STEVENSON AGGREGATES - DRURY QUARRY EXPANSION

BLAST VIBRATION AND NOISE STUDY

13/12/2023

ORICA

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PROJECT INTRODUCTION

Stevenson Aggregates Limited (SAL) Drury Quarry is located in Drury, within the Auckland Region, and has been in operation for over 80 years. Drury Quarry is a greywacke hard rock quarry supplying concrete, asphalt and roading aggregate to the Auckland market. The Drury Quarry pit is located within the wider landholdings owned by SAL which encompasses an area of approximately 562ha. This landholding includes quarry activities, a clean fill, farmland and large swathes of native vegetation.

Based on current demand estimates, the existing pit will provide approximately 20 years of aggregate supply to Auckland. To continue to provide a local supply of aggregate resource SAL proposes to develop a new pit within the existing site, called the “Sutton Block”. The Sutton Block pit has been designed to provide approximately 185 million tonnes of additional aggregate to supply the market.

The Sutton Block is located to the northeast of the existing pit. The development of the Sutton Block will involve the staged development of an area of approximately 87.7 ha to a maximum pit depth of approximately RL -60 m. The overall site layout, including staging plans are provided at Appendix C attached to the Assessment of Environmental Effects (AEE) report. The Sutton Block is designed to be a separate quarry pit although it will be serviced by the existing Drury Quarry ancillary site infrastructure and facilities. These include the “Front of House” (FOH) activities such as the weigh bridge, processing plant(s), storage bins and stockpile area, the lamella, staff facilities etc.

It is anticipated that as the existing Drury Quarry pit nears the end of its life and reduces aggregate extraction, the Sutton Block pit will increase its aggregate extraction. This will ensure a continuous aggregate supply to the market.

To enable the development of the Sutton Block, and support the extraction of aggregate, the project will also include the construction of road infrastructure to establish haul road access, overburden removal, stockpiles including bunding; stormwater ponds and supporting infrastructure, and construction of a conveyor belt connecting the Sutton Block pit to the existing Drury Quarry FOH area. The works will also require stream diversions, stream reclamation, wetland reclamation, vegetation removal and mitigation offset. The Sutton Block will generally be developed in the following four stages:

Stage 1 – Infrastructure establishment (three-year plan)

The initial stage of work (Years 1 -3) involves the construction of the roading infrastructure required to access the site, draining of the existing farm dam to establish a sediment retention pond, associated stream diversion, initial offset planting, commencement of overburden removal, stockpiles (including bunding), and establishment of the conveyor system. Figure 1 below shows the extent of Stage 1.

Stage 2 -Operating Quarry (15-year plan)

The second stage of work is the 15-year plan which involves the commencement of quarrying within the interim pit boundary (refer to Figure 2 below). The direction of the expansion will depend on market demand for blue or brown rock. However, the indicative staging plan shows the expansion of the pit to the east. Regardless, expansion of the pit will be incremental, deepening and widening as resource is extracted. Internal pit roads will be constructed as the pit expands. Offset planting and weed and pest control will continue.

Stage 3 – Operating Quarry (15-year plan)

The third stage of works is further expansion of the interim pit boundary (refer to Figure 3 below). Like Stage 2, the direction of the expansion will depend on market demand. However, an indicative staging plan shows the expansion of the pit to the east. During this stage of the works, the expansion of the pit will be incremental, widening and deepening as resource is extracted. Internal pit roads will be constructed as the pit expands.

The works involved in Stage 3 will generally include the same activities as Stage 2.

Stage 4 – Life of Quarry Plan (50-year plan)

The fourth stage reflects the full extent of the quarry pit over an approximate 30-35-year period (refer to Figure 3). As with Stage 2, expansion of the pit will be incremental, deepening and widening as resource is extracted. Internal pit roads will be constructed as the pit expands.

SUMMARY

This report summarises the results and methodology that have been used to develop a site law for future blasting at the Drury quarry. By completing this blasting noise and vibration study, we can now confidently and accurately determine blast vibration and associated noise specifically for the Drury quarry. Distance and explosive charge weights play a key factor in determining the vibration output from blasting. This study has captured valuable seed waveforms which can now be used to accurately model blast vibrations in SHOTPlus™ 6.

Previous technical services engineers have used theoretical site constants to help generate vibration estimations at key points of interest. Vibration results have been well below consented levels at the Drury quarry and have not warranted the need for such a study to be completed. However, with the high demand for aggregate in the Auckland region, the Drury quarry is expanding and applying for resource consent to develop the nearby Sutton Block. This report details the test work that has been carried out and the resulting analysis that can be used in future blast design and blast planning.

This report is based on some key assumptions:

1. Geology in the Sutton block contain the same characteristics as the northern end of the current pit.
2. Ground vibration attenuation remains constant between the monitoring location and the Sutton block, and current pit.
3. Bulk explosive type and design standards remain the same for future blasting in the Sutton block.
4. Electronic blasting is continued in the Sutton block along with engineering and technology standards.

Based on vibration recordings during this study, the effects from the Sutton block on neighbouring property should be achievable under the current pit's DIN4150 standard, (guidelines for evaluating the effects of short-term vibration on structures). This standard has been adopted into the Auckland Unitary Plan (AUP) and is considered appropriate to assess potential structural effects from continuous vibration. However, this standard is less suitable to assess potential amenity effects associated with blast-related activities. Section J of the Australian Standard AS2187.2-2006 is comprehensive and contains limits for ground vibration and air overpressure levels for maintaining human comfort together with limits for preventing cosmetic damage to structures. We consider Australian StandardAS2187.2-2006 is a more acceptable standard to be adopted to assess blast vibration and noise from the Sutton Block. For completeness, this report assesses vibration and noise from blasting against both standards.

It is estimated vibration levels from the Sutton block would be similar to 151 MacWhinney Drive (one of the closest residential neighbours from the northern extension of the current pit). With controlled blasting techniques, these are expected to be from 0.00mm/s to 3.5mm/s between 500m and 1000m distance. As blast distances reduce below 500m significant intervention in the blast design phase will be required to manipulate and control vibration.

Blasting in the northern area of the current pit has been as close as 163m to Ballard's cone (also known as Kārearea pā). The area has historically never been monitored for vibration. Blast damage is unlikely with no

visible ground cracking or damaged reported. This can be justified by the nature of development blasting with short holes and limited explosive volumes. Vibration emitted from these types of blasts is minimal. This is also expected for the Sutton block pit. Blasting is likely to be at similar distances, explosive volumes and blast design. The blast programme will be intermittent at close range with blasting only occurring if the ground becomes too strong for excavators to free dig. Recent recordings of blast vibration at the boundary of Ballard's cone have been between 0.00mm/s and 15.44mm/s, with blast noise between 0dBL to 118.1dBL.

CONCLUSIONS

THEORETICAL CONSTANTS ESTIMATE VIBRATION LEVELS FOR GENERAL PURPOSE

- The theoretical vibration constants are general and should be used as a guideline if vibration modelling is unable to be achieved or there are no major constraints.
- Previous vibration predictions have been slightly varied from actual vibration results. In general, these have been acceptable for the current pit design.

SITE LAW ENABLES MORE ACCURATE VIBRATION ESTIMATES

Site constants depend on geology and rock structure, water and monitor locations. The scaled distance calculation of existing blast results as well as seed waveforms enables site specific K and n constants. A 95% confidence interval can be used to predict the vibration for distance and charge weight used.

This vibration study found that by using P wave velocity the vibration prediction for arrival times at certain distances reduces. The timing envelop tool in SHOTPlus^{TM}6 can be used to offset individual blast holes to counteract the effects of vibration.

The Monte Carlo vibration prediction can be used to calculate vibration at specific monitoring locations using seed waveforms. Simulations are run using the waveform to predict vibration accurately based on the data input.

SUTTON BLOCK FEASIBILITY

Based on current blast vibration recordings with similar rock types and distances to the current pit, the feasibility of compliant blasting in Sutton block is very realistic. The use of advanced technology, software programs, and managed loading practices mean that blasting can be manipulated to mitigate vibration. This report demonstrates that compliant blasting in the proposed Sutton pit can be achieved at the current neighbouring residential areas, under the current Drury pit limits (DIN4150 / AUP Standards). However, the Australian Standard AS2187.2-2006 is more applicable as a blasting criteria and is recommend to be the standard adopted in consent conditions.

RECOMMENDATIONS

BLASTING CONSENT CONDITIONS SHOULD USE AUSTRALIAN STANDARD AS2187.2-2006

The current Drury pit blast vibration criteria is using the DIN4150 standard as required by the AUP and existing consent conditions. The German Standard (DIN4150) specifies a method for measuring and evaluating the effects of vibration on structures. This is appropriate for continuous vibration emitted on a construction site. However, blast induced vibration is complex with a typical duration of quarry blasting between 0.5 seconds and 2.5 seconds.

Section J of the Australian Standard AS2187.2-2006 is comprehensive and contains limits for ground vibration and air overpressure levels for maintaining human comfort together with limits for preventing cosmetic damage to structures. Limits for both standards are similar with a peak particle velocity (PPV) of 5mm/s being the prominent figure.

PERMANENT VIBRATION MONITORING STATIONS

Permanent blast monitoring stations should be established at the closest neighbouring properties and historical sites. Calibrated vibration monitors should comply with the relevant blasting standards (AS2187.2:2006). A vibration monitoring and data management system should be used to measure blast induced vibration. Data from the instrumentation should be uploaded at each of the monitoring locations for analysis and modelling of future blasts.

Ballards cone (Kārearea Pā) is a scheduled Significant Ecological Area and a Historic Heritage and Special Character extent of Place[1] under the AUP. This site has not been monitored for vibration or noise from blasting in the past. Recently monitoring at the boundary of the site has been conducted with some results published in the Ballard’s Cone section of this report. Monitoring on the boundary will give an indication of what ground vibration and noise has been received for the past 20 years of blasting. However, effects within the centre of the site will differ based on natural barriers and a greater distance to the blast.

CARRY OUT INITIAL SEED HOLES TO UPDATE THE MODEL FOR SUTTON BLOCK

Seed holes should be completed once the Sutton block has reached the solid rock mass and before production blasting begins. The model will need to be updated and calibrated to ensure that there are no unforeseen conditions such as geological strata. Although this is unlikely based on core drilling samples and geological studies in the area. Best practice is to gain an absolute understanding of the ground attenuation through analysing vibration in the Sutton pit.

[1] Extent of Place 693 Ballards Cone pa site R12_278

VIBRATION PREDICTION AND CALLIBRATION

Vibration estimates should be run for each blast. The Monte Carlo vibration prediction tool in SHOTPlus™6 is an accurate form of vibration prediction. Simulations can be run to generate estimates as well as a vibration prediction map to see where vibration generation is. These should be used to predict the vibration at the given monitoring sites based on the blast design being used.

As the pit progresses vibration attenuation may change at different RL levels and locations within the pit. Data collection over time can help update and calibrate the model to ensure accuracy. More seed holes can be fired to keep waveforms updated in different rock types or deep down in the pit. A set of seed holes may be required during wet winter months as this may have an impact on the vibration attenuation.

SCOPE OF WORK

As ground vibration waves travel through the earth, they cause each particle of earth to vibrate in three dimensions. Ground vibration travels elastically as rock particles are temporarily displaced and return to their original position. A blast contains a number of charges detonating milliseconds apart. When these charges detonate at different delay times, vibration from individual blast holes interact. These interactions make vibration from blasting very complex. There are many ways to mitigate blasting through loading practices and understanding the way vibration travel through the earth using seismographs and computer software.

Drury quarry is located 3km south of the heart of Drury suburb in Auckland and has been in operation since 1939. The quarry historically was situated on farmland but with a high level of urban sprawl has now become neighbours to residential properties. Orica mining services has been the supplier of blasting services at Drury quarry for over 20 years. Consent vibration and noise limits have always been adhered to. The main reason is due to large distances from the blast location, as well as managed blast loading practices.

Uni tronic ™ 600 electronic detonators enable programming detonators at specific timing intervals and reduce air over pressure with no surface delays. Blast sizes range from 5,000m^3 - 25,000m^3 with a maximum instantaneous charge (MIC) between 60-200kg depending on the bench height. Key controls for mitigating vibration at the blasting site are timing manipulation. By using electronic detonators, each charge is timed for single detonation in regard to arrival times at key points of interest. Blasting MIC, size and shape are other design features that are used to mitigate blasting vibration. There has not been any requirement to further control vibration from blasting with the current levels being below human comfort levels.

Currently the blast vibration and air overpressure monitoring are regularly carried out at 3-4 houses surrounding the quarry. The quarry typically blasts 1 - 2 times per week between 400m and 1000m from the closest residence. Any blast related complaints are handled by Stevenson Aggregates communication team with support from Orica. Six complaints were received year to date out of 75 blasts. These come from the closest MacWhinney Drive households and Ramarama Road residence.

This vibration study was conducted to develop a field vibration site law and gain valuable seed waveforms. The site law and seed waveforms are currently applied to blast designs to minimise the effect of blasting at neighbouring properties while ensuring productivity for the quarry operation. This report details the test work that has been carried out and the resulting analysis that can be used in future blast design and blast planning. This report will also define the feasibility of blasting at the neighbouring Sutton Block to help inform the resource consent application.

In November 2021 Tonkin and Taylor was engaged by SAL as an independent consultant to assess vibration on the neighbouring property of 151 MacWhinney Drive. Tonkin and Taylor are a reputable environmental and engineering consultancy within New Zealand. Information has been included and referenced in this report.

METHODS

Creating a site law - methodology:

- Define points of concern and area of the operation to be modelled;
- Analyse available geological information;
- Decide where to monitor;
- Design seed hole locations, charge weights and firing sequence;
- Field measurements; Survey seed hole and monitor locations. Loading QA/QC. Fire seed holes with several monitors for a wide range of distances and charge weights. Collect data set;
- Analyse data, investigate anomalies;
- Calculate vibration wave velocities (P Wave velocity) and calculate K and n constants;
- Build a site specific model to predict vibration;
- Calibrate that model.

On February 10, 2023, two seed holes were initiated in the northern area of the pit. Seven (7) vibration monitors were placed at various distances from the blast. Along within two neighbouring properties at 95 MacWhinney Drive and 151 MacWhinney Drive. Figure 1 below displays the arrangement of seed holes and monitoring locations. Kelunji Gecko monitors were used in near field locations at a distance from 85m to 347m. Each monitor has a GNSS synchronised internal clock which also locates its exact position. This enables vibration P-wave velocity to be calculated by analysing the time the waveform reaches each monitor. The P-wave velocity is used in the final vibration site law and is critical to accurately predict blasting vibration. Vibration waves from every charged deck in a blasthole will arrive at the monitor at different times depending on how fast the wave travels and direction to the monitor. Texcel monitors that are predominately used for blast vibration recordings were used further afield and at the regular monitoring block at 151 MacWhinney Drive for consistency. These vibration monitors were picked up using an external GPS source. Note; the vibration monitor was set up at 95 MacWhinney Drive to see if vibration would be recorded at the greater distance, representing the lower MacWhinney residence.

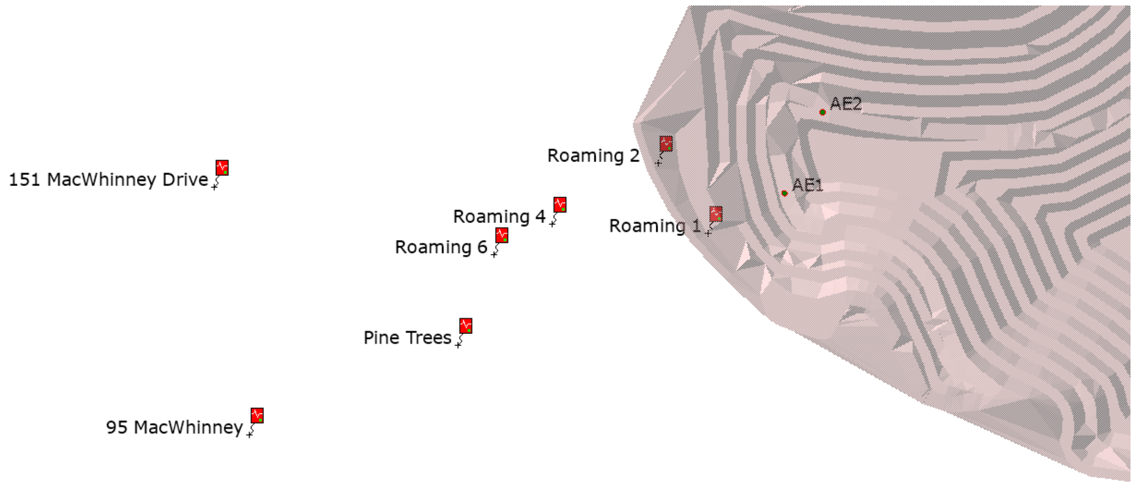


Figure 1 Vibration monitoring locations with seed holes AE1, AE2

SCALED DISTANCE WHY IS THIS IMPORTANT?

Vibration prediction: PPV = $K(\frac{D}{\sqrt{W}})^{-n}$ or PPV = $K(SD)^{-n}$

Where:

PPV = peak particle vibration

SD = scaled distance

K = wave amplitude constant or a coefficient of safety value

n = wave attenuation constant or rate of decay

Scaled distance allows a determination of vibration intensity with consideration of the combined effect of charge weight and distance. For example, the same vibration intensity for a given scaled distance is obtained whether it comes from a large blast at a large distance or a small blast at a small distance.

The seed hole location and charge weight have been designed to ensure a wide range of scaled distances are sampled. AE1 seed hole was drilled vertically to a depth of 15m with a charge weight of 104.6kg. AE2 was drilled on 10 degrees at 16m with a charge weight of 97.4kg. These were designed to simulate actual blast loading, typical for Drury quarry. Table 1 below shows a summary of seed hole and monitor locations and seed hole charge weight. Figure 2 shows the proposed scaled distance spread of results.

Table 1 Blasthole and monitor locations

ID	X	Y	Z	Kg
AE1	419779.69	772804.57	104.57	110.20
AE2	419865.61	772792.70	110.39	97.40
R1	419685.01	773047.73	127.15	-
R2	419774.02	773114.11	135.85	-
R4	419676.56	773236.41	124.70	-

ID	X	Y	Z	Kg
R6	419658.84	773258.64	134.77	-
151 MacWhinney Dr	419620.69	773334.71	117.86	-
95 MacWhinney Dr	419401.64	773230.41	62.00	-
Pine trees	419545.12	773063.16	75.00	-

The seed holes were fired on the same day as a production blast on site. A delay of two seconds (minimum) was left between each seed hole, to ensure there would be no interference of wave forms arriving at the monitoring positions. The holes were fired in a sequence on two separate benches to reduce the risk of 'screening', meaning that vibration waves will not be affected travelling through broken ground from a previously fired seed hole.

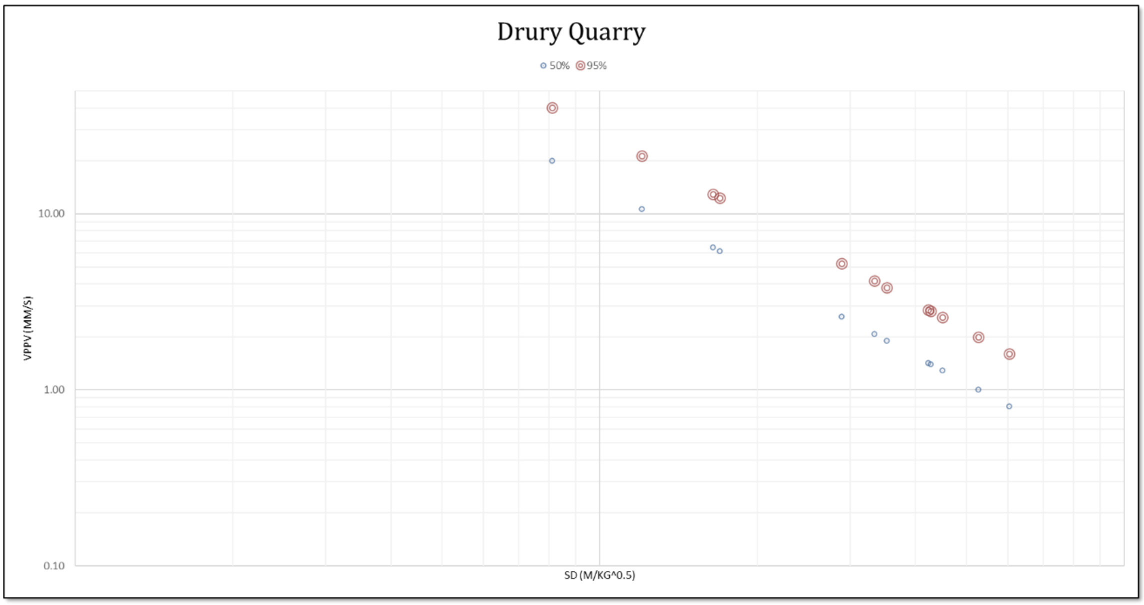


***Figure 2** Proposed scale distance, seed hole design ensures a spread of scale distance results*

GEOLOGY

"The rock produced by the quarry is greywacke (Waipapa Terrane) and the dominant rock types are sandstone and mudstone (argillite). Greywacke is the basement rock over much of the North Island. The unweathered rock is overlaid by weathered ("brown rock") highly to moderately weathered rock with a capping layer of volcanic ash. A geological map of the area is included in Figure 3 *and a borehole describing the geological sequence in the northern face of the quarry is also included in the appendix.*

A thin ash layer is expected to extend onto MacWhinney Drive but historical investigations undertaken by Tonkin + Taylor on several nearby properties indicates a layer of carbonaceous mudstone is present at a relatively shallow depth. We infer this is a zone of Tertiary Age rock which does not extend into the quarry *zone. The Tertiary mudstone is likely to be susceptible to swelling and shrinkage effects where it is exposed to wetting and drying cycles" (Blast Vibration Effects Report – MacWhinney Drive Drury, Peter Millar, Tonkin & Taylor 2021)*

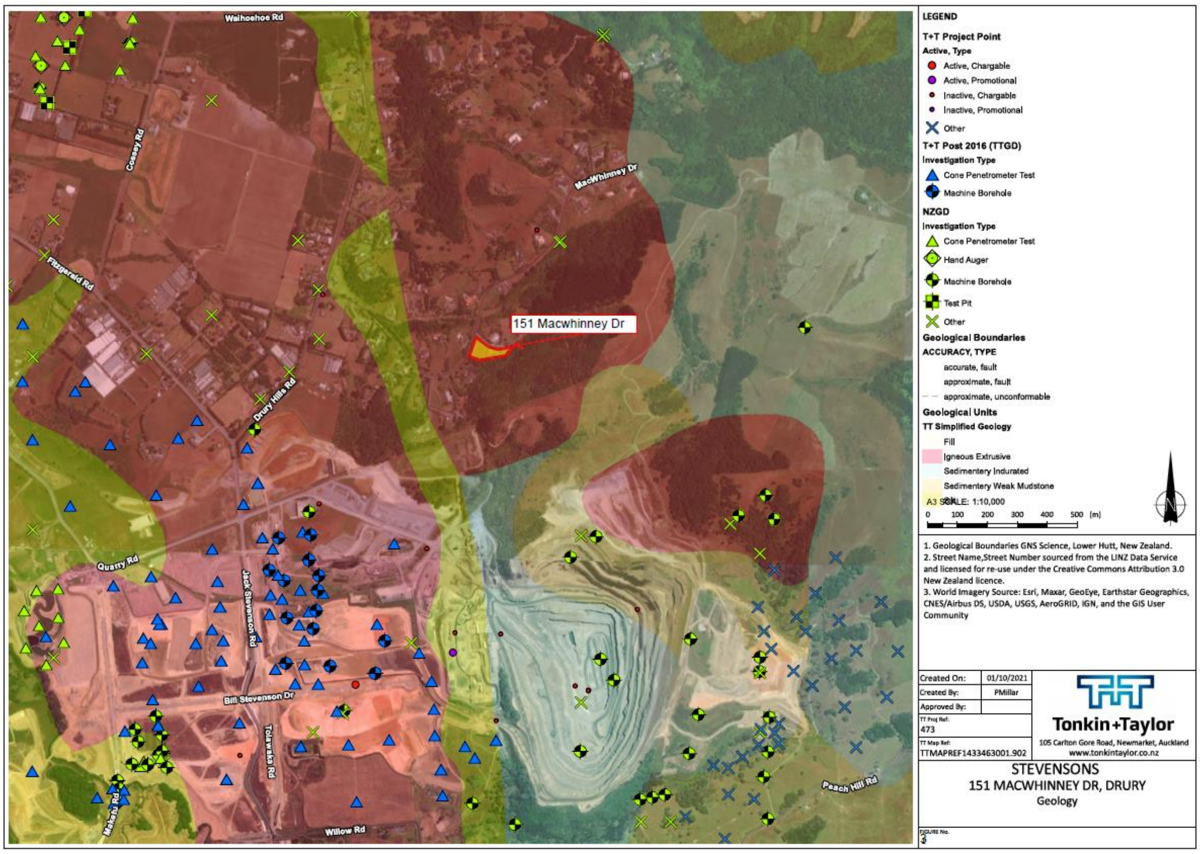


Figure 3 Geological and investigation features in Drury (Tonkin and Taylor, 2021)

ANALYSIS

The aim of the site law is to create an accurate model to predict vibration from blasting. The key site law values are the K and n constants which are used in the vibration prediction formula. A 50% K and 95% K confidence constants will be calculated for the site law. A different site law may be applied for different parts of a quarry and/or for different monitor locations. Site constants depend on geology and rock structure, water and monitor location (and monitor mounting).

Vibration prediction: $PPV = K\left(\frac{D}{\sqrt{W}}\right)^{-n}$ or $PPV = K(SD)^{-n}$

Defining the K and n values:

K = Site amplitude constant or a coefficient of safety value. The Australian standard AS2187 K is 1140, for large distance free face mining K may be around 500, for close proximity construction blasting K is a much higher value like 18000 for example.

n = Site attenuation constant, the rate of decay of PPV with distance hence n being a negative number.

Scaled distance (SD) compares combinations of charge weight and distance SD = $\frac{D}{\sqrt{W}}$

D = distance

W = explosives charge weight

Method to analysing data and finding K and n constants:

- Monitor at specific locations;
- Fire seed holes with several monitors for a wide range (of scaled distance samples);
- Collect the PPV results, calculate distances between seed holes and monitor, and calculate scaled distance;
- Plot/regression analysis using PPV and scaled distance (statistical analysis for predicting vibration). The regression can be done with specific confidence interval, this report will refer to the regression for a 50% confidence and 95% confidence interval;
- Calculate K and n constants.

SEED HOLE DESIGN AND DATA COLLECTION

Seed hole design, monitor locations, quarry development data and all other blast design and survey data has been plotted and/or completed using SHOTPlus™ 6. All data is in the geographical coordinate set: Geocentric datum of Mount Eden 2000 (NZGD2000). All data in the same coordinates enables accurate distance and travel time calculations.

Vibration data is measured and recorded using blast monitors, the close proximity and time trigger locations used Kelungi™ monitors that have synchronised clocks that are GNSS time set, the data is uploaded into vibration analysis software Cycad™, Figure 4 shows the seed holes and blast fired two seconds apart. At the monitoring location of 151 MacWhinney Drive Texcel monitors were used as these are the regular vibration monitors used during normal blasting operations.

Cycad™ will show the measured vibration in specific units and allows the user to measure arrival times for P Wave velocity calculations.

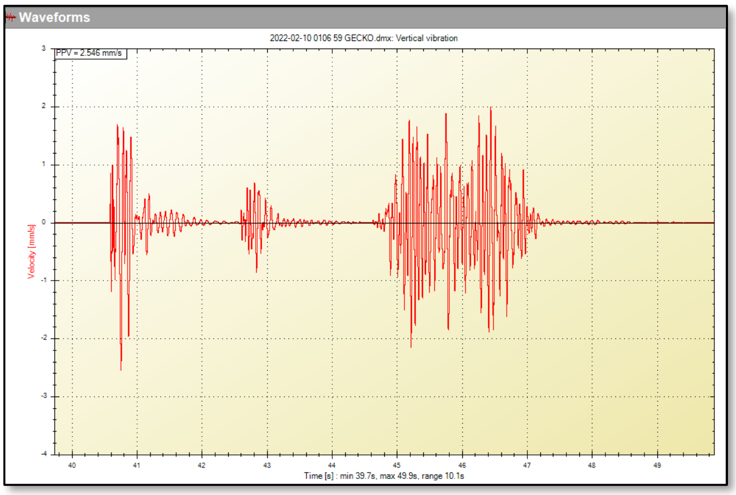


Figure 4 Vibration trace for seed holes and blast 22-SA006

ANALYSING THE DATA COLLECTION

Regression analysis is a set of statistical processes for estimating the relationships among data sets. This regression analysis helps us to understand how the predicted vibration changes when the independent variable, Maximum Instantaneous Charge (MIC), is varied while the other independent variable, Distance remains constant. The regression line is a 'line of best fit' for the data. Using measured PPV and calculated scale distance a site law can be created.

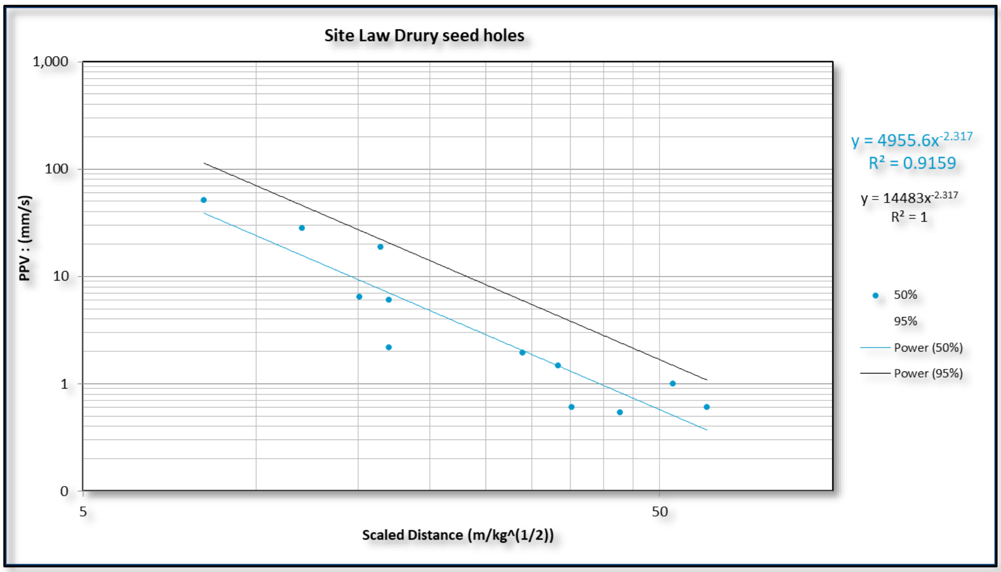


Figure 5 Drury seed hole vibration results with 50% and 95% confidence lines

The K and n values are calculated from a straight line drawn through the middle of the data set. This is the 50% confidence line meaning there is a 50% chance of exceeding a given vibration limit, 50% of the data is above this line. A site law can use a 95% confidence value therefore the line is moved up the graph so that 5% of the data is above the line. This is exhibited in Figure 5 above.

P WAVE VELOCITY

Vibration waves from blastholes travel with finite velocities, vibration that the monitor sees depends on more than just blast timing and charge weights, it also depends on the travel time in the ground. The P Wave velocity for this vibration study has been calculated from thew two holes initiated. Calculations from the two data sets are very close confirming accurate field measurement.

VIBRATION MODEL

A vibration model can be built using the calculated K and n values, P wave velocity and vibration waveforms from seed holes. This has been completed using SHOTPlus™6 as displayed in Figure 6 and Figure 7 below. The blast monitoring points, and the seed holes have been surveyed and accurately located in SHOTPlus™6. Current and future production blasts are also surveyed correctly to ensure accuracy for the model. When a blast design is complete with loading and initiation design the vibration can be predicted by using the modelling tools in SHOTPlus™6. Below is the 151 MacWhinney Drive monitoring point updated with data from the vibration study. A number of tools are available to calculate vibration prediction for example vibration site maps with PPV contours.

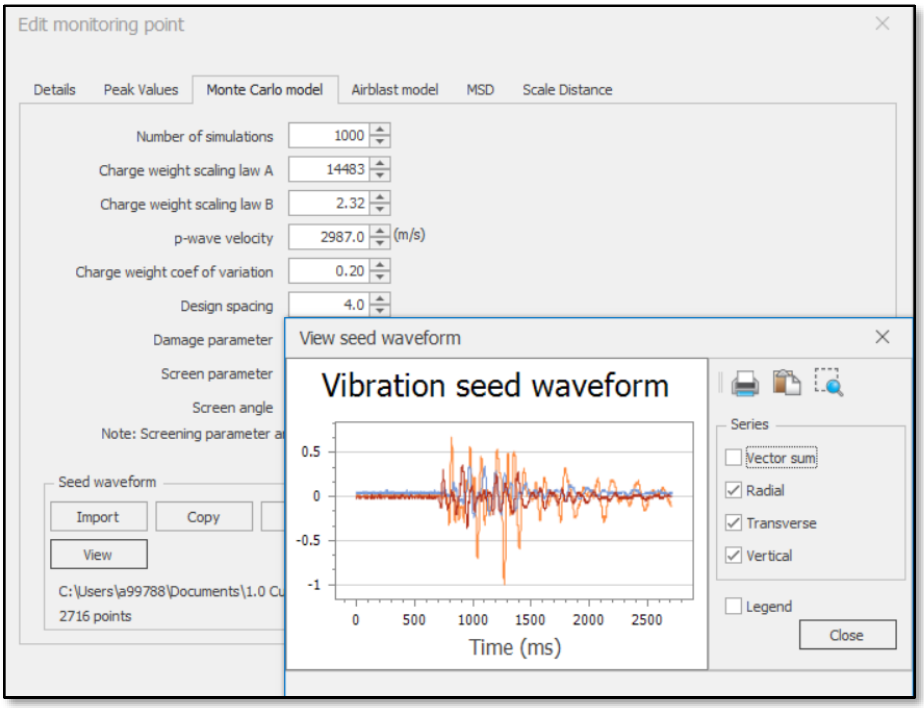


Figure 6 Monitor point edited with K and n with seed waveform

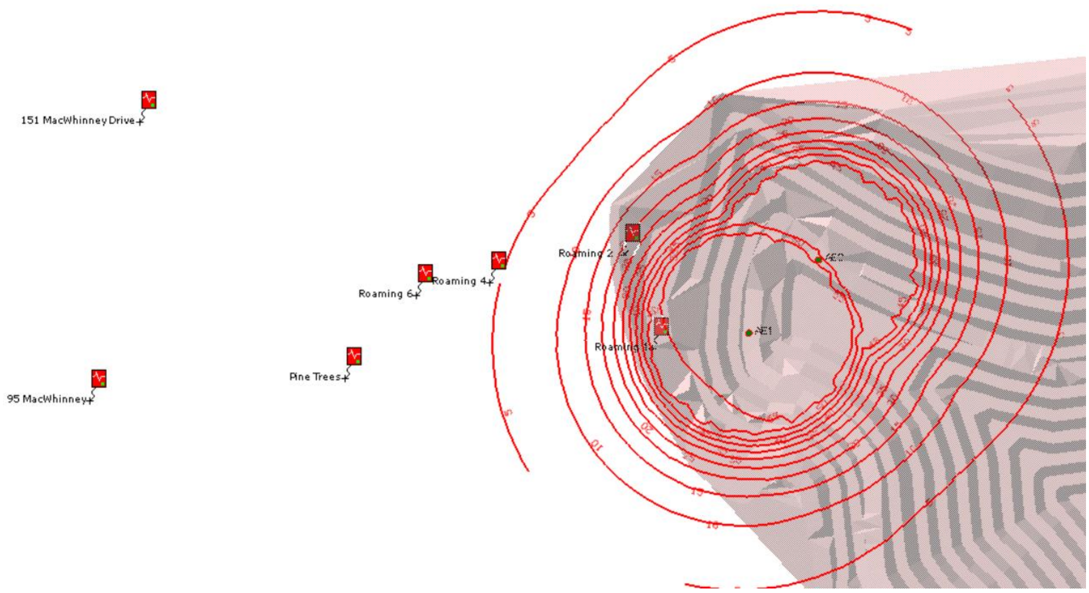


Figure 7 Vibration map. Contours are 5mm/s intervals

RESULTS

The aim of the vibration study was to develop a near field vibration site law that will be applied to future blast designs with focus on minimising the effect of blasting to local residences, while maintaining productivity of the quarry operation. The relevant K and n factors have been calculated for blasting at the northern end of the existing quarry pit. In particular, 151 MacWhinney Drive as one of the closest residential neighbours.

Table 2 Summary of Data from Seed hole 1

LOCATION	HOLE	MIC (KG)	DISTANCE (M)	PPV (MM/S)
Monitor 1	SH1	110	85	51.4
Monitor 2	SH1	110	126	28.27
Monitor 4	SH1	110	228	6.44
Monitor 6	SH1	110	288	2.17
Pine trees	SH1	110	350	1.46
151 MacWhinney	SH1	110	553	1.0
95 MacWhinney	SH1	110	571	-

Table 3 Summary of Data from Seed hole 2

LOCATION	HOLE	MIC (KG)	DISTANCE (M)	PPV (MM/S)
Monitor 1	SH2	97	162	18.73
Monitor 2	SH2	97	167	5.98
Monitor 4	SH2	97	285	1.94
Monitor 6	SH2	97	347	0.605
Pine trees	SH2	97	421	0.545
151 MacWhinney	SH2	97	595	0.596
95 MacWhinney	SH2	97	640	-

Table 4 Summary of K and n values for Drury seed holes

SITE COEFFICENT	50% CONFIDENCE	R^2	95% CONFIDENCE
K	4956	0.92	14483
n	-2.32	-	-2.32

Site constants depend on geology and rock structure, water and monitor location. It can be seen in Table 2 and Table 4 above that the results show a high ground vibration attenuation as well as amplitude. An average P wave velocity of 2987m/s has been calculated based on arrival times of the seed waveforms at the monitoring location for 151 MacWhinney Drive. The next step is to calibrate the model against a history of blasts and the initial production blasts.

PREDICTION VS ACTUAL

Table 5 below contains results from blasts in the northern area of the Drury quarry pit. Predictions were generated by using the seed holes and vibration prediction tools in SHOTPlus™6 for each individual blast. 151 MacWhinney Drive was used as the key point of interest where a permanent vibration monitoring block has been established. The vibration prediction model can be calibrated over time as vibration changes due to blast location in the pit.

Generally, the correlation between predicted and actual received vibrations closely aligns, with an average variance of approximately 6% observed in the previous blasts at 151 MacWhinney Drive, as indicated in Table 5 below. It's important to acknowledge that various factors, such as ground conditions for blast holes, can lead to disparities between blast design and actual loading. As the vibration predictions consistently fall well below levels considered uncomfortable for humans, there hasn't been a need to implement absolute control of the Maximum Instantaneous Charge (MIC). This significantly impacts the results when making comparisons, as the design parameters are not precisely adhered to. Figure 8 Predicted vibration level vs Actual recorded level.

Table 5 151 MacWhinney Drive MIC and vibration data

Shot Number	MIC (kg)	PPV Estimate (mm/s)	Distance (m)	Actual MIC (kg)	PPV Actual (mm/s)	% Difference	MIC Difference (kg)
22-SA041	211	0.52	1072	230	0.72	-20%	19
22-SA040	114	1.20	607	133	1.08	12%	19
22-SA039	114	0.92	855	155	0.73	19%	41
22-SA036	137	2.00	540	153	1.84	16%	16
22-SA037	114	1.09	887	130	0.66	43%	16
22-SA031	209	1.11	567	245	1.13	-2%	36
22-SA035	120	1.19	820	150	1.05	14%	30
22-SA032	310	0.89	678	376	0.95	-6%	66
22-SA030	143	1.51	623	120	1.23	28%	-23
22-SA028	117	0.98	842	140	1.05	-7%	23
22-SA026	110	0.92	1143	140	0.73	19%	30
22-SA024	147	0.60	1022	150	0.73	-13%	3
22-SA023	134	1.67	543	136	1.59	8%	2
22-SA022	137	1.24	830	138	1.19	5%	1
22-SA019	162	2.90	638	188	2.79	11%	26
22-SA021	120	0.96	871	200	0.88	8%	80
22-SA014	118	1.28	552	124	1.26	2%	6
22-SA011	140	0.71	841	145	0.85	-14%	5
22-SA009	213	0.49	1101	230	0.61	-12%	17

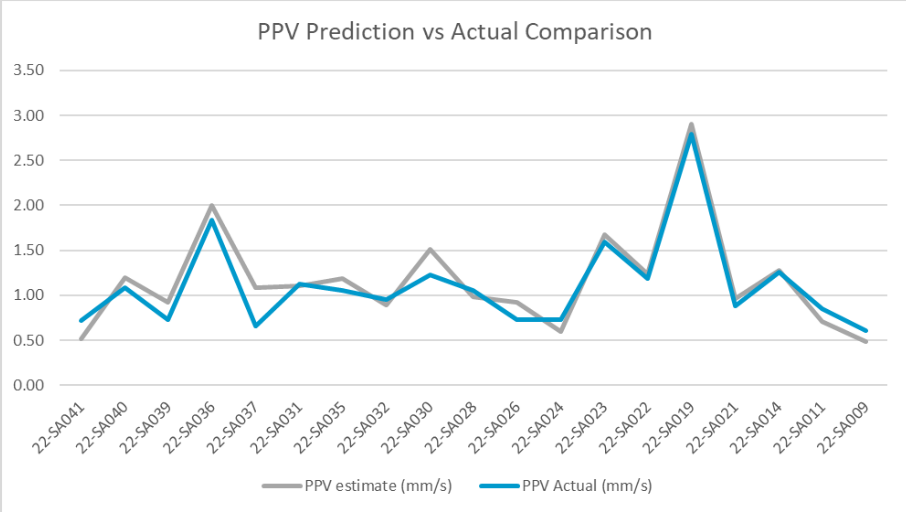


Figure 8 Predicted vibration level vs Actual recorded level.

DIN4150 STANDARD

The Auckland Unitary Plan (AUP) provides rules for noise and vibration limits applied to special purpose quarry zones. These are provided in section H28.6.2.2 of the AUP and are summarized below.

(1) Noise created from the use of explosives must not exceed a peak overall sound pressure of 128dB $_{Lzpeak}$.

(2) The measurement of blast noise (air blast) and ground vibration from blasting must be measured at the notional boundary of a dwelling that existed at 1 January 2001.

(3) Vibration generated by blasting shall be measured within a building in accordance with Appendix J of Part 2 of Australian Standard AS 2187 2006.

(4) All blasting is restricted to:

(d) 9am-5pm, Monday to Saturday;

(e) an average of two occasions per day over a calendar fortnight; and

(f) except where necessary because of safety reasons.

(5) Blasting activities must be controlled to ensure any resulting ground vibration does not exceed the limits set out in German standard DIN 4150-3 1999: Structural vibration – Part 3 Effects of vibration on structures

when measured on the foundation in the horizontal axis on the highest floor of an affected building.

(6) A siren must be used prior to blasting to alert people in the vicinity.

For vibration, the AUP refers to the limits set out in German Standard DIN4150 – 3: 1999 "Structural Vibration – Part 3. Effects of vibration on structures." The criteria are shown in 6 and summarised in **Error! Reference source not found.** below.

These show the recommended vibration limits in terms of Peak Particle Velocity (PPV) as this is directly related to strain, and hence potential for damage to structures. They are lowest in the frequency range of 1-10 Hz which is the normal range of natural frequency of most structures. For residential structures the recommended PPV limit at low frequencies is 5mm/s. The limits increase at higher frequencies where the potential for harmonic effects is reduced. The standard also allows for some amplification between the foundations and upper level of a structure, with a limit of 15mm/s at the upper level.

Table 6 DIN 4150:1999 standard guidelines for evaluating the effects of short-term vibration on structures

LINE	TYPE OF STRUCTURE	VIBRATION AT THE FOUNDATION AT A FREQUENCY OF			VIBRATION AT HORIZONTAL PLANE OF THE HIGHEST FLOOR
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz	All frequencies
1	Buildings used for commercial purposes, industrial buildings, and buildings of similar design	20 mm/s	20 to 40 mm/s	40 to 50 mm/s	40 mm/s
2	Dwellings and buildings of similar design and/or occupancy	5 mm/s	5 to 15 mm/s	15 to 20 mm/s	15 mm/s
3	Structures that, because of their particular sensitivity to vibration, cannot be classified under lines 1 and 2 and are of great intrinsic value	3 mm/s	3 to 8 mm/s	8 to 10 mm/s	8 mm/s

The German Standard (DIN4150) specifies a method for measuring and evaluating the effects of vibration on structures. The standard gives guideline values, which when complied with, will not result in damage that will have an adverse effect on the structure's serviceability, and further if damage nevertheless occurs, it is to be assumed that other causes are responsible. The standard lists acceptable values for both short and long term vibration with the distinction based as to whether there may be any fatigue related failure of the structure. The standard is directed towards preventing cosmetic damage such as crack formation in plaster, rather than damage.

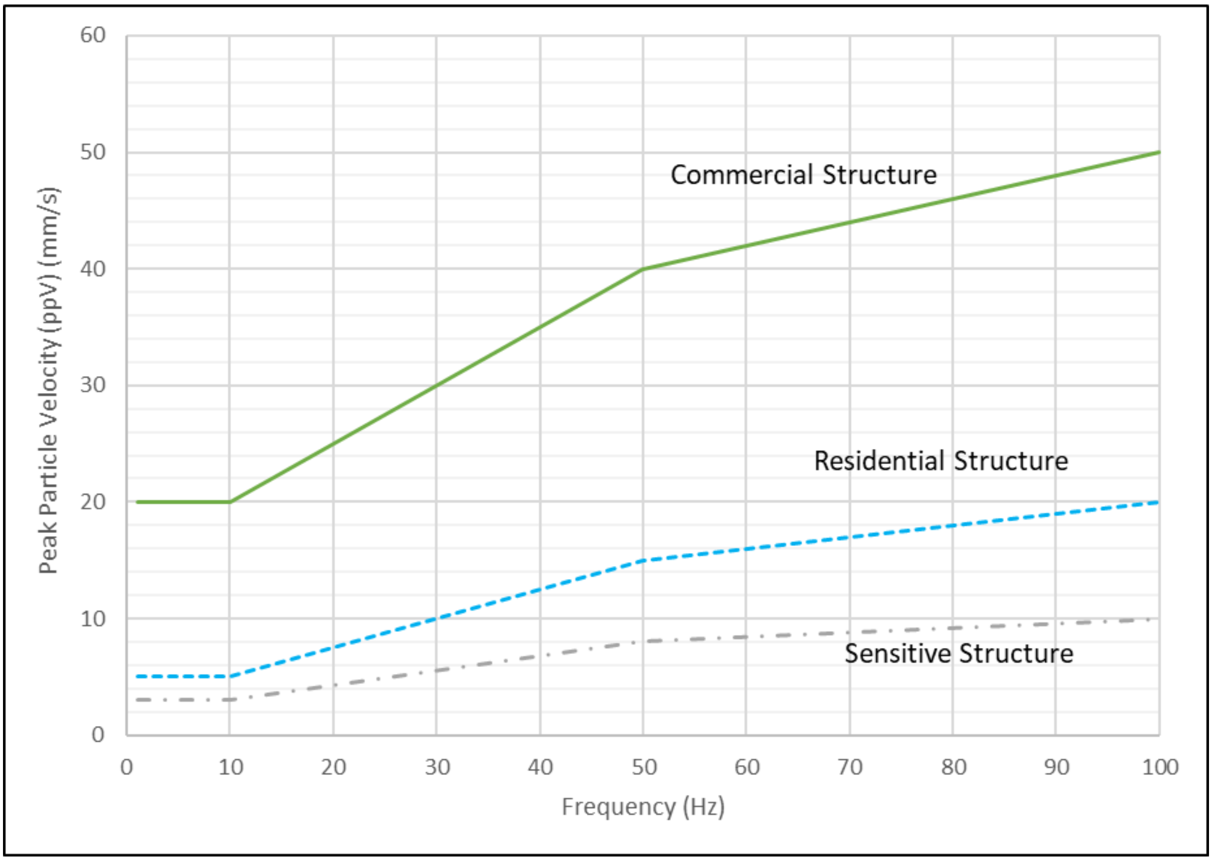


Figure 9 DIN 4150-3: 1999 Short-term standard baseline curves

These criteria have been established by experience and are conservatively based to provide a low probability of cosmetic damage (fine cracking of plaster joints and finishings) while enabling work to be progressed economically and often over a shorter duration. The standard recognises there will be some disturbance to people but for most, this will be acceptable. Based on this site study and extensive site data collected, blasting at the Sutton block will comply within the DIN4150 standard at neighbouring residential properties.

AUSTRALIAN STANDARD

Section J of the Australian Standard AS2187.2-2006 is comprehensive and contains limits for ground vibration and air overpressure levels for maintaining human comfort together with limits for preventing cosmetic damage to structures. Table J4.5(A) of the Australian Standard is reproduced as the following Figure 10 lists the human comfort criteria.

Category	*Type of blasting operations*	*Peak component particle velocity (mm/s)*
Sensitive site	Operations lasting longer than 12 months or more than 20 blasts	5mm/s for 95% blasts per year 10mm/s maximum unless agreement is reached with the occupier that a higher limit may apply
Sensitive site	Operations lasting less than 12 months or less than 20 blasts	10mm/s maximum unless agreement is reached with occupier that a higher limit may apply
Occupied non-sensitive sites such as factories and commercial premises	All blasting	25mm/s maximum value unless agreement is reached with occupier that a higher limit may apply. For sites containing equipment sensitive to vibration, the vibration should be kept below manufacturer's specification or levels that can be shown to adversely affect the equipment operation

Figure 10 Ground vibration limits for human comfort (reproduced from AS2187.2-2006)

Table J4.4.2.1 of the Australian Standard AS2187.2-2006 contains limits for vibration for prevention of cosmetic damage (that are also consistent with the British Standard BS7385-2:1993).

Type of Building	*Peak component particle velocity in frequency range of predominant pulse*	
	4Hz to 15Hz	*15 Hz and above*
Reinforced or framed structures. Industrial and heavy commercial buildings	50mm/s at 4 Hz and above	
Un-reinforced or light framed structure. Residential or light commercial type buildings	15mm/s at 4 Hz increasing to 20mm/s at 15Hz	20mm/s at 15 Hz increasing to 50mm/s at 40 Hz and above

Figure 11 Transient vibration guide values for cosmetic damage (reproduced from AS2187.2-2006)

The Australian Standard AS2187.2-2006 further defines cosmetic damage as the formation of hairline cracks on drywall surfaces, the growth of existing cracks in plaster or drywall surfaces or the formation of hairline cracks in the mortar joints of brick/concrete constructions. Minor damage is defined as the formation of cracks or loosening and falling of plaster or drywall surfaces, or cracks through brick/concrete blocks.

It is well documented that vibration becomes perceptible to persons at levels between 0.5mm/s and 1mm/s, acceptable at levels between 5 and 10mm/s for long term projects and acceptable to the majority at higher values in the short term. Although blasting has been happening for many years on site, blast vibration is only emitted 0.5 – 2.5 seconds at a time.

The Australian Standards AS 2187.2-2006 includes a limit between 115dBL and 125dBL. Overpressure also known as airblast or noise, is also likely to be less than several seconds per blast. When compared with other natural phenomena, like cyclones, wind and thunder, these effects would often exceed 115dBL for many hours during a day. However, to follow best practice limiting blasting activities for neighbouring residence is recommended. The AS2187.2-2006 values for overpressure from blasting are reproduced in Figure 12 below.

Category	*Type of blasting operations*	*Peak Overpressure Value (dBL)*
Sensitive site	Operations lasting longer than 12 months or more than 20 blasts	115dBL for 95% blasts per year. 120dBL maximum unless agreement with occupier that a higher limit may apply
Sensitive site	Operations lasting less than 12 months or less than 20 blasts	120dBL for 95% blasts per year. 125dBL maximum unless agreement with occupier that a higher limit may apply
Occupied non-sensitive sites such as factories and commercial premises	All blasting	125dBL maximum value unless agreement is reached with occupier that a higher limit may apply. For sites containing equipment sensitive to vibration, the vibration should be kept below manufacturer's specification or levels that can be shown to adversely affect the equipment operation

Figure 12 Overpressure limits for human comfort

Again, based on this site study and extensive site data collected, blasting at the Sutton block will comply within the Australian standard AS2187.2-2006 at neighbouring residential properties. The AS2187.2-2006 is consistent with international standards and like those of the DIN4150. With appropriate monitoring and management measures in place, activity occurring within these parameters will not generate unreasonable effects to neighbouring properties. Blast vibration at Ballards cone will also achieve compliance with AS2187.2-2006.

BALLARDS CONE

Ballards cone (Kārearea Pa) is a scheduled Significant Ecological Area and a Historic Heritage and Special Character extent of Place[2] under the AUP. The site is protected by a deer fence, and regular pest and weed control is undertaken. The site is also an ancient basalt shield volcano, part of the Auckland volcanic field. It is adjacent to the northern end of the current pit.

Ballards cone has not been monitored in the past for blast vibration or air overpressure. A trial was started in September 2023 to record data on the boundary of the quarry pit and Ballards cone. The site itself has not been accessed due to cultural sensitivity. Therefore, only recordings from the boundary have been recorded. Figure 13 Ballards cone vibration monitor locationshows the vibration monitor location and the surveyed boundary of Ballards cone in purple. Blasts outlined in table 7 are coloured maroon in Figure 13. Figure 14 Distance between Boundary and centre of Ballards conebelow shows the distance between the boundary and the centre of Ballards cone.

The location of the blast within the Sutton Block will significantly influence vibration levels on Ballards cone. When detonation occurs in close proximity and within the line of sight, noise levels experienced at the boundary will be substantially elevated. This is the same for vibration. However, the frequency of the vibrational

[2] Extent of Place 693 Ballards Cone pa site R12_278

waveforms will be notably higher. Consequently, any objects affixed to the ground will register a perceived motion of lesser magnitude compared to that induced by a lower frequency occurring at a greater distance.

Specifically, SA-063 and SA-065 recorded a frequency ranging from 23.9Hz to 37.7Hz, whereas SA-066 recorded frequencies within the range of 6.9Hz to 12.8Hz. Notwithstanding, the peak particle velocity values were notably distinct, with SA-063 and SA-065 registering 9.54mm/s and 15.44mm/s respectively, in contrast to 1.68mm/s for SA-066. This can be directly attributed to the distance from the blast site.

It should be noted that to date no vibration control measures towards Ballards cone have been implemented to mitigate potential effects, and therefore vibration levels have exceeded the DIN4150 standard. The DIN4150 standard setting vibration limits are set at a level to protect buildings structural integrity. Given no buildings are located on Ballards Cone no vibration controls have been implemented. However, despite a lack of built structures. the results indicate there may be a need for vibration mitigation measures at Ballards Cone to protect what is a culturally significant site.

Figure 13 Ballards cone vibration monitor location

Blast vibration and air overpressure recorded are displayed in 7 below. Monitoring will continue at this location for the next 3 months to gather more data.

Table 7 Monitoring results at Ballards cone boundary from recent blasts

Shot Number	MIC (kg)	Distance (m)	Bench height	PPV (mm/s)	Air overpressure (dBL)
23-SA062	195	460	15.0	2.61	98
23-SA066	215	625	15.0	1.68	116.2
23-SA067	87	457	14.0	0.14	110.2
23-SA063	184	280	15.0	9.54	112.2
23-SA065	144	150	10.0	15.44	118.1

23-SA070	231	585	18.0	4.73	109.2
23-SA071	164	453	15.8	5.09	112.1
23-SA072	128	470	18.5	4.05	116.2
23-SA075	180	325	17.5	6.11	111.5

As stated above, the distance to the centre of Ballards cone is much greater. Using drone surveying this is estimated at 180m. Using Orica vibration prediction software, 23-SA065 had a theoretical vibration prediction of 14.11mm/s. By assuming a vibration monitor could be positioned at the centre shown below, it gives a theoretical prediction of 5.55mm/s, which is a significant reduction compared to the reading at the boundary. This is because the distance from the blasting source is critical in reducing impacts. It is considered, with blast vibration control measures, 5mm/s can be achieved as a maximum level of vibration effect across Ballards Cone.

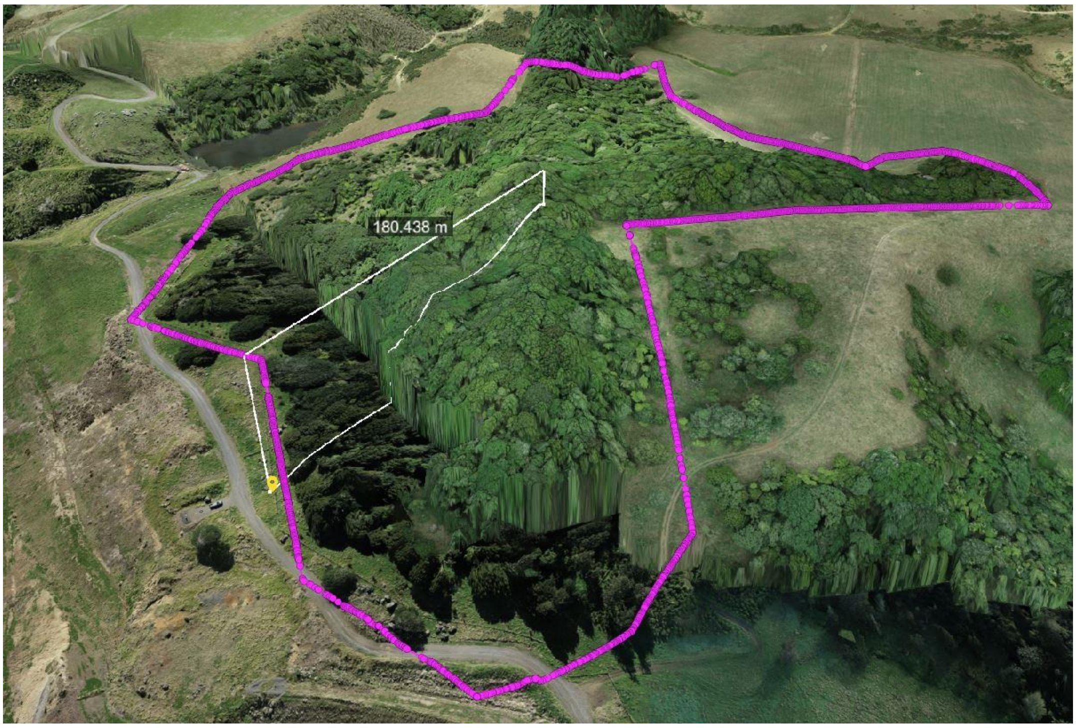


Figure 14 Distance between Boundary and centre of Ballards cone

Below Figure 15 Vibration contour map using theoretical numbers from 23-SA065. This demonstrates very basically how ground vibration attenuates from the blast. At a greater distance the contours become less showing depreciation of vibration levels. The contours are set to 1mm/s for this example.

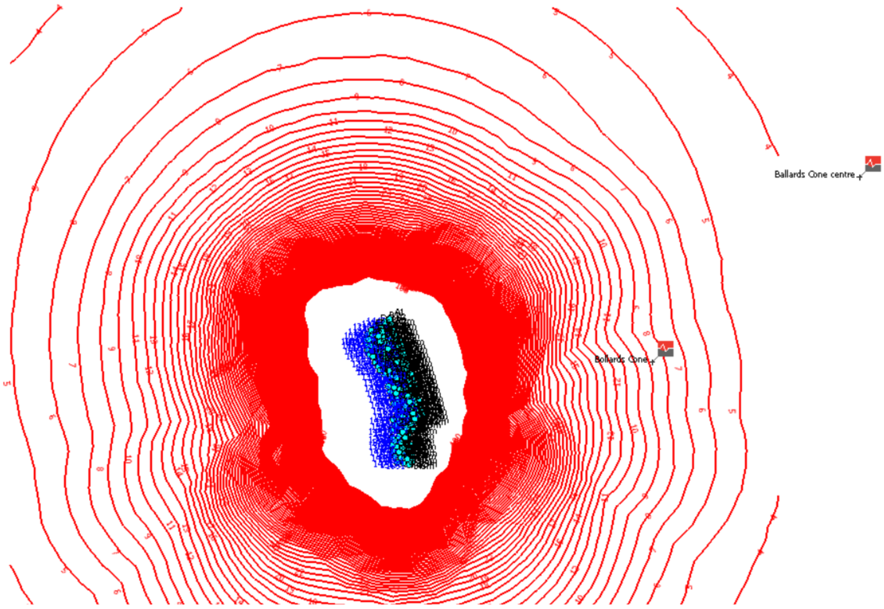


Figure 15 Vibration contour map using theoretical numbers from 23-SA065

SUTTON BLOCK

Blasting in the Sutton block area will only commence once the pit has been excavated down to a bedrock of such strength that efficient excavation becomes challenging. According to drill logs, the required depths for blasting vary. Consequently, both excavation and bench establishment will have been completed beforehand. It's important to note that the blasting operations will not take place at the outer perimeter of the pit design. The benches will serve a dual purpose: they will offer protection against airblast for the houses along MacWhinney Drive and provide a safe separation distance. Blast orientation will be strategically planned to redirect blast vibration and airblast away from the nearby residences, utilizing specialized blasting techniques.

The closest residence to the proposed Sutton block pit is 359 MacWhinney Drive displayed in Figure 16. Estimated to be 400m North of where blasting will occur (once the overburden has been stripped). It is assumed, based on vibration results from the current pit at 151 MacWhinney Drive that blasting can be achieved below the 5mm/s threshold with managed blasting techniques. Current blasts are successfully designed with adjusted timing delays based on the study earlier in this report. Although seed wave information hasn’t been collected for the Sutton block specifically, ground attenuation based on geology, distance and design can be used as a good indication. Initial seed holes should be completed along with smaller trial blasts to calibrate the vibration model to best determine blast design constraints.

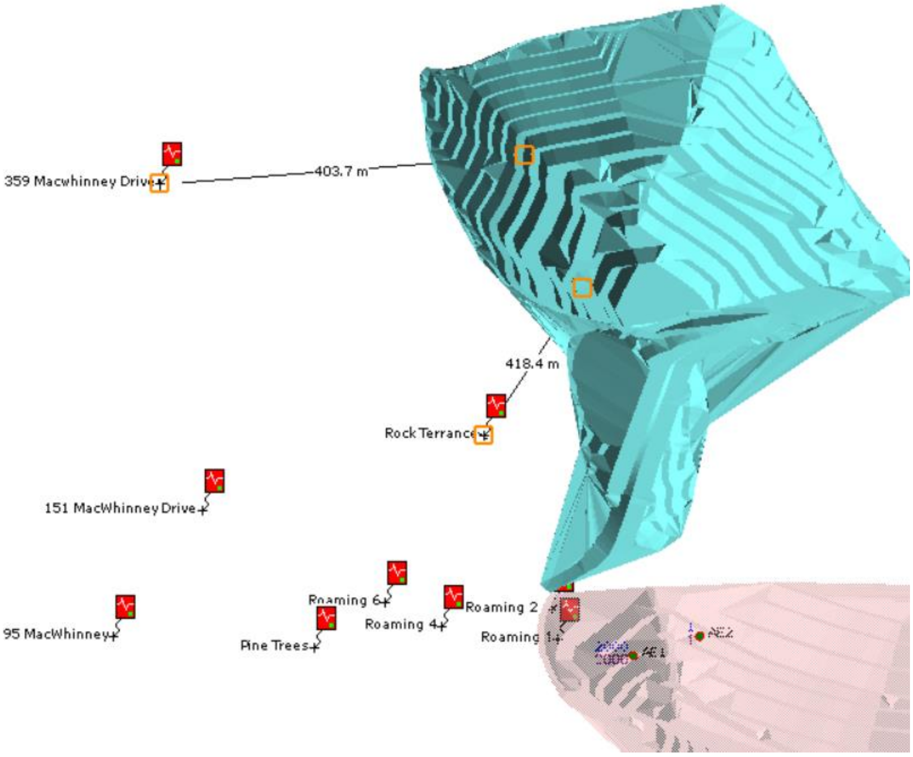


Figure 16 Distance from key points of interest to Sutton Block pit in Shotplus™6

Figure 17 Aerial with overlay of Pit design and features

AIR BLAST - NOISE

Air blast refers to the shockwave of compressed air that is generated during the detonation of explosives used to break apart rock formations. This shockwave is a byproduct of the sudden release of energy from the explosion.

The air blast travels through the air, creating a pressure wave that can be felt and heard in the surrounding area. The intensity and effect of the air blast depend on various factors, including the type and amount of explosives used, the depth and configuration of the blast holes, and the geological characteristics of the rock being blasted.

The primary concern with air blasts in quarry operations is their potential to cause vibration, noise, and even structural damage to nearby buildings or structures. Blasting contractors take measures to mitigate the impact of air blasts, such as monitoring blast parameters, using appropriate blast design techniques, and establishing blast exclusion zones to ensure safety for both workers and nearby communities.

The noise generated from a blast is typically a very short pulse with a duration of less than one second. An example is shown below in Figure 18. 116.2dBL was recorded on 23-SA066.

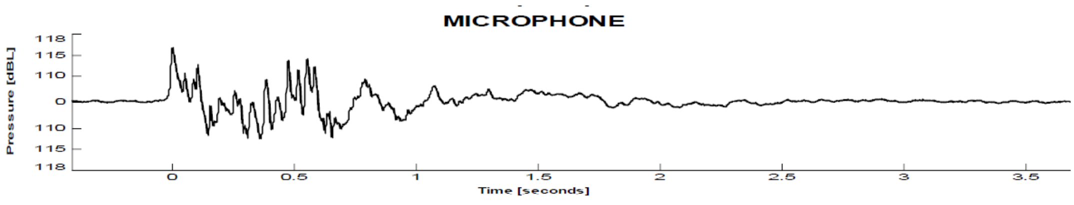


Figure 18 Microphone recording from 23-SA066 at Ballards cone boundary

To help understand what level of noise was recorded, below Figure demonstrates different noise levels that are experienced by most humans daily for much longer durations than the output of a blast.

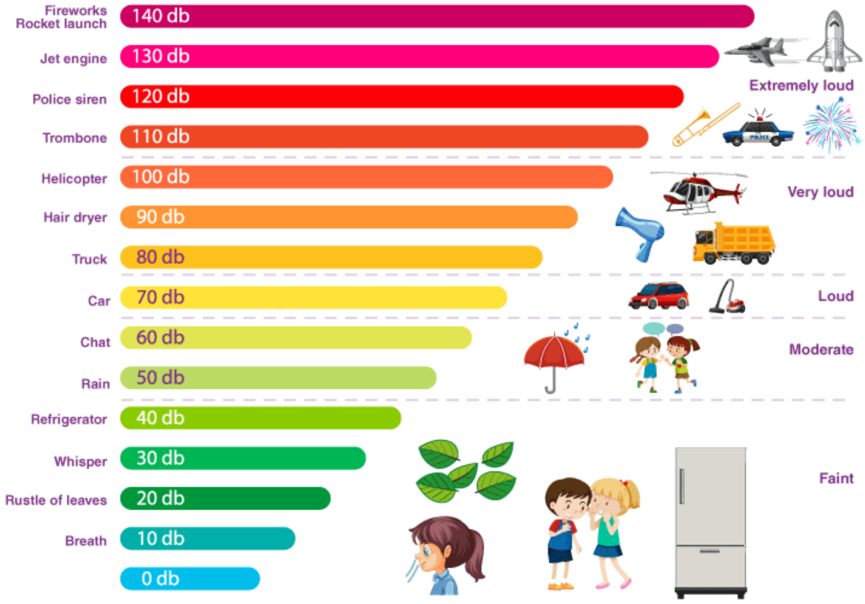
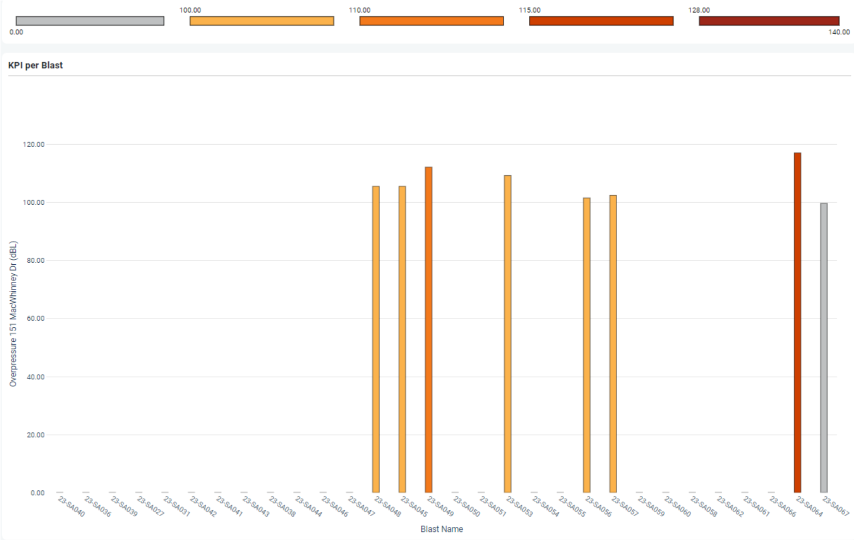


Figure 19 Decibel scale reproduced from BYJU's Educational technology company website

Of the previous 30 blast to date, 6 blasts have recorded readings at 151 MacWhinney Drive. Below figure 20 displays the readings with 99.7dBL being the lowest recorded and 117.10dBL being the highest. All other blast did not produce enough noise or vibration to trigger the geophone or microphone.



KPI per Blast Details

Blast Name	Fire Date	KPI (dBL)
23-SA067	2023-10-11 14:36	99.70
23-SA064	2023-10-09 12:37	117.10
23-SA066	2023-10-03 14:05	0.00
23-SA061	2023-09-27 12:45	0.00
23-SA062	2023-09-21 13:00	0.00
23-SA058	2023-09-18 13:33	0.00
23-SA060	2023-09-15 14:15	0.00
23-SA059	2023-09-07 13:11	0.00
23-SA057	2023-09-04 13:09	102.50
23-SA056	2023-08-29 13:23	101.60
23-SA055	2023-08-23 01:08	0.00
23-SA054	2023-08-17 11:50	0.00
23-SA053	2023-08-15 13:54	109.30
23-SA051	2023-08-02 14:44	0.00
23-SA050	2023-08-02 14:31	0.00
23-SA049	2023-07-26 13:45	112.20

Figure 18 151 MacWhinney microphone records for previous 30 blasts.

It is assumed that blasting at Sutton block will produce similar air blast to the above levels. Distances and geographic conditions are similar to the northern end of the current Drury pit. The Sutton block has a natural buffer zone in the form of pine trees and the rolling hillside. See **Error! Reference source not found.**below. This will help to absorb and shelter the upper MacWhinney Drive residence. Blasting will not occur until the pit has already been excavated down a considerable amount to hard rock. Therefore, blasts will not be in line of sight of the neighboring houses, reducing air blast further.

Sonja Drive is to the northeast of the Sutton block (located off the aerial in Figure). The closest residence to the quarry boundary is 650m horizontally. The above statements apply for Sonja Drive with houses hidden by vegetation and a hillside. These will block the direct line of sight to the quarry. It is expected, residents of Sonja Drive will experience limited effects from blasting at Sutton block.

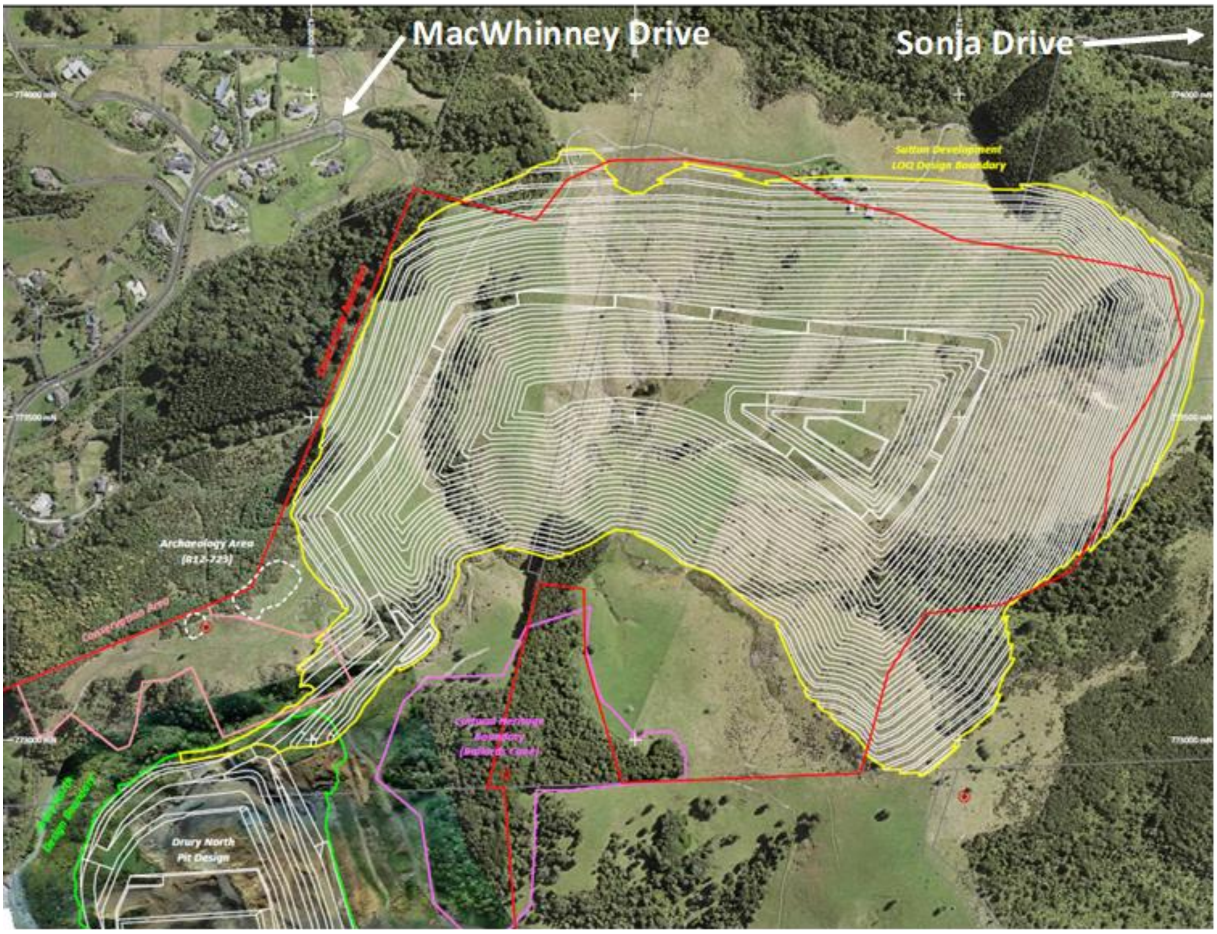


Figure 21 Aerial photo of Life of Quarry with MacWhinney Drive and Sonja Drive locations

A major factor of air blast is atmospheric conditions. Clear, still skies allow for air blast to quickly move through the atmosphere in all directions as they dissipate. However, windy conditions blowing towards a point of interest will increase noise levels, as well as temperature inversions.

A temperature inversion occurs when there is a layer of warm air above a layer of cooler air near the ground. This is the opposite of what typically happens in the atmosphere, where temperature tends to decrease with altitude. In a normal situation, warm air rises and cool air sinks, leading to vertical mixing of the atmosphere.

However, during a temperature inversion, the warm layer acts like a lid, trapping cooler air beneath it. This creates a stable stratification of the atmosphere, preventing vertical mixing and trapping pollutants, sound waves, and blast waves near the ground. In order to mitigate the effects of this blasting can be scheduled to be on days with clear atmospheric conditions and favourable wind direction. A common practice in noise sensitive areas across Australia.

HUMAN RESPONSE

Human response to blast induced ground vibration is a relatively complex and is dependent upon a range of factors. It is well recognized that the human body is very sensitive to the onset of vibration although very poor at distinguishing relative magnitudes. Sensitivity to vibration varies significantly between individuals. A person will generally become aware of blast induced vibration at levels of around 1.0 -1.5mm/s PPV, and under some circumstances at levels as low as 1.0 - 0.5mm/s. Once a received vibration is greater than an individual's perception threshold then it is possible for concern to be expressed about the blasting. Such concern normally relates to the vibration's potential for causing damage to the complainant's property. Concern may be expressed that damage has already occurred due to the recent discovery of cracking that may have been present for some time or have been caused by natural processes. More often, however, concerns are based on the fear that damage will be caused at some time in the future as a result of repeated vibration.

The susceptibility of individuals to vibration will vary from person to person depending on factors such as age, health and, to a large extent, previous exposure. It is usually the case that adverse comments are less likely once a neighbour has become accustomed to the perceived effects of blasting.

Humans are quite sensitive to motion and noise that accompany blast-induced ground and air born disturbances. Complaints resulting from blast vibration and air overpressure (or noise), to a large extent, are mainly due to the annoyance effect, fear of damage, and the startling effect rather than damage. The human body is very sensitive to low vibration and air blast level, but unfortunately it is not reliable damage indicator. With air overpressure blast generally levels of over 120dBL will produce some annoyance, fright and rattle dishes. Together these tend to produce more noise inside a structure than outside. In most cases, personal contact, assurance, and a good public relations program with the residential owners in question should alleviate the problem, assuming no structural damage. In this regard psychophysiological perception of the blast is generally more important than the numerical values of the ground vibration and air overpressure.

HANDLING COMPLAINTS

Stevenson Aggregates currently has a team dedicated to community liaison with a contact person for neighbour complaints. This helps with successful public relations. Previously the blast crew had temporary recorded vibration and noise at multiple residence. No anomalies were found. However, this provides reassurance for neighbours. Below forms part of Stevenson Aggregates complaint process.

- On receipt of a complaint, the complainant's name and address, nature of the complaint, date and time of the event recorded. Complaints are then investigated in person by the person in charge of blasting and a genuine attempt made to satisfy the complainant.
- Monitoring of subsequent blasts and follow-up visits to gauge response. Vibration levels are made available to specific neighbour to demonstrate transparency and reassurance of compliance.

BLAST VIBRATION MITIGATION

Blast vibration mitigation techniques are used to minimize the potentially harmful effects of ground vibrations generated by activities such as mining, construction, quarrying, and controlled explosions. These techniques aim to protect nearby structures, the environment, and the safety of individuals. Here is a list of common blast vibration mitigation techniques:

- Blast Design Optimization: Careful design of the blasting parameters, including the type and amount of explosives, delay times, and drilling techniques, to reduce vibration levels while achieving the desired result.
- Controlled Blasting: Using electronic detonators for precise timing and sequencing of explosive charges to control the direction and distribution of vibrations.
- Reduced Charge Size: Reducing the amount of explosives used in each blast hole to minimize the energy released and consequently, the vibration generated. This may include two separate charges in one hole known as double decking.
- Buffer Zones: Creating buffer zones or setbacks between blasting operations and sensitive structures or areas to reduce the impact of vibrations.
- Continued seed wave analysis and calibration: Complete and build on the seed wave analysis as completed in this report. Calibrate the monitor regularly based on actual blasting vibration received. Adjust blasting parameters in response to measured ground vibrations and updated prediction modelling.
- Blasting Scheduling: Coordinating blasting activities to minimize their impact on nearby communities, infrastructure, and wildlife habitats.
- Public Communication: Informing and engaging with the local community to keep them informed about blasting activities and mitigation efforts.
- Regulatory Compliance: Setting up permanent monitoring stations adhering to local regulations and guidelines for blast vibration limits and mitigation measures.

These techniques are often employed in combination, depending on the specific requirements of a project and the surrounding environment. Effective blast vibration mitigation is crucial to ensure the safety of people, protect infrastructure, and minimize environmental impacts in areas where blasting is necessary. All of the above controls are employed at the Drury quarry except for buffer zones, double decking and blast scheduling. Vibration recordings have not warranted the need to use these methods.

AIR BLAST MITIGATION

As with vibration, if not managed appropriately, may lead to unintended consequences for nearby structures and the environment. To address this concern, a number of techniques and methodologies have been developed to mitigate the impact of quarry air blasts. The list below outlines proven strategies for air blast management. By adopting these techniques, quarry operators can achieve production goals meanwhile adhere to stringent regulatory standards.

- Use of electronic detonators:
    - Electronic detonators have no surface delays which mean that all explosives are contained inside the rock face.
    - Using electronic detonators for precise timing and sequencing of explosive charges to control the direction of rock movement as well as volume of air blast.
- Increase burdens (distance between blast hole and face) to reduce blast gases escaping and excess rock movement.
- Increase stemming to help contain the blast.
- Alter explosive properties to a lower velocity of detonation for less energy release.
- Change the face direction to face away from neighbouring properties.
- Weather considerations: Only blast when the wind is in a favourable direction. Do not blast on days likely to have a temperature inversion.
- Buffer Zones - Create open spaces or green areas around structures to absorb and dissipate blast energy.

All of the above controls are in place at Drury quarry apart from: increased stemming, changing type of explosive or weather considerations. These have not been deemed necessary at the time of this report with noise levels well below the controlled activity standards.

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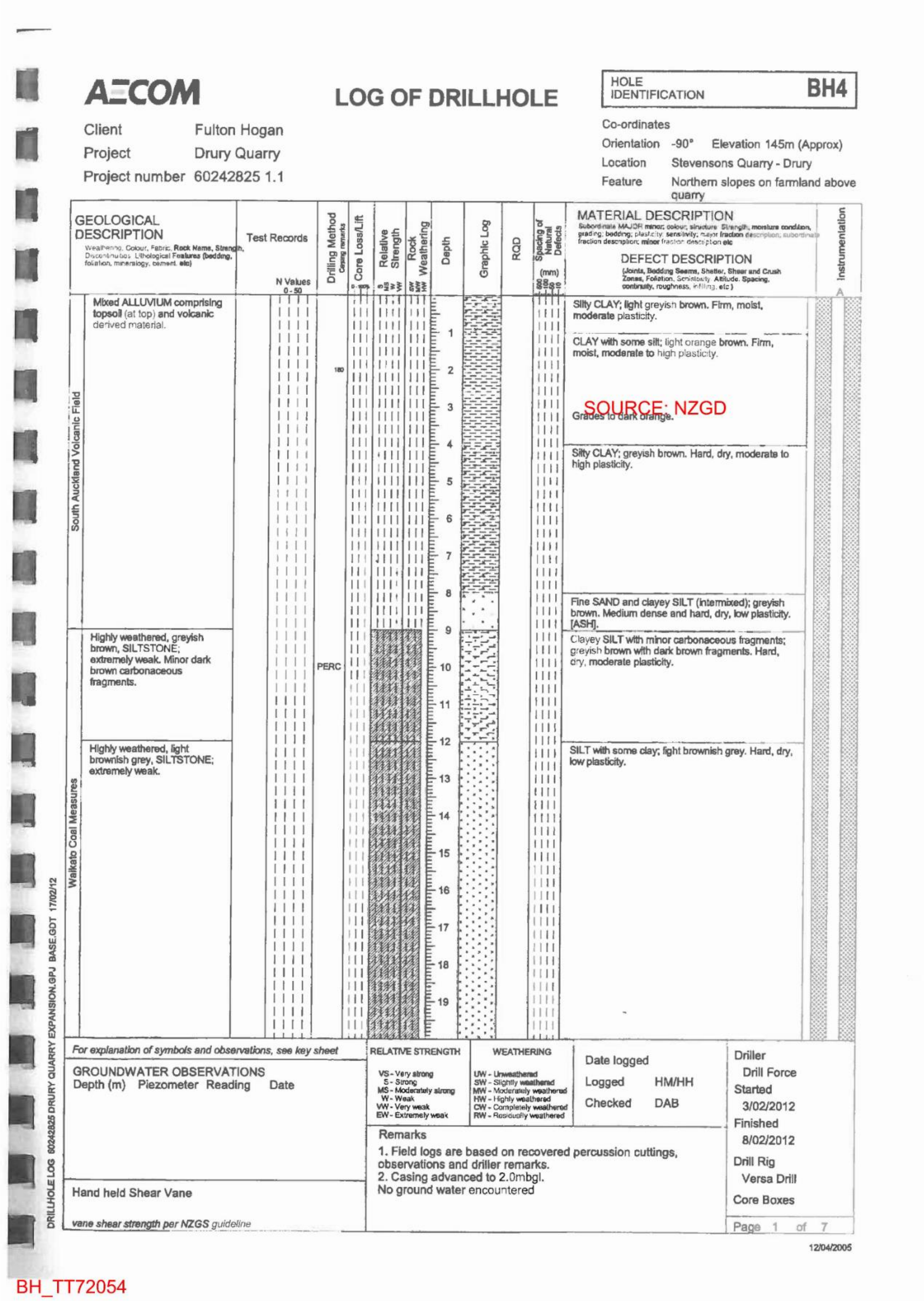
APPENDICES

DRILL LOG



AECOM

LOG OF DRILLHOLE

HOLE IDENTIFICATION BH4

Client Fulton Hogan
Project Drury Quarry
Project number 60242825 1.1

Co-ordinates
Orientation -90° Elevation 145m (Approx)
Location Stevensons Quarry - Drury
Feature Northern slopes on farmland above quarry

Geological unit	GEOLOGICAL DESCRIPTION	Depth (m)	MATERIAL DESCRIPTION
South Auckland Volcanic Field	Mixed ALLUVIUM comprising topsoil (at top) and volcanic derived material.	0–1	Silty CLAY; light greyish brown. Firm, moist, moderate plasticity.
		1–3.5	CLAY with some silt; light orange brown. Firm, moist, moderate to high plasticity. Grades to dark orange.
		3.5–8	Silty CLAY; greyish brown. Hard, dry, moderate to high plasticity.
		8–9	Fine SAND and clayey SILT (intermixed); greyish brown. Medium dense and hard, dry, low plasticity. [ASH].
Waikato Coal Measures	Highly weathered, greyish brown, SILTSTONE; extremely weak. Minor dark brown carbonaceous fragments.	9–12	Clayey SILT with minor carbonaceous fragments; greyish brown with dark brown fragments. Hard, dry, moderate plasticity.
	Highly weathered, light brownish grey, SILTSTONE; extremely weak.	12–19	SILT with some clay; light brownish grey. Hard, dry, low plasticity.

Drilling Method: PERC

For explanation of symbols and observations, see key sheet

GROUNDWATER OBSERVATIONS
Depth (m) Piezometer Reading Date

Hand held Shear Vane
vane shear strength per NZGS guideline

RELATIVE STRENGTH
VS - Very strong
S - Strong
MS - Moderately strong
W - Weak
VW - Very weak
EW - Extremely weak

WEATHERING
UW - Unweathered
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
CW - Completely weathered
RW - Residually weathered

Date logged
Logged HM/HH
Checked DAB

Remarks
1. Field logs are based on recovered percussion cuttings, observations and driller remarks.
2. Casing advanced to 2.0mbgl.
No ground water encountered

Driller Drill Force
Started 3/02/2012
Finished 8/02/2012
Drill Rig Versa Drill
Core Boxes

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12/04/2005

DRILLHOLE LOG 60242825 DRURY QUARRY EXPANSION.GPJ BASE.GDT 17/02/12

SOURCE: NZGD

BH_TT72054

AECOM

LOG OF DRILLHOLE

HOLE IDENTIFICATION **BH4**

Client Fulton Hogan
Project Drury Quarry
Project number 60242825 1.1

Co-ordinates
Orientation -90° Elevation 145m (Approx)
Location Stevensons Quarry - Drury
Feature Northern slopes on farmland above quarry

GEOLOGICAL DESCRIPTION (Weathering, Colour, Fabric, Rock Name, Strength, Discontinuities, Lithological Features (bedding, foliation, mineralogy, cement, etc))	Test Records (N Values 0 - 50)	Drilling Method (Casing remarks)	Core Loss/Lift	Relative Strength	Rock Weathering	Depth	Graphic Log	RQD	Spacing of Natural Defects (mm)	MATERIAL DESCRIPTION (Subordinate MAJOR minor; colour; structure. Strength; moisture condition; grading; bedding; plasticity; sensitivity; major fraction description; subordinate fraction description; minor fraction description etc) / DEFECT DESCRIPTION (Joints, Bedding Seams, Shatter, Shear and Crush Zones, Foliation, Schistosity, Attitude, Spacing, continuity, roughness, infilling, etc)	Instrumentation
WAIPAPA TERRANE: Highly to moderately weathered, light bluish grey, fine sandy SILTSTONE; extremely weak.						21–27				Fine sandy SILT; light bluish grey. Hard, dry, low plasticity.	A
Highly weathered, light brown, silty fine SANDSTONE: very weak to weak.		PERC				28–30					
Moderately weathered, brown (fines) with bluish grey (fragments), silty fine SANDSTONE; strong. Some orange brown staining on surfaces and minor thin hard white veins. (When fragments are washed they appear: Slightly weathered, bluish grey with trace brown, silty fine SANDSTONE; strong. Some orange brown staining and minor thin hard white veins.)						31–39				36m: Advance rate: 36-42m 35mins	

SOURCE: NZGD

For explanation of symbols and observations, see key sheet

GROUNDWATER OBSERVATIONS
Depth (m) Piezometer Reading Date

Hand held Shear Vane
vane shear strength per NZGS guideline

RELATIVE STRENGTH	WEATHERING
VS - Very strong	UW - Unweathered
S - Strong	SW - Slightly weathered
MS - Moderately strong	MW - Moderately weathered
W - Weak	HW - Highly weathered
VW - Very weak	CW - Completely weathered
EW - Extremely weak	RW - Residually weathered

Date logged
Logged HM/HH
Checked DAB

Remarks
1. Field logs are based on recovered percussion cuttings, observations and driller remarks.
2. Casing advanced to 2.0mbgl.
No ground water encountered

Driller Drill Force
Started 3/02/2012
Finished 8/02/2012
Drill Rig Versa Drill
Core Boxes

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12/04/2005

DRILLHOLE LOG 60242825 DRURY QUARRY EXPANSION.GPJ BASE.GDT 17/02/12

BH_TT72054

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LOG OF DRILLHOLE

HOLE IDENTIFICATION **BH4**

Client Fulton Hogan
Project Drury Quarry
Project number 60242825 1.1

Co-ordinates
Orientation -90° Elevation 145m (Approx)
Location Stevensons Quarry - Drury
Feature Northern slopes on farmland above quarry

GEOLOGICAL DESCRIPTION	Test Records (N Values 0-50)	Drilling Method	Core Loss/Lift	Relative Strength	Rock Weathering	Depth	Graphic Log	RQD	Spacing of Natural Defects (mm)	MATERIAL DESCRIPTION / DEFECT DESCRIPTION	Instrumentation
WAIPAPA TERRANE. Moderately weathered, brown (fines) with bluish grey (fragments), silty fine SANDSTONE; strong. Some orange brown staining on surfaces and minor thin hard white veins. (When fragments are washed they appear: Slightly weathered, bluish grey with trace brown, silty fine SANDSTONE; strong. Some orange brown staining and minor thin hard white veins.)		PERC				41–59				42m: Advance rate: 42-48m 30mins 48m: Advance rate: 48-54m 25mins 54m: Advance rate: 54-60m 28mins	

SOURCE: NZGD

For explanation of symbols and observations, see key sheet

GROUNDWATER OBSERVATIONS
Depth (m) Piezometer Reading Date

Hand held Shear Vane

vane shear strength per NZGS guideline

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Date logged
Logged HM/HH
Checked DAB

Driller Drill Force
Started 3/02/2012
Finished 8/02/2012
Drill Rig Versa Drill
Core Boxes

Remarks
1. Field logs are based on recovered percussion cuttings, observations and driller remarks.
2. Casing advanced to 2.0mbgl.
No ground water encountered

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12/04/2005

DRILLHOLE LOG 60242825 DRURY QUARRY EXPANSION.GPJ BASE.GDT 17/02/12

BH_TT72054

AECOM

LOG OF DRILLHOLE

HOLE IDENTIFICATION **BH4**

Client Fulton Hogan
Project Drury Quarry
Project number 60242825 1.1

Co-ordinates
Orientation -90° Elevation 145m (Approx)
Location Stevensons Quarry - Drury
Feature Northern slopes on farmland above quarry

GEOLOGICAL DESCRIPTION (Weathering, Colour, Fabric, Rock Name, Strength, Discontinuities, Lithological Features (bedding, foliation, mineralogy, cement, etc))	Test Records (N Values 0 - 50)	Drilling Method (Casing remarks)	Core Loss/Lift	Relative Strength (S MS W VW)	Rock Weathering (SW MW HW)	Depth	Graphic Log	RQD	Spacing of Natural Defects (mm) (600 100 50 10)	MATERIAL DESCRIPTION (Subordinate MAJOR minor; colour; structure Strength; moisture condition; grading; bedding; plasticity; sensitivity; major fraction description; subordinate fraction description; minor fraction description etc) DEFECT DESCRIPTION (Joints, Bedding Seams, Shatter, Shear and Crush Zones, Foliation, Schistosity, Attitude, Spacing, continuity, roughness, infilling, etc)	Instrumentation
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SOURCE: NZGD

For explanation of symbols and observations, see key sheet

GROUNDWATER OBSERVATIONS
Depth (m) Piezometer Reading Date

Hand held Shear Vane

vane shear strength per NZGS guideline

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Date logged
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Driller Drill Force
Started 3/02/2012
Finished 8/02/2012
Drill Rig Versa Drill
Core Boxes

Remarks
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2. Casing advanced to 2.0mbgl.
No ground water encountered

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DRILLHOLE LOG 60242825 DRURY QUARRY EXPANSION.GPJ BASE.GDT 17/02/12

BH_TT72054

AECOM

LOG OF DRILLHOLE

HOLE IDENTIFICATION **BH4**

Client: Fulton Hogan
Project: Drury Quarry
Project number: 60242825 1.1

Co-ordinates
Orientation: -90° Elevation 145m (Approx)
Location: Stevensons Quarry - Drury
Feature: Northern slopes on farmland above quarry

GEOLOGICAL DESCRIPTION (Weathering, Colour, Fabric, Rock Name, Strength, Discontinuities, Lithological Features (bedding, foliation, mineralogy, cement, etc))	Test Records (N Values 0-50)	Drilling Method	Core Loss/Lift	Relative Strength	Rock Weathering	Depth	Graphic Log	RQD	Spacing of Natural Defects (mm)	MATERIAL DESCRIPTION / DEFECT DESCRIPTION	Instrumentation
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						82					
						83					
						84				84m: Advance rate: 84-90m 38mins	
						85					
						86					
						87					
						88					
						89					
		PERC				90				90m: Advance rate: 90-96m 45mins	
						91					
						92					
						93					
						94					
						95					
Fines grade to bluish brown.						96				96m: Advance rate: 96-102m 42mins	
						97					
						98					
						99					

SOURCE: NZGD

For explanation of symbols and observations, see key sheet

GROUNDWATER OBSERVATIONS
Depth (m) Piezometer Reading Date

Hand held Shear Vane

vane shear strength per NZGS guideline

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CW - Completely weathered
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Date logged
Logged: HM/HH
Checked: DAB

Remarks
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No ground water encountered

Driller: Drill Force
Started: 3/02/2012
Finished: 8/02/2012
Drill Rig: Versa Drill
Core Boxes

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DRILLHOLE LOG 60242825 DRURY QUARRY EXPANSION.GPJ BASE.GDT 17/02/12

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LOG OF DRILLHOLE

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				108m: Advance rate: 108-112m 38mins
				112m: Advance rate: 112-120m 37mins

SOURCE: NZGD

For explanation of symbols and observations, see key sheet

GROUNDWATER OBSERVATIONS
Depth (m) Piezometer Reading Date

Hand held Shear Vane

vane shear strength per NZGS guideline

RELATIVE STRENGTH
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Driller Drill Force
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12/04/2005

DRILLHOLE LOG 60242825 DRURY QUARRY EXPANSION.GPJ BASE.GDT 17/02/12

BH_TT72054

CHAPTER H26 (RULES H28.6.2.2)

2. Land use controls

Development that does not comply with clauses 2.1-2.3 below is a discretionary activity.

2.1 Noise (mineral extraction activities)

1. Noise from mineral extraction must not exceed the following sound levels at a notional boundary from any occupied dwelling that existed at 1 January 2001 outside the Quarry zone:

Table 1

7am-10pm, Monday to Saturday	L_{Aeq}(15 min) 55dB
All other times and on public holidays	L_{Aeq}(15 min) 45dB L_{AFmax} 75dB

2. Noise created from the use of explosives must not exceed a peak overall sound pressure of 128dB Lzpeak.

2.2 Vibration and blasting (mineral extraction activities)

1. The measurement of blast noise (air blast) and ground vibration for blasting must be:
   a. measured at a notional boundary from a dwelling that existed at 1 January 2001
2. All blasting is restricted to:
   a. 9am-5pm, Monday to Saturday
   b. an average of two occasions over a calendar fortnight
   c. except where necessary because of safety reasons.
3. Blasting activities must be controlled to ensure any resulting ground vibration does not exceed the limits set out in Table 1 German standard DIN 4150-3 1999: Structural vibration – Part 3 Effects of vibration on structures when measured on the foundation or the horizontal plane of the highest floor of an affected building.
4. A siren must be used prior to blasting to alert people in the vicinity.