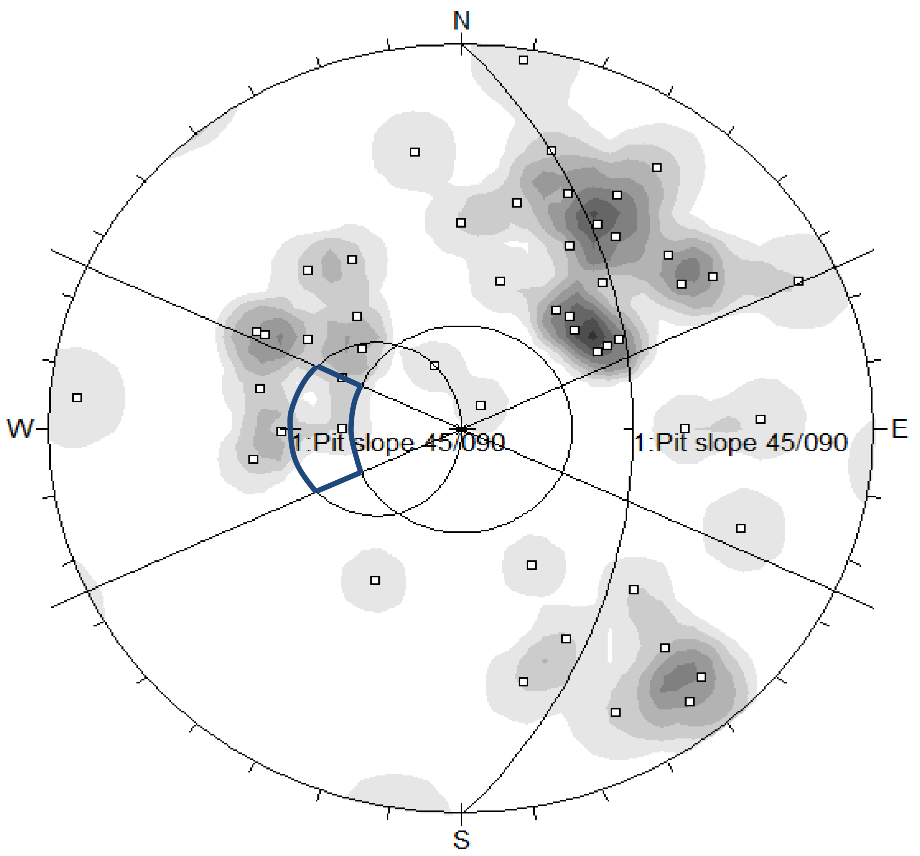


Control on Stability: Moderate potential for toppling failure for cut slopes with 55° batter angle and East orientation

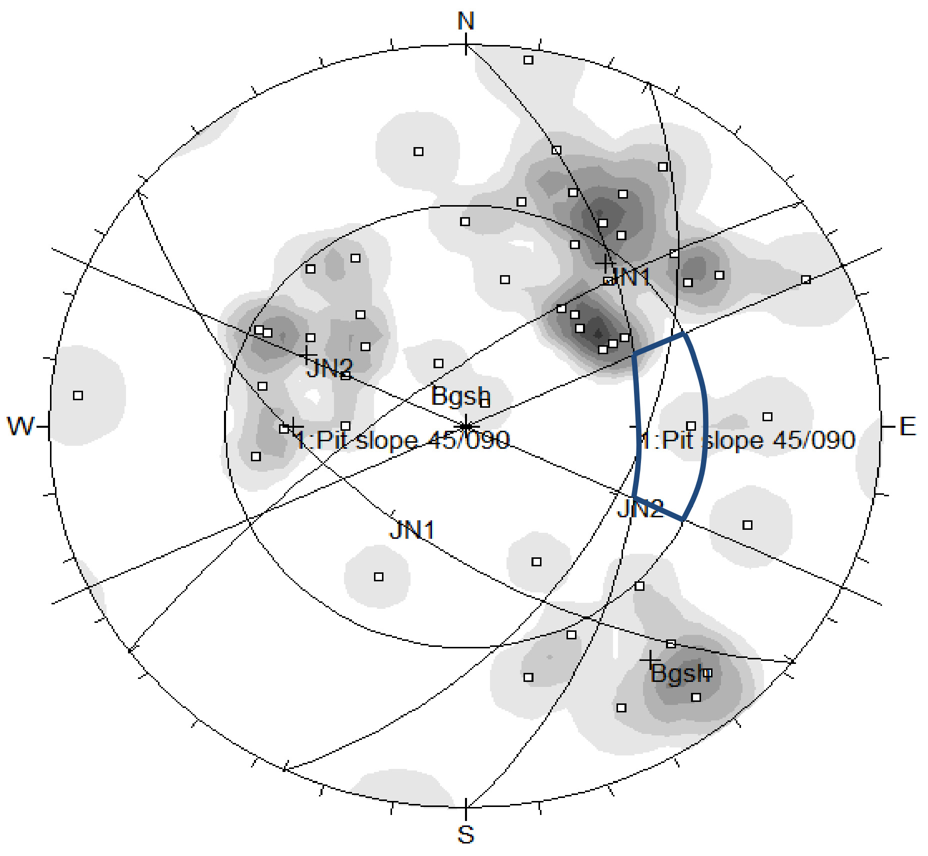
Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

GEOSCIENCE A proud partner of ENGEO

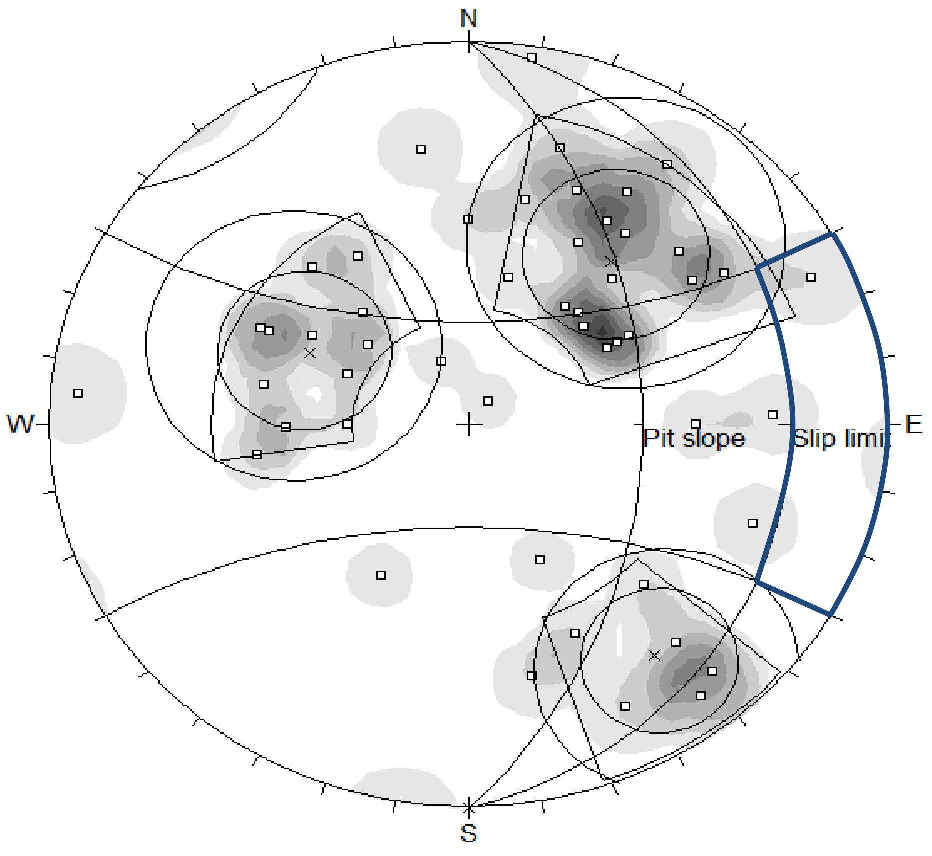
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 45° EAST FACING BATTER BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: Moderate potential for planar failure for cut slopes with 45° batter angle and East orientation



Control on Stability: Low potential for wedge failure for cut slopes with 45° batter angle and East orientation

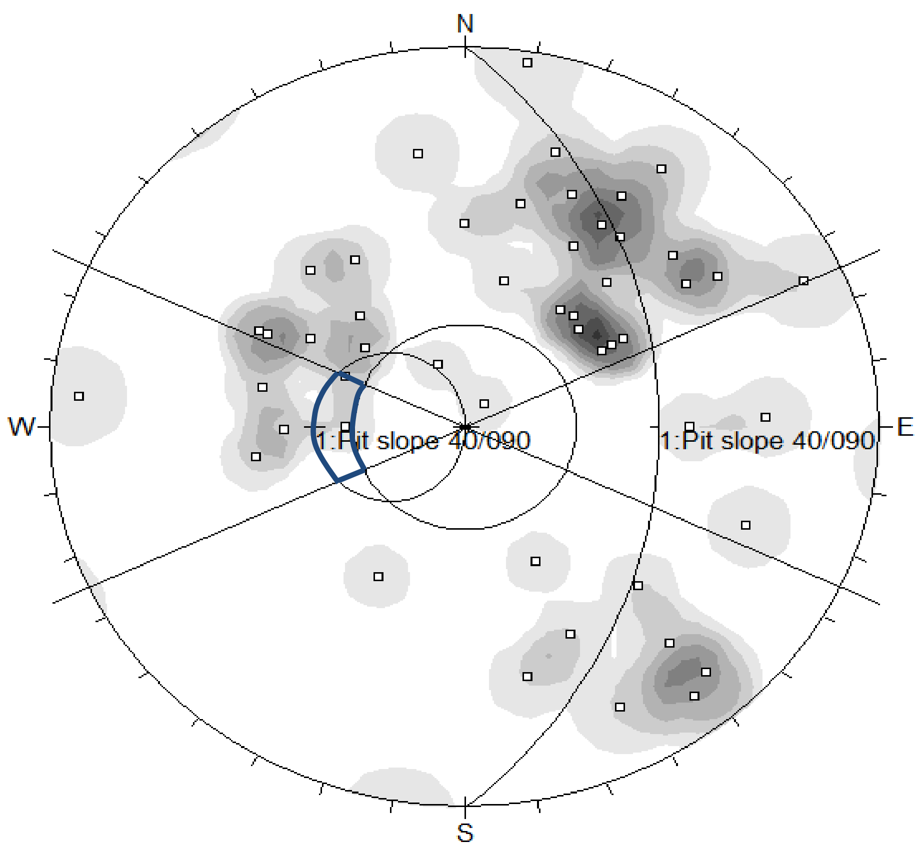


Control on Stability: Low potential for toppling failure for cut slopes with 45° batter angle and East orientation

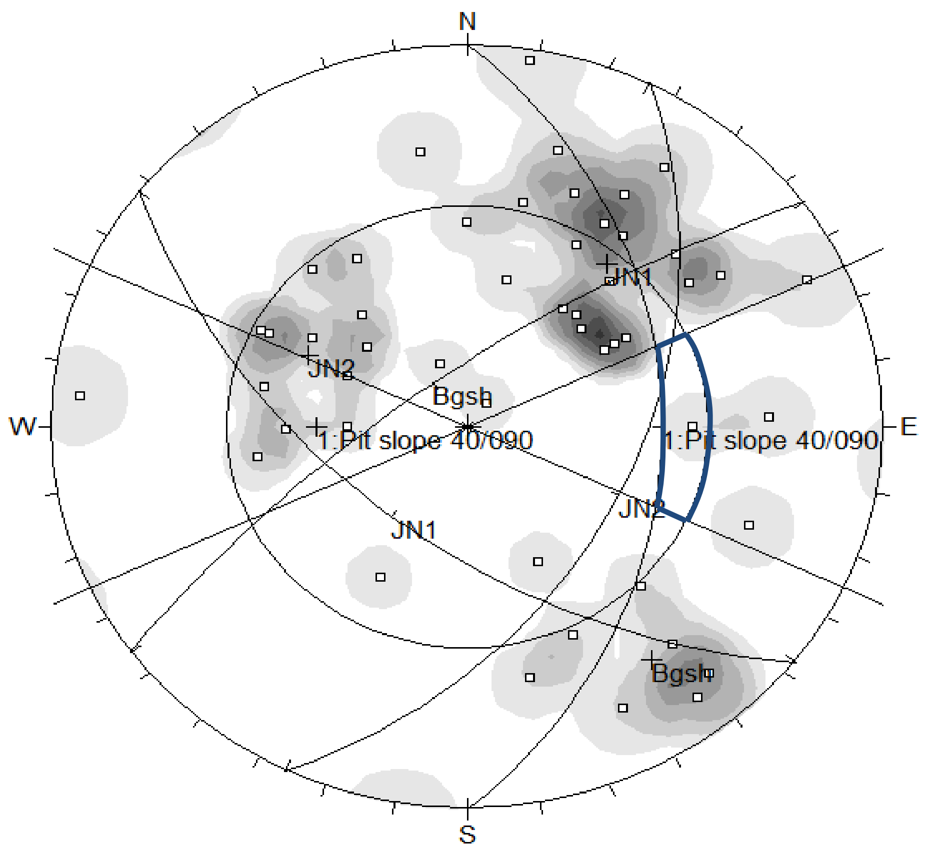
GEOSCIENCE
A proud partner of ENGEO

Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

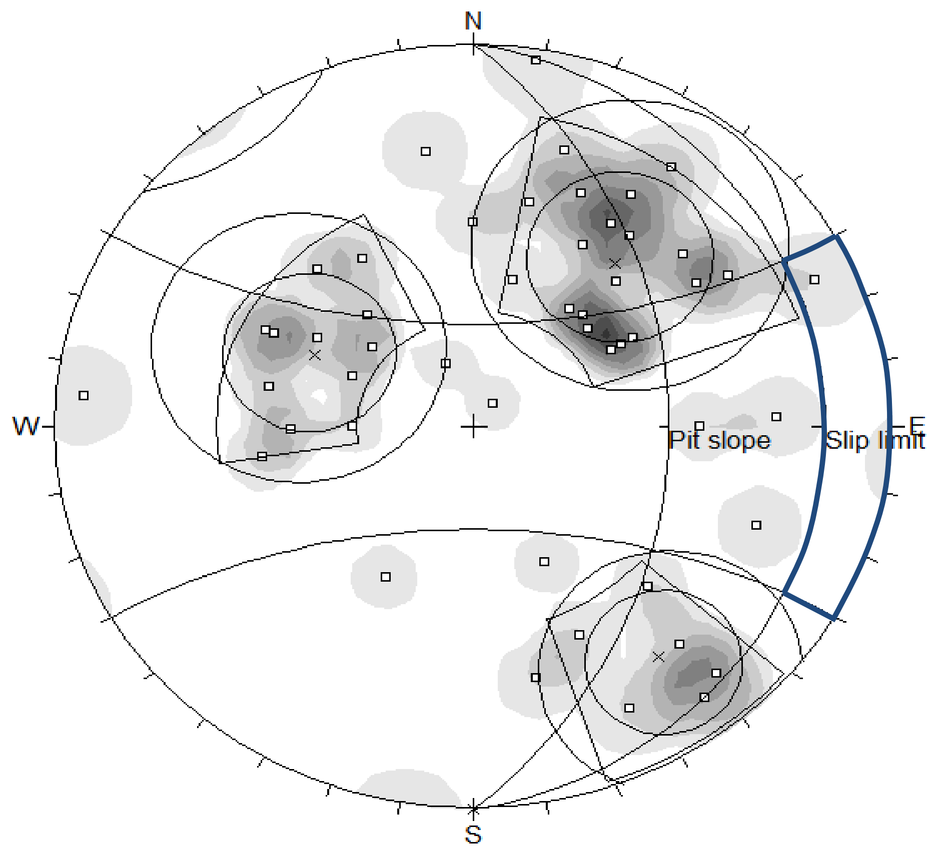
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 40° EAST FACING BATTER BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: Moderate potential for planar failure for cut slopes with 40° batter angle and East orientation



Control on Stability: Low potential for wedge failure for cut slopes with 40° batter angle and East orientation

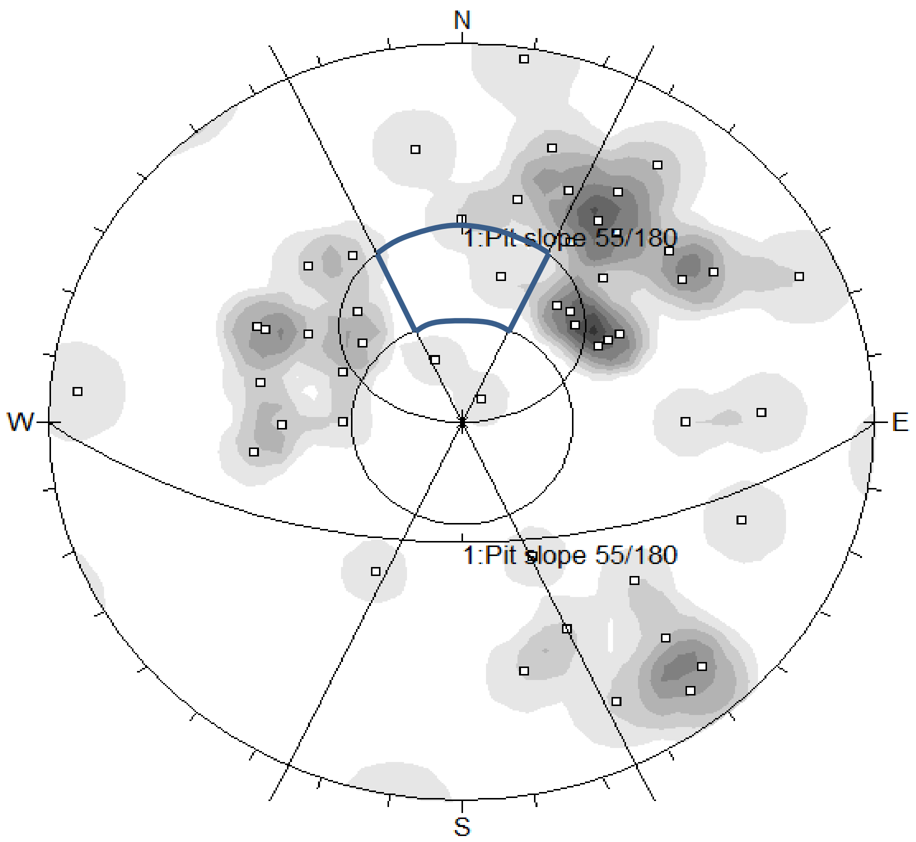


Control on Stability: Low potential for toppling failure for cut slopes with 40° batter angle and East orientation

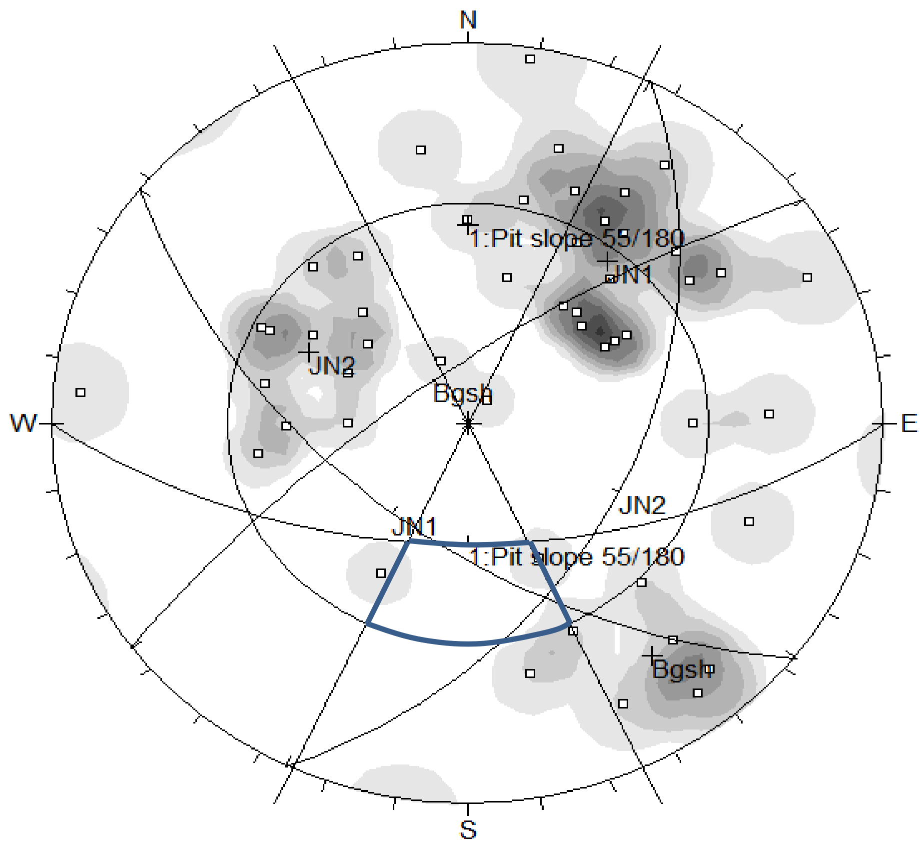
GEOSCIENCE A proud partner of ENGEO

Date	20/02/15	**Client**	**Holcim (NZ) Limited**
Drawn by	GL	**Project**	**Kiwi Point Quarry Stability Analyses**
Approved by	KJ	**Description**	**Failure Analysis**
Scale	N/A	**Project Number**	10315

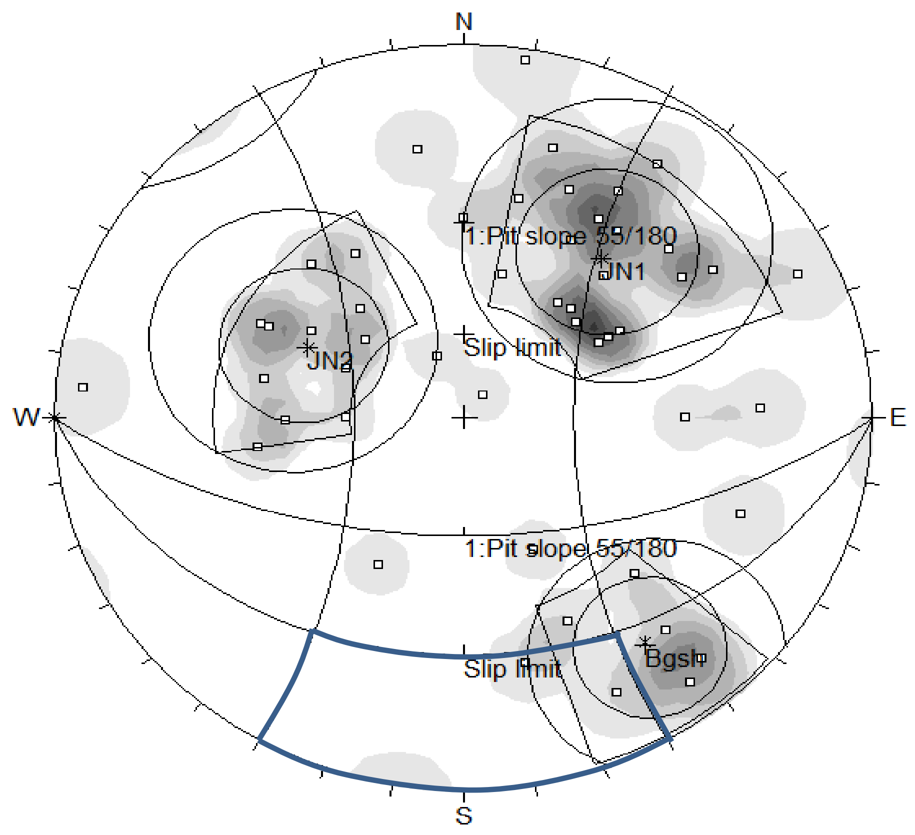
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 55° SOUTH FACING BATTER BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: Moderate potential for planar failure for cut slopes with 55° batter angle and South orientation



Control on Stability: High potential for wedge failure for on joint sets JN1 and JN2 for cut slopes with 55° batter angle and South orientation

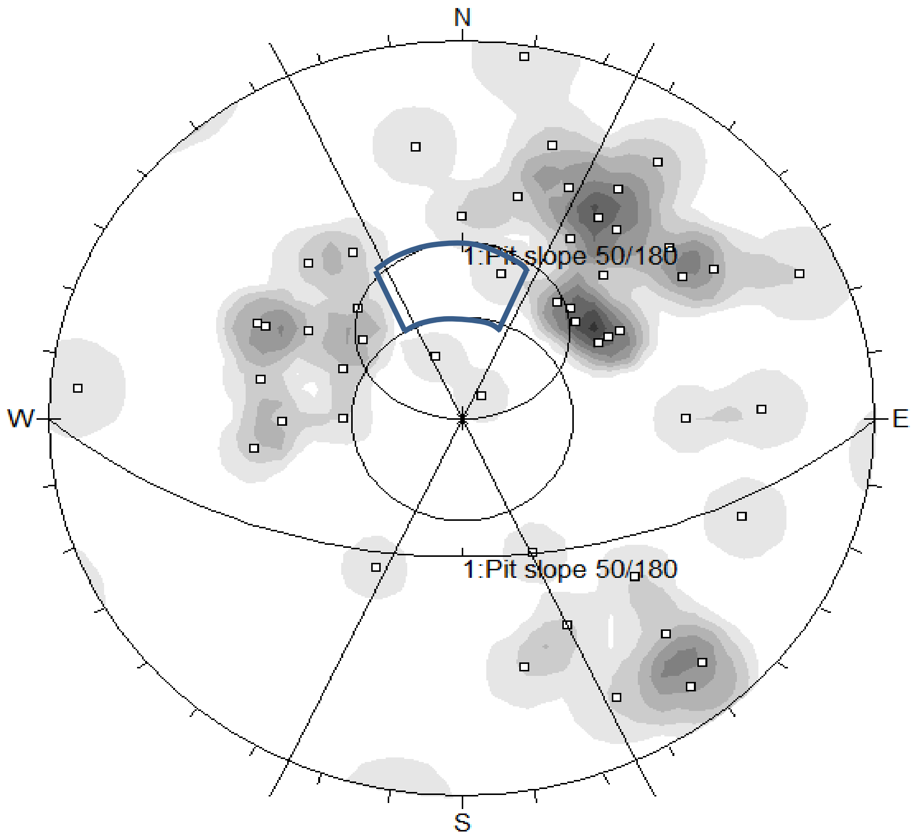


Control on Stability: Moderate potential for toppling failure for cut slopes with 55° batter angle and South orientation

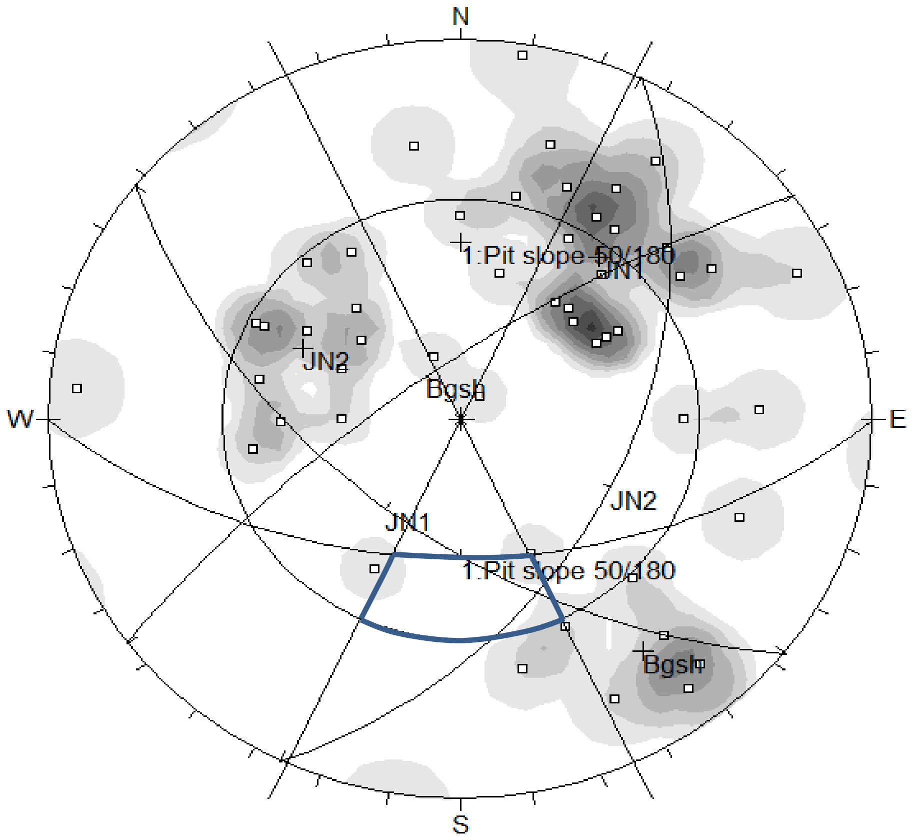
GEOSCIENCE A proud partner of ENGEO

Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

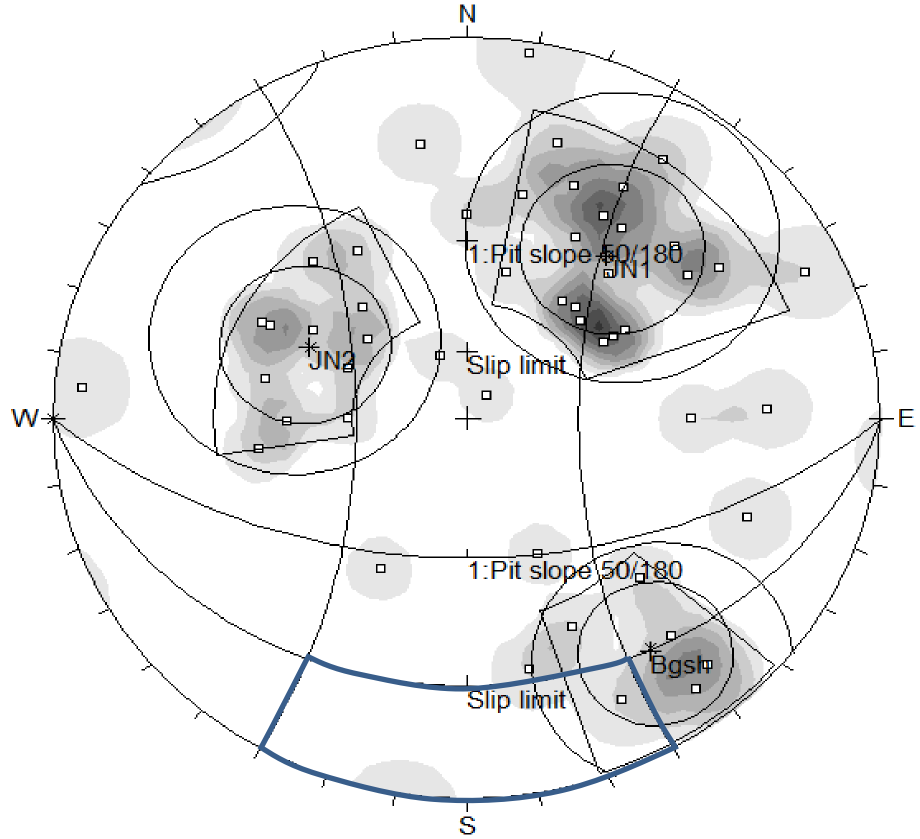
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 50° SOUTH FACING BATTER BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: Moderate potential for planar failure for cut slopes with 50° batter angle and South orientation



Control on Stability: High potential for wedge failure for on joint sets JN1 and JN2 for cut slopes with 50° batter angle and South orientation

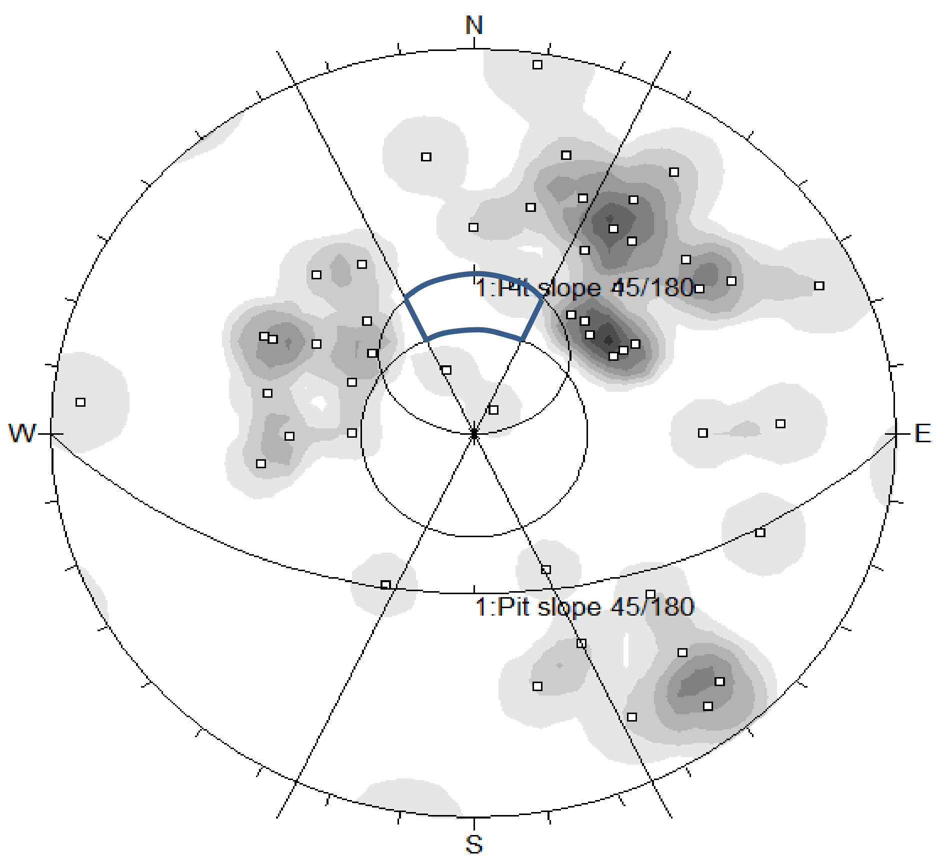


Control on Stability: Moderate potential for toppling failure for cut slopes with 50° batter angle and South orientation

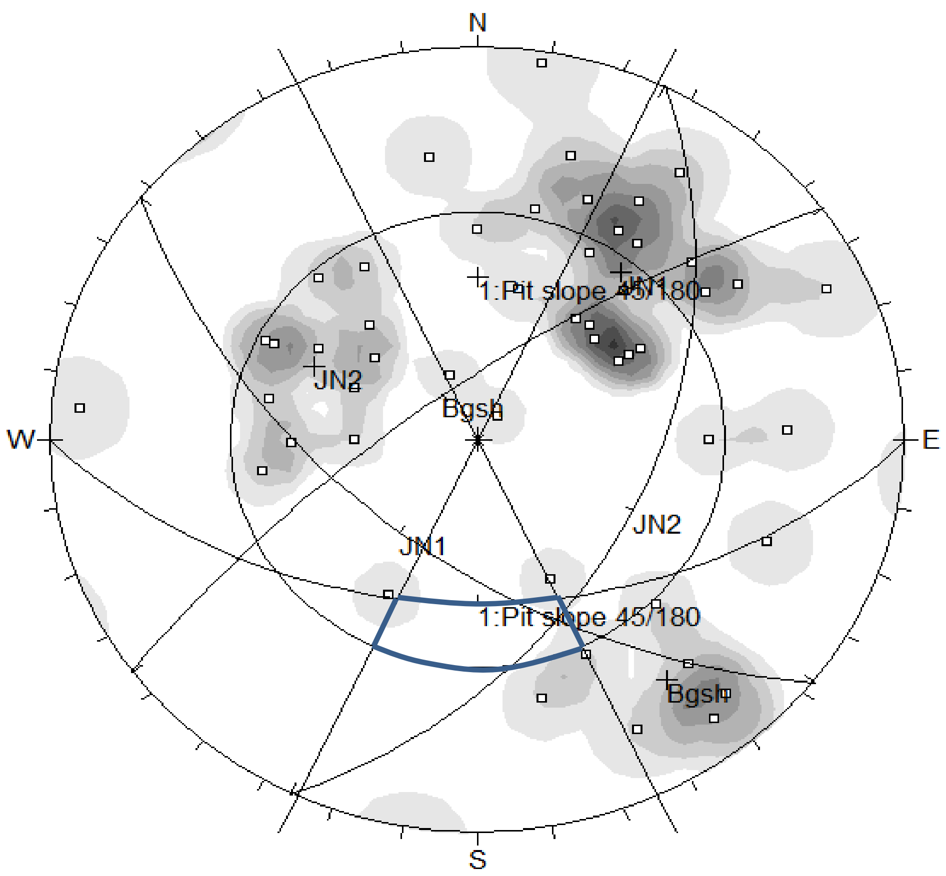
GEOSCIENCE A proud partner of ENGEO

Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

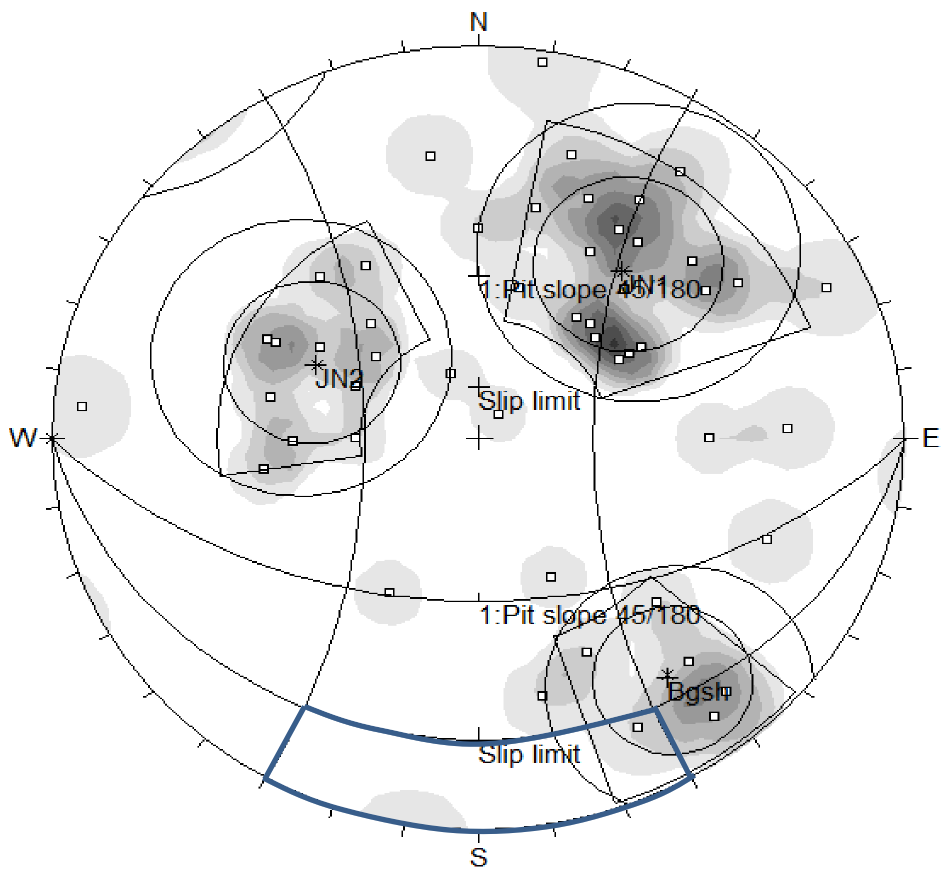
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 45° SOUTH FACING BATTER BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: Low potential for planar failure for cut slopes with 45° batter angle and South orientation



Control on Stability: High potential for wedge failure for on joint sets JN1 and JN2 for cut slopes with 45° batter angle and South orientation

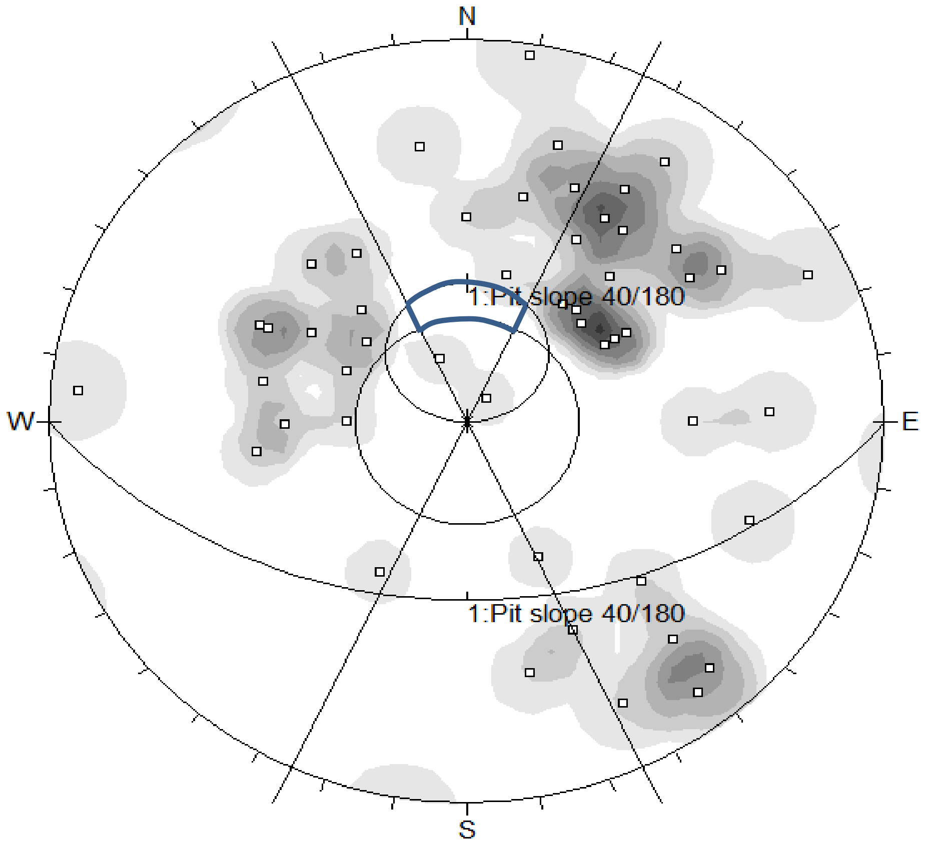


Control on Stability: Low potential for toppling failure for cut slopes with 45° batter angle and South orientation

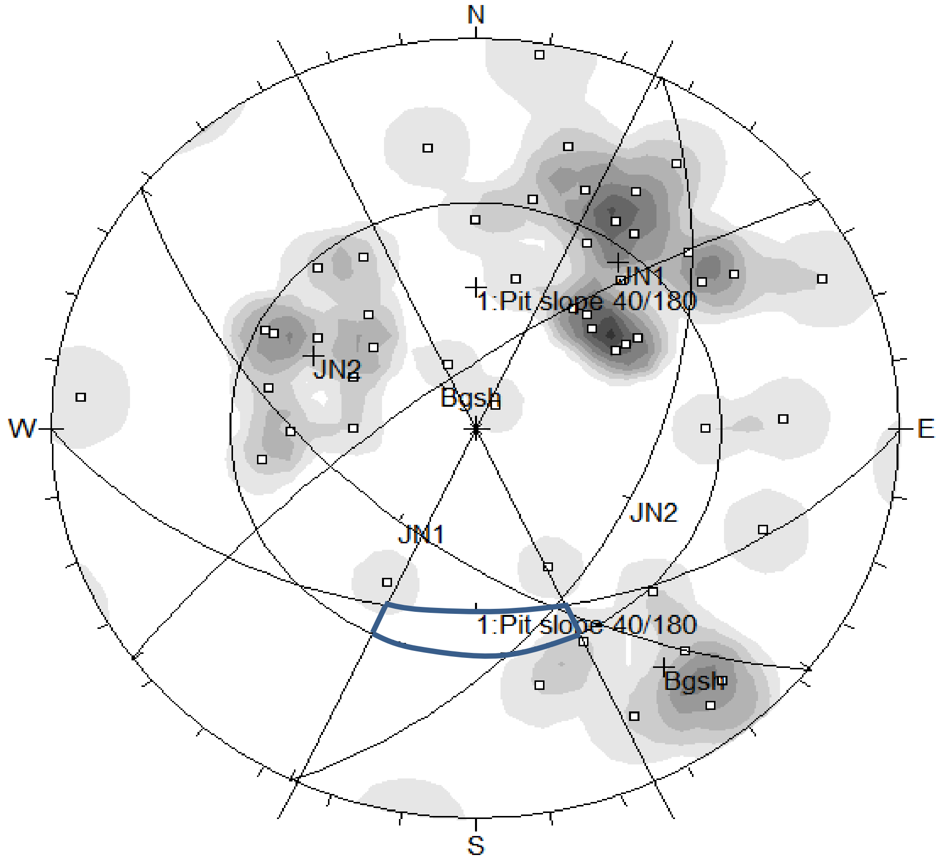
GEOSCIENCE
A proud partner of ENGEO

Date	20/02/15	**Client**	**Holcim (NZ) Limited**
Drawn by	GL	**Project**	**Kiwi Point Quarry Stability Analyses**
Approved by	KJ	**Description**	**Failure Analysis**
Scale	N/A	**Project Number**	10315

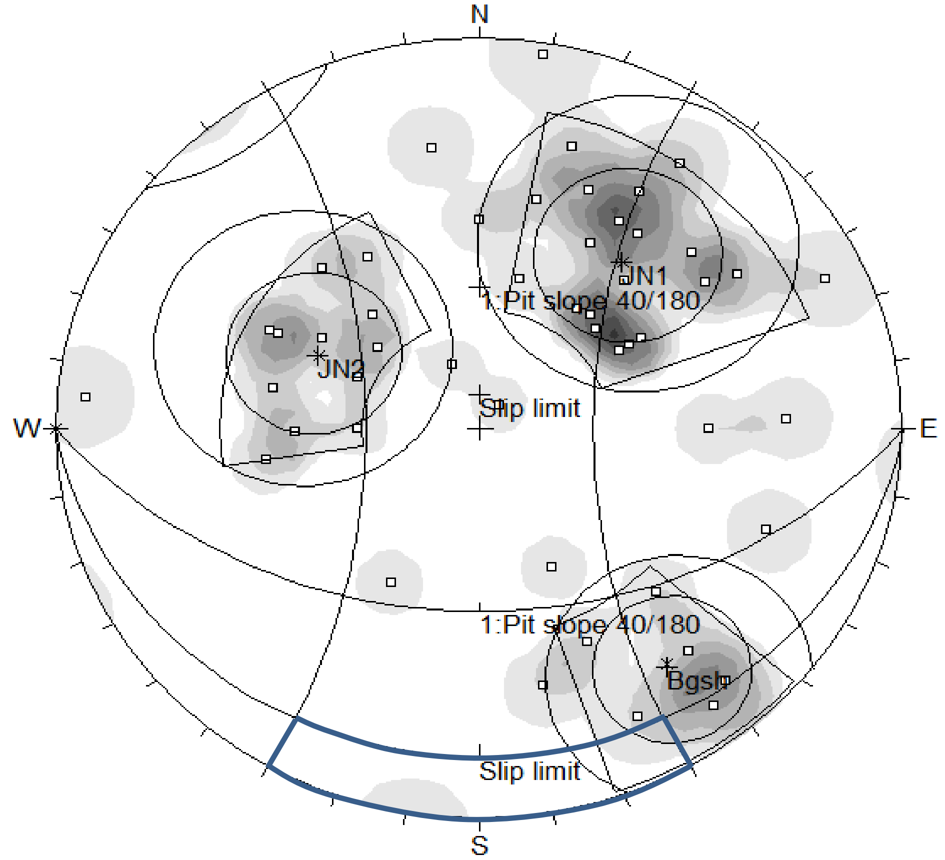
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 40° SOUTH FACING BATTER BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: Low potential for planar failure for cut slopes with 40° batter angle and South orientation



Control on Stability: Moderate potential for wedge failure on joint sets JN1 and JN2 for cut slopes with 40° batter angle and South orientation

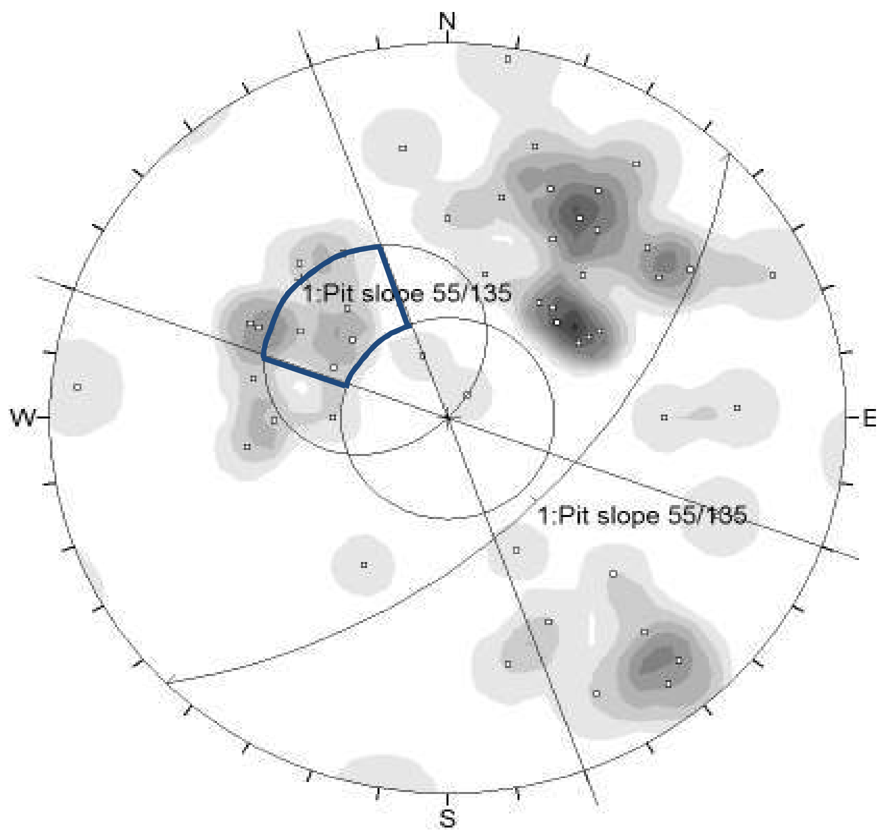


Control on Stability: Low potential for toppling failure for cut slopes with 40° batter angle and South orientation

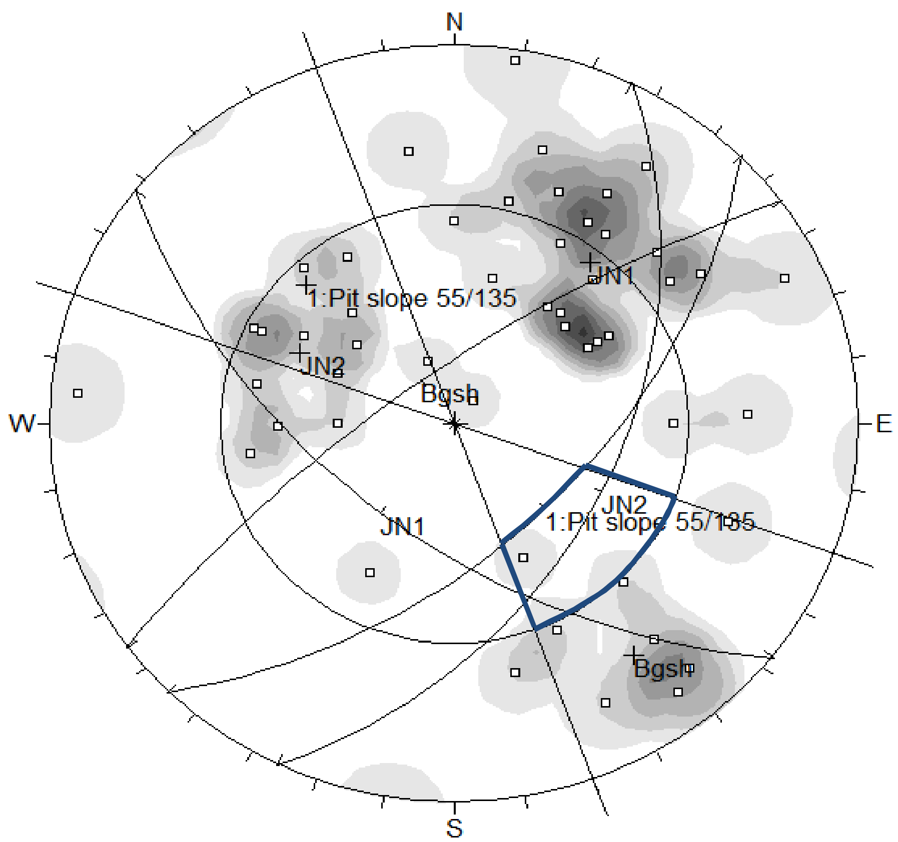
GEOSCIENCE
A proud partner of ENGEO

Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

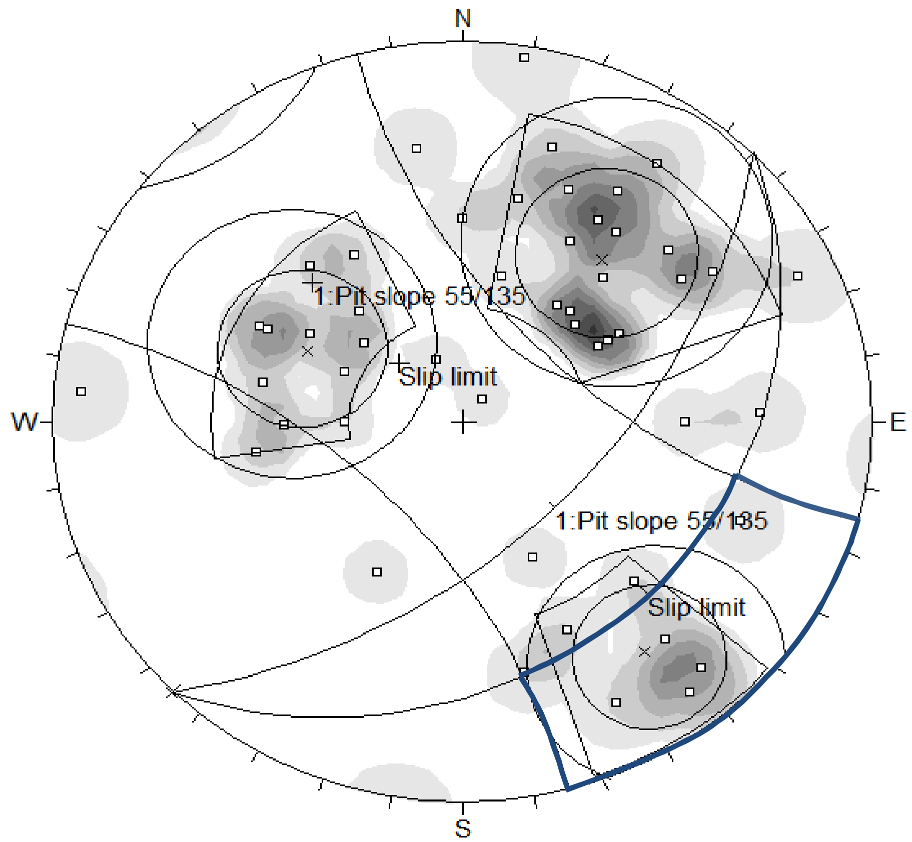
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 55° SOUTH-EAST FACING BATTER BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: High potential for planar failure for cut slopes with 55° batter angle and South-East orientation



Control on Stability: Moderate potential for wedge failure on joint sets JN1 and JN2 for cut slopes with 55° batter angle and South-East orientation

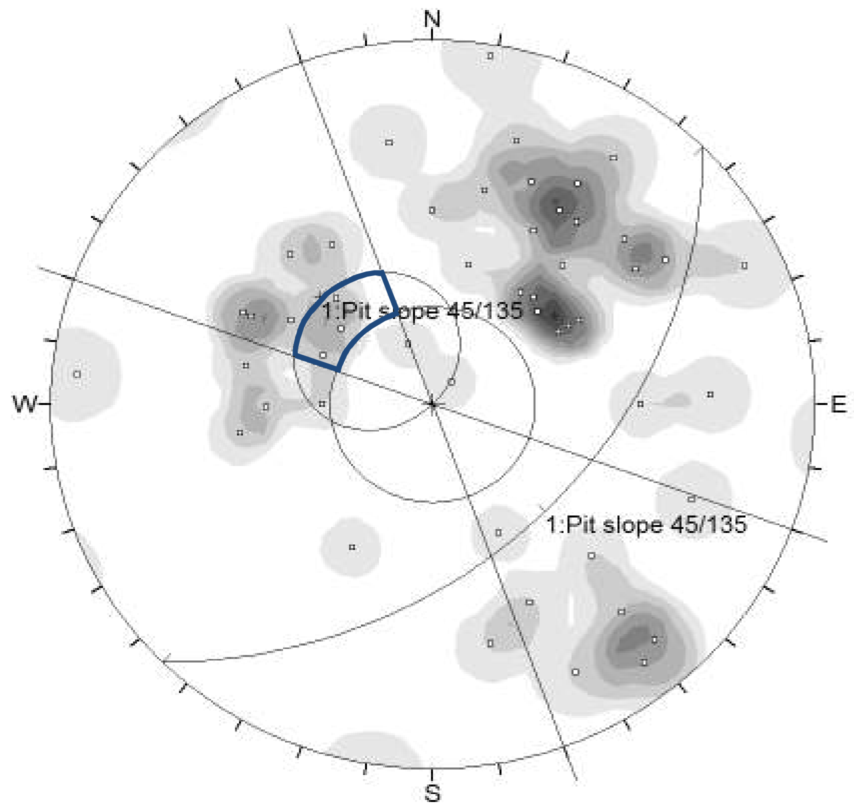


Control on Stability: Moderate potential for toppling failure for cut slopes with 55° batter angle and South-East orientation

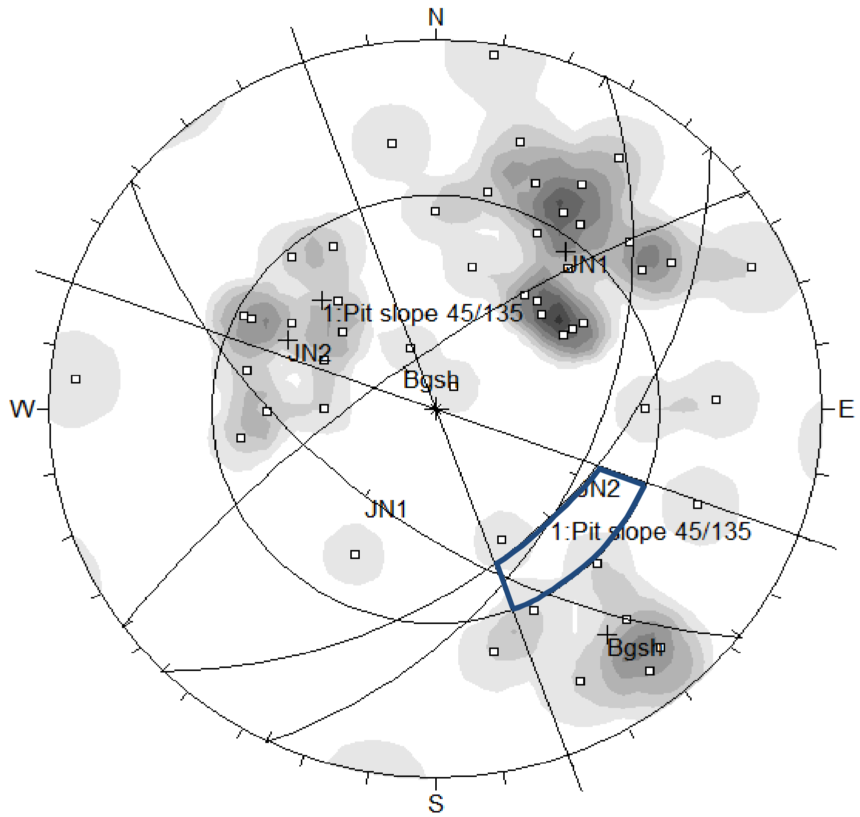
GEOSCIENCE A proud partner of ENGEO

Date	20/02/15	**Client**	**Holcim (NZ) Limited**
Drawn by	GL	**Project**	**Kiwi Point Quarry Stability Analyses**
Approved by	KJ	**Description**	**Failure Analysis**
Scale	N/A	**Project Number**	10315

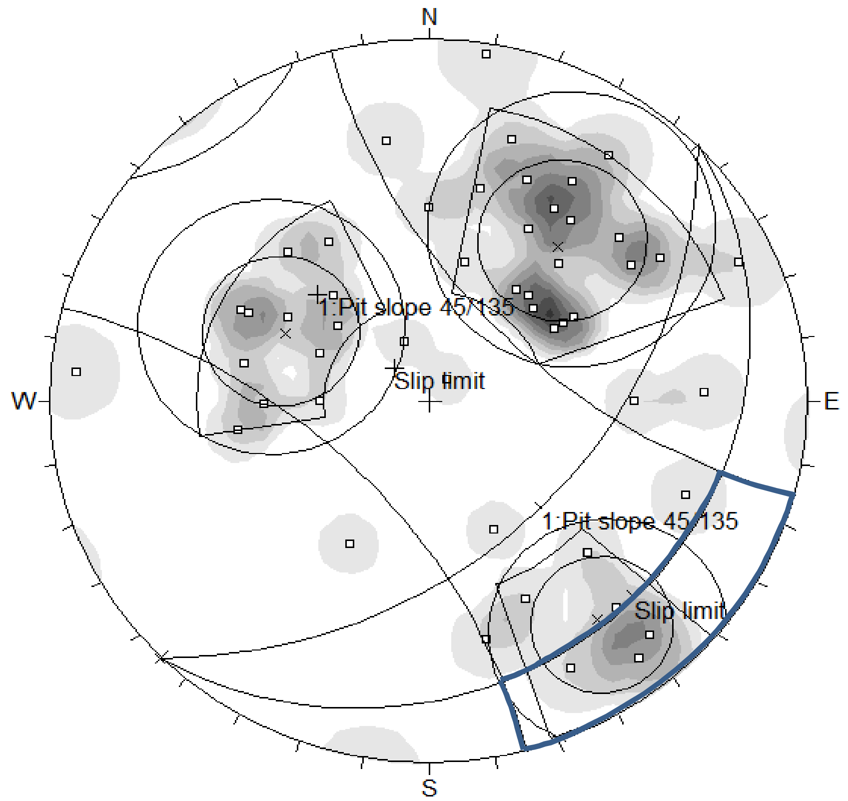
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 45° SOUTH-EAST FACING BATTER
BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: High potential for planar failure for cut slopes with 45° batter angle and South-East orientation



Control on Stability: Moderate potential for wedge failure on joint sets JN1 and JN2 for cut slopes with 45° batter angle

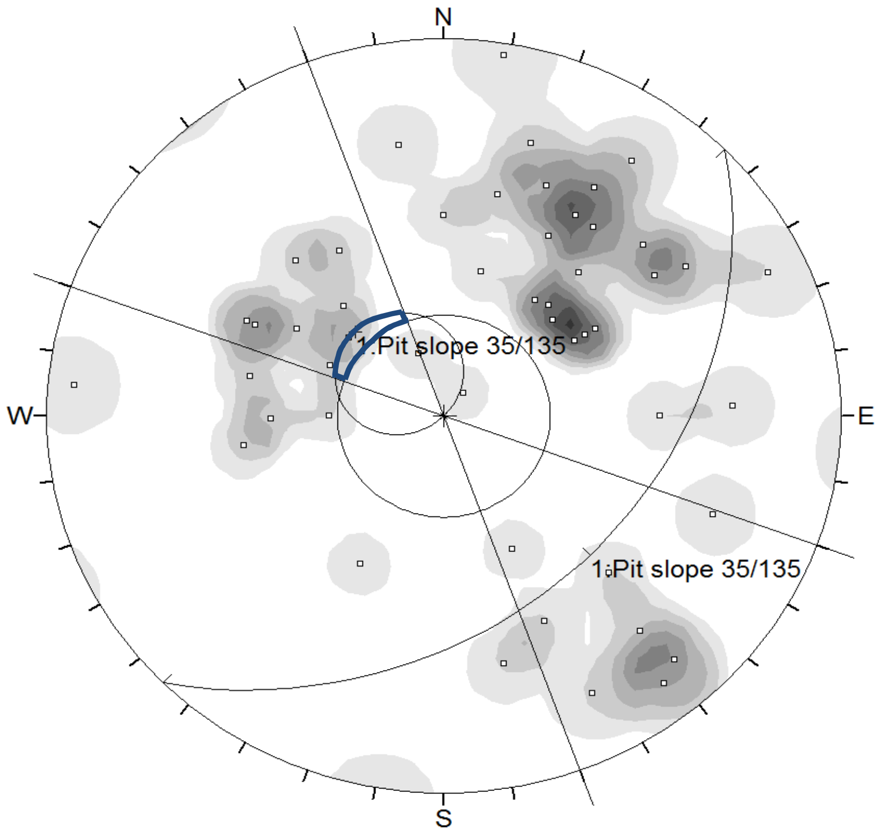


Control on Stability: Moderate potential for toppling failure for cut slopes with 45° batter angle and South-East orientation

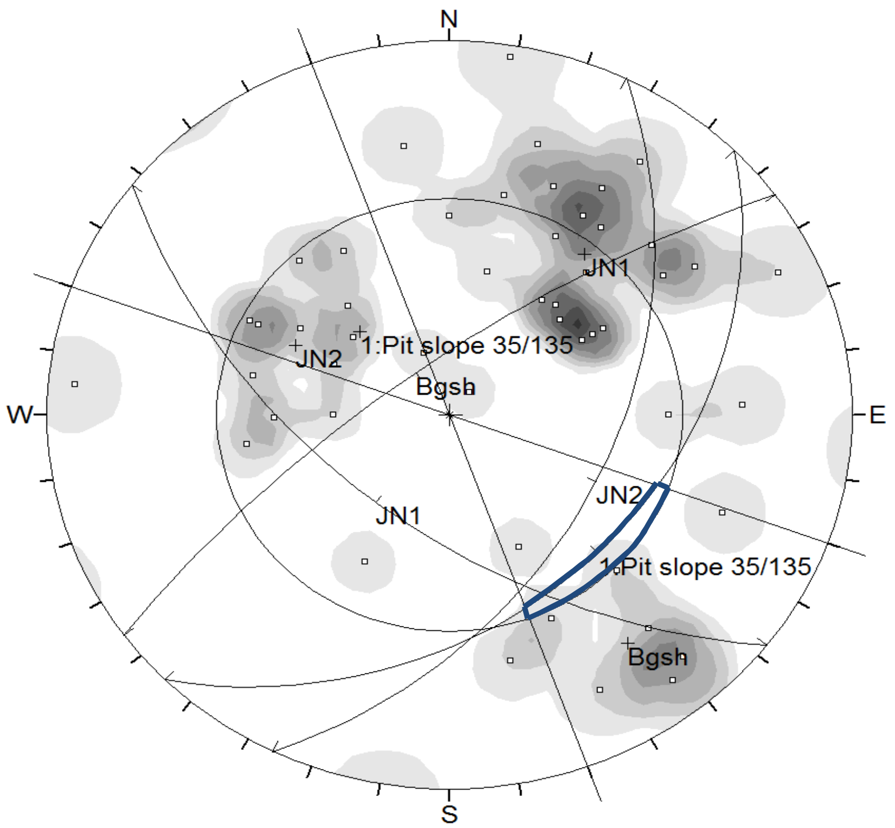
GEOSCIENCE A proud partner of ENGEO

Date	20/02/15	**Client**	**Holcim (NZ) Limited**
Drawn by	GL	**Project**	**Kiwi Point Quarry Stability Analyses**
Approved by	KJ	**Description**	**Failure Analysis**
Scale	N/A	**Project Number**	10315

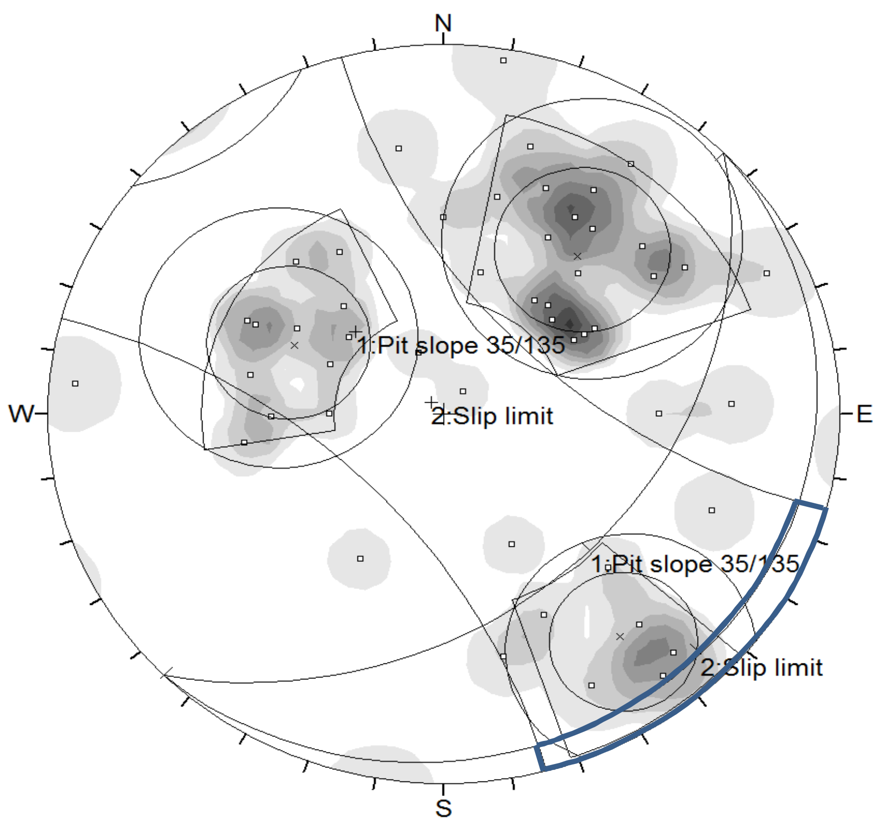
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 35° SOUTH-EAST FACING BATTER BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: Low potential for planar failure for cut slopes with 35° batter angle and South-East orientation



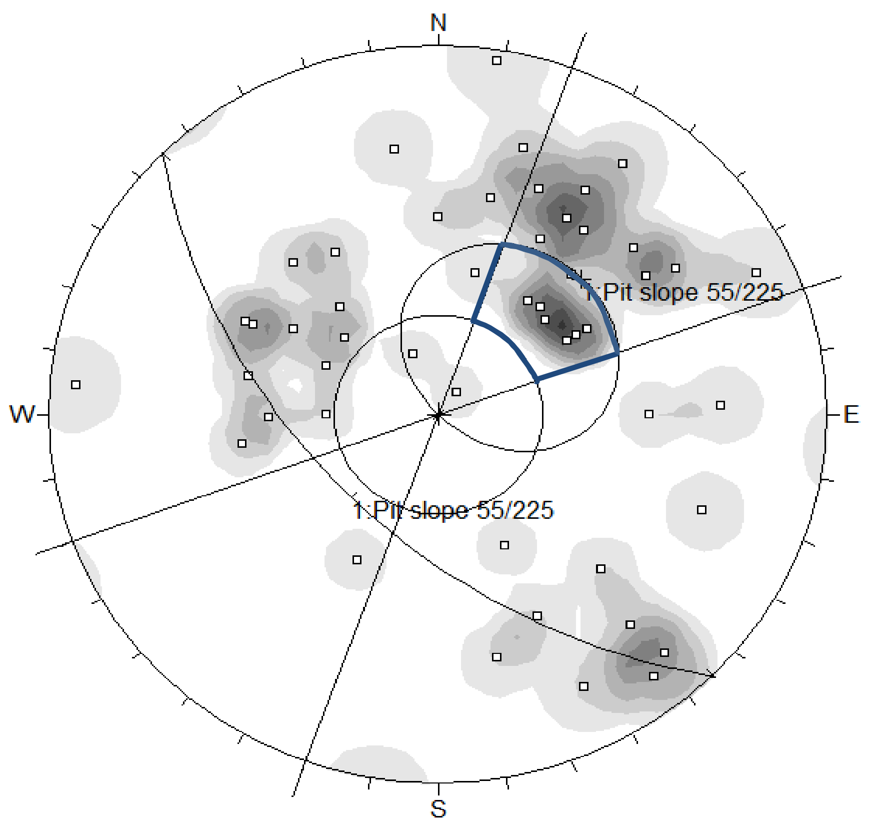
Control on Stability: Low potential for wedge failure for cut slopes with 35° batter angle and South-East orientation



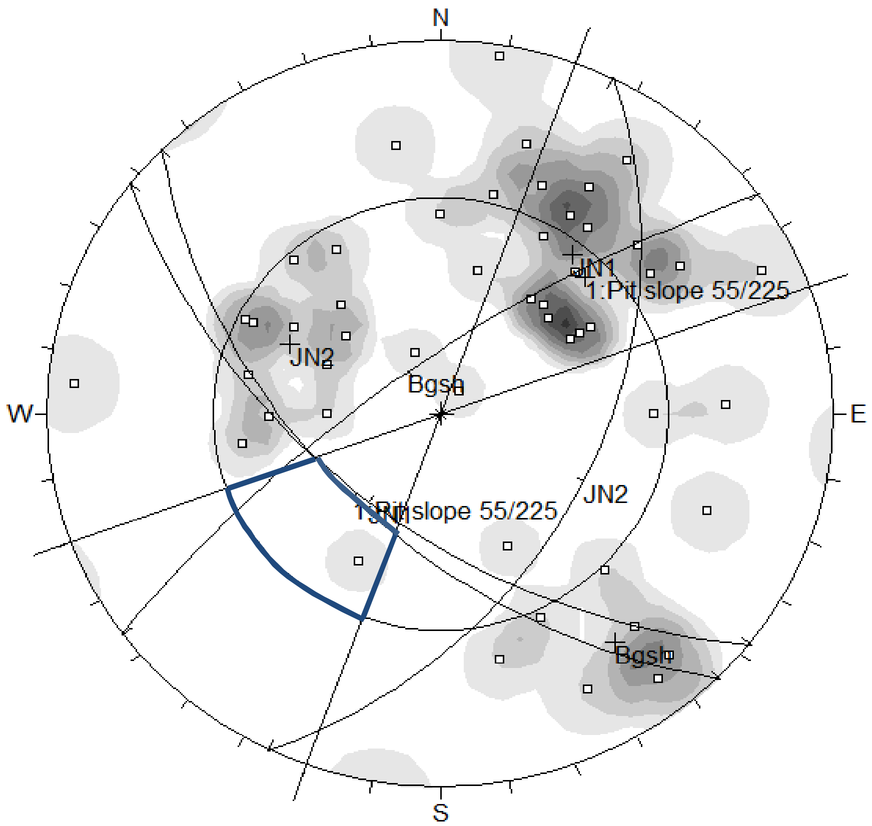
Control on Stability: Low potential for toppling failure for cut slopes with 35° batter angle and South-East orientation

GEOSCIENCE A proud partner of ENGEO	Date	20/02/15	Client	Holcim (NZ) Limited
	Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
	Approved by	KJ	Description	Failure Analysis
	Scale	N/A	Project Number	10315

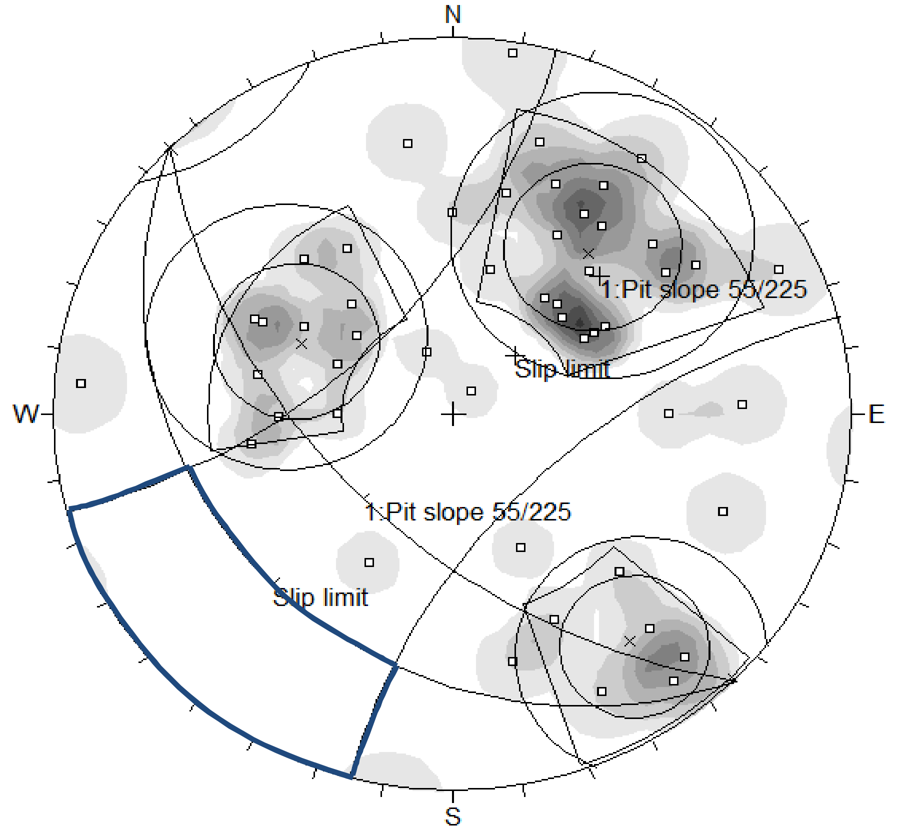
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 55° SOUTH-WEST FACING BATTER BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: High potential for planar failure for cut slopes with 55° batter angle and South-West orientation



Control on Stability: Low potential for wedge failure for cut slopes with 55° batter angle and South-West orientation

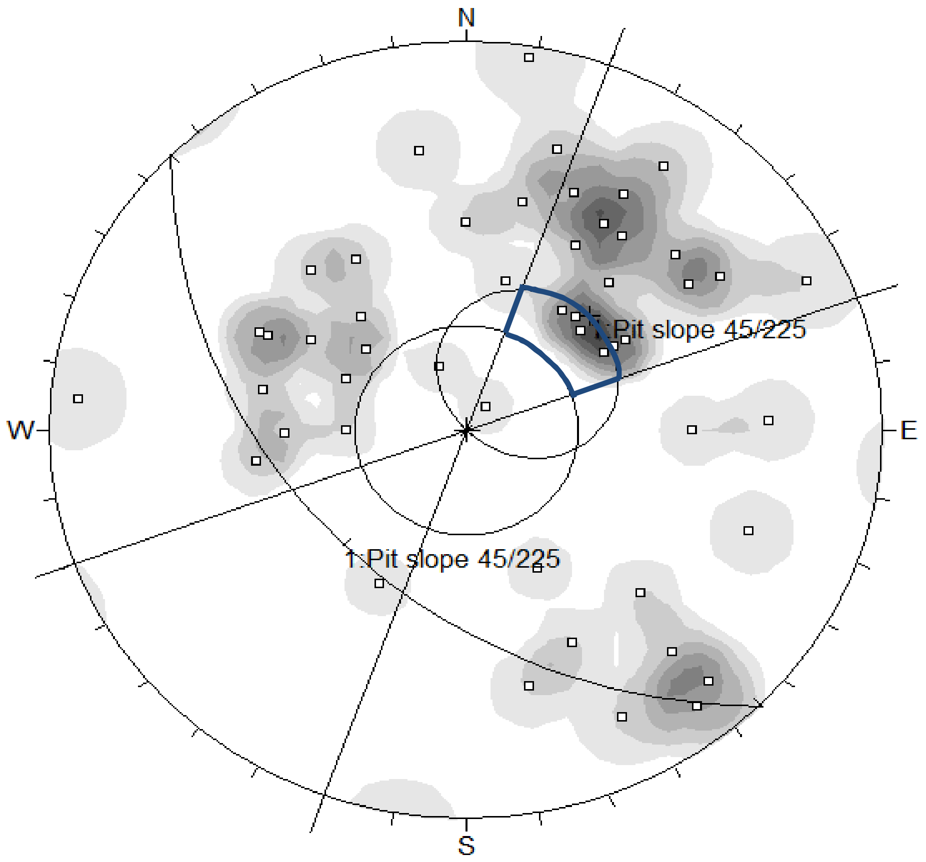


Control on Stability: Low potential for toppling failure for cut slopes with 55° batter angle and South-West orientation

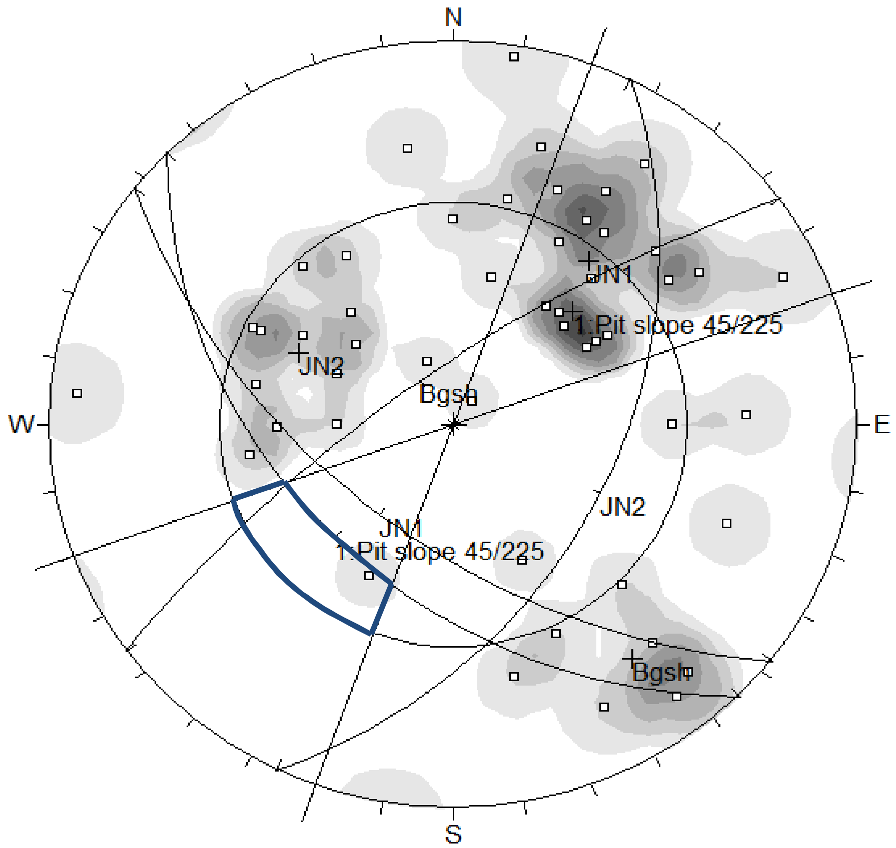
GEOSCIENCE A proud partner of ENGEO

Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

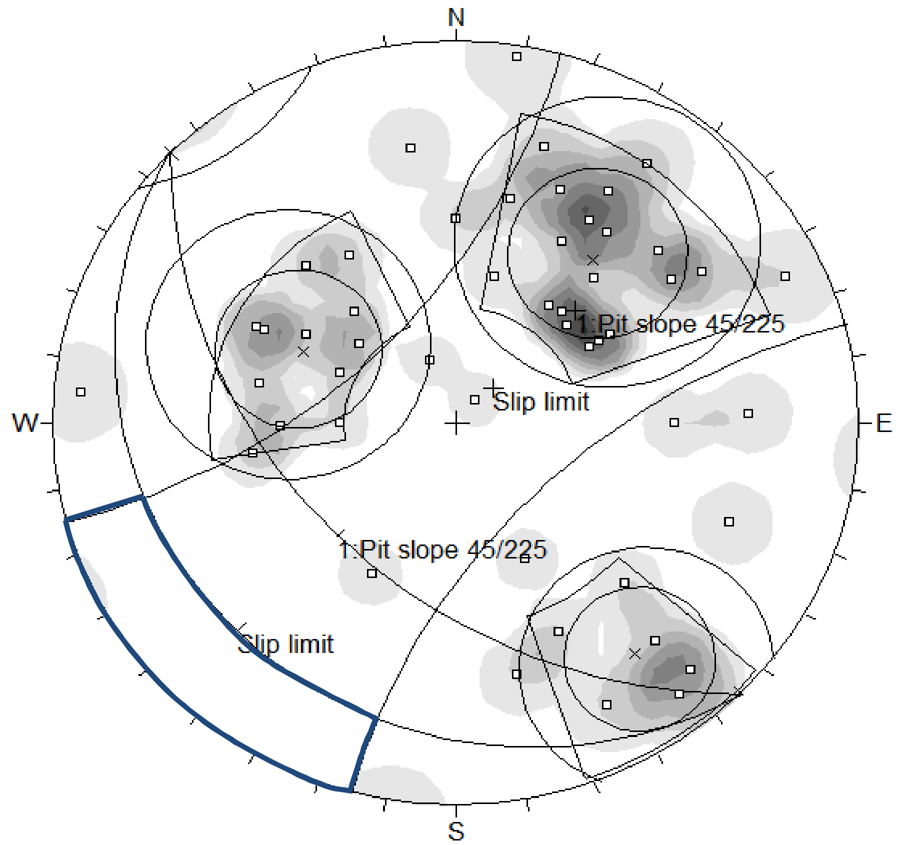
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 45° SOUTH-WEST FACING BATTER
BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: High potential for planar failure for cut slopes with 45° batter angle and South-West orientation



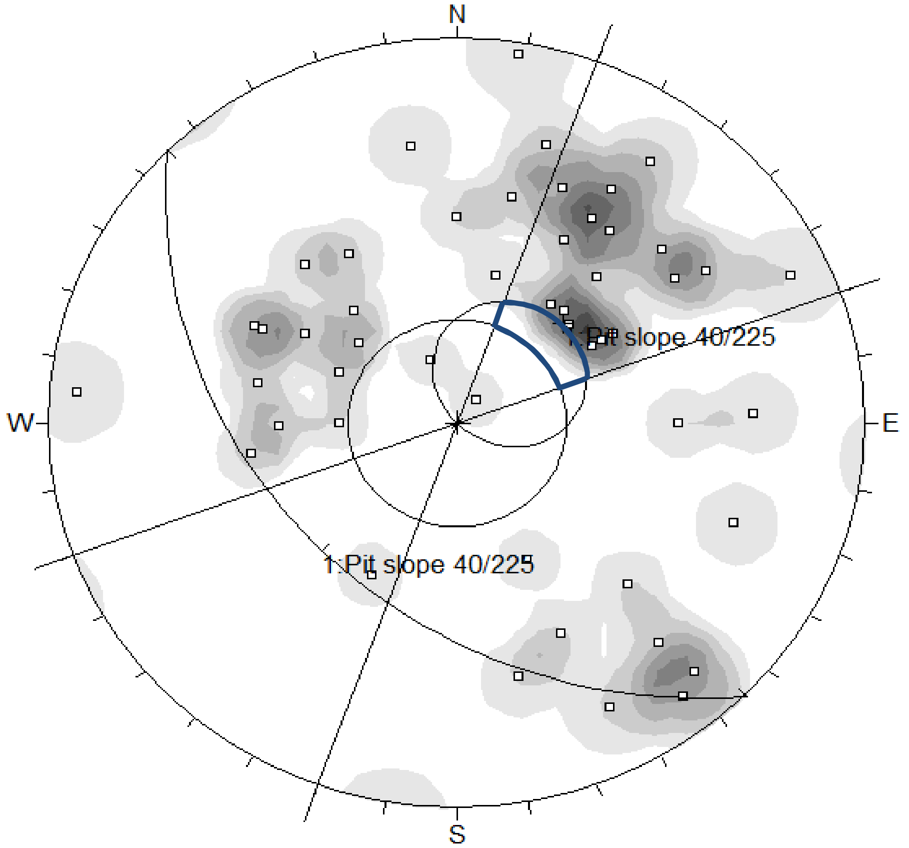
Control on Stability: Low potential for wedge failure for cut slopes with 45° batter angle and South-West orientation



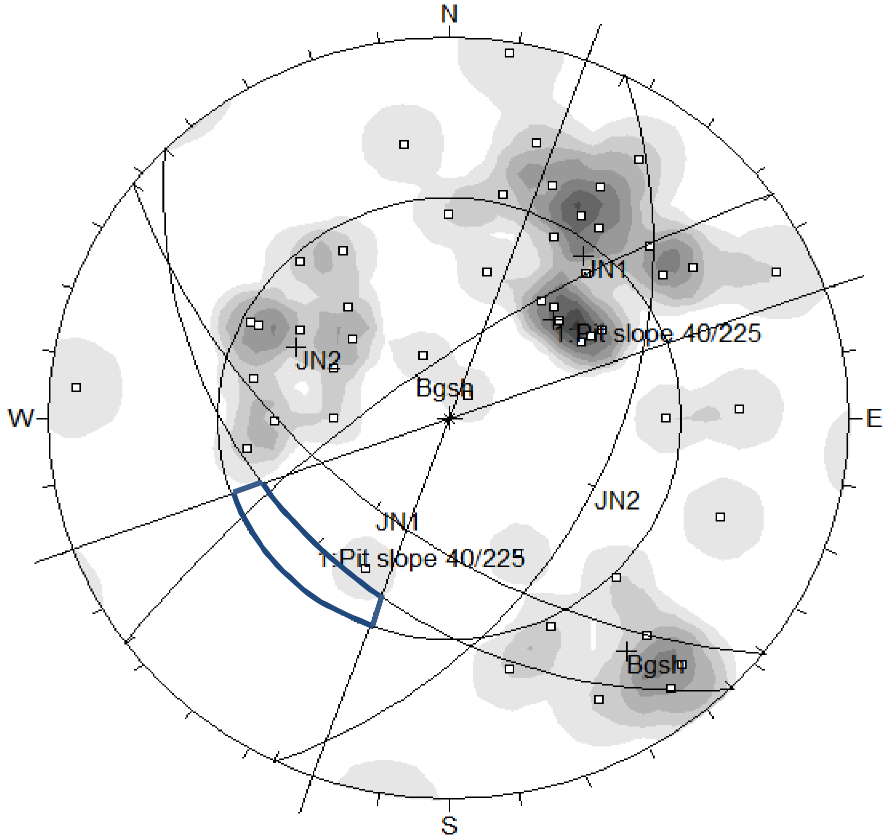
Control on Stability: Low potential for toppling failure for cut slopes with 45° batter angle and South-West orientation

Date	20/02/15	**Client**	**Holcim (NZ) Limited**
Drawn by	GL	**Project**	**Kiwi Point Quarry Stability Analyses**
Approved by	KJ	**Description**	**Failure Analysis**
Scale	N/A	**Project Number**	10315

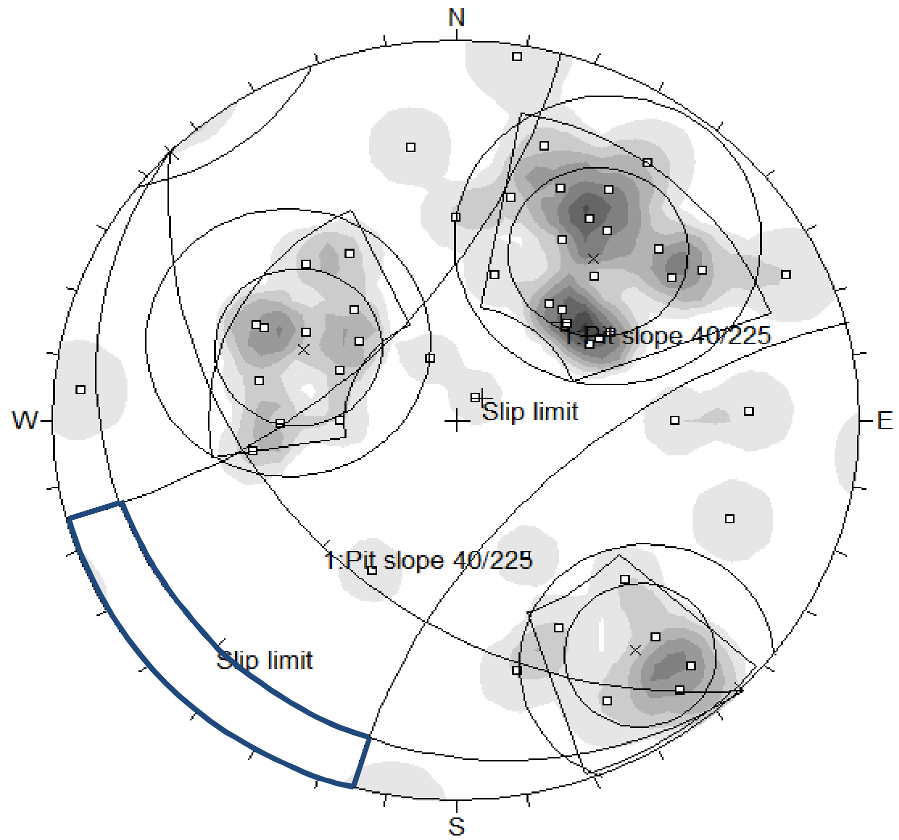
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 40° SOUTH-WEST FACING BATTER BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: Moderate potential for planar failure for cut slopes with 40° batter angle and South-West orientation



Control on Stability: Low potential for wedge failure for cut slopes with 40° batter angle and South-West orientation



Control on Stability: Low potential for toppling failure for cut slopes with 40° batter angle and South-West orientation

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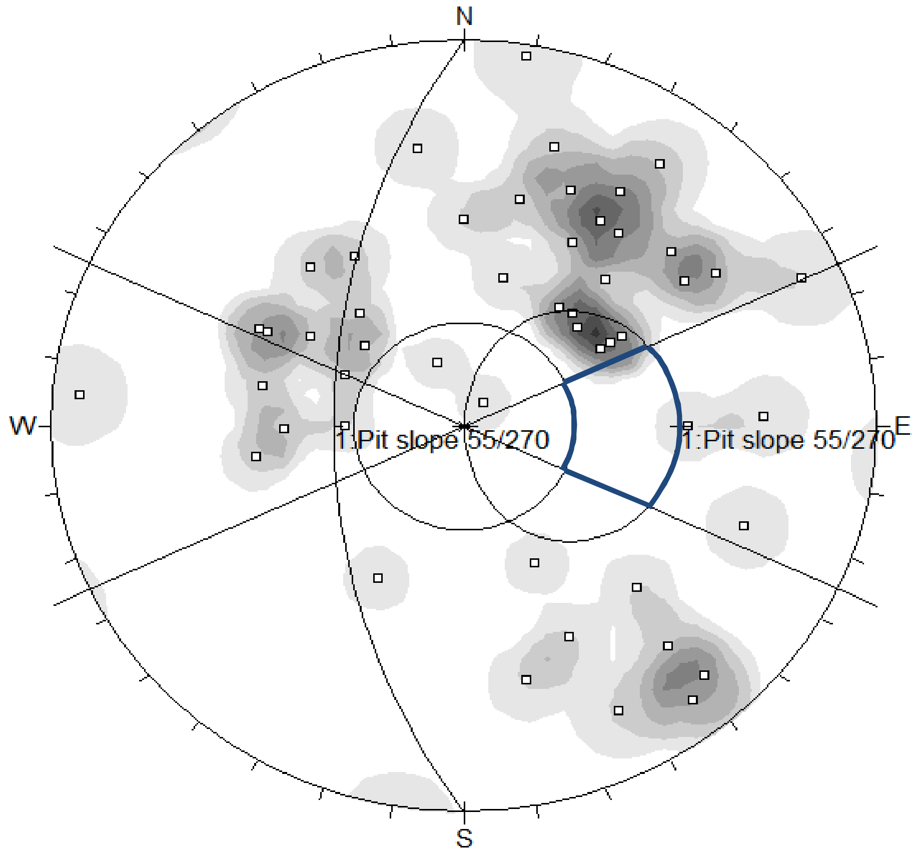
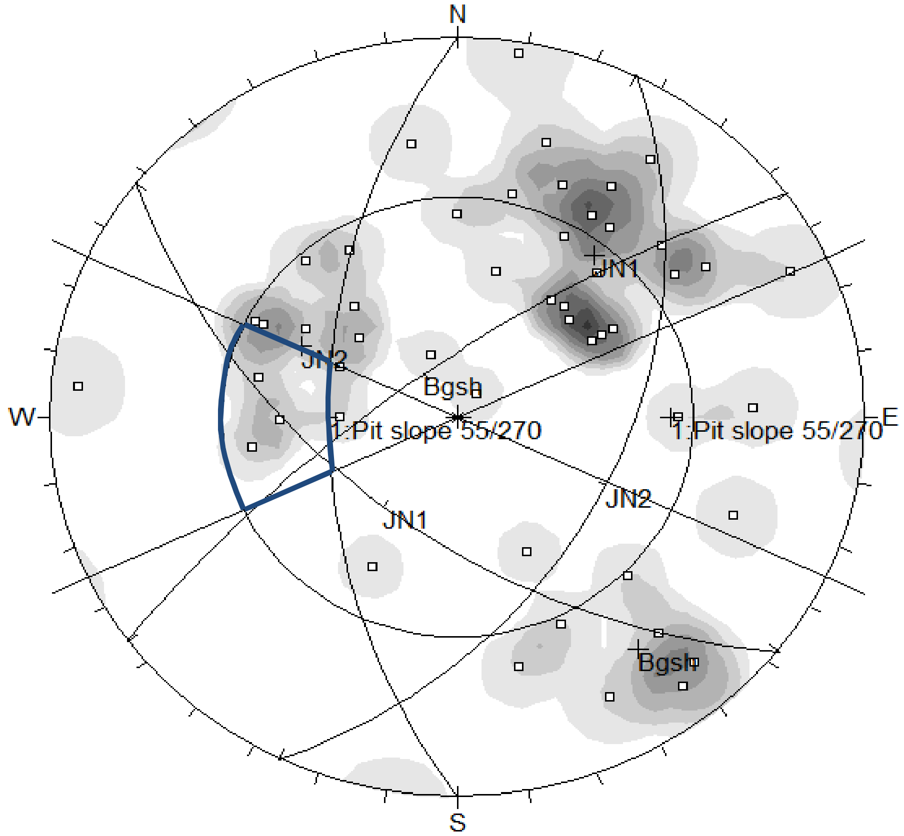
Date	20/02/15	**Client**	**Holcim (NZ) Limited**
Drawn by	GL	**Project**	**Kiwi Point Quarry Stability Analyses**
Approved by	KJ	**Description**	**Failure Analysis**
Scale	N/A	**Project Number**	10315

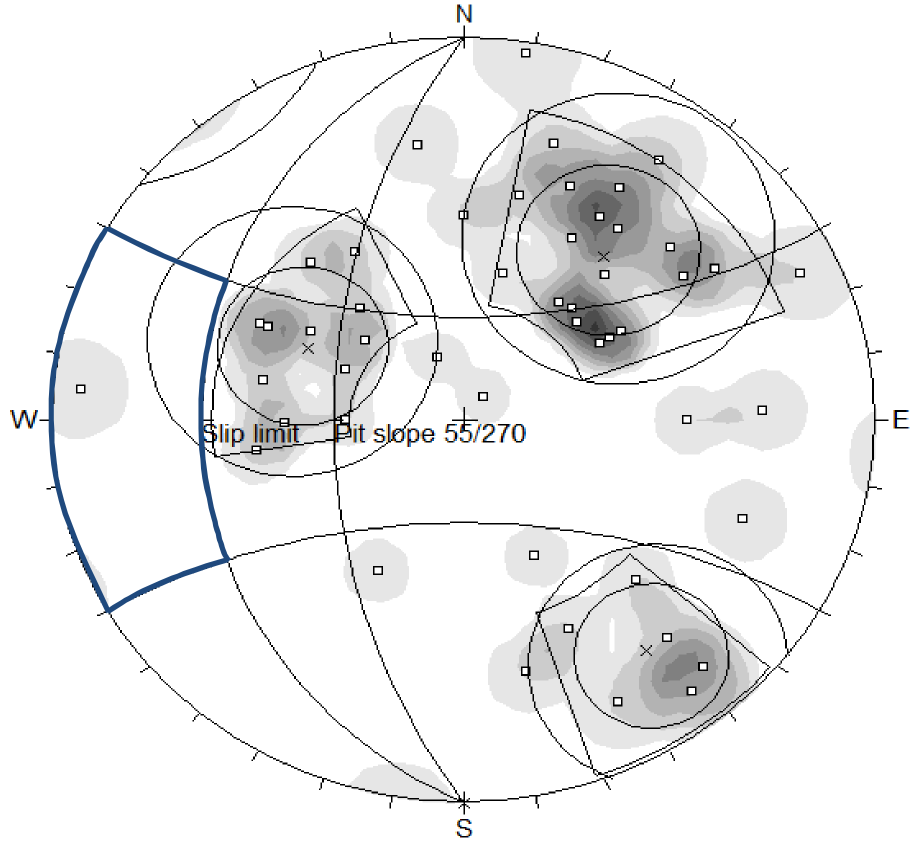
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 55° WEST FACING BATTER BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: Low potential for planar failure for cut slopes with 55° batter angle and West orientation



Control on Stability: High potential for wedge failure on joint sets JN1 and Bgsh for cut slopes with 55° batter angle and West orientation

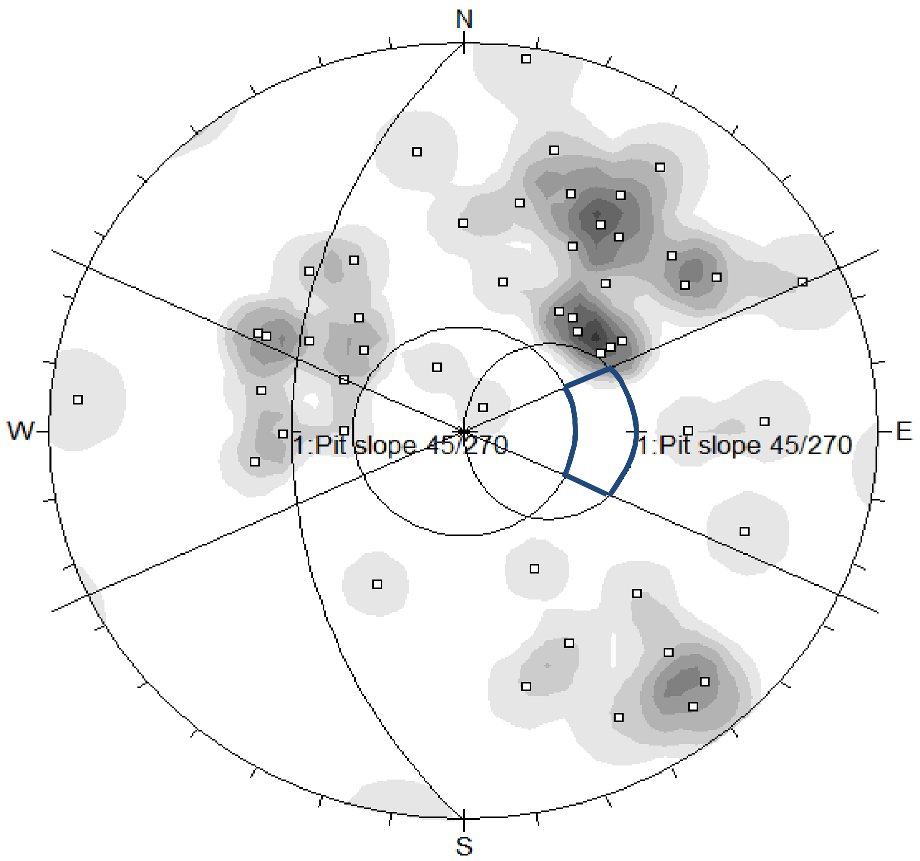


Control on Stability: Low potential for toppling failure for cut slopes with 55° batter angle and West orientation

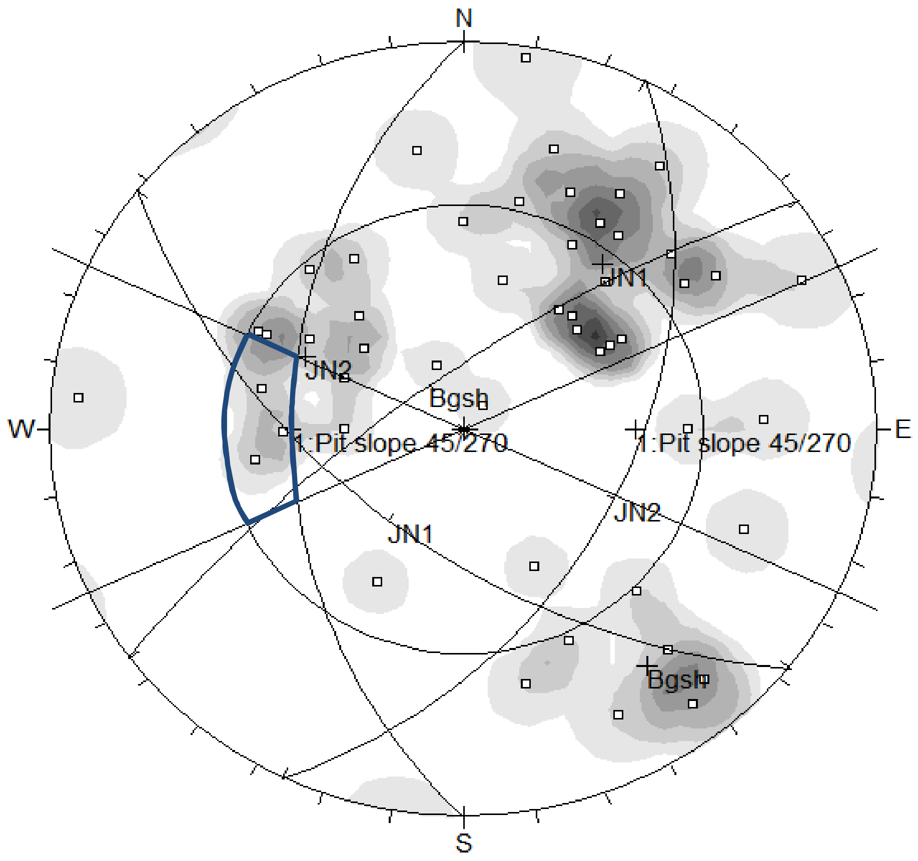
GEOSCIENCE A proud partner of ENGEO

Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

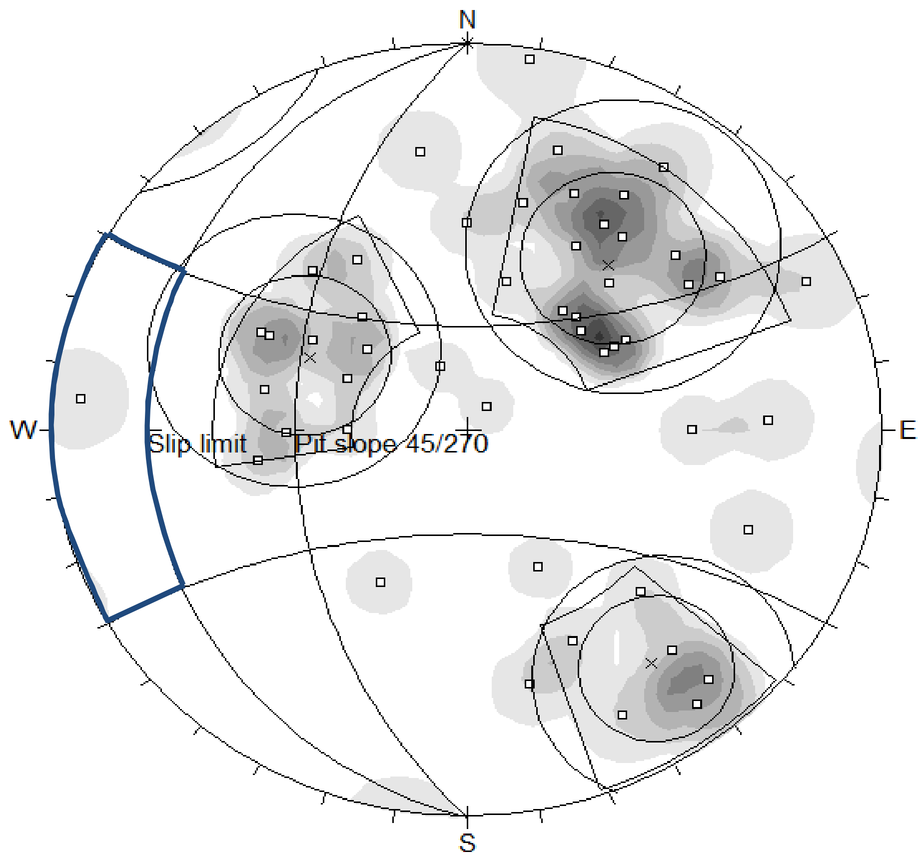
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 45° WEST FACING BATTER BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: Low potential for planar failure for cut slopes with 45° batter angle and West orientation



Control on Stability: Low potential for wedge failure for cut slopes with 45° batter angle and West orientation



Control on Stability: Low potential for toppling failure for cut slopes with 45° batter angle and West orientation

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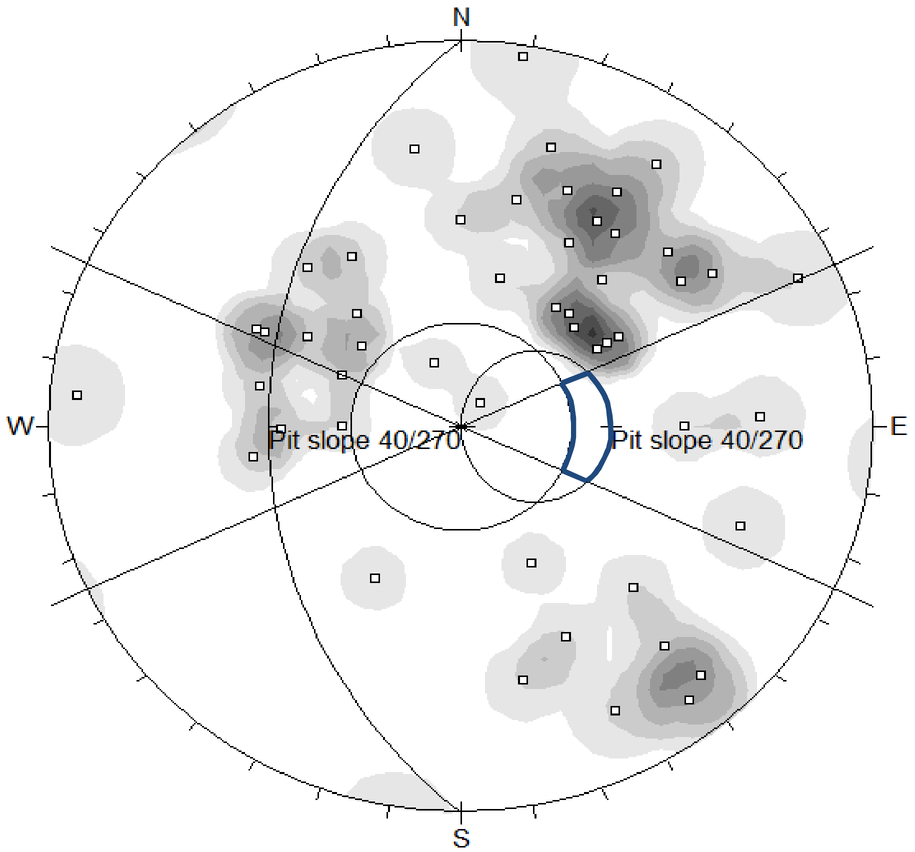
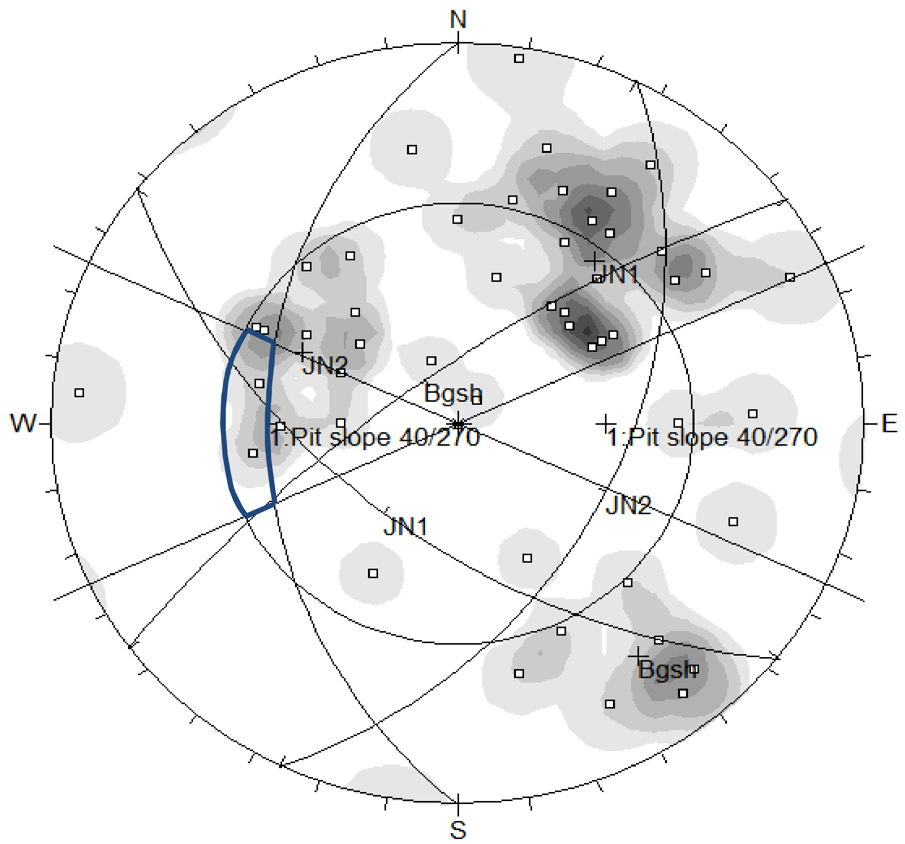
Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

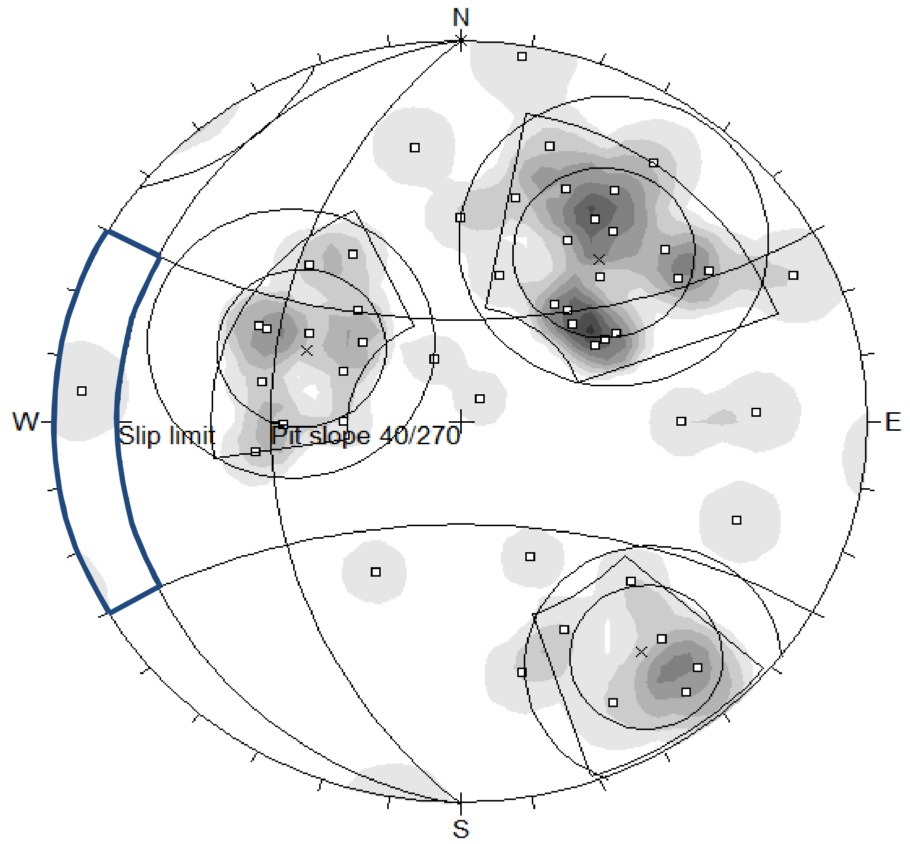
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 40° WEST FACING BATTER
BASED ON OBSERVATIONS FROM THE NORTH WALL



Control on Stability: Low potential for planar failure for cut slopes with 40° batter angle and West orientation



Control on Stability: Low potential for wedge failure for cut slopes with 40° batter angle and West orientation

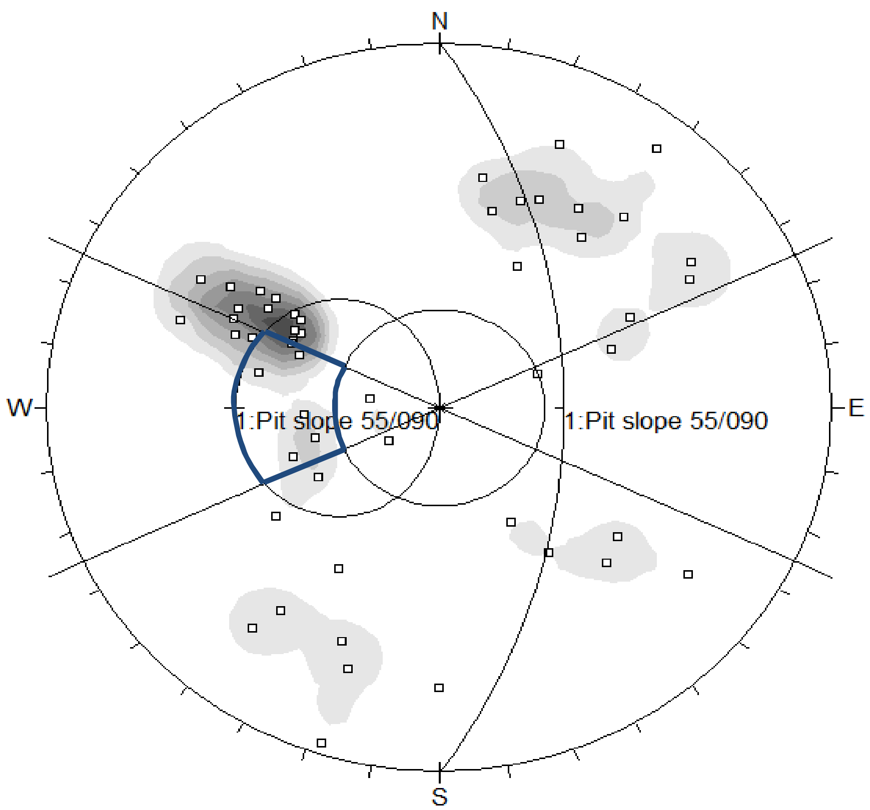


Control on Stability: Low potential for toppling failure for cut slopes with 40° batter angle and West orientation

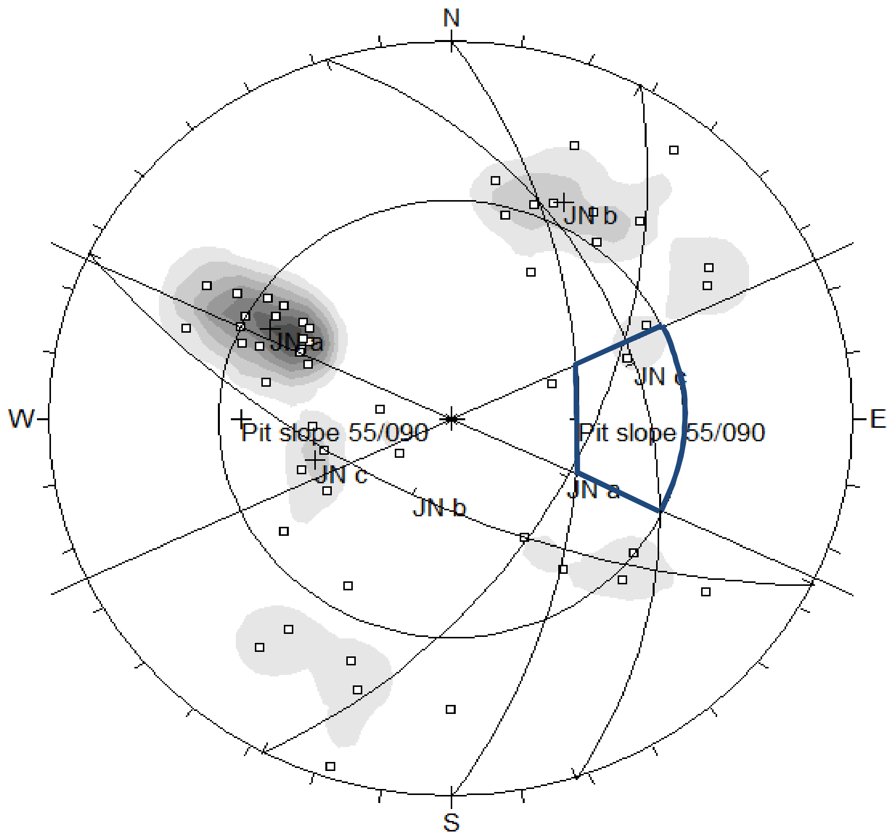
GEOSCIENCE A proud partner of ENGEO

Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

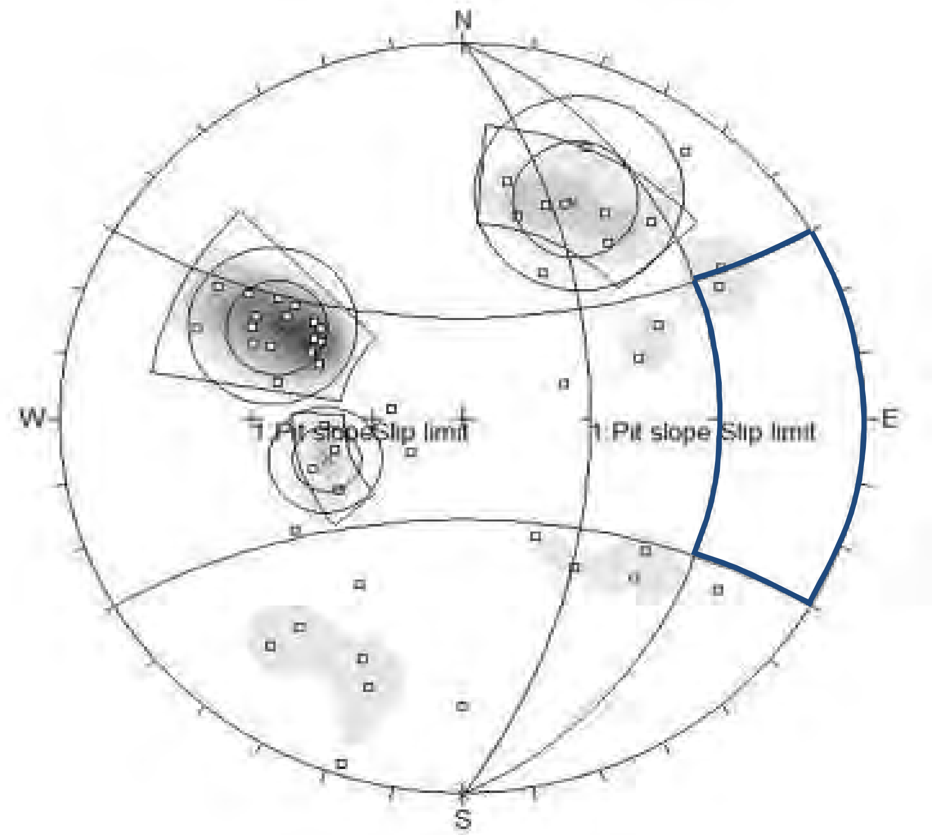
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 55° EAST FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: High potential for planar failure for cut slopes with 55° batter angle and East orientation



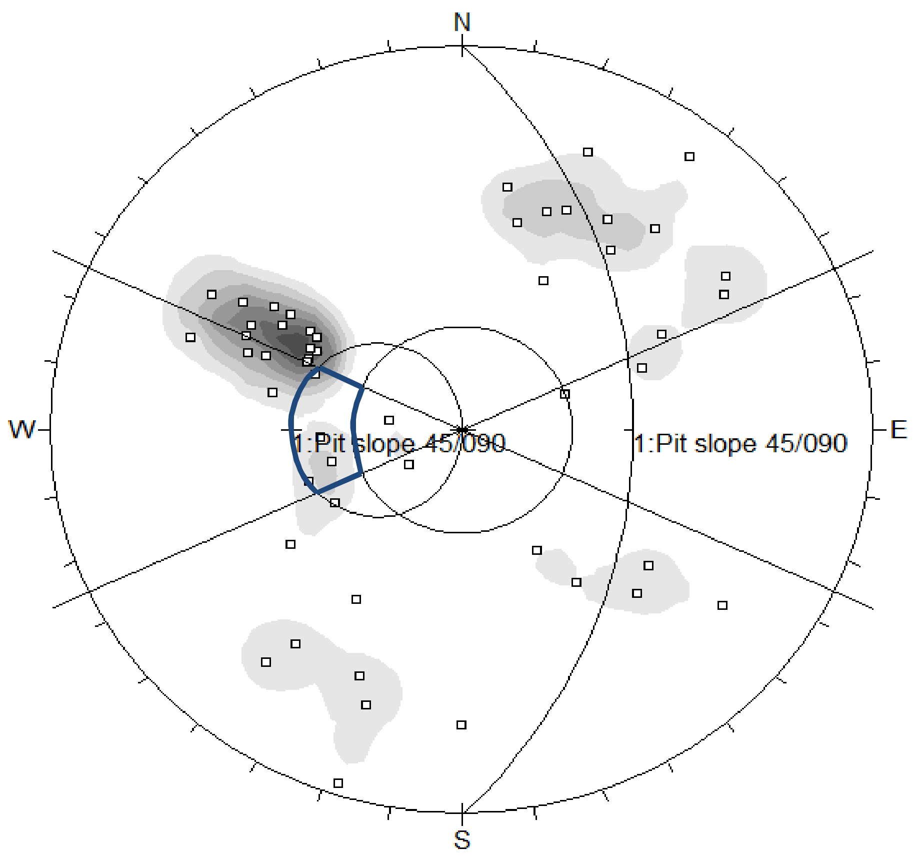
Control on Stability: Moderate potential for wedge failure on joint sets JNa and JNc for cut slopes with 55° batter angle and East orientation



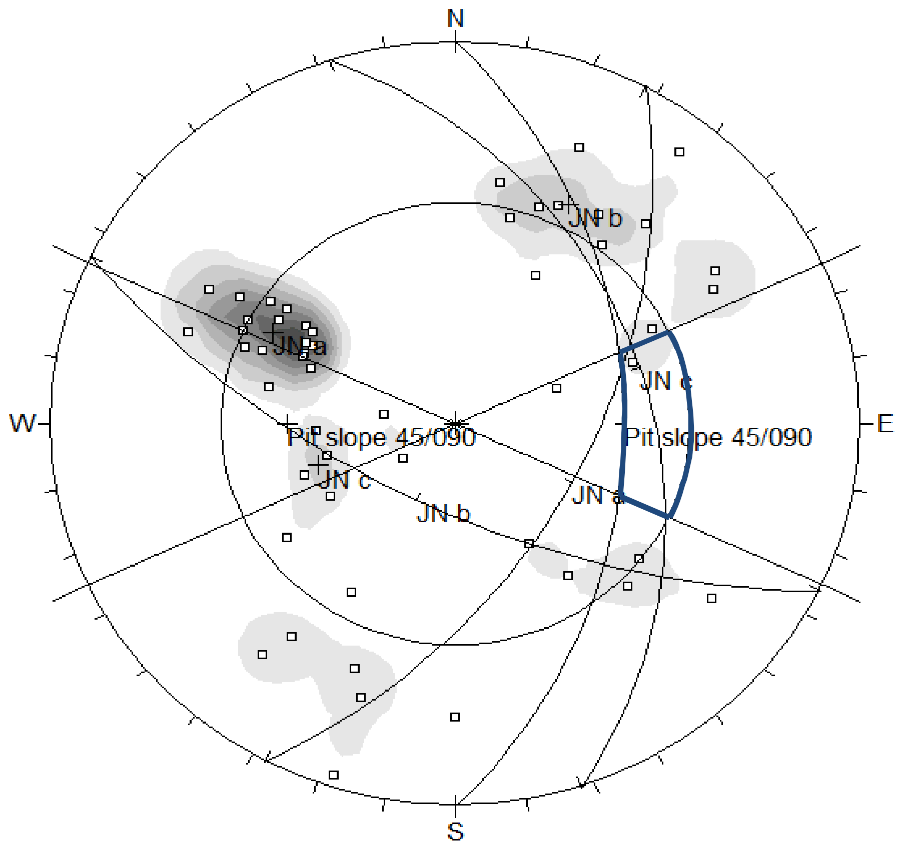
Control on Stability: Low potential for toppling failure for cut slopes with 55° batter angle and East orientation

GEOSCIENCE A proud partner of ENGEO	Date	20/02/15	Client	Holcim (NZ) Limited
	Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
	Approved by	KJ	Description	Failure Analysis
	Scale	N/A	Project Number	10315

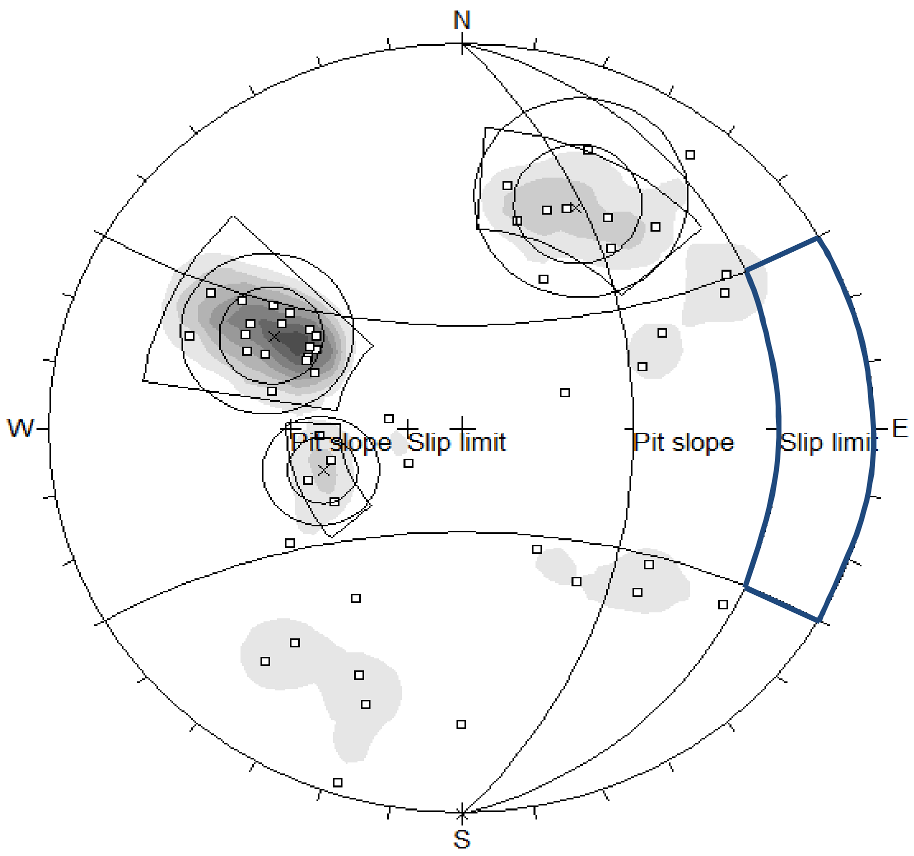
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 45° EAST FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: Moderate potential for planar failure for cut slopes with 45° batter angle and East orientation



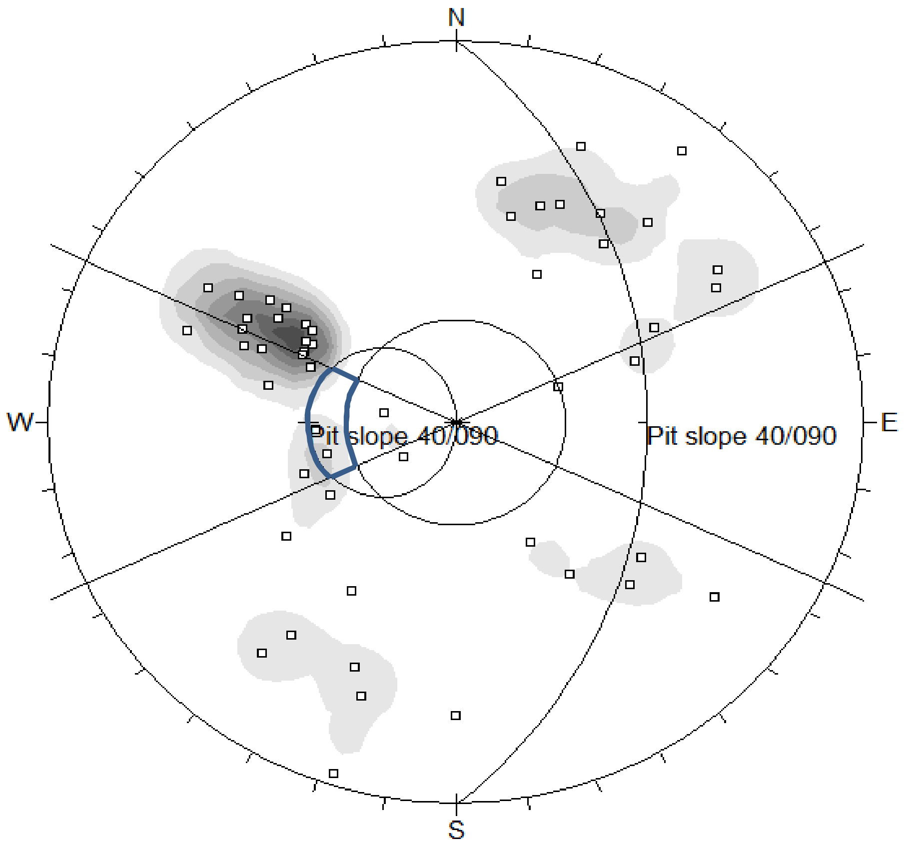
Control on Stability: Moderate potential for wedge failure on joint sets JNa and JNc for cut slopes with 45° batter angle and East orientation



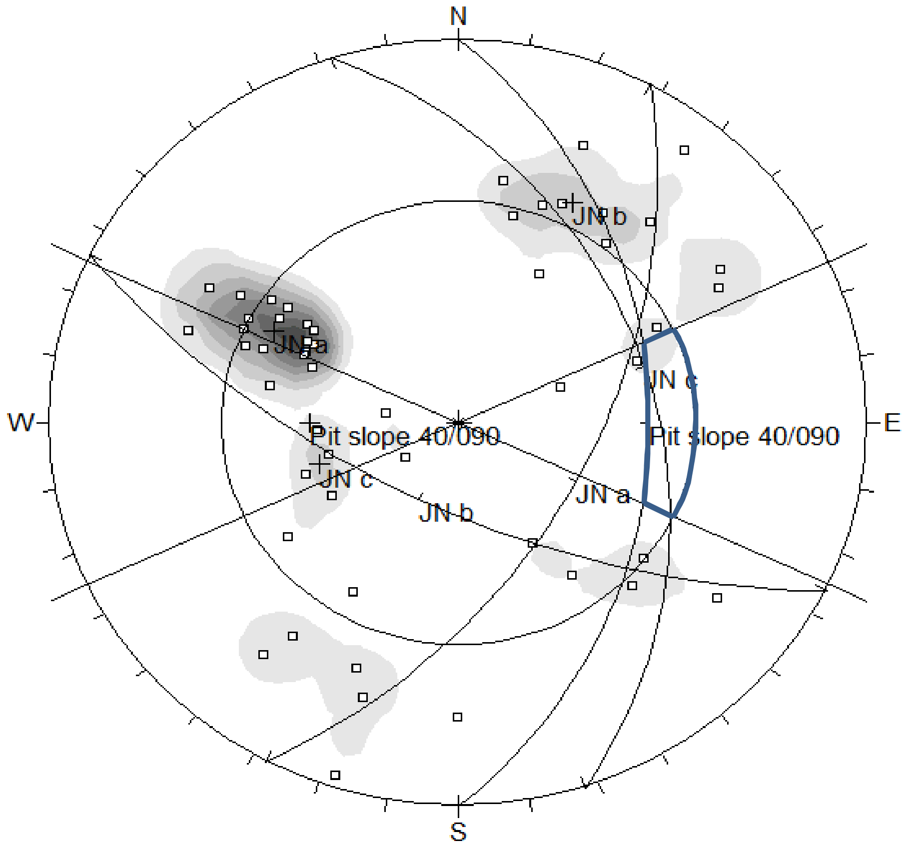
Control on Stability: Low potential for toppling failure for cut slopes with 45° batter angle and East orientation

GEOSCIENCE A proud partner of ENGEO	Date	20/02/15	Client	Holcim (NZ) Limited
	Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
	Approved by	KJ	Description	Failure Analysis
	Scale	N/A	Project Number	10315

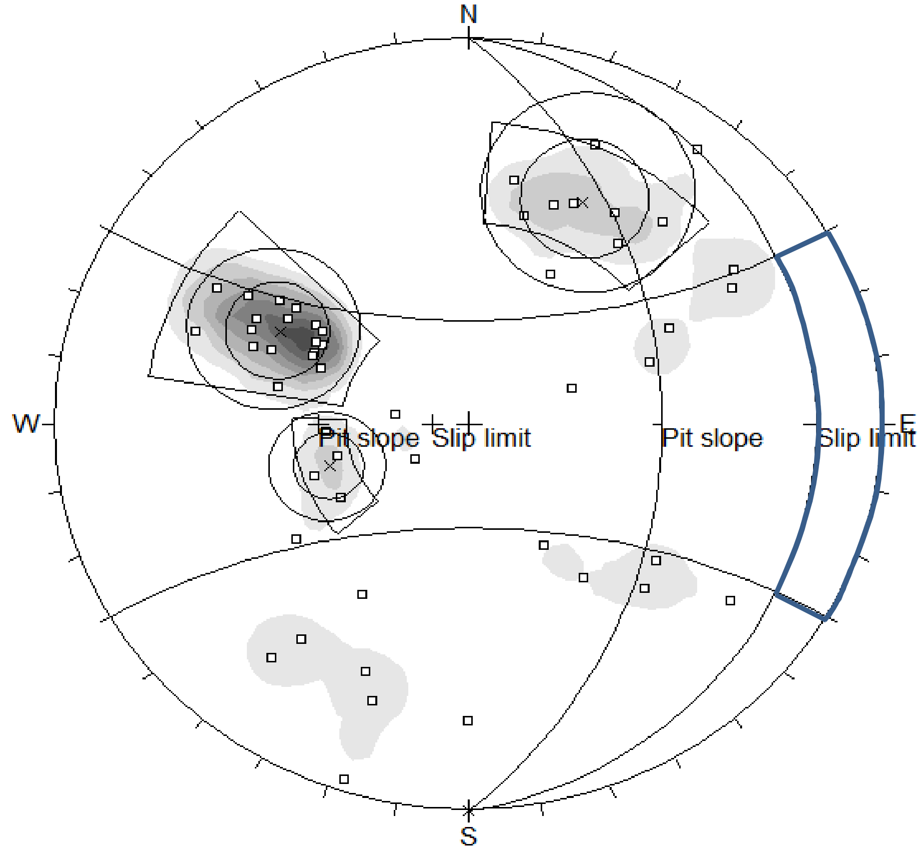
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 40° EAST FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: Low potential for planar failure for cut slopes with 40° batter angle and East orientation



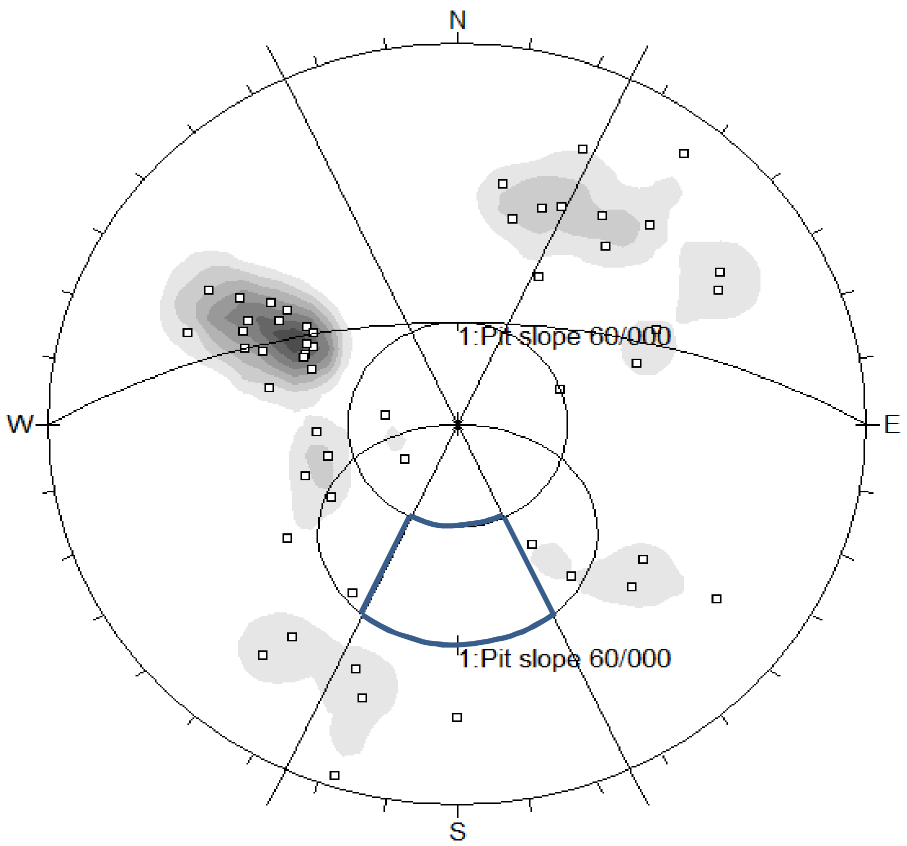
Control on Stability: Low potential for wedge for cut slopes with 40° batter angle and East orientation



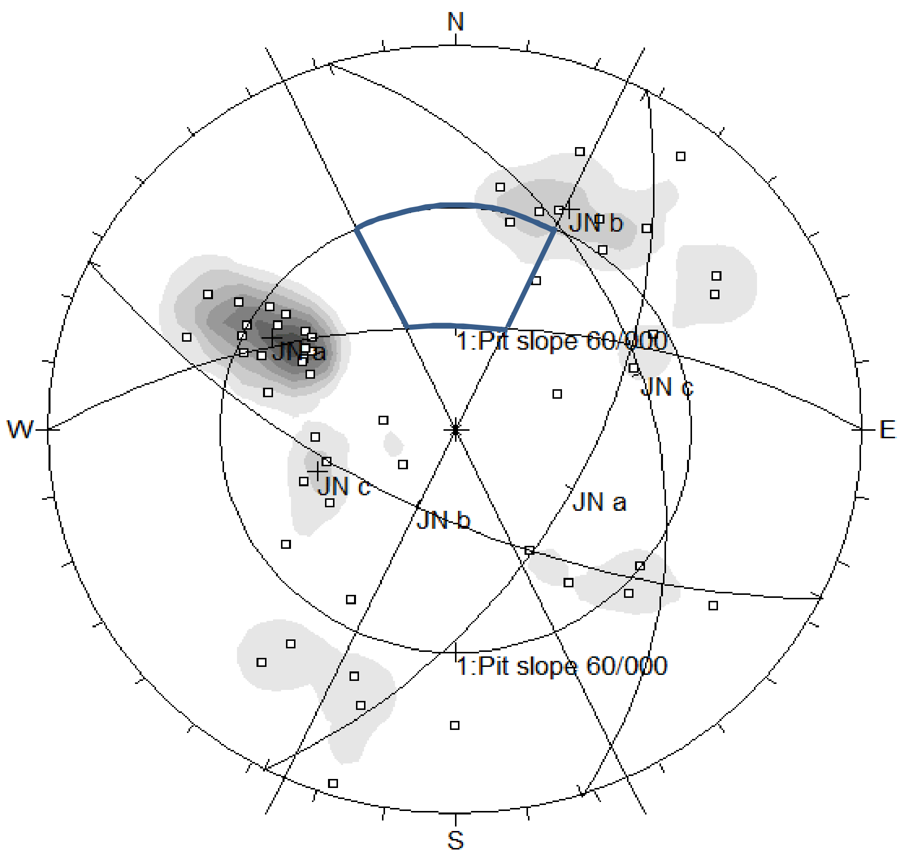
Control on Stability: Low potential for toppling failure for cut slopes with 40° batter angle and East orientation

Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

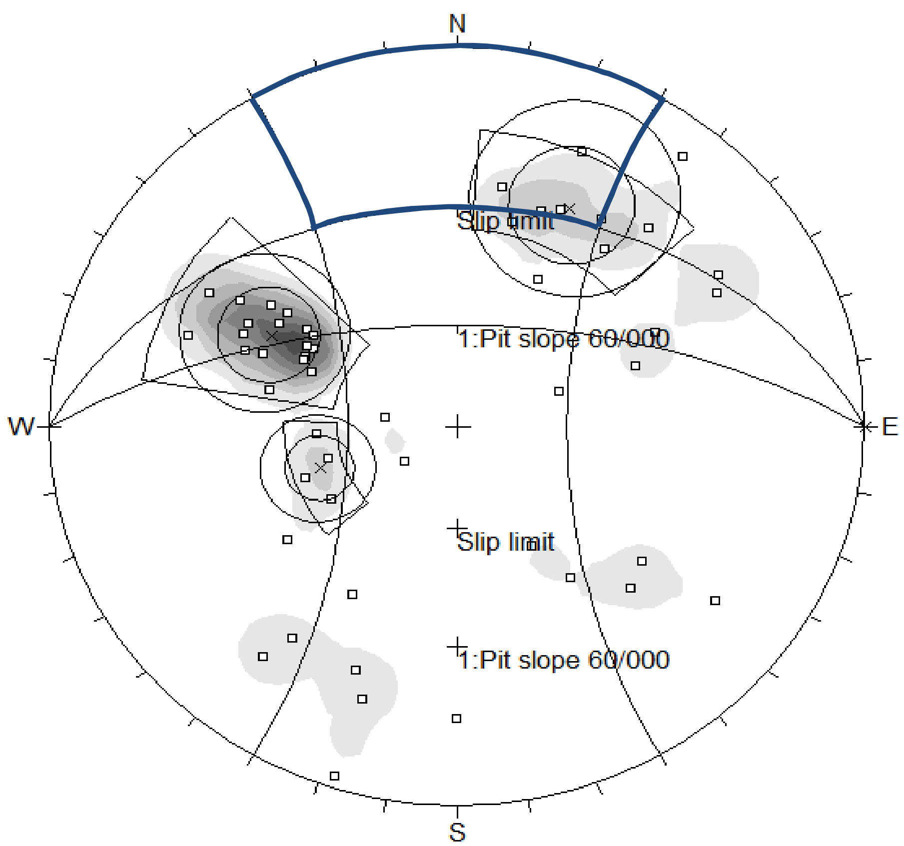
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 60° NORTH FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: Low potential for planar failure for cut slopes with 60° batter angle and North orientation



Control on Stability: Low potential for wedge failure for cut slopes with 60° batter angle and North orientation



Control on Stability: Moderate potential for toppling failure for cut slopes with 60° batter angle and North orientation

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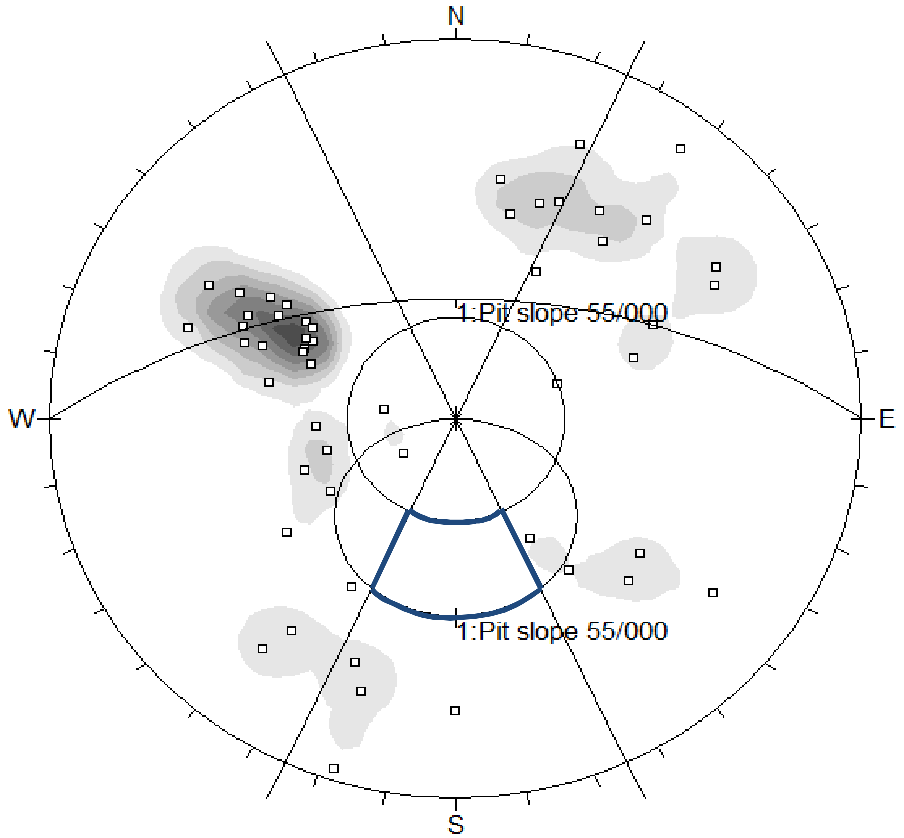
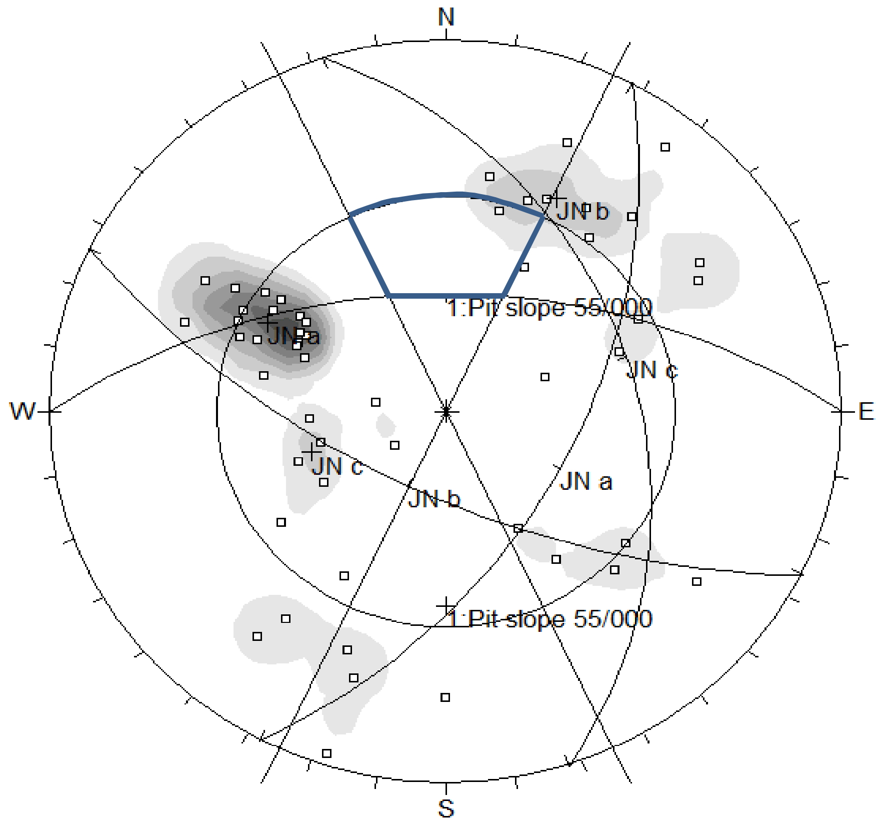
Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

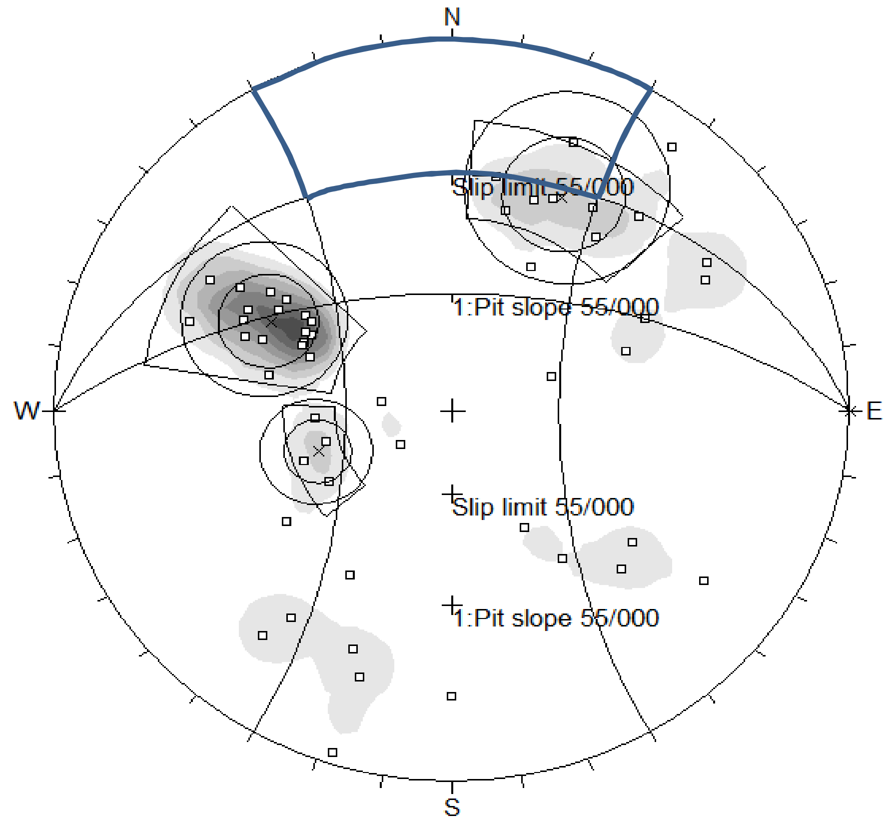
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 55° NORTH FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: Low potential for planar failure for cut slopes with 55° batter angle and North orientation



Control on Stability: Low potential for wedge failure for cut slopes with 55° batter angle and North orientation

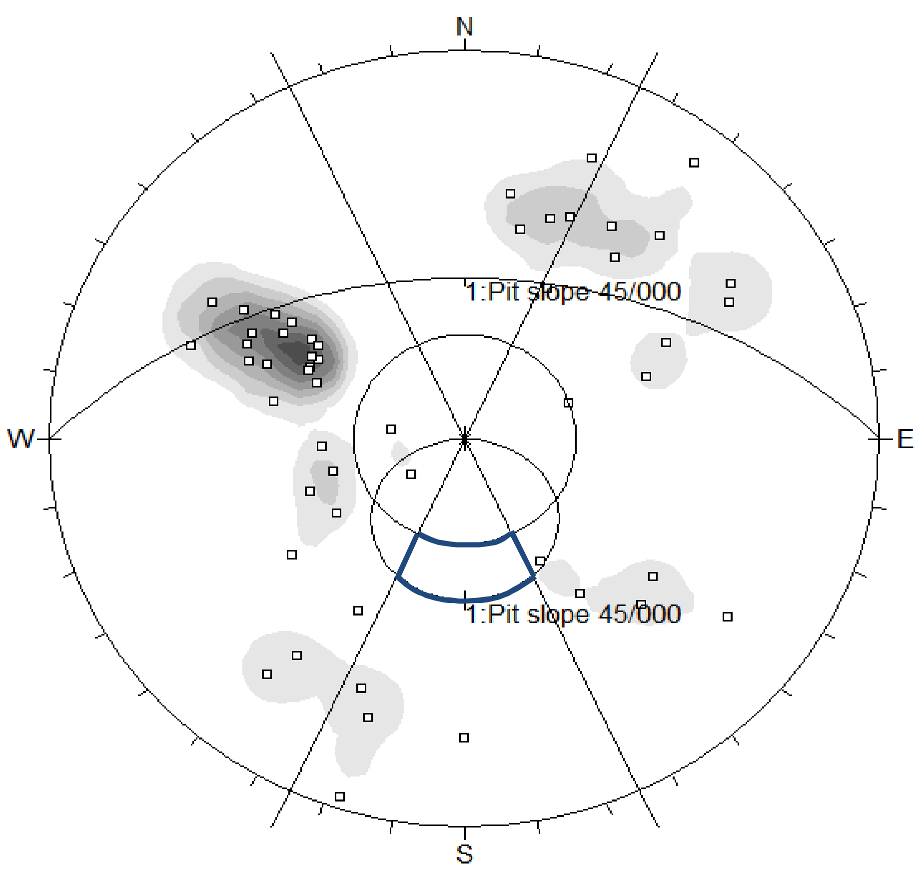


Control on Stability: Moderate potential for toppling failure for cut slopes with 55° batter angle and North orientation

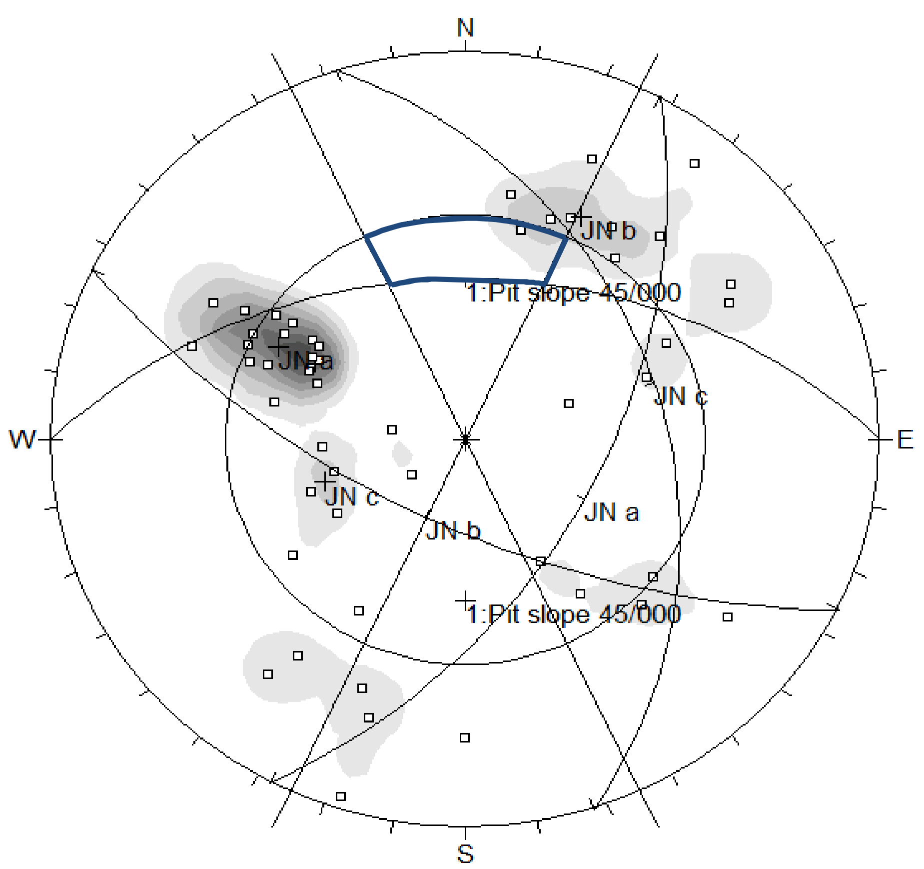
GEOSCIENCE A proud partner of ENGEO

Date	20/02/15	**Client**	**Holcim (NZ) Limited**
Drawn by	GL	**Project**	**Kiwi Point Quarry Stability Analyses**
Approved by	KJ	**Description**	**Failure Analysis**
Scale	N/A	**Project Number**	10315

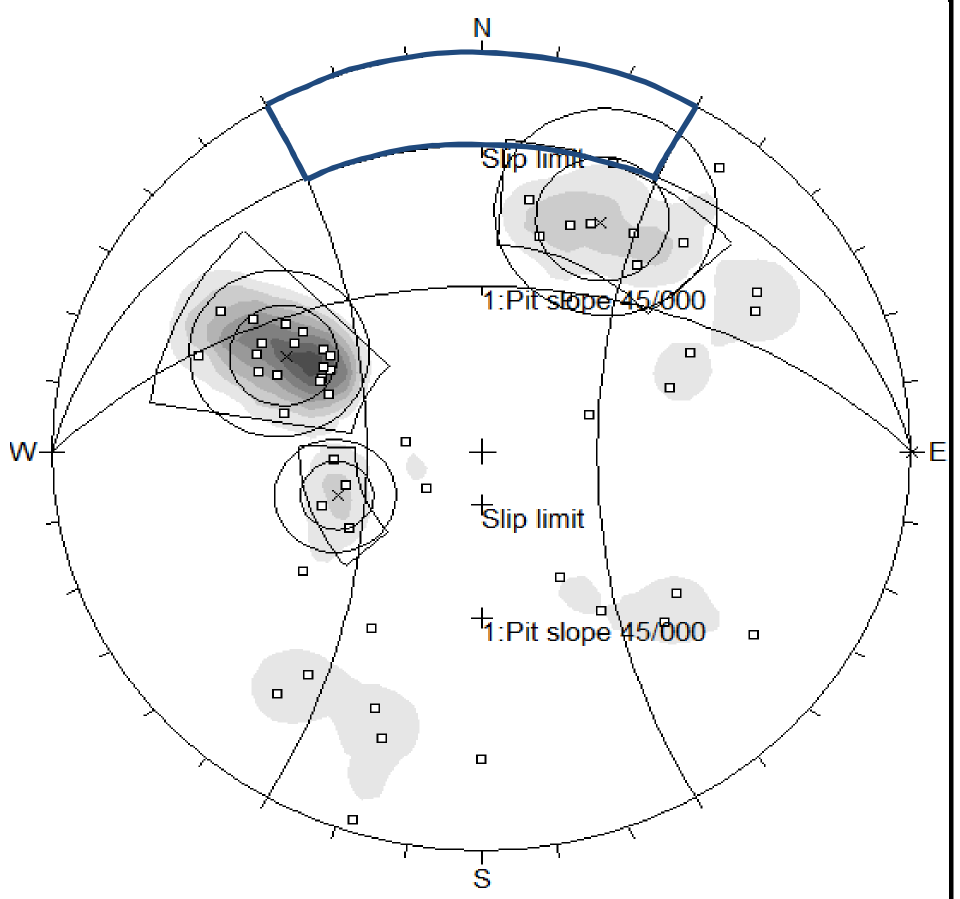
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 45° NORTH FACING BATTER
BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: Low potential for planar failure for cut slopes with 45° batter angle and North orientation



Control on Stability: Low potential for wedge failure for cut slopes with 45° batter angle and North orientation



Control on Stability: Low potential for toppling failure for cut slopes with 45° batter angle and North orientation

Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

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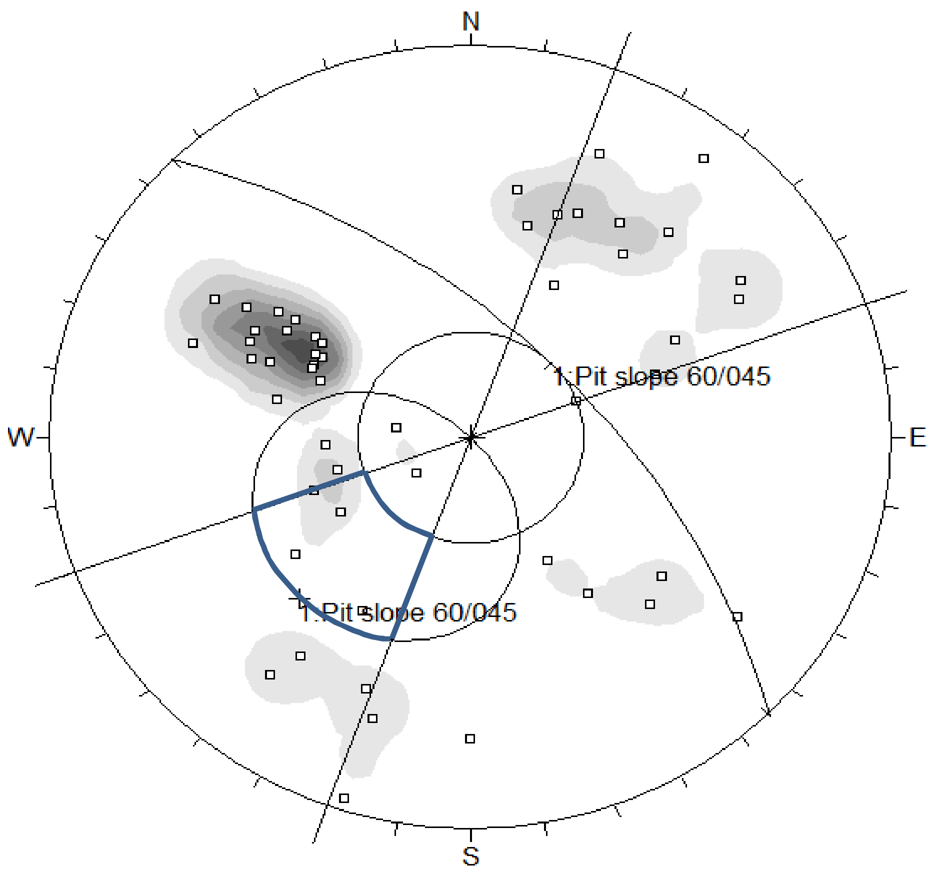
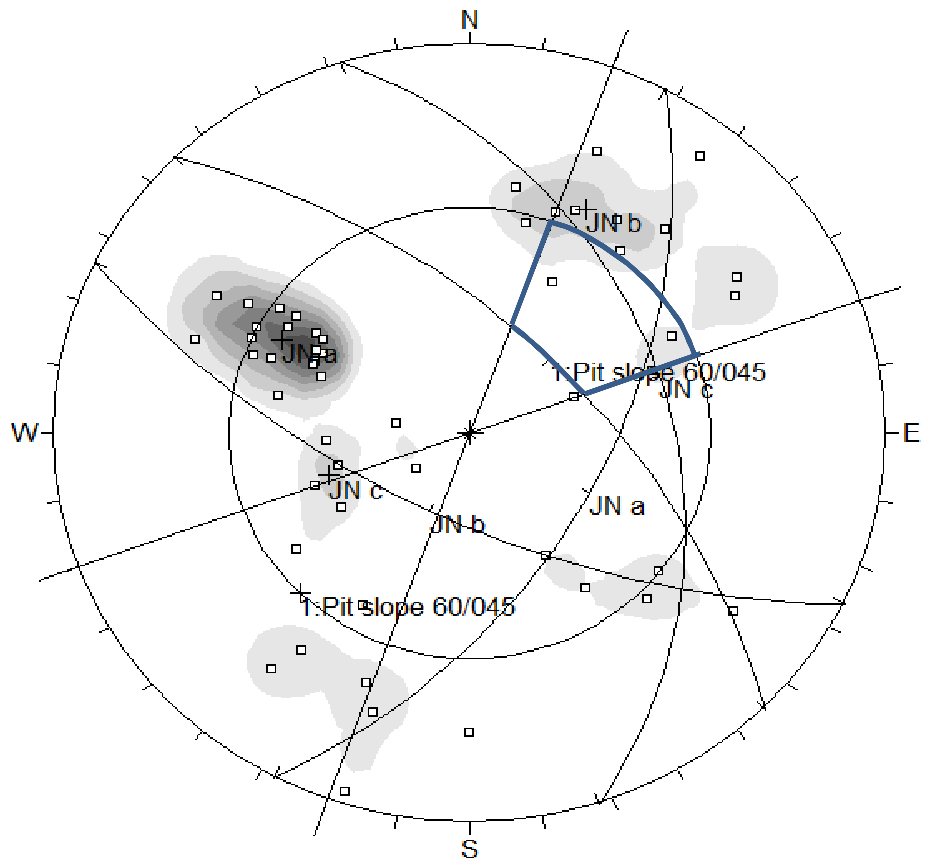
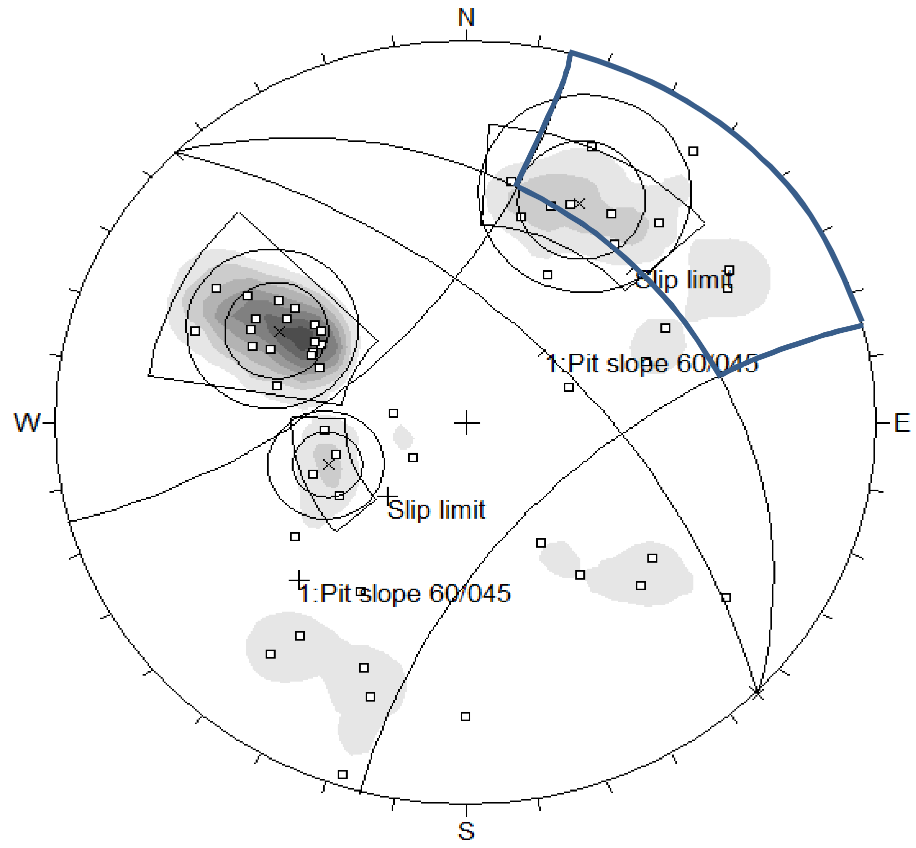
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 60° NORTH-EAST FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: Moderate potential for planar failure for cut slopes with 60° batter angle and North-East orientation



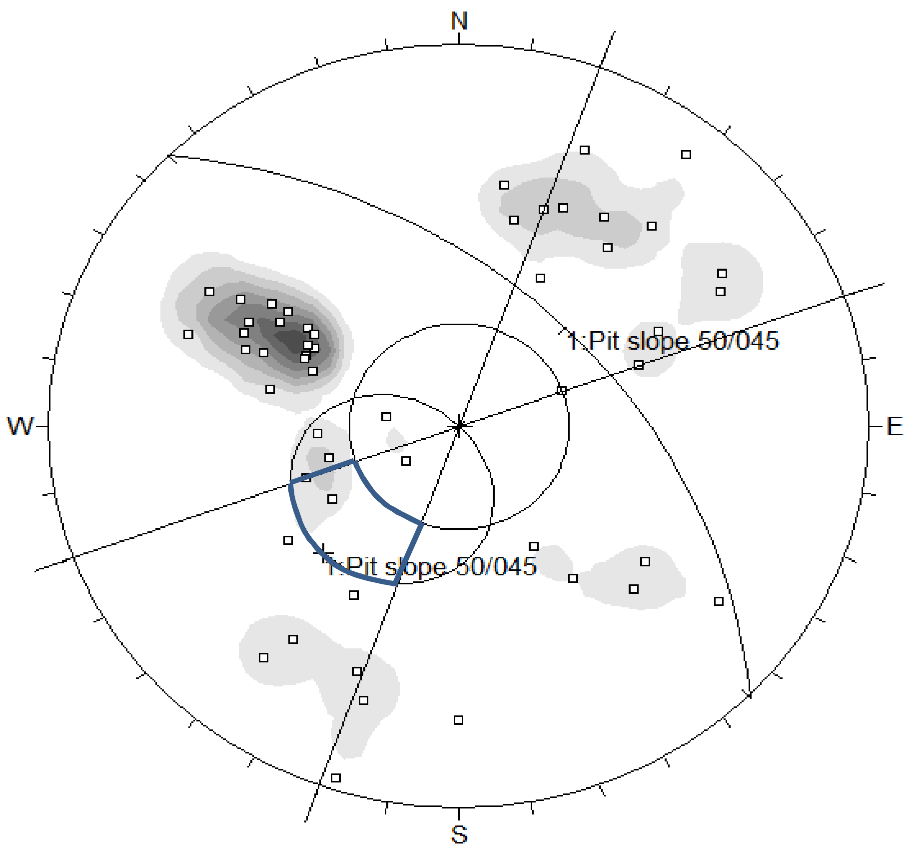
Control on Stability: High potential for wedge failure on joint sets on JNa and JNc for cut slopes with 60° batter angle and North-East orientation



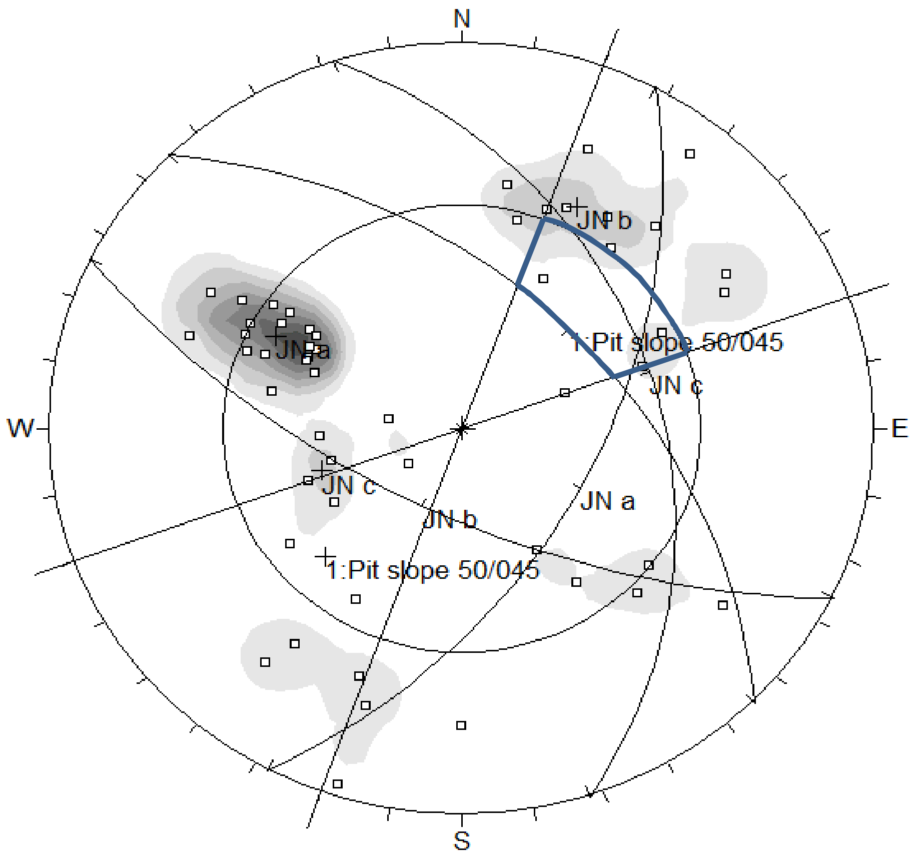
Control on Stability: High potential for toppling failure for cut slopes with 60° batter angle and North-East orientation

Date	20/02/15	**Client**	**Holcim (NZ) Limited**
Drawn by	GL	**Project**	**Kiwi Point Quarry Stability Analyses**
Approved by	KJ	**Description**	**Failure Analysis**
Scale	N/A	**Project Number**	10315

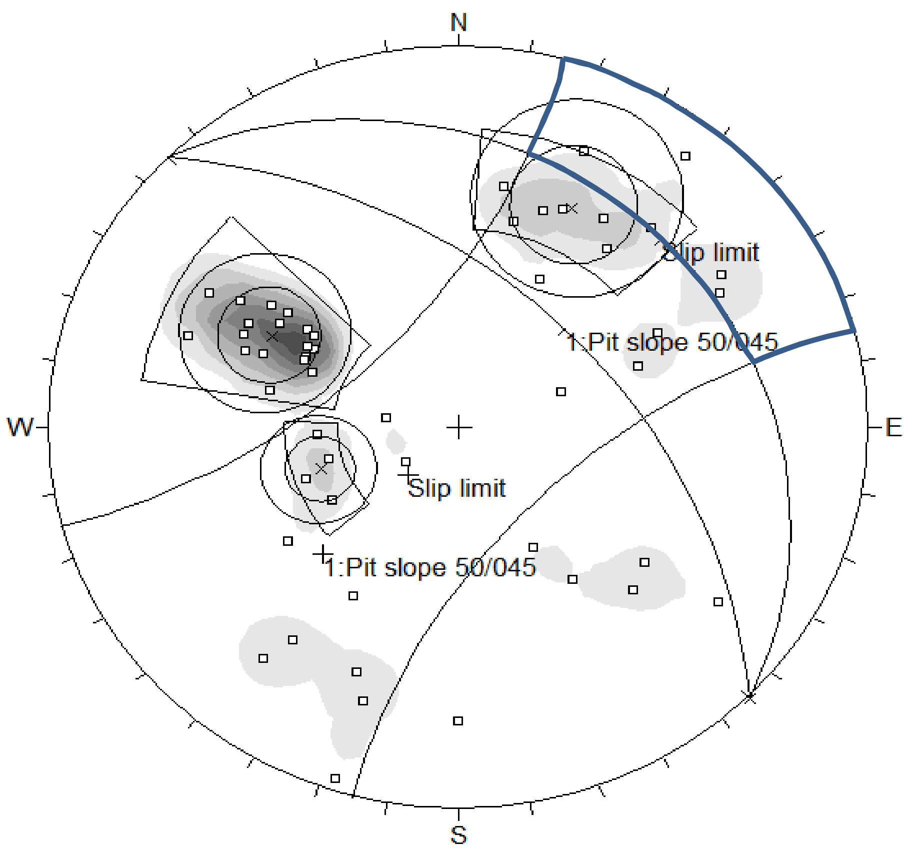
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 50° NORTH-EAST FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: Moderate potential for planar failure for cut slopes with 50° batter angle and North-East orientation



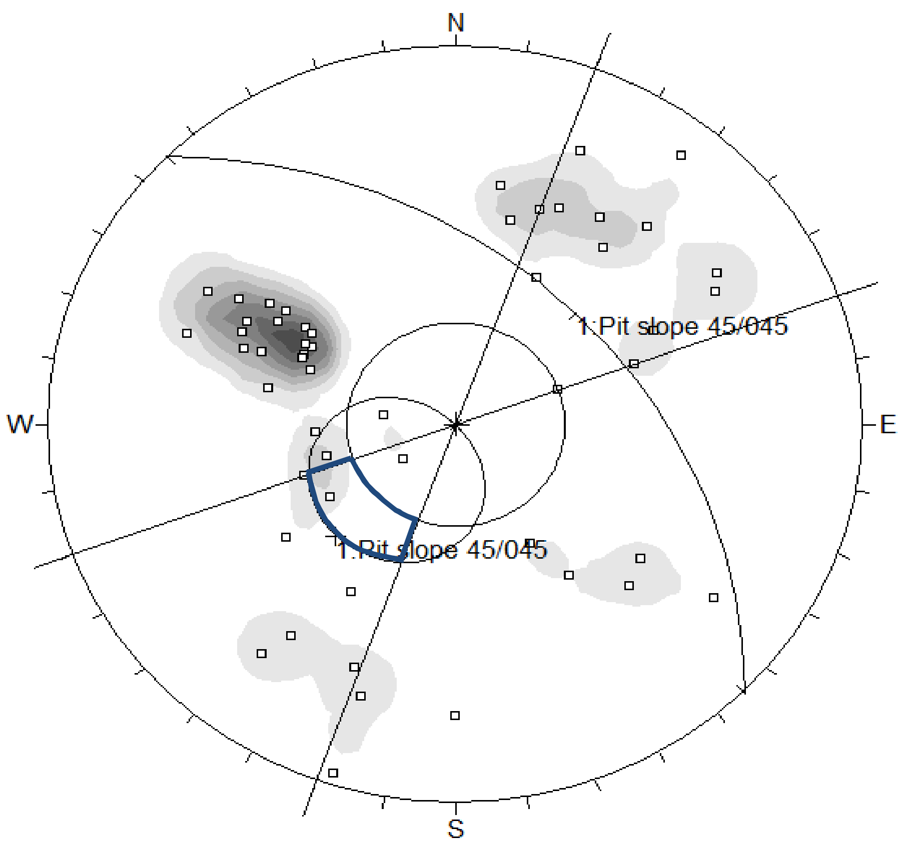
Control on Stability: High potential for wedge failure on joint sets JNa and JNc for cut slopes with 50° batter angle and North-East orientation



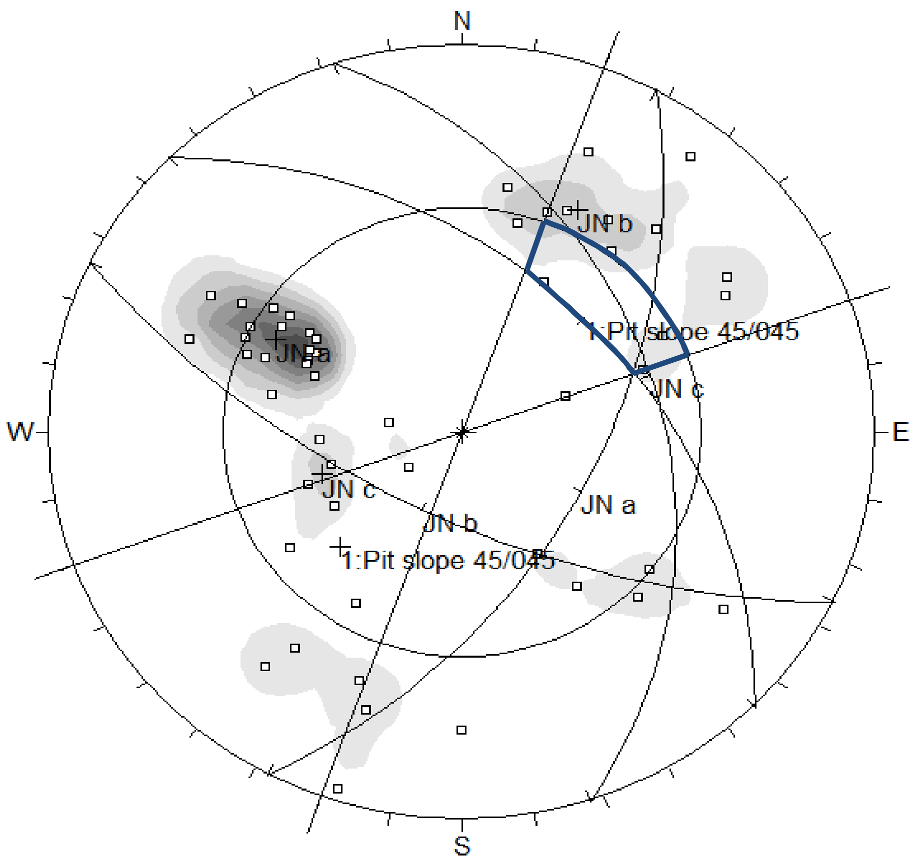
Control on Stability: Moderate potential for toppling failure for cut slopes with 50° batter angle and North-East orientation

GEOSCIENCE A proud partner of ENGEO	Date	20/02/15	Client	Holcim (NZ) Limited
	Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
	Approved by	KJ	Description	Failure Analysis
	Scale	N/A	Project Number	10315

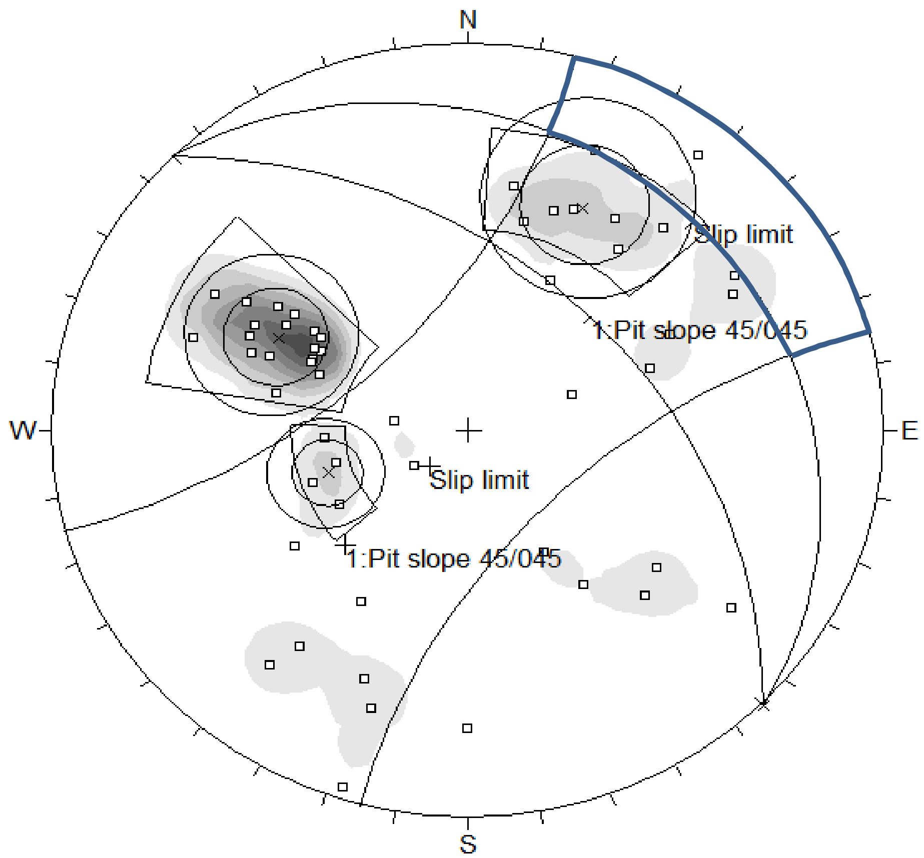
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 45° NORTH-EAST FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: Low potential for planar failure for cut slopes with 45° batter angle and North-East orientation



Control on Stability: High potential for wedge failure on joint sets JNa and JNc for cut slopes with 45° batter angle and North-East orientation



Control on Stability: Low potential for toppling failure for cut slopes with 45° batter angle and North-East orientation

GEOSCIENCE
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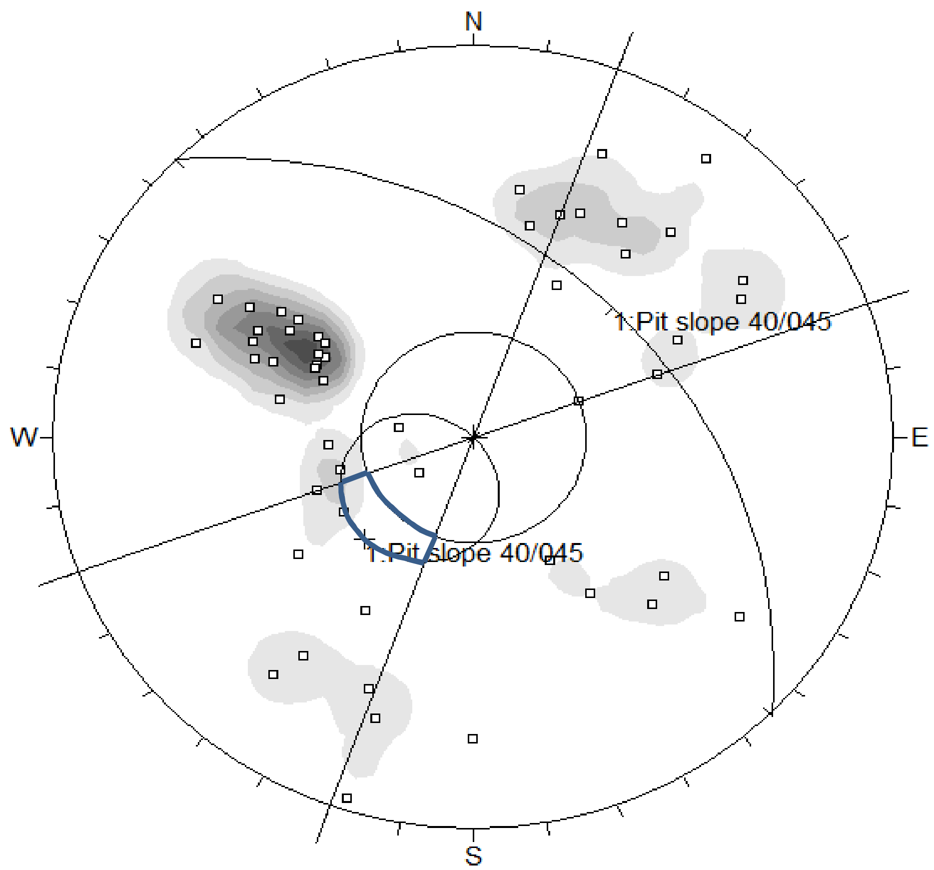
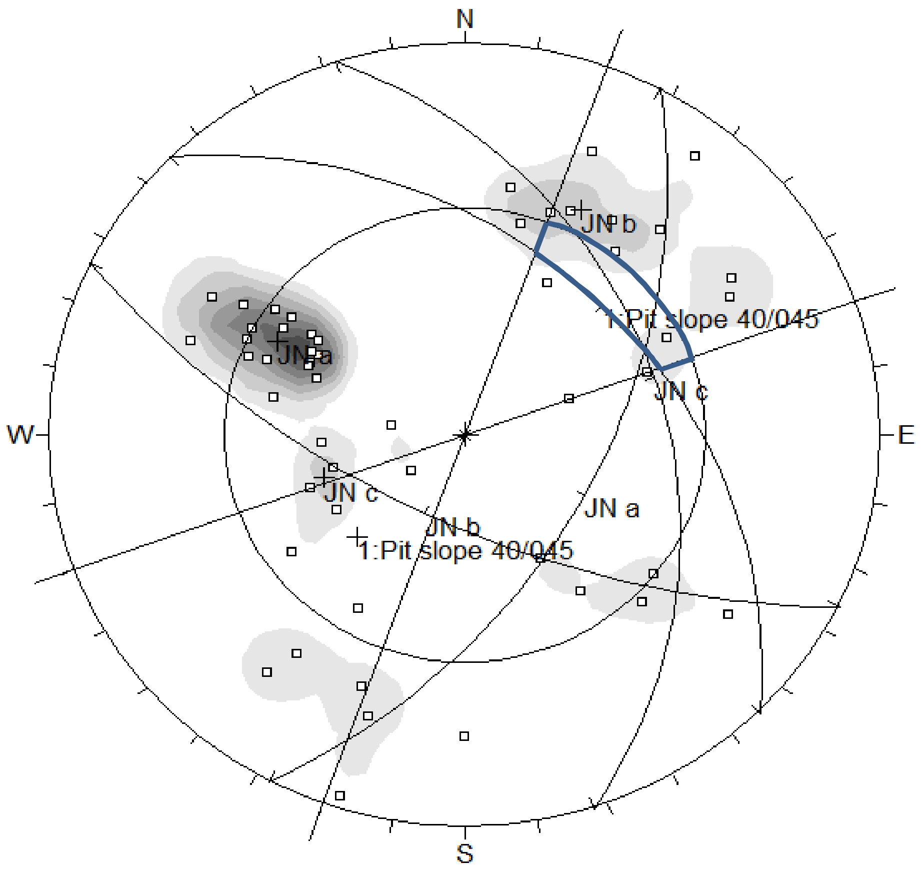
Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

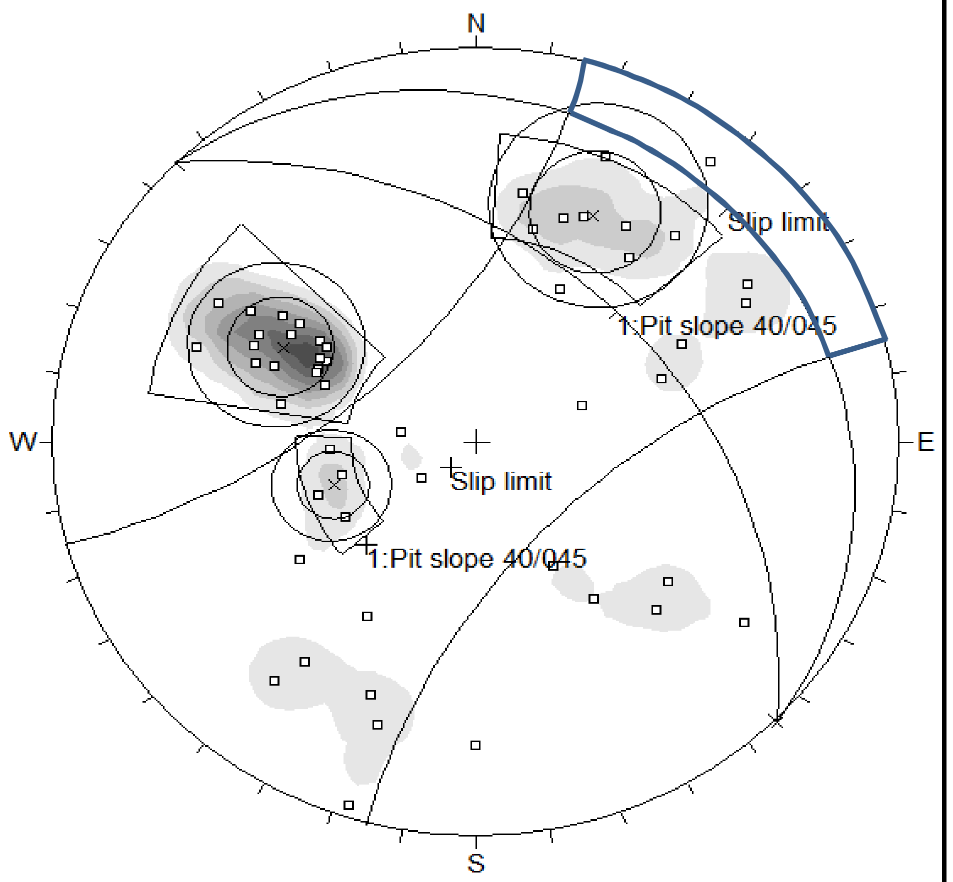
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 40° NORTH-EAST FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: Low potential for planar failure for cut slopes with 40° batter angle and North-East orientation



Control on Stability: Moderate potential for wedge failure on joint sets JNa and JNc for cut slopes with 40° batter angle and North-East orientation



Control on Stability: Low potential for toppling failure for cut slopes with 40° batter angle and North-East orientation

GEOSCIENCE
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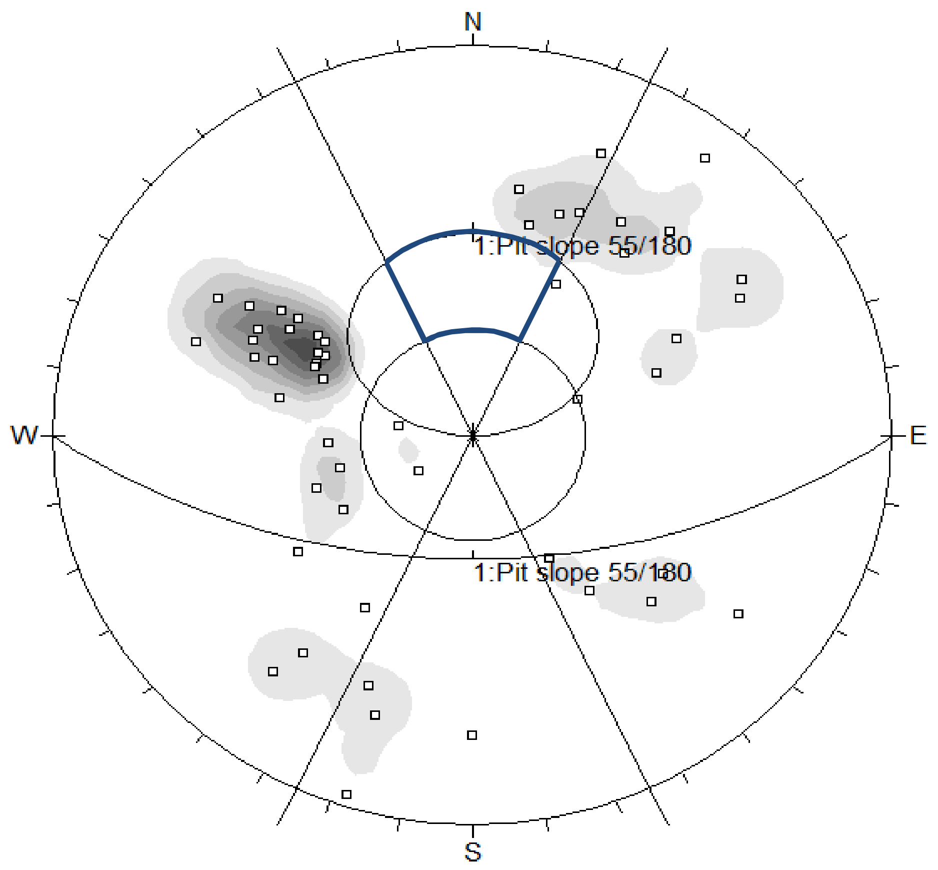
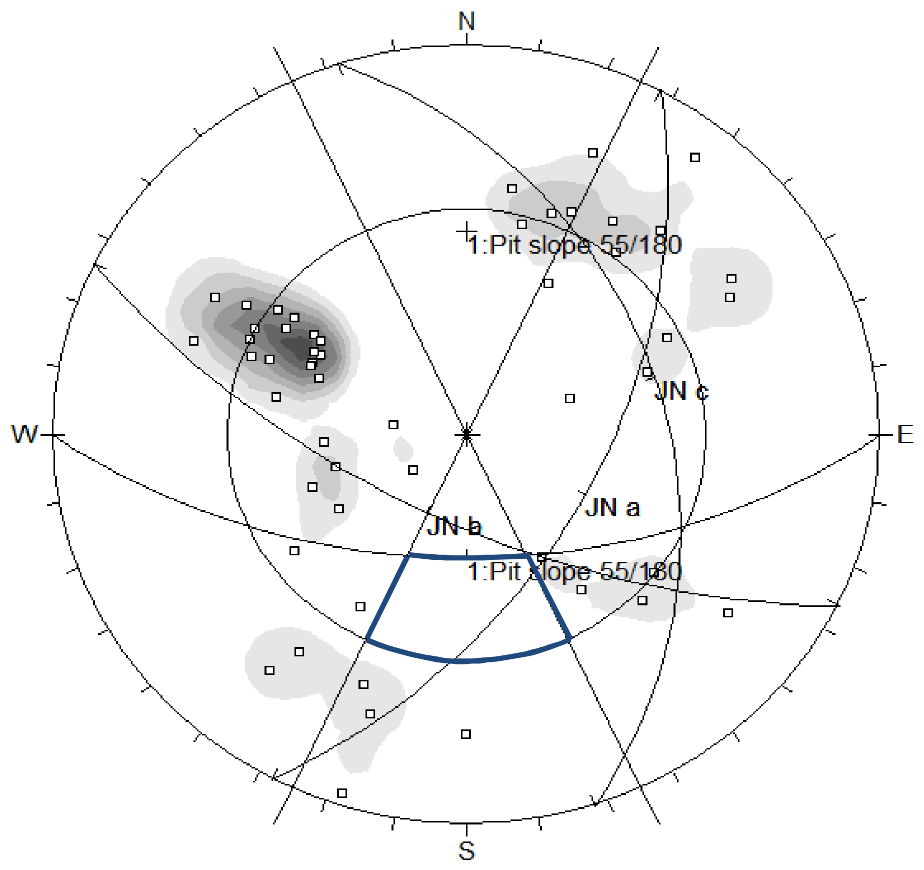
Date	20/02/15	**Client**	**Holcim (NZ) Limited**
Drawn by	GL	**Project**	**Kiwi Point Quarry Stability Analyses**
Approved by	KJ	**Description**	**Failure Analysis**
Scale	N/A	**Project Number**	10315

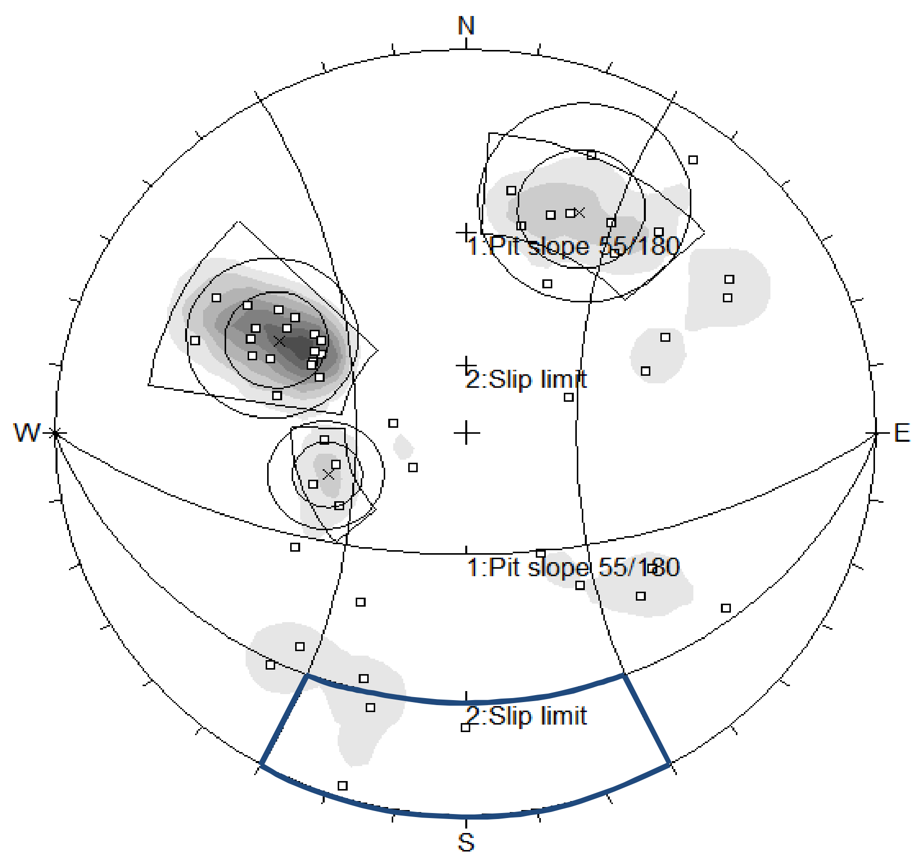
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 55° SOUTH FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: Low potential for planar failure for cut slopes with 55° batter angle and South orientation



Control on Stability: Moderate potential for wedge failure on joint sents JNa and JNb for cut slopes with 55° batter angle and South orientation



Control on Stability: Low potential for toppling failure for cut slopes with 55° batter angle and South orientation

GEOSCIENCE
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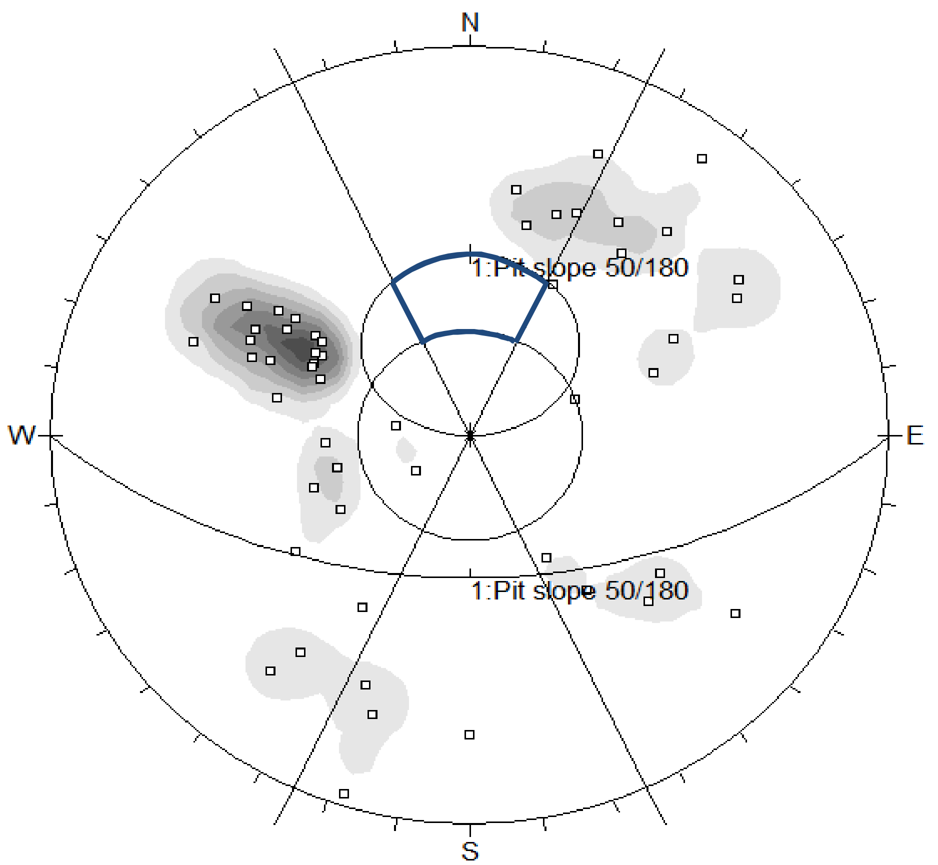
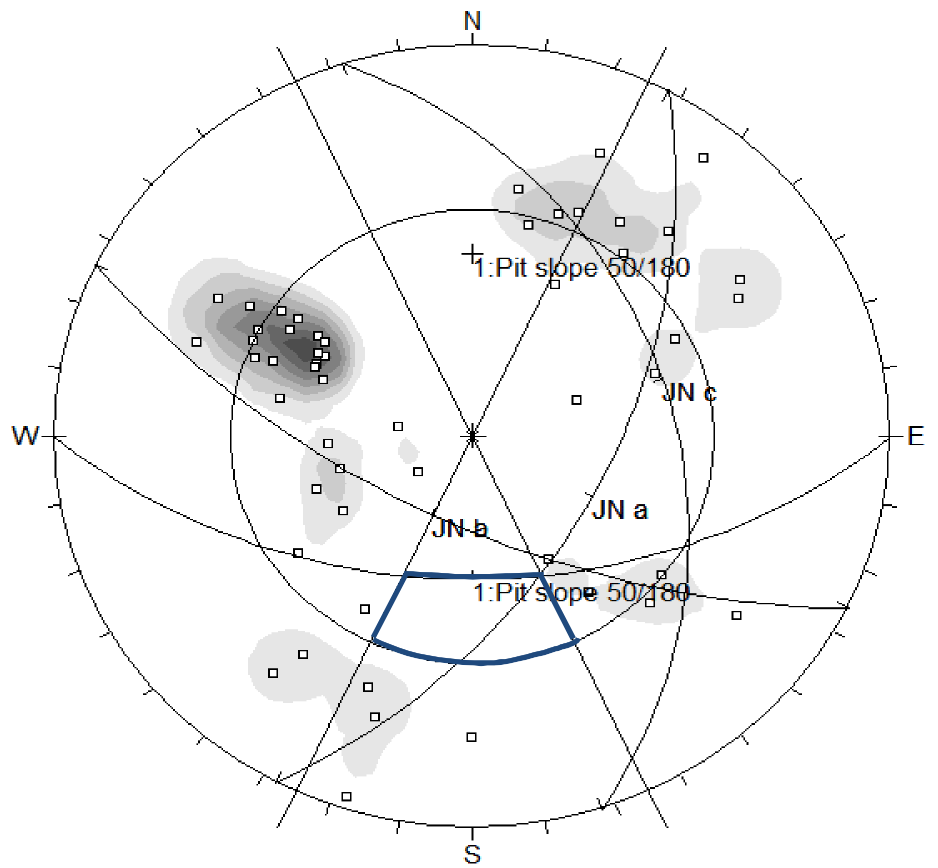
Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

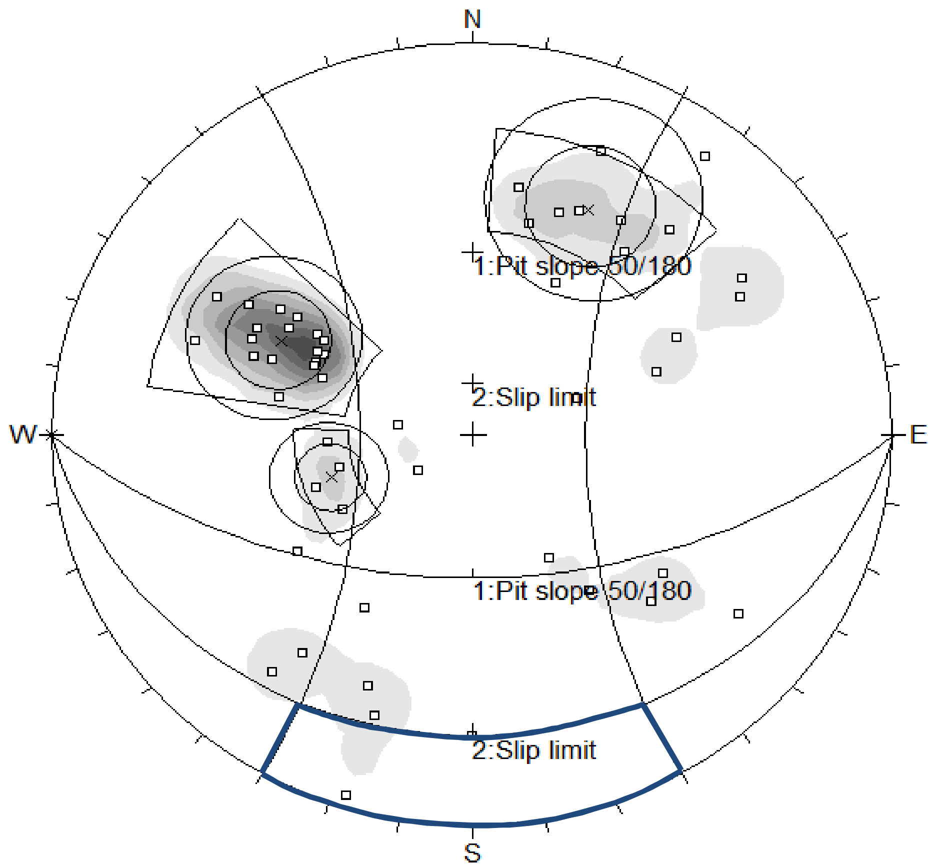
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 50° SOUTH FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: Low potential for planar failure for cut slopes with 50° batter angle and South orientation



Control on Stability: Low potential for wedge failure for cut slopes with 50° batter angle and South orientation

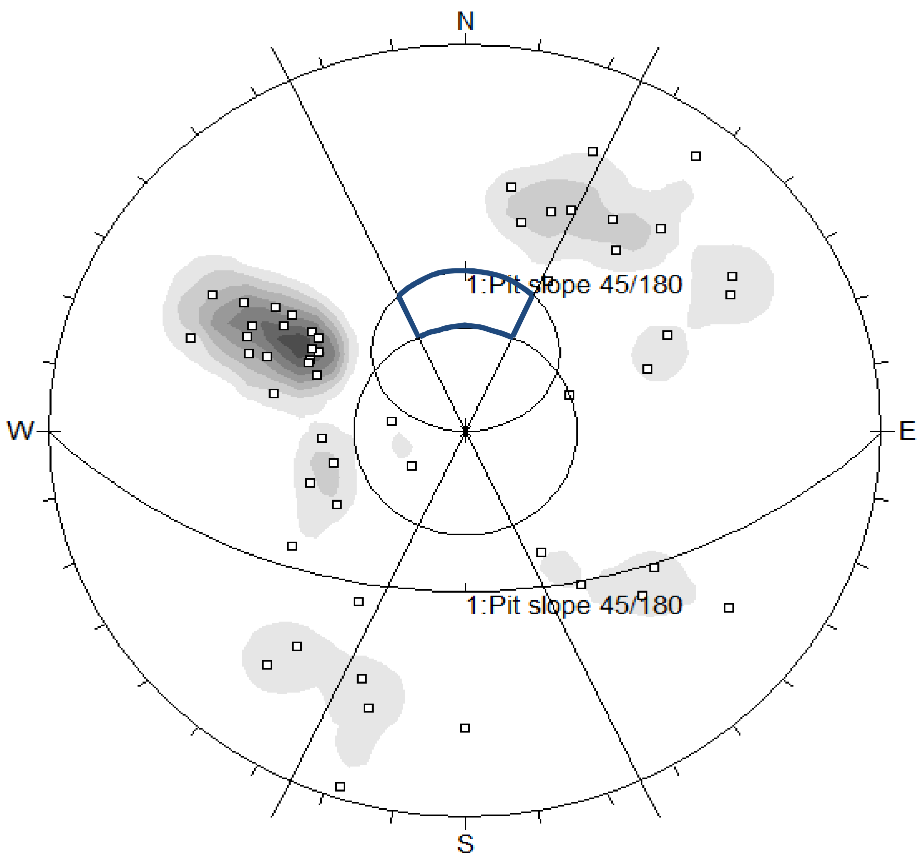


Control on Stability: Low potential for toppling failure for cut slopes with 50° batter angle and South orientation

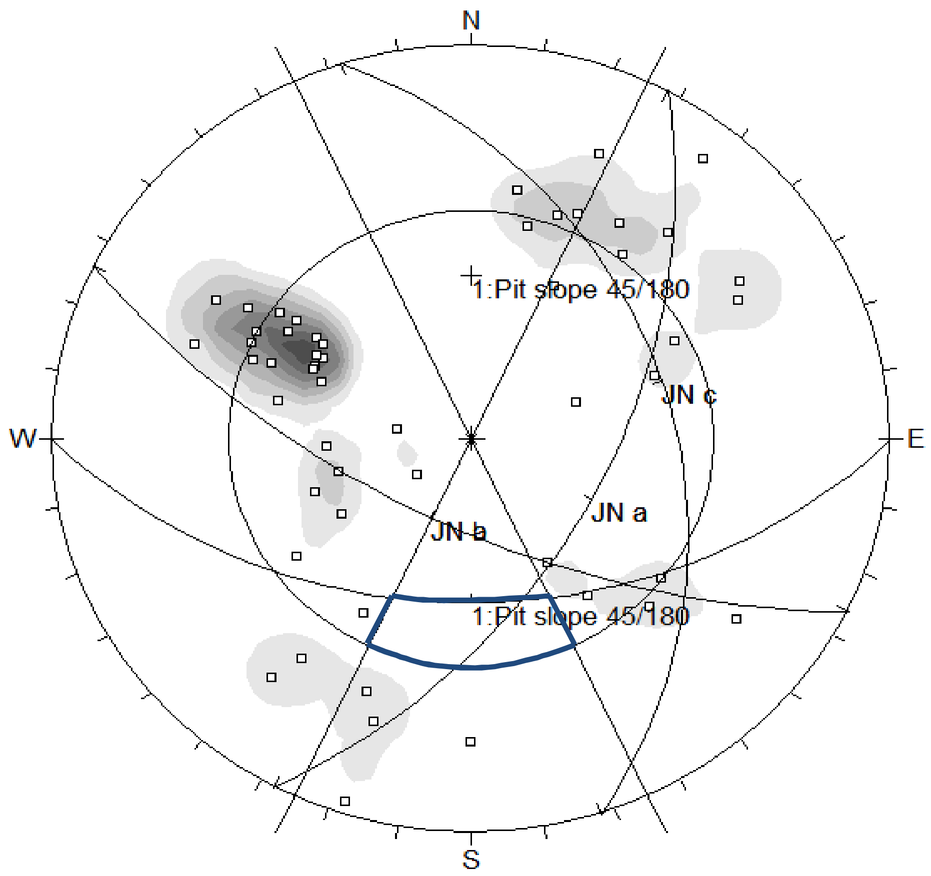
GEOSCIENCE A proud partner of ENGEO

Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

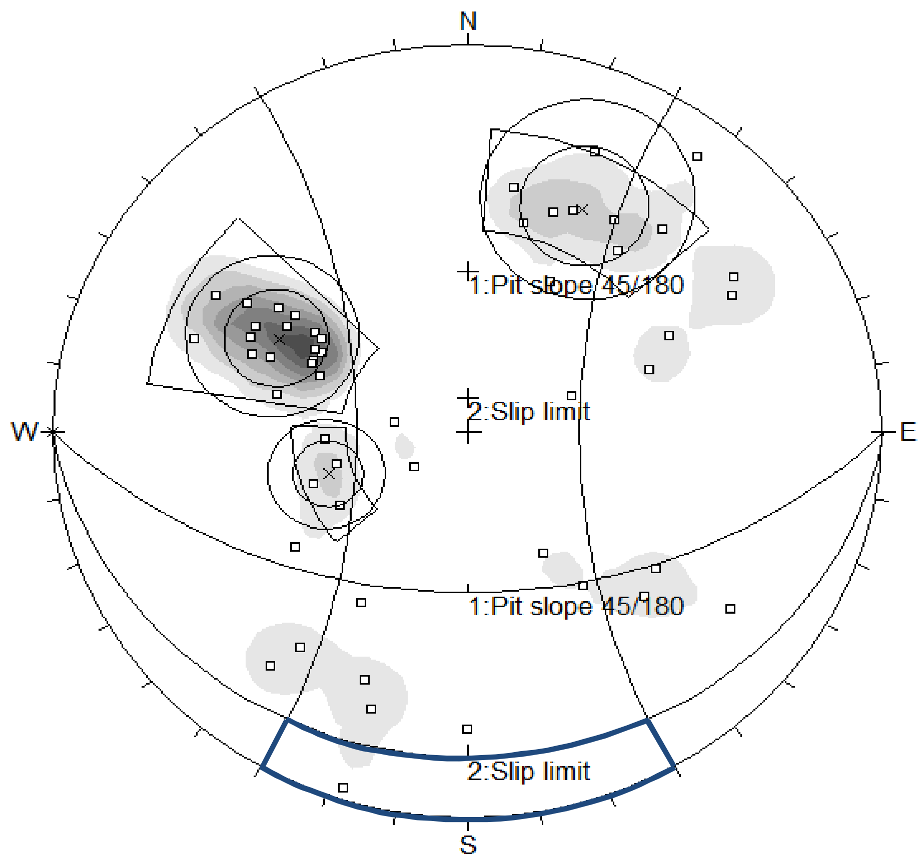
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 45° SOUTH FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: Low potential for planar failure for cut slopes with 45° batter angle and South orientation



Control on Stability: Low potential for wedge failure for cut slopes with 45° batter angle and South orientation



Control on Stability: Low potential for toppling failure for cut slopes with 45° batter angle and South orientation

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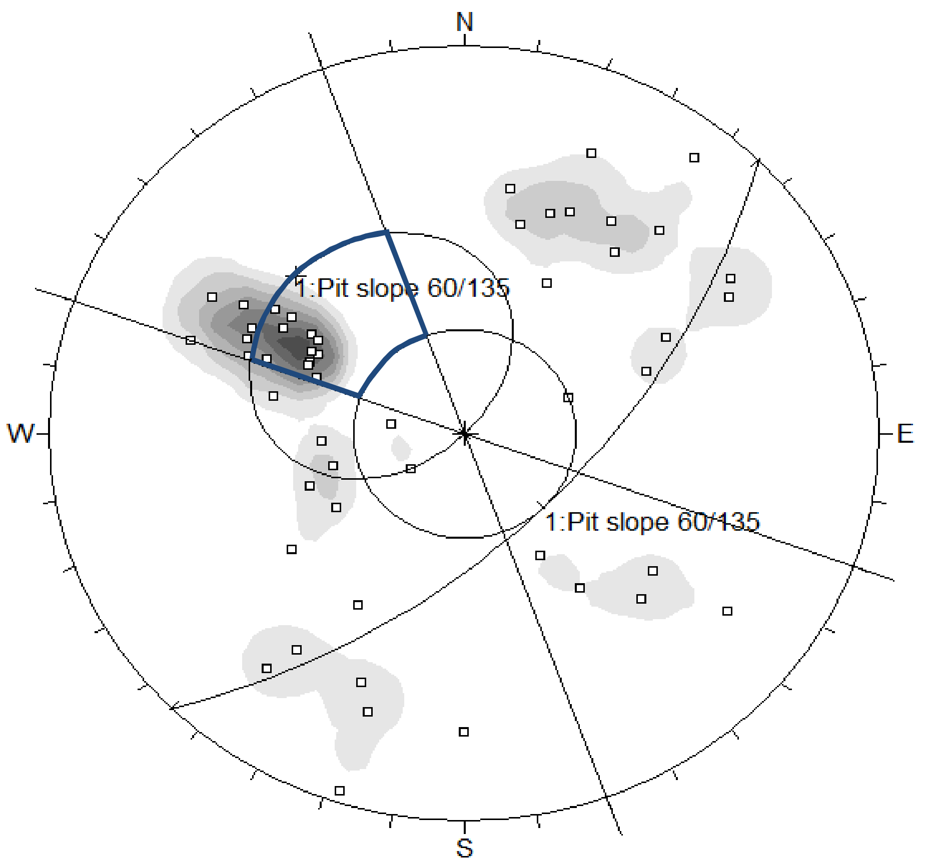
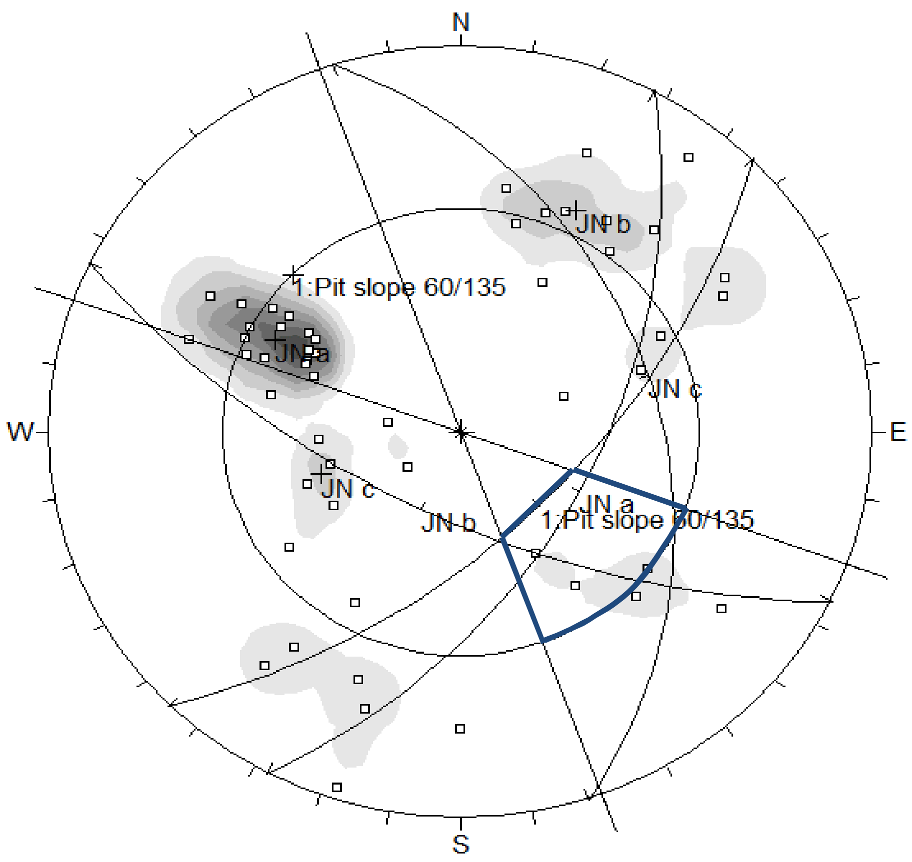
Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

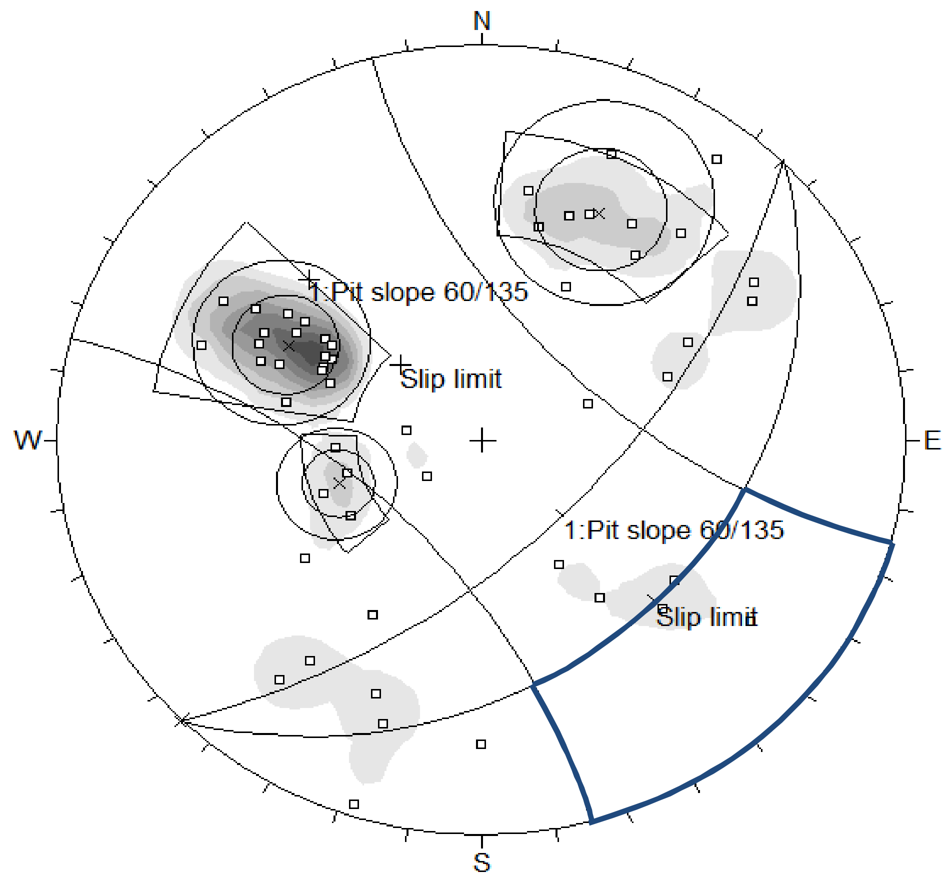
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 60° SOUTH-EAST FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: High potential for planar failure for cut slopes with 60° batter angle and South-East orientation



Control on Stability: High potential for wedge failure on joint sets JNa and JNb for cut slopes with 60° batter angle and South-East orientation

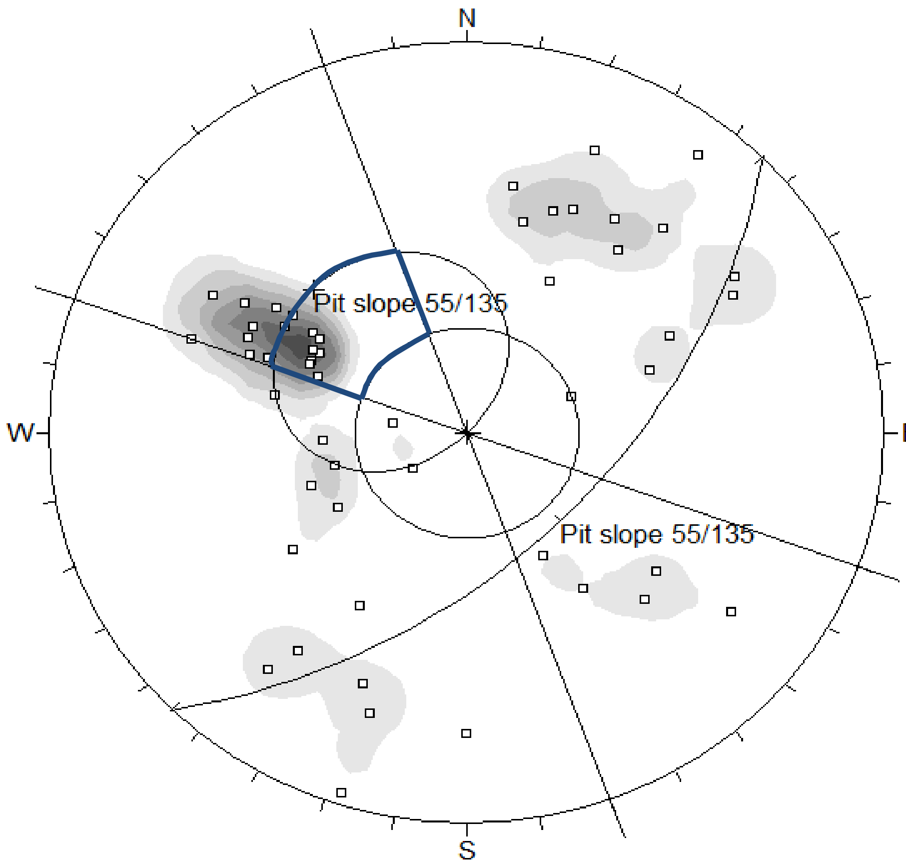


Control on Stability: Low potential for toppling failure for cut slopes with 60° batter angle and South-East orientation

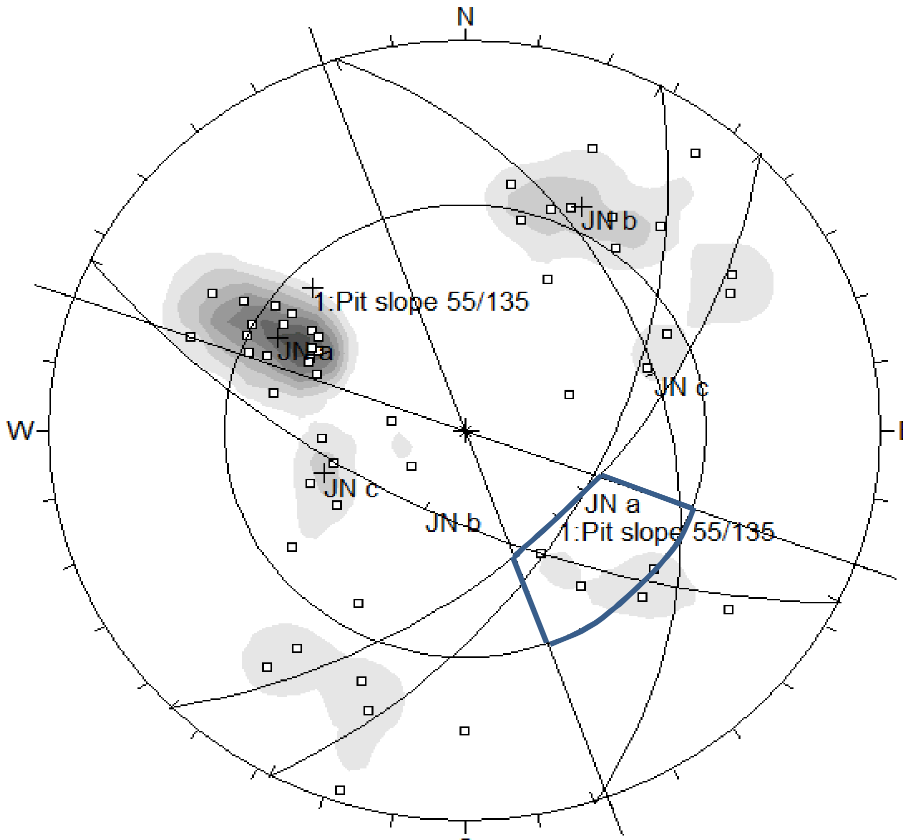
GEOSCIENCE A proud partner of ENGEO

Date	20/02/15	**Client**	**Holcim (NZ) Limited**
Drawn by	GL	**Project**	**Kiwi Point Quarry Stability Analyses**
Approved by	KJ	**Description**	**Failure Analysis**
Scale	N/A	**Project Number**	10315

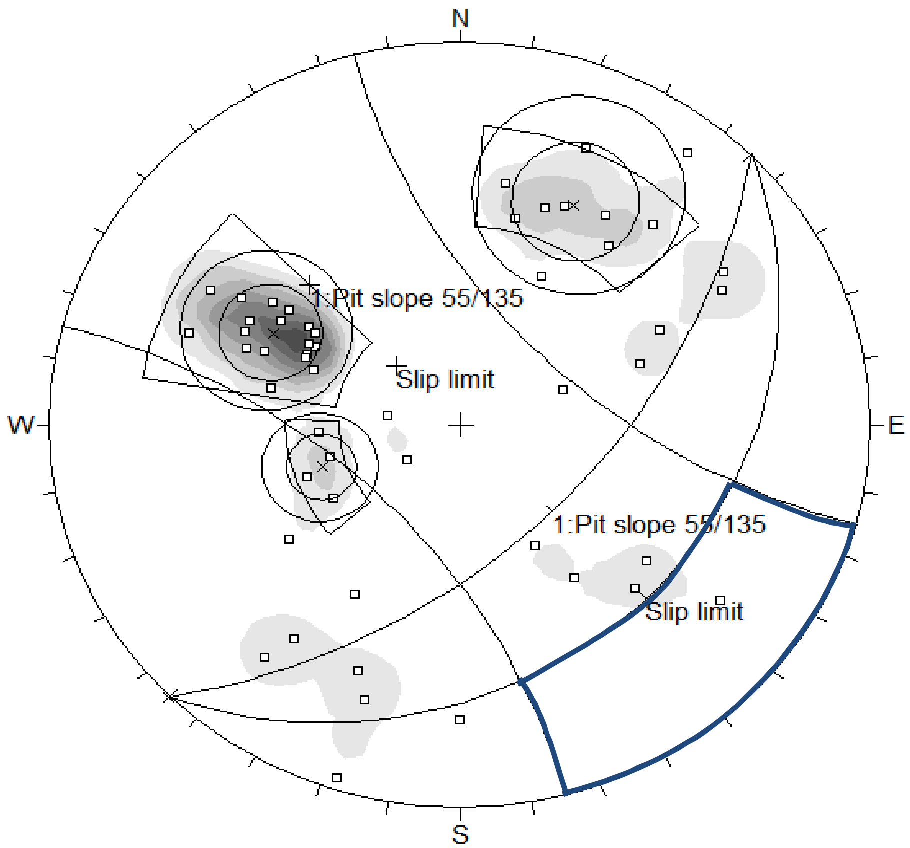
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 55° SOUTH-EAST FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: High potential for planar failure for cut slopes with 55° batter angle and South-East orientation



Control on Stability: High potential for wedge failure on joint sets JNa and JNb for cut slopes with 55° batter angle and South-East orientation

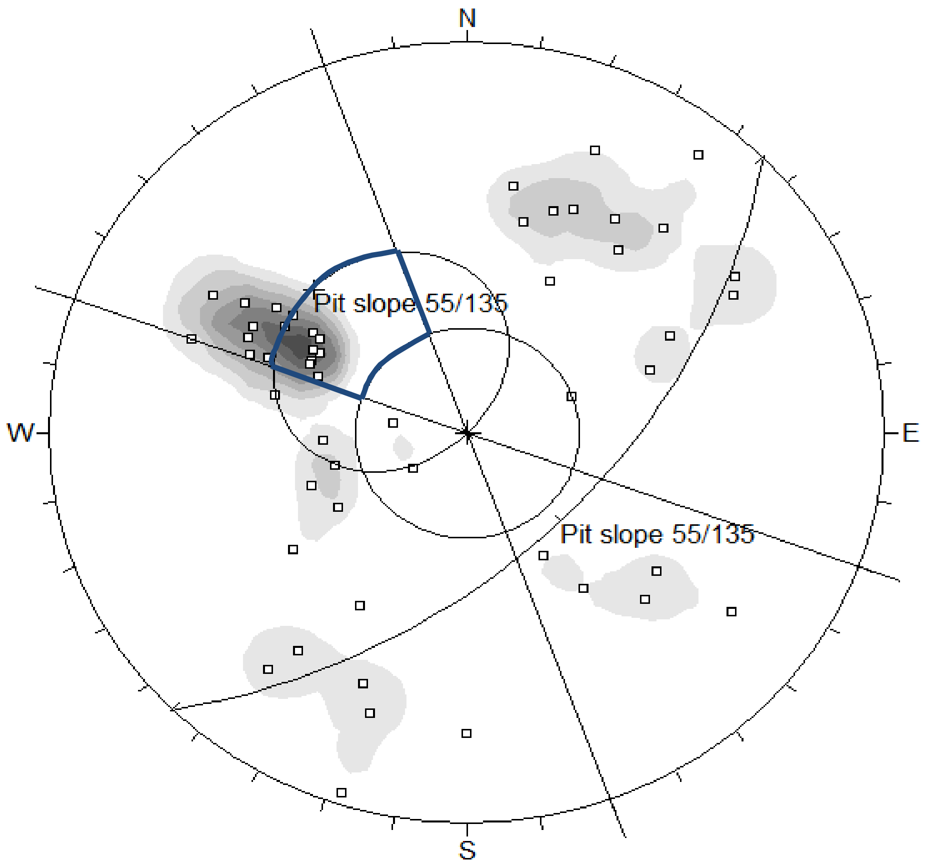


Control on Stability: Low potential for toppling failure for cut slopes with 55° batter angle and South-East orientation

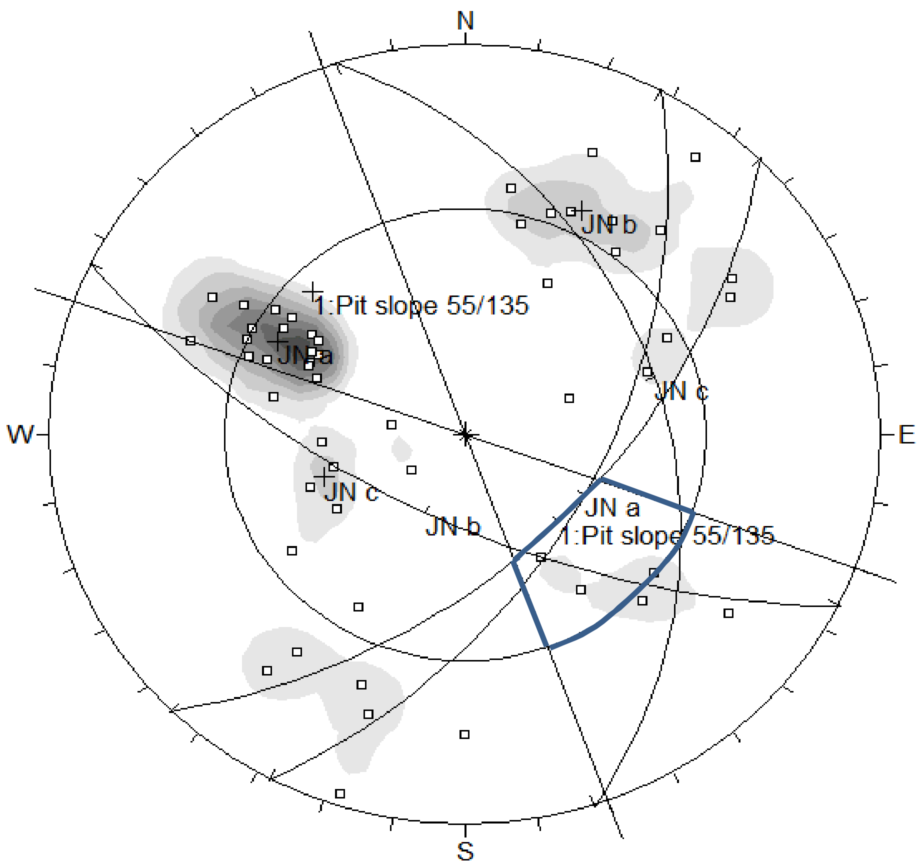
GEOSCIENCE A proud partner of ENGEO

Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

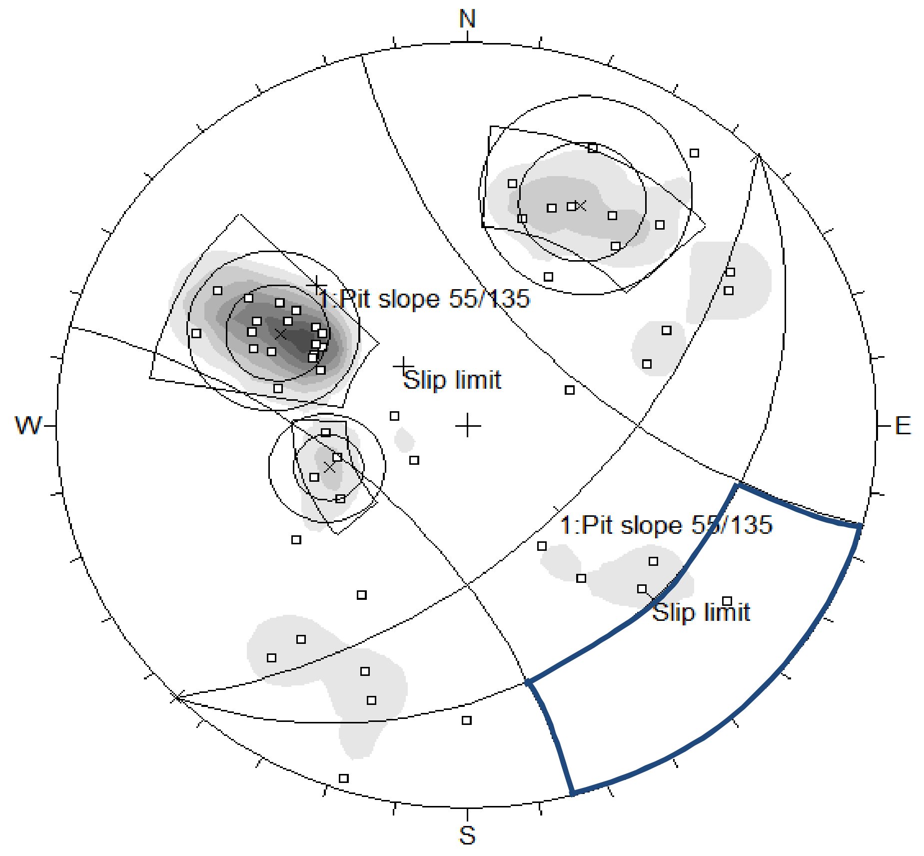
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 55° SOUTH-EAST FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: High potential for planar failure for cut slopes with 55° batter angle and South-East orientation



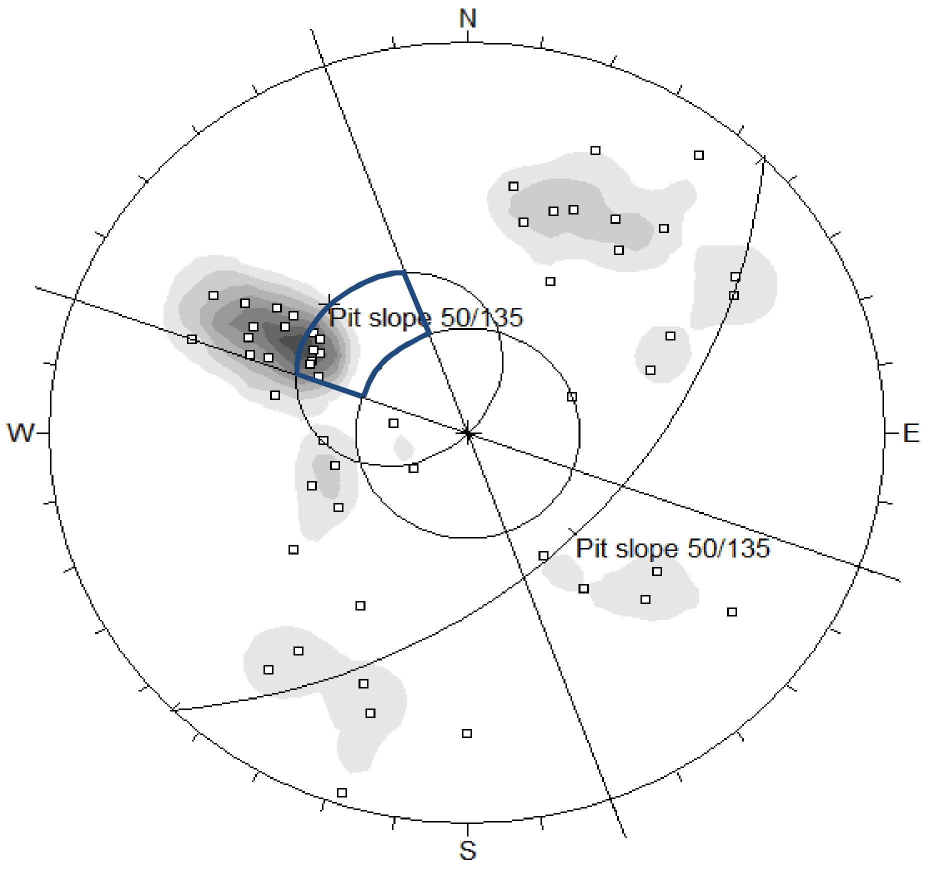
Control on Stability: High potential for wedge failure on joint sets JNa and JNb for cut slopes with 55° batter angle and South-East orientation



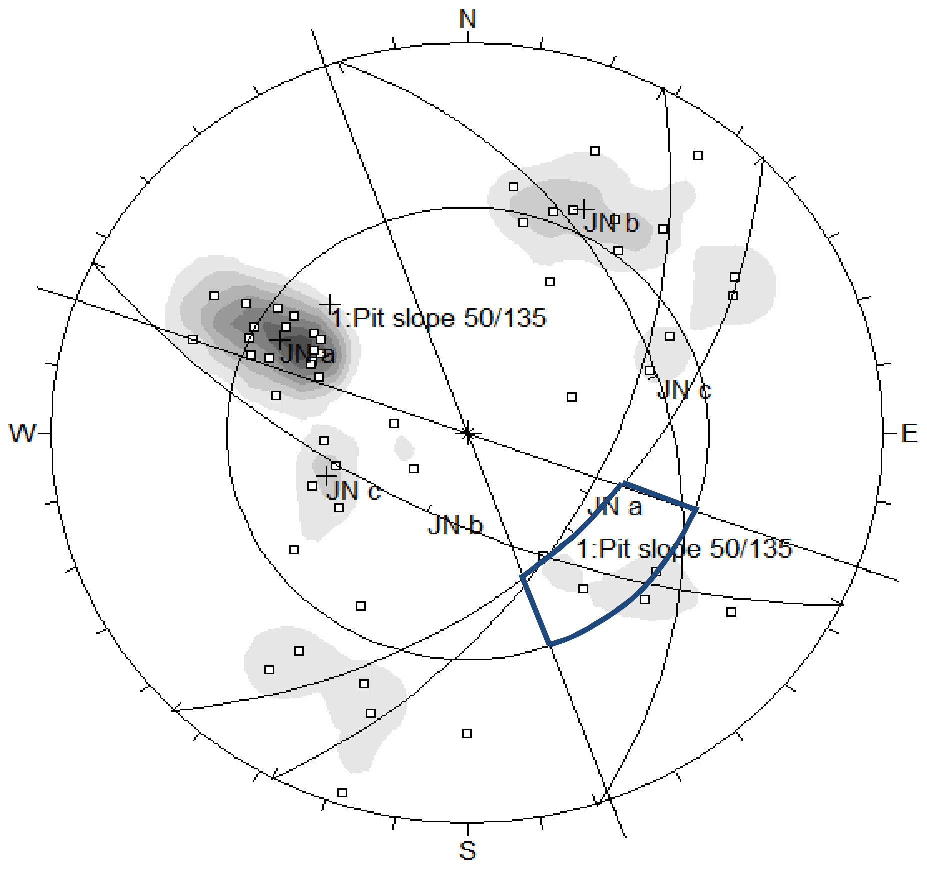
Control on Stability: Low potential for toppling failure for cut slopes with 55° batter angle and South-East orientation

Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

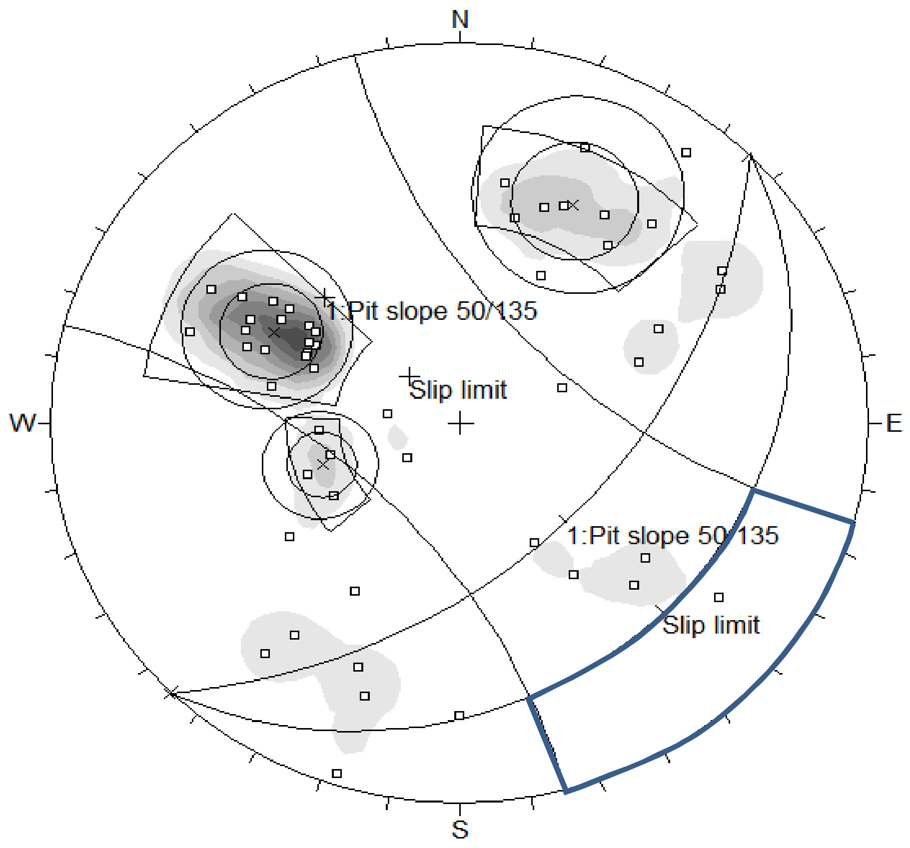
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 50° SOUTH-EAST FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: High potential for planar failure for cut slopes with 50° batter angle and South-East orientation



Control on Stability: Moderate potential for wedge failure on joint sets JNa and JNb for cut slopes with 50° batter angle and South-East orientation



Control on Stability: Low potential for toppling failure for cut slopes with 50° batter angle and South-East orientation

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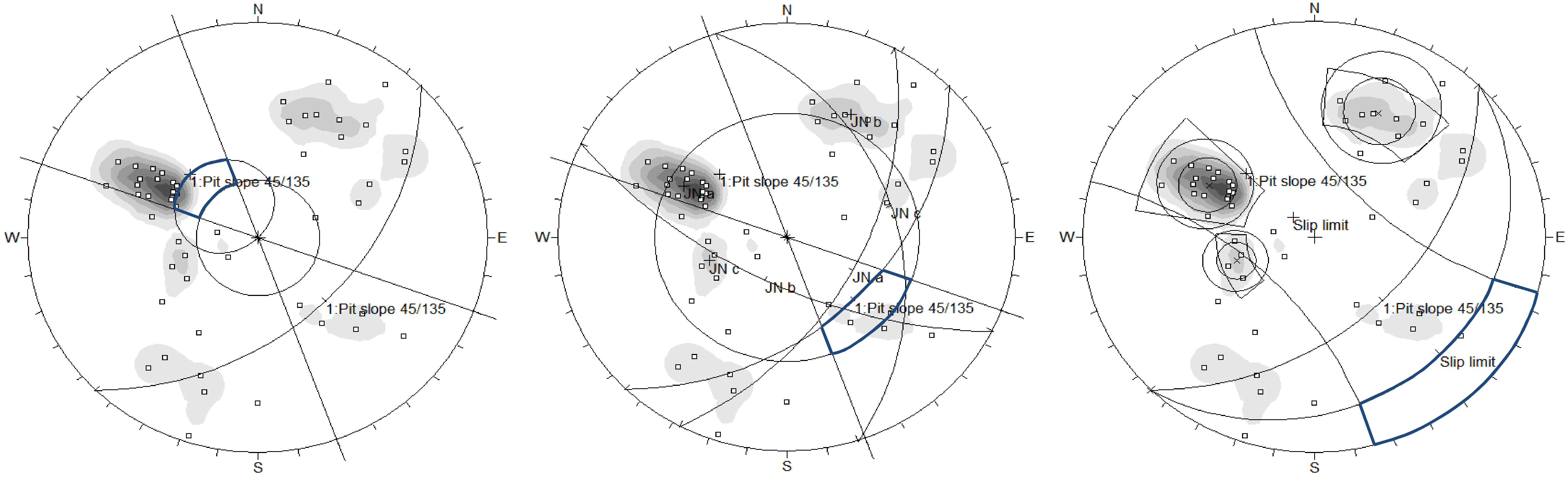
Date	20/02/15	**Client**	**Holcim (NZ) Limited**
Drawn by	GL	**Project**	**Kiwi Point Quarry Stability Analyses**
Approved by	KJ	**Description**	**Failure Analysis**
Scale	N/A	**Project Number**	10315

PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 45° SOUTH-EAST FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



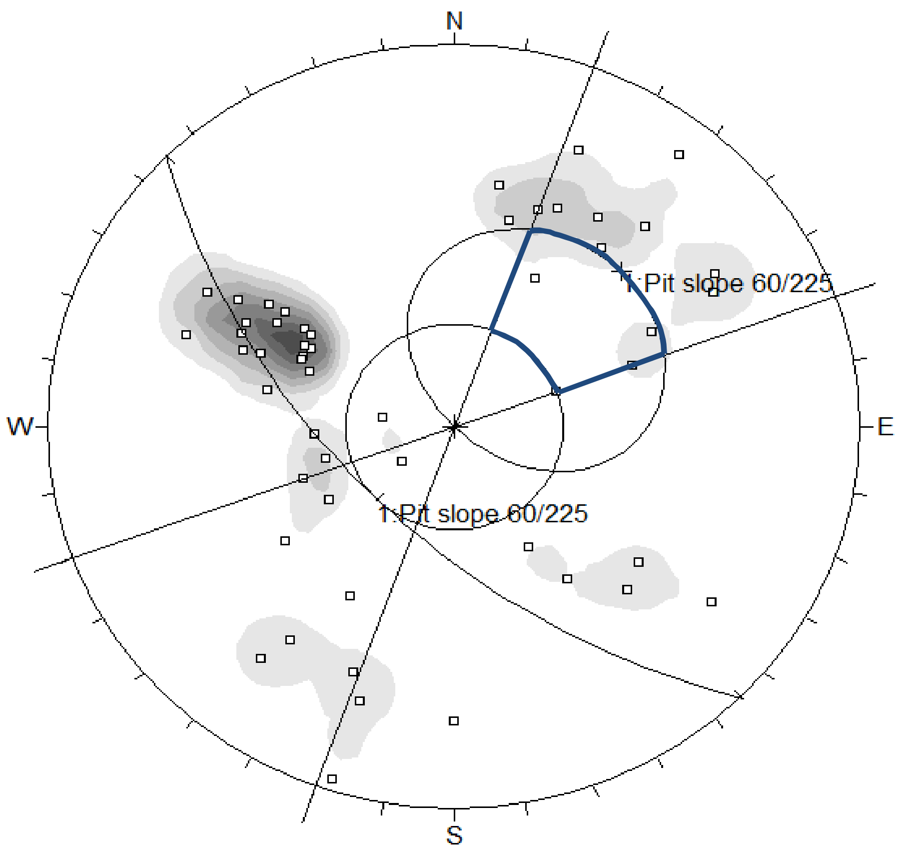
Control on Stability: Moderate potential for planar failure for cut slopes with 45° batter angle and South-East orientation

Control on Stability: Low potential for wedge failure on joint sets JNa and JNb for cut slopes with 45° batter angle and South-East orientation

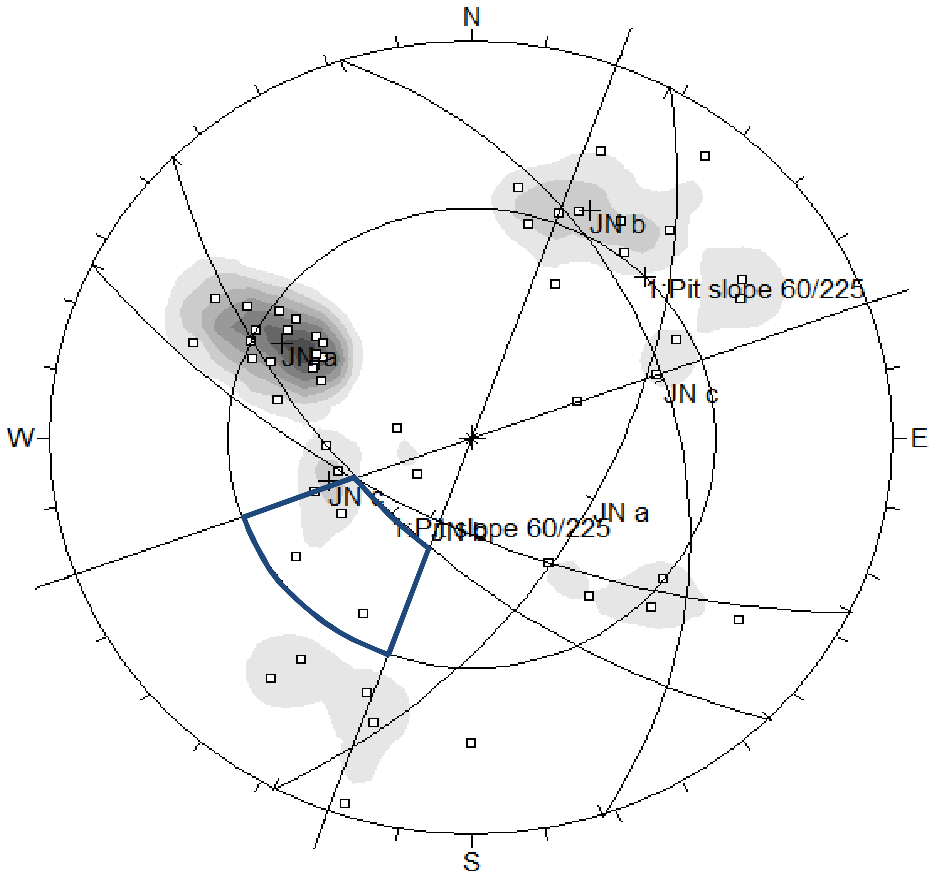
Control on Stability: Low potential for toppling failure for cut slopes with 45° batter angle and South-East orientation

GEOSCIENCE A proud partner of ENGEO	**Date**	20/02/15	**Client**	**Holcim (NZ) Limited**
	Drawn by	GL	**Project**	**Kiwi Point Quarry Stability Analyses**
	Approved by	KJ	**Description**	**Failure Analysis**
	Scale	N/A	**Project Number**	10315

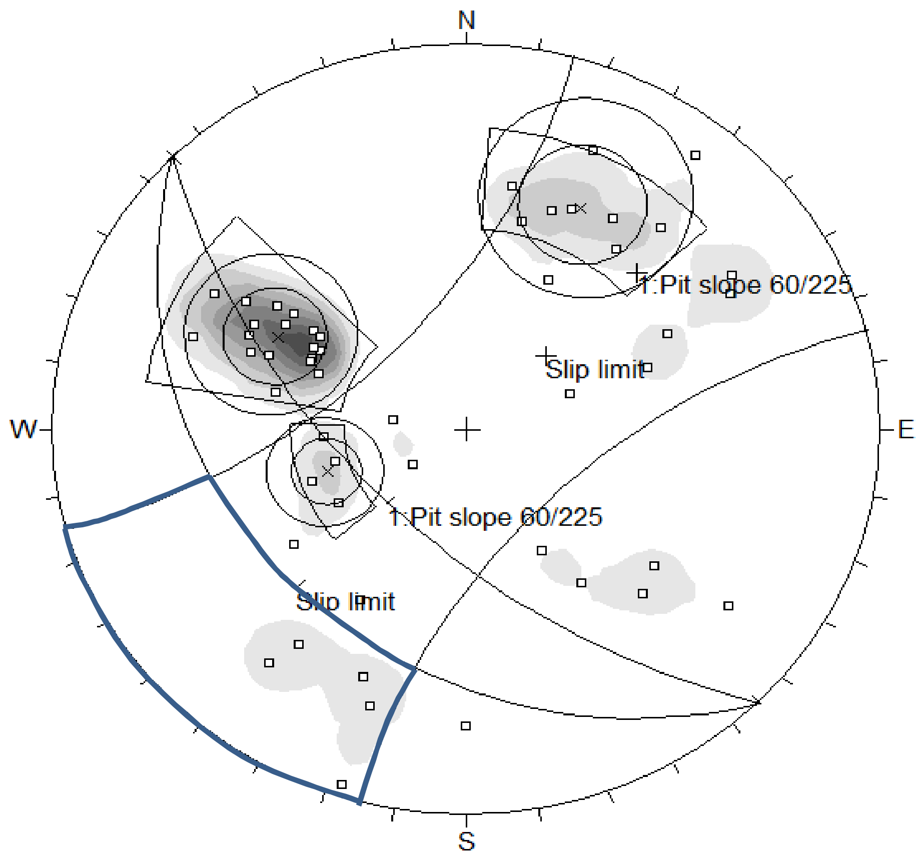
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 60° SOUTH-WEST FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: Moderate potential for planar failure for cut slopes with 60° batter angle and South-West orientation



Control on Stability: Low potential for wedge failure for cut slopes with 60° batter angle and South-West orientation

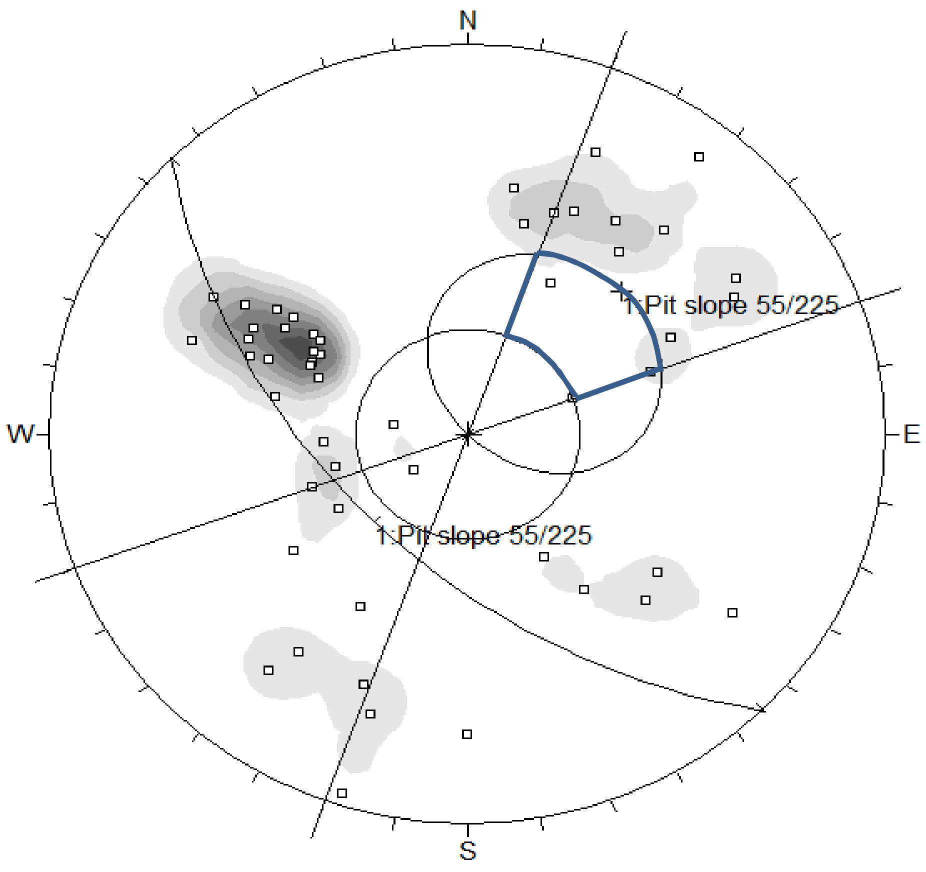


Control on Stability: Moderate potential for toppling failure for cut slopes with 60° batter angle and South-West orientation

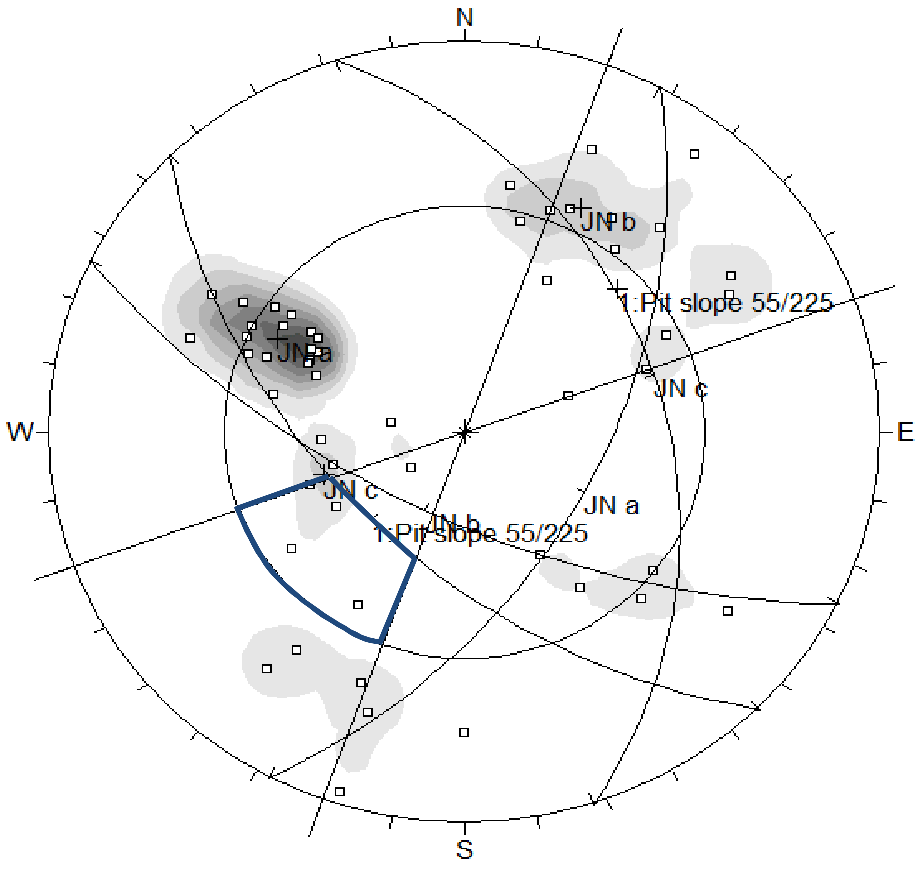
GEOSCIENCE A proud partner of ENGEO

Date	20/02/15	Client	Holcim (NZ) Limited
Drawn by	GL	Project	Kiwi Point Quarry Stability Analyses
Approved by	KJ	Description	Failure Analysis
Scale	N/A	Project Number	10315

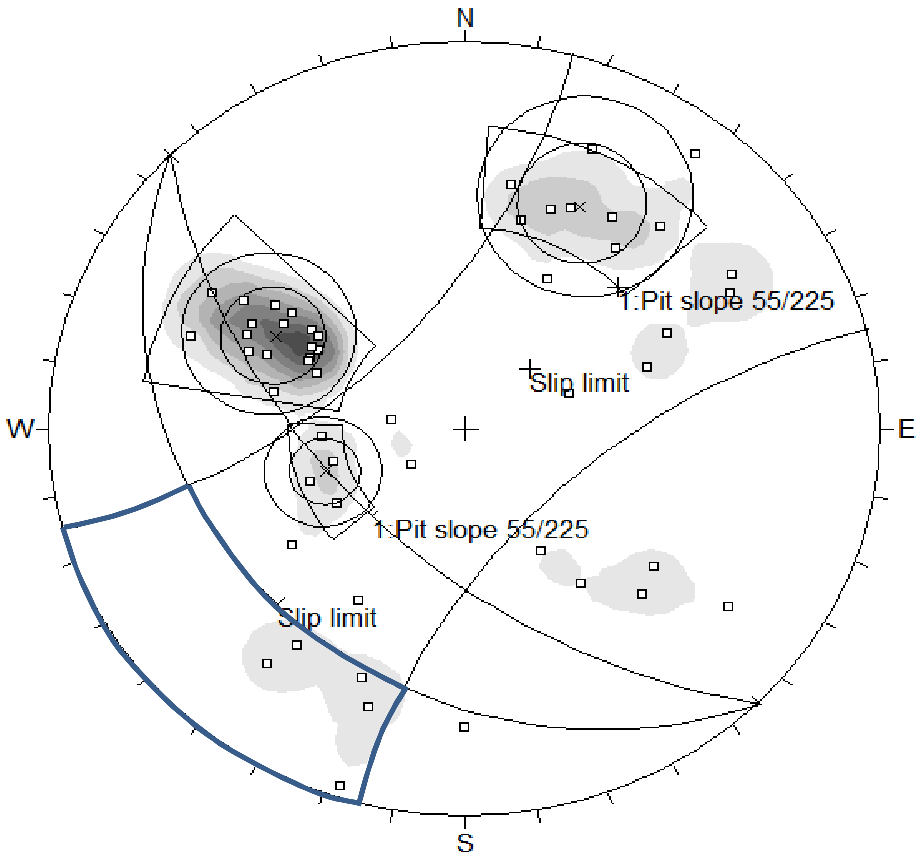
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 55° SOUTH-WEST FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: Moderate potential for planar failure for cut slopes with 55° batter angle and South-West orientation



Control on Stability: Low potential for wedge failure for cut slopes with 55° batter angle and South-West orientation



Control on Stability: Moderate potential for toppling failure for cut slopes with 55° batter angle and South-West orientation

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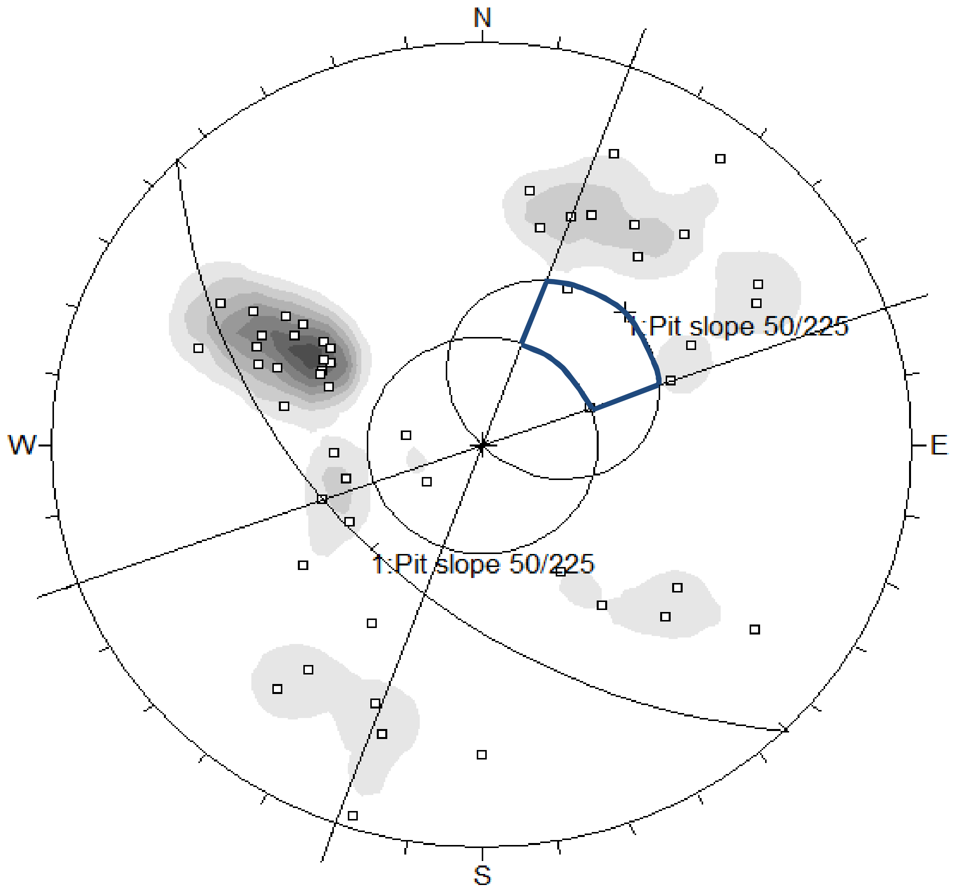
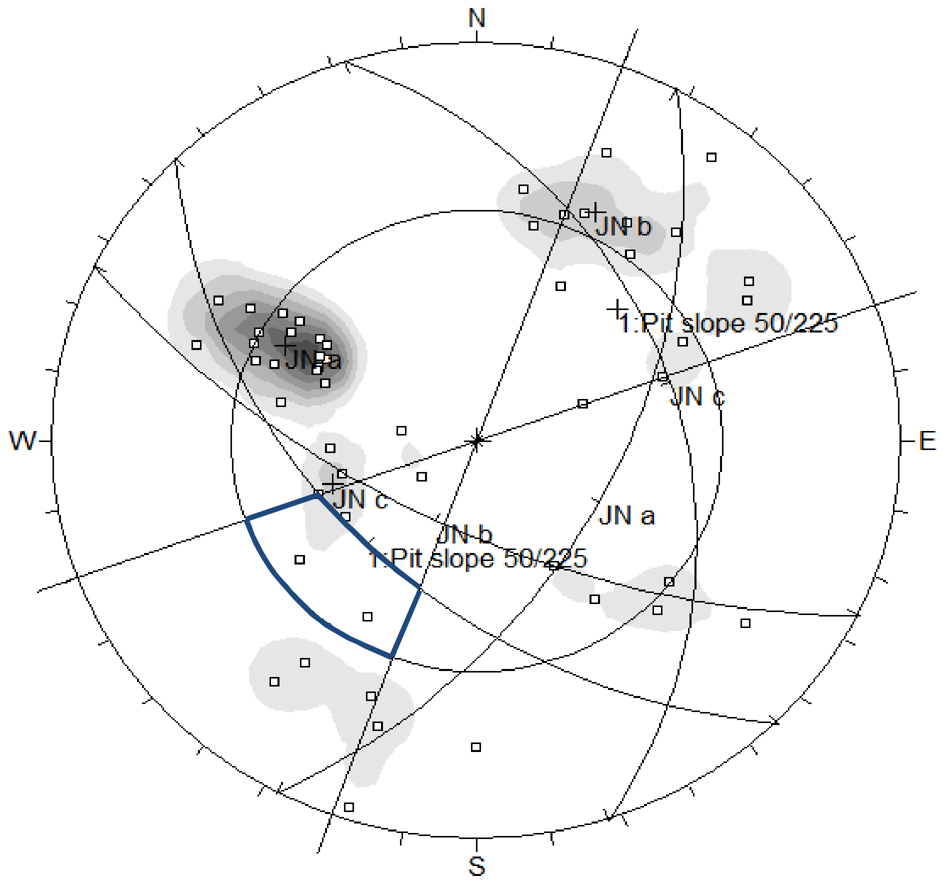
Date	20/02/15	**Client**	**Holcim (NZ) Limited**
Drawn by	GL	**Project**	**Kiwi Point Quarry Stability Analyses**
Approved by	KJ	**Description**	**Failure Analysis**
Scale	N/A	**Project Number**	10315

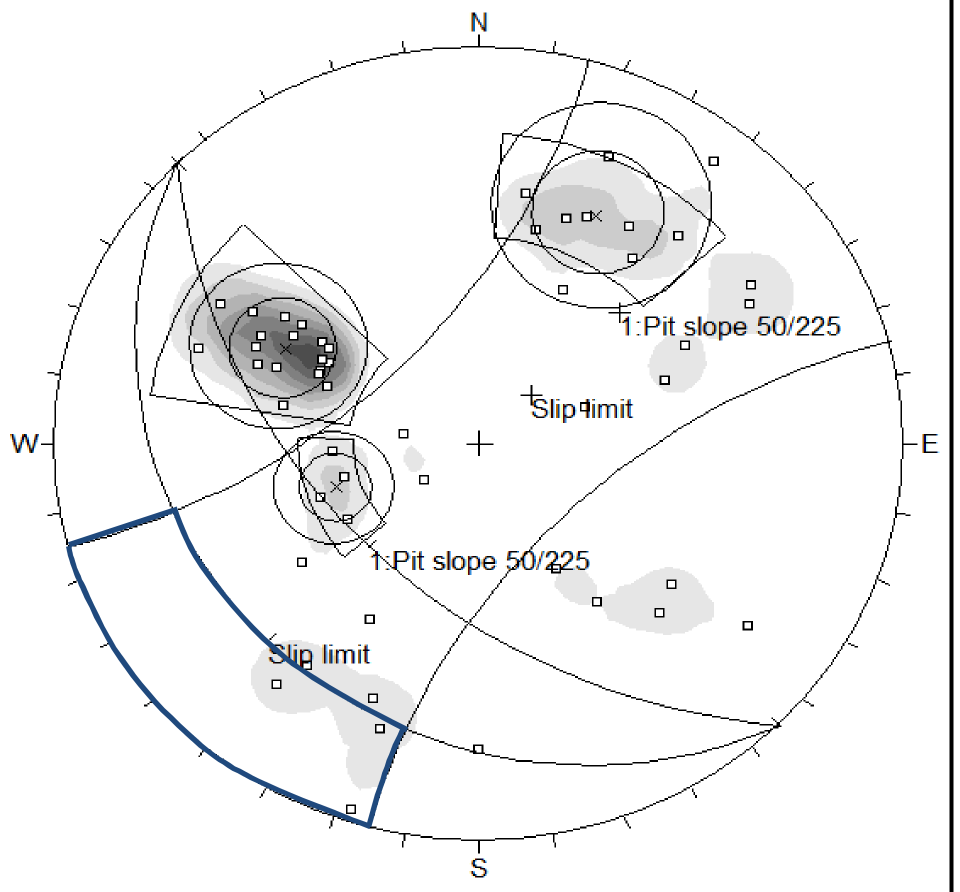
PLANAR, WEDGE AND TOPPLING FAILURE ANALYSIS FOR 50° SOUTH-WEST FACING BATTER BASED ON OBSERVATIONS FROM THE WEST WALL



Control on Stability: Low potential for planar failure for cut slopes with 50° batter angle and South-West orientation



Control on Stability: Low potential for wedge for cut slopes with 50° batter angle and South-West orientation



Control on Stability: Low potential for toppling failure for cut slopes with 50° batter angle and South-West orientation

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Date	20/02/15	**Client**	**Holcim (NZ) Limited**
Drawn by	GL	**Project**	**Kiwi Point Quarry Stability Analyses**
Approved by	KJ	**Description**	**Failure Analysis**
Scale	N/A	**Project Number**	10315