APPENDIX 8

Blast Impact Assessment

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UMWELT AUSTRALIA ON BEHALF OF MOUNT OWEN PTY LIMITED

BLAST IMPACT ASSESSMENT OF THE MOUNT OWEN CONTINUED OPERATIONS PROJECT

REPORT NO. UM-1404-081014

Thomas Lewandowski
8th October 2014

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1.0 INTRODUCTION

Enviro Strata Consulting Pty Limited (ESC) was engaged by Umwelt Australia Pty Limited (Umwelt), to undertake a blast impact assessment for the Mount Owen Continued Operations Project (the Project) on behalf of Mount Owen Pty Limited (Mount Owen), a subsidiary of Glencore Coal Pty Limited. The Mount Owen Complex is located in the Upper Hunter Valley of New South Wales (NSW), approximately 20 kilometres north-west of Singleton, 24 kilometres south-east of Muswellbrook and to the north of Camberwell. The Mount Owen Complex is comprised of three open cut operations, Mount Owen Mine (North Pit), Ravensworth East Mine (West Pit) and Glendell Mine (Barrett Pit). Mount Owen anticipate that mining will commence in the northern portion of the Ravensworth East in an area known as the Bayswater North Pit in 2015. The Project proposes a continuation of the existing mining activities within the North Pit to the south of the approved North Pit mining limit and to undertake mining operations within the Bayswater North Pit (BNP), followed by mining within the Ravensworth East Resource Recovery (RERR) Mining Area.

The assessment presented below addresses the potential impact of blasting, including ground vibration, airblast/overpressure and flyrock associated with the Project, on the following:

- Surrounding local community
- Existing and proposed infrastructure facilities
- Adjacent Integra underground mine

The potential impacts of blast fume are assessed in the Air Quality Impact Assessment for the Project.

This assessment is based on vibration modelling utilising the parameters representative for the area. All three assessments and their findings are presented in the context of the relevant vibration and overpressure limits for the local community, infrastructure facilities and Integra underground mine.

The report also includes a review of the blast emission and control measures and the approaches available to the mine to minimise the impact on the surrounding area.

2.0 PROJECT DETAILS

The Project is a continuation of the current mining operations within the existing Mount Owen and Ravensworth East Mines. The Project seeks approval to continue mining the North Pit to the south of the current approved North Pit mining limit (the North Pit Continuation) and in the BNP located in the northern section of the Ravensworth East Mine, and in the RERR Mining area located immediately east of the West Pit see **Figure 1A**. The proposed North Pit Continuation area is variable in shape and ranges from 1.1 to 1.8 km in width and 2.2 to 3.0 km in length, with a much smaller area subject to mining in any one year. The proposed North Pit Continuation is bounded by the existing Mount Owen Biodiversity Offset Areas to the east and by previous mining activities and the existing Mount Owen Complex Rail Line to the west. The BNP shell is approximately rectangular in shape with estimated dimensions of 1.3 by 0.8 km. The BNP is bounded by Hebden Road to the west and the Mount Owen Complex infrastructure to the east. The proposed RERR Mining area represents a rhomboidal form with approximate dimensions of 0.5 x 1 km. The RERR Mining area is located between the West Pit and the Mount Owen Complex rail line.

The Project will enable the extraction of approximately 74 million tonnes (Mt) run-of-mine (ROM) of additional mineable coal from the North Pit beyond the currently approved mining limit, approximately 12 Mt of ROM coal from the BNP and 6 Mt of ROM coal from the RERR Mining Area. These additional minable coal tonnes would allow the continuation of mining operations to approximately 2030. Pending approval, commencement of the Project is scheduled for approximately 2016.

Should the Project be approved Mount Owen seeks a single development consent covering both the Ravensworth East and Mount Owen Mines. Operations within the North Pit Continuation, BNP and the RERR Mining Area will overlap with time, see **Figure 1B**. Subject to market conditions, mining within the North Pit Continuation is scheduled for approximately 2016 to 2030; mining within the BNP is scheduled to be undertaken from approximately 2015 to 2022, after mining in the BNP has been completed mining in the RERR would follow from approximately 2022 to 2027. Blasting at the Mount Owen and Ravensworth East Mines (including North Pit Continuation, BNP and RERR Mining area) will be managed such that blasting at these operations is not conducted simultaneously.

The proposed drill and blast activities for the Project will be consistent with the current blasting activities, i.e. the Project will utilise the same drill rig size and similar blasting benches. The parameters for blasting in the North Pit Continuation, BNP and RERR Mining Area will therefore be similar to those used at the existing North Pit and the West Pit, with similar strata layout and interburden thickness. The primary focus of the drilling and blasting will be to blast the interburden material between the coal seams, although occasional coal seam blasting can also be anticipated, depending on the strength of the coal material.

The North Pit Continuation will include the extraction of a number of coal seams down to the Bayswater seam in the southern section and to the Hebden seam in the northern section of the North Pit Continuation. Due to seam dipping, mining depths will vary between 180 and 300 metres below surface level (refer to **Figure 2A**).

The final North Pit Continuation boundary and void is dictated by the steep dip of the coal seams to the south. It is expected that ultimately, as the North Pit Continuation becomes deeper, the impact of the mine blasting upon community and surface infrastructure will potentially be reduced. This is due to the increased topographical shielding effect as well as the indirect vibration transfer mechanism due to lower strata blasting, which will generally cause a reduction in vibration levels.

The BNP will involve the extraction of several coal seams down to the Bayswater seam, which is approximately 140 metres from the current surface level in this area. The extraction of the Bayswater North Pit will be for a relatively short duration of approximately eight years commencing in approximately 2015.

The RERR Mining Area is to be located adjacent to the existing operational pits, including Barrett and West Pits. A section of the RERR Mining Area is also located immediately adjacent to the two previously extracted smaller pits including Tailings Pit 1 (TP1) and the Eastern Rail Pit (ERP) extracted in 2005/2006. The parameters for blasting in the RERR Mining Area will be similar to those for the West Pit, as the seams are the same with similar dips and interburden thicknesses. The RERR Mining Area will include the extraction of a number of coal seams down to the Bayswater seam, which is approximately 200 metres from the current surface level. The initial material to be excavated is previously mined spoil, which will not require blasting. Drill and blast activities will commence once sufficient spoil has been removed. The extraction of the RERR Mining area will be for a relatively short duration of approximately six years.

Figure 1A – The Location and Boundaries of the North Pit Continuation, BNP and RERR Mining Areas

3.0 CONCEPTUAL BLAST DESIGN

The Mount Owen Complex is a mature operation with well-developed blasting systems. Blasting is conducted in accordance with an approved Blast Management Plan (BMP). The BMP will be reviewed following project approval, and updated, as necessary.

The Project will continue open cut extraction utilising drill and blast methods for coal recovery. The current Mount Owen conditions of consent (DA 14-1-2004 as modified) limit blasting times to 9am and 5pm (EST) and 9am and 6pm (DST) Monday to Saturday inclusive and allow for up to 12 blasts per year between 7am and 9am Monday to Saturday. The Ravensworth East conditions of consent (DA 52-03-99) allows for *blasting at the development between 9 am and 5 pm (EST) and 9 am and 6 pm (DST) Monday to Saturday inclusive. No blasting is allowed on Sundays, public holidays, or at any other time without the written approval*. The Ravensworth East conditions of consent provide for up to 2 blasts per day.

The BMP enables the design of each blast to minimise dust, fumes and airblast overpressure on the surrounding environment, while at the same time maximise blast efficiency. This will enable compliance with the site specific blasting conditions.

Blasting activities at the Mount Owen and Ravensworth East Mines generally utilise combinations of products including standard ammonium nitrate fuel oil (ANFO) for dry conditions, and Heavy ANFO and emulsion blends for wet conditions. The same explosive materials are proposed to be used for the Project.

The proposed layouts of the North Pit Continuation, BNP and RERR Mining Area are shown in **Figure 1A**, while the anticipated North Pit Continuation, BNP and RERR Mining Area outlines for the years 1, 5 and 10 of the Project are highlighted in **Figure 1B**. The extraction plans for years 1, 5 and 10 are representative of the mine plans for the life of the Project and capture the likely worst case impacts associated with the Project.

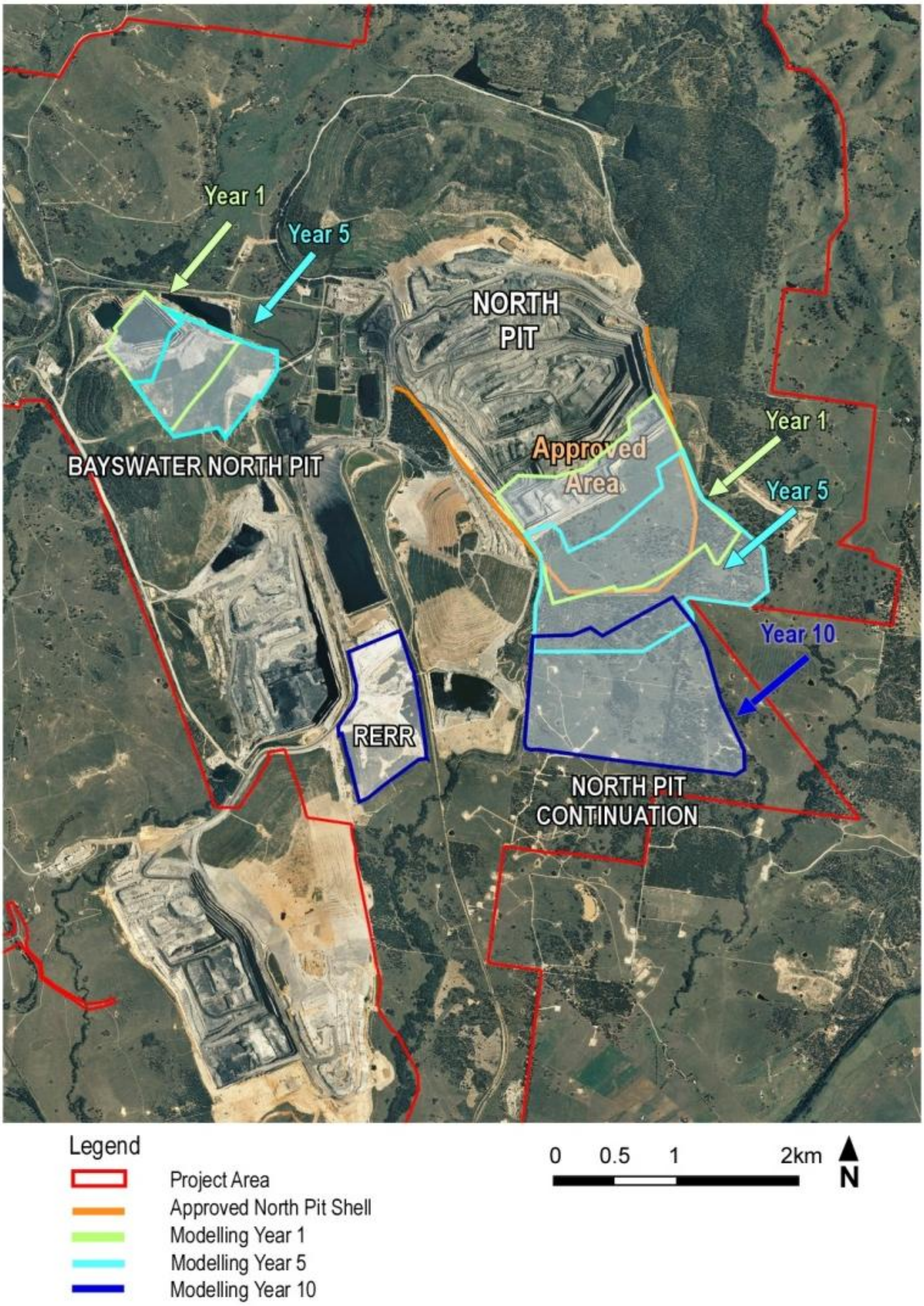

Figure 1B – The Project and Proposed North Pit Continuation, BNP and RERR Mining Area Boundaries by Selected Modelling Year

North Pit Continuation

Mining in the North Pit Continuation will allow for the extraction of approximately 74 Mt of ROM coal. The operational activities are scheduled for approximately 2016 – 2030.

The conceptual mine stage plans (years 1, 5 and 10) were selected as they are considered to represent indicative key features of the proposed mining progression for the Project as outlined below:

- **Year 1**: To allow for an efficient continuation of mining, mining activities (primarily pre strip operations) would be undertaken south of the currently approved North Pit shell during Year 1.
- **Year 5**: In Year 5, mining has progressed in a southerly direction closer to the residents of Middle Falbrook and Falbrook and represents the maximum production rate.
- **Year 10**: Year 10 represents the southernmost extent of the North Pit Continuation mining limit and the closest point to the residents of Middle Falbrook and Falbrook. The operational activities in this section will continue for a number of years until 2030; however the Year 10 pit boundary is still representative of the final pit boundary.

Currently, within the approved North Pit, coal is being extracted down to the Hebden seam (i.e. deeper seam, below the Bayswater seam). The North Pit Continuation area of the Project would include the extraction of coal seams down to the Bayswater seam and the existing mining lease limits in the southern section and to the Hebden seam in the northern section of the North Pit Continuation, see **Figure 2A**. The figure also highlights the Integra Underground target seams.

The detailed geology of the area has been provided according to the latest updated geological model (2014). The model indicates various bench sizes scheduled for blasting (variable thicknesses of interburden material between the coal seams). There are a total of nine coal seams, down to the Bayswater seam. The estimated thickness of the interburden material that will require blasting is presented in **Table 1**. It is anticipated that for the western section of the North Pit Continuation, blasting could involve maximum instantaneous charge masses (charge masses / MIC) in the order of 33 to 791 kg and for the eastern section of the North Pit Continuation 33 to 544 kg, refer to **Figure 2B** for the location of the western and eastern sections.

Table 1: Maximum Coal Seam / Interburden Thickness for the North Pit Continuation

Coal Seam	Seam / Interburden Thickness (m)	
	Seam	Interburden
Ravensworth V	1.9	
		4.7
Ravensworth U	1.7	
		16.1
Ravensworth T	1.0	
		13.9
Ravensworth S	0.9	
		11.1
Ravensworth Q	0.7	
		3.9
Ravensworth P	0.7	
		14.3
Ravensworth O	1.0	
		10.4
Ravensworth North / Ravensworth Lower	5.1	
		26.2
Ravensworth H / Ravensworth F	2.0	
		25.8
Bayswater	9.5	

Four (4) bench heights were selected for modelling to represent the possible range of blasting scenarios (4, 8, 15 and 20 metre benches). The blast design parameters used for modelling purposes are summarised in **Table 2**.

Table 2: Summary of Blast Design Parameters Used for Modelling Purposes for the North Pit Continuation

Bench Height	ANFO MIC (kg)	Heavy ANFO MIC (kg)	Explosive Column (m)	Stemming Column (m)
Applicable to Eastern and Western Sections				
4-m bench	33.0	49.4	1	3
8-m bench	-	250	5	3
15-m bench	363	544	11	4
Applicable to Western Section only				
20-m bench	527	791	16	4

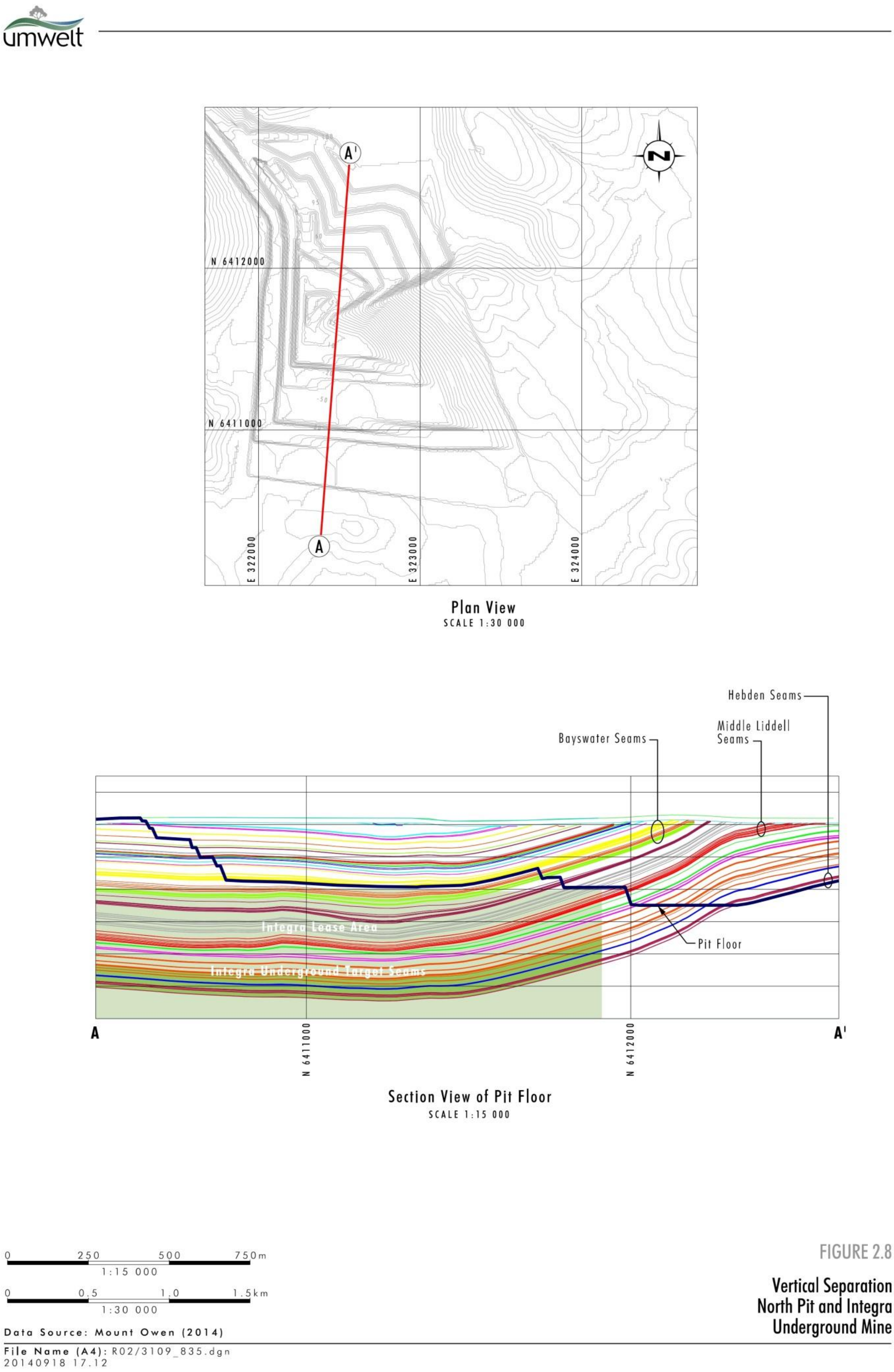

Figure 2A – Vertical Separation – North Pit Continuation and Integra Underground Mine (after Umwelt, 2013)

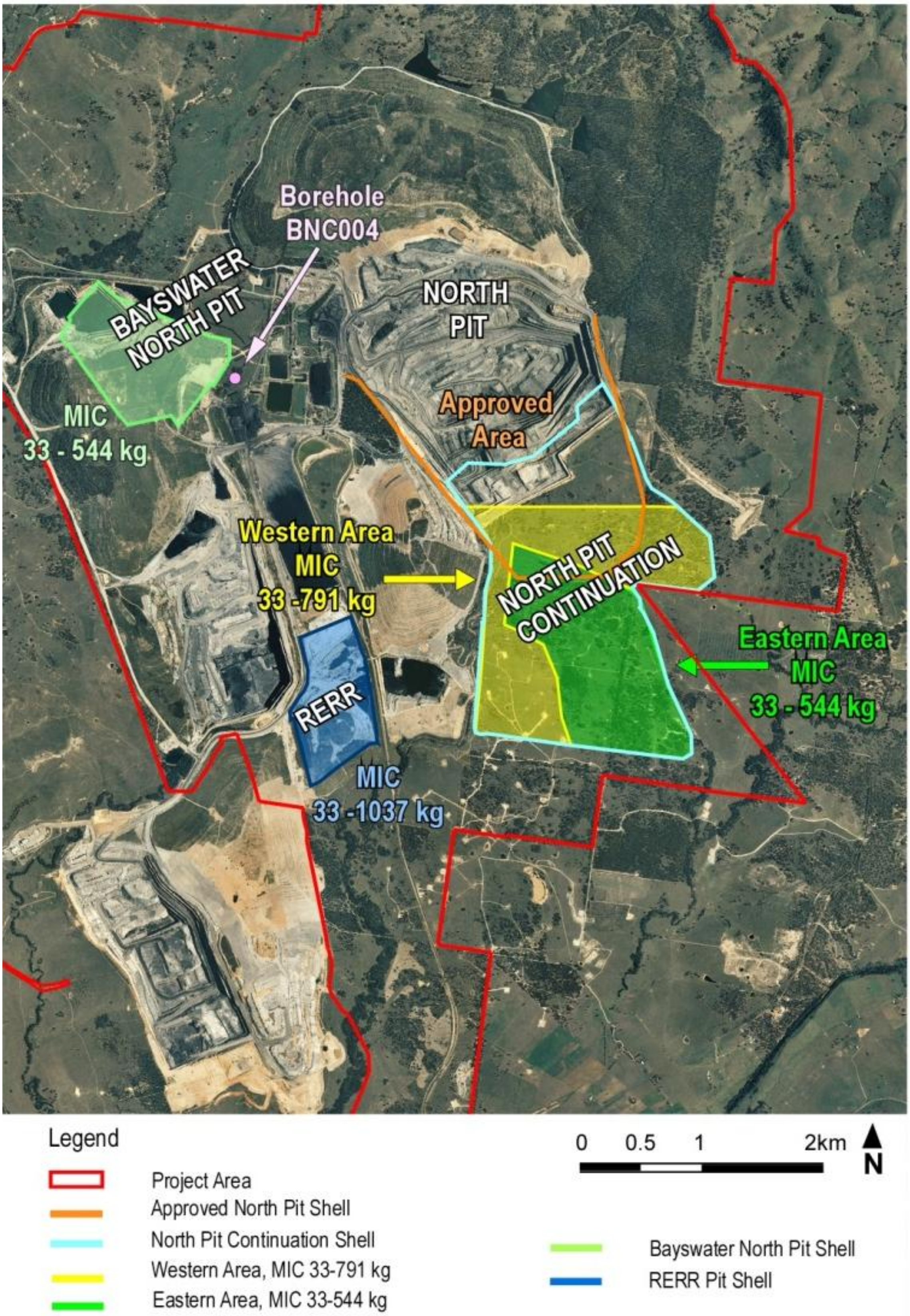

Figure 2B – Eastern and Western Areas of North Pit Continuation showing modelled Instantaneous Charge Masses

Bayswater North Pit

Mining in the BNP will allow for the extraction of approximately 12 Mt of ROM coal. The Project's operational activities in the BNP are scheduled for eight years from 2015 to 2022.

- **Year 1**: Commencement of coal extraction in the BNP approximately 1.5 km to the west of the old (i.e. already extracted) section of the North Pit boundary. The mining activities are proposed in the location of the Stage 3 Water Storage and adjacent RW Pit areas.
- **Year 5**: Mining has progressed in a south-easterly direction. The distance to the closest residents will be well in excess of 5 km. The Year 5 pit boundary is representative of the final pit boundary.

The BNP includes the extraction of coal seams down to the Bayswater seam. The size of the blasting benches for the BNP were based on representative borehole log data (i.e. borehole No. BNC004, see **Figure 2B** for the borehole location and **Appendix 1** for details). The information was used to estimate the thickness of the interburden material that will require blasting. There are a total of nine coal seams proposed to be extracted, down to the Bayswater seam. The estimated interburden thickness between coal seams varies from 0.5 to 29.6 metres, see **Table 3**. There is some variability in each seam's bench height, showing other thicknesses such as 3 and 16 metre interburden thicknesses.

Table 3: Maximum Coal Seam / Interburden Thickness for the Bayswater North Pit

Coal Seam	Seam / Interburden Thickness (m)	
	Seam	Interburden
		Top Soil - 12
		16
Ravensworth SU	0.2	
		6.1
Ravensworth S	1.2	
		19.0
Ravensworth Q, P, PL	1.9	
		16.7
Ravensworth O	1.0	
		1.5
Ravensworth NT, NU, NL	4.0	
		3.8
Ravensworth JL	0.5	
		2.5
Ravensworth HM	0.5	
		2.2
Ravensworth F	0.8	
		29.6
Bayswater Y1	0.6	
		1.4
Bayswater Y2A2, Y2A1	0.8	
		0.9
Bayswater Y2A2	0.5	
		0.2
Bayswater Y2BU	0.2	
		0.3
Bayswater Y2B, Y2BL, Y3, Y3L	2.4	
		0.4
Bayswater Y4U1	0.2	
		0.8
Bayswater Y4	1.1	
		5.8
Bayswater Y5U3	0.5	
		2.9
Bayswater Y5U1, Y5	1.7	

Blasting in the BNP will be limited to a 15 metre bench size, splitting the largest interburden of approximately 29.6 metres into two 15 metre benches. Subsequently, three bench heights were selected for modelling to represent the possible range of benches (4, 8 and 15 metre benches). It is anticipated that charge masses in the order of 33 to 544 kg will be used for the BNP. The blast design parameters used for modelling purposes are summarised in **Table 4**.

Table 4: Summary of Blast Design Parameters used for Modelling Purposes for Bayswater North Pit

Bench Height	ANFO MIC (kg)	Heavy ANFO MIC (kg)	Explosive Column (m)	Stemming Column (m)
4-m bench	33.0	49.4	1	3
8-m bench	-	250	5	3
15-m bench	363	544	11	4

RERR Mining Area

Mining in the RERR Mining Area will allow for the extraction of approximately 6 Mt of coal. The Project's operational activities are scheduled for 2022 – 2027 following sequentially after mining extraction in the BNP.

To assess the size of the blasting benches for the RERR Mining Area, detailed geological plans were used to estimate the thicknesses of the interburden material that will require blasting. Based on the current geological model, there are a total of nine coal seams proposed to be extracted, down to the Bayswater seam. The estimated interburden thickness between coal seams varies from 3.9 to 26.2 metres, see **Table 5**. There is however substantial variability in each seam's bench height, showing other thicknesses such as 11 and 16 metre interburden thicknesses.

Table 5: Maximum Coal Seam / Interburden Thickness for the RERR Pit

Coal Seam	Seam / Interburden Thickness (m)	
	Seam	Interburden
Ravensworth V	1.9	
		4.7
Ravensworth U	1.7	
		16.1
Ravensworth T	1.0	
		13.9
Ravensworth S	0.9	
		11.1
Ravensworth Q	0.7	
		3.9
Ravensworth P	0.7	

Coal Seam	Seam / Interburden Thickness (m)	
	Seam	Interburden
		14.3
Ravensworth O	1.0	
		10.4
Ravensworth North / Ravensworth Lower	5.1	
		26.2
Ravensworth H / Ravensworth F	2.0	
		25.8
Bayswater	9.5	

Subsequently, three bench heights were selected for modelling to represent the possible range of benches (4, 16 and 26 metre benches, with 26 metres corresponding to the maximum bench height). The blast design parameters used for modelling purposes are summarised in **Table 6**.

Table 6: Summary of Blast Design Parameters Used for Modelling Purposes for the RERR Mining Area

Bench Height	ANFO MIC (kg)	Heavy ANFO MIC (kg)	Explosive Column (m)	Stemming Column (m)
4-m bench	33.0	49.4	1	3
16-m bench	396	593	12	4
26-m bench	692	1,038	21	5

The above-listed charge masses for the North Pit Continuation, BNP and RERR areas have been used for modelling of blast impacts. The projected charge masses are based on the estimated blasting benches from the geological models and a proposed hole diameter of 229 mm.

All of these details were taken into consideration when undertaking vibration modelling.

The modelled charge masses provide a representative sample of the various blasting scenarios and their potential impact on the surrounding area, including the local community and infrastructure.

4.0 GROUND VIBRATION AND AIRBLAST PREDICTIVE MODELS

4.1 PREDICTIVE MODELS

4.1.1 Ground Vibration Predictive Model for Surface Conditions

A site law formula is used to predict expected ground vibration levels. The site law formula equation is specified as follows:

$$V = k\left(\frac{D}{\sqrt{m}}\right)^{a}$$

where:	V	=	Ground Vibration as vector Peak Particle Velocity (mm/s)
	D	=	Distance between charge and point of measurement (m)
	m	=	Maximum Instantaneous Charge (MIC), effective charge Mass per delay (kg)
	a	=	Site exponent
	k	=	Site constant

This site law formula recommended by Australian Standard (AS 2187.2-2006) is accepted by relevant NSW Government agencies as being appropriate for blast assessments for mining.

Also, it is highlighted that for ground vibration assessment the square-root scaled distance is more appropriate (than a cube-root scaled distance) and is widely used across the mining industry. This assessment has utilised the square-root scaled distance.

The ground vibration predictive model used in the assessment is based on vibration monitoring data collected from blasts undertaken within the Mount Owen Complex. The analysed sample of data is in excess of 170 blasts collected over a one year period in 2011/2012.

The vibration monitoring data used in the assessment includes results from the monitoring stations used by Mount Owen Complex. These stations are located to the south and south-west in relation to the North Pit Continuation area. The collated results were used to develop a site law formula, which is specific for Mount Owen conditions.

The site law analysis for Mount Owen conditions is presented in **Figure 3**. The parameters determined by the site law analysis, specific for Mount Owen conditions and thus governing ground vibration behaviour are as follows:

- site exponent $a = -1.6$
- site constant $k = 2{,}694$

The formula used for modelling purposes is therefore:

$$\mathbf{V} = 2694\left(\frac{D}{\sqrt{m}}\right)^{-1.6}$$

Where:

	V	=	Ground Vibration as vector Peak Particle Velocity (mm/s)
	D	=	Distance between charge and point of measurement (m)
	m	=	Maximum Instantaneous Charge (MIC), effective charge Mass per delay (kg)

The above specified model is based on a 95% confidence level. The 95% confidence level, advocated by the Australian and New Zealand Environment and Conservation Council (ANZECC) Guidelines (1990), allows for the inherent variation in emission levels. This is by allowing for a 5% exceedance of general criterion. Also, for completeness the site law diagram includes a median level (that is, Peak Particle Velocity (PPV) 50% level).

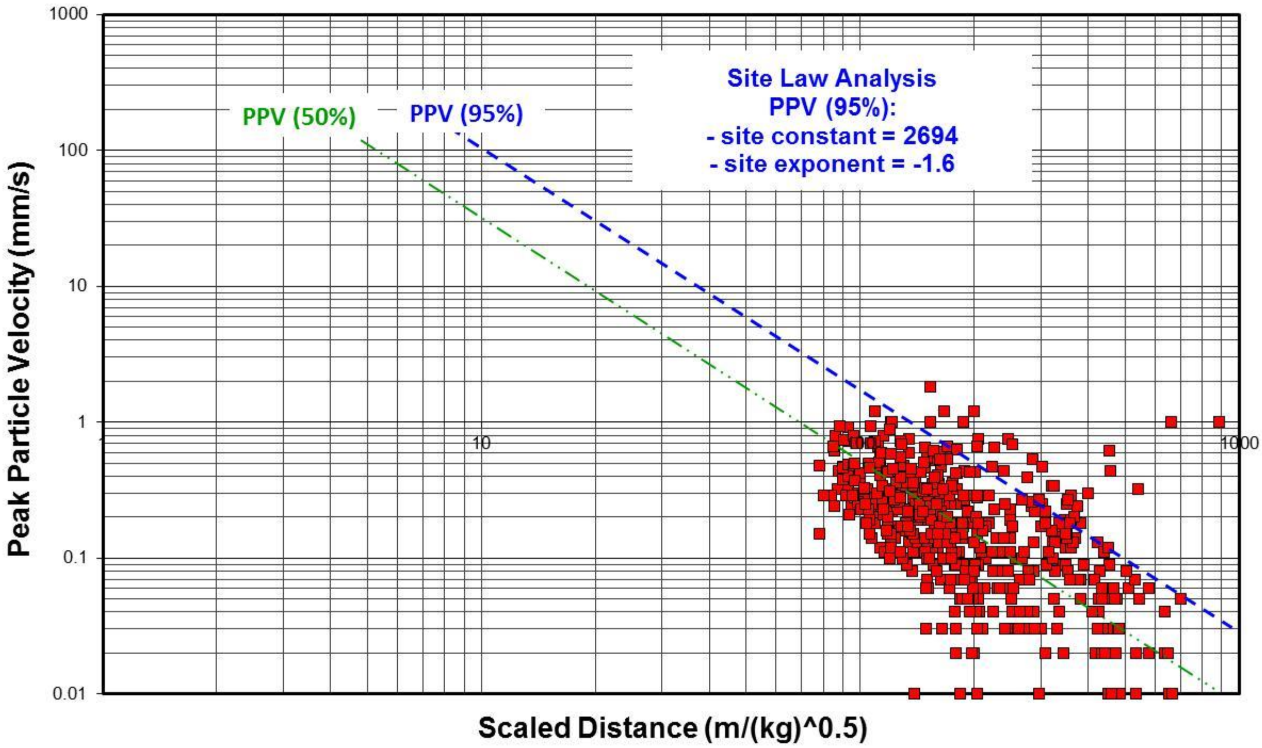

Figure 3 – Site Law Analysis for Mount Owen Surface Conditions

4.1.2 Ground Vibration Predictive Model to assess interaction with Integra Underground Workings

The vibration predictive model for underground workings used in the Project assessment was previously developed from underground monitoring data associated with blasting in the Eastern Rail Pit (ERP) in 2005/06 (Terrock, 2006), see **Figures 4A** and **4B**. The model is based on the actual ground vibration measurements undertaken at Integra Underground Mine (IUM). The measurements were collected in the underground workings and on the surface directly above. The ERP is located directly above the IUM and next to the North Pit Continuation Area, see **Figure 8**. Due to the proximity of the two open cut operations, the geological conditions are comparable and hence a similar blasting interaction can be expected. The developed underground vibration predictive model is therefore considered fully applicable for the Project. The parameters summarising the site law analysis (governing ground vibration behaviour) are specified as follows:

- site exponent a = -1.6
- site constant k = 842

The formula used for modelling purposes is therefore:

$$\mathbf{V} = 842\left(\frac{D}{\sqrt{m}}\right)^{-1.6}$$

Where:

	V	=	Ground Vibration as vector Peak Particle Velocity (mm/s)
	D	=	Distance between charge and point of measurement (m)
	m	=	Maximum Instantaneous Charge (MIC), effective charge Mass per delay (kg)

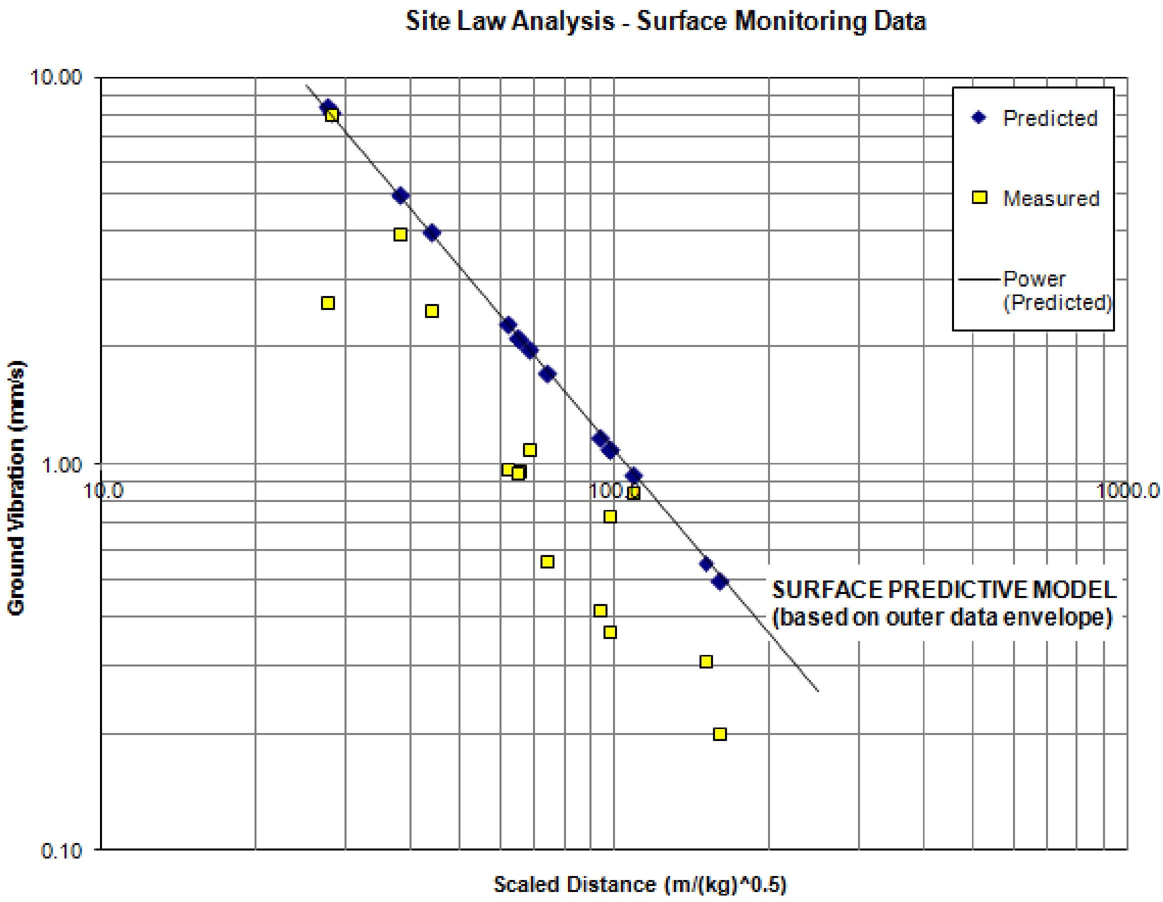

Figure 4A – Site Law for Surface Conditions – Based on Past Data (after Terrock's Report 2006)

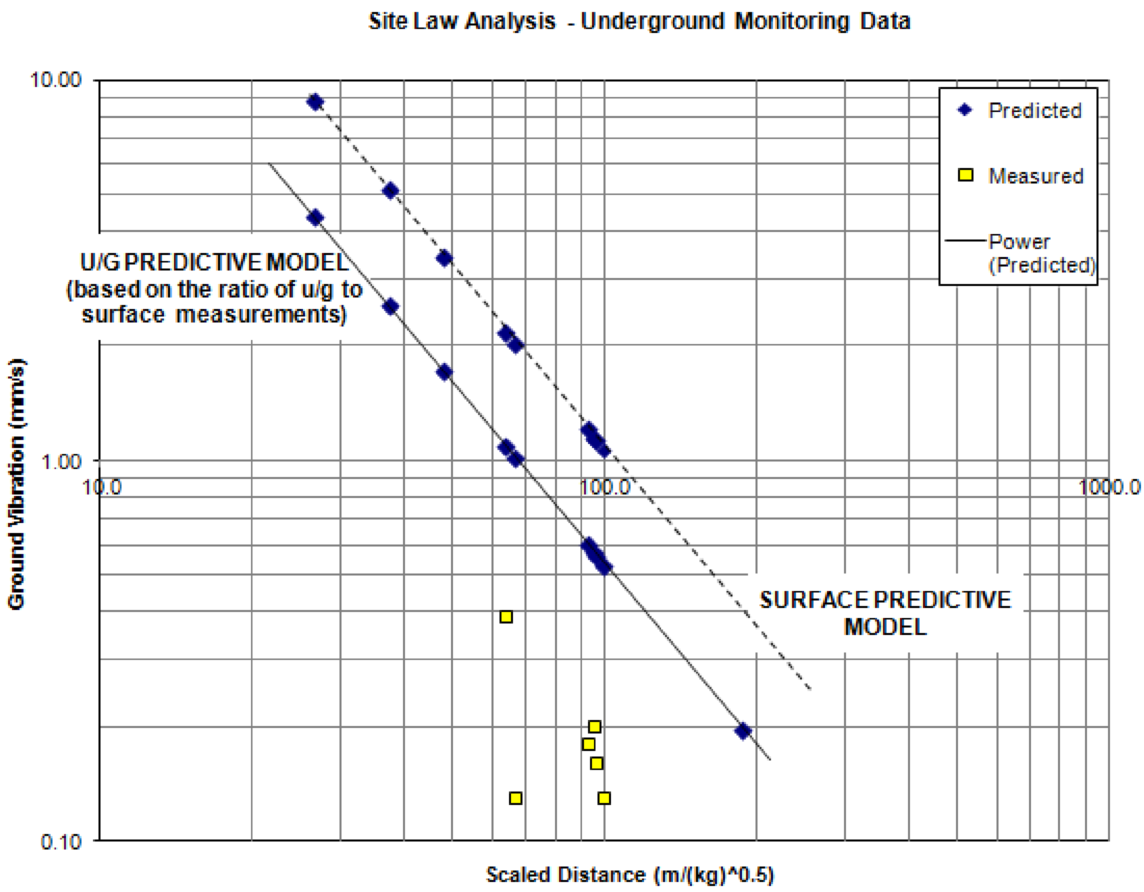

Figure 4B – Site Law for Underground Conditions – Based on Past Data (after Terrock's Report 2006)

4.1.3 Airblast Overpressure Predictive Model

To address the airblast overpressure (or air vibration) impacts from the Project on the adjacent area, an airblast predictive model has been developed. As in the ground vibration model, monitoring data has been used from the Mount Owen Complex blast monitoring stations to emulate potential airblast overpressure impacts. The analysed sample of data is in excess of 170 blasts collected over a one year period (2011/12). The results were recorded by stations located to the south and south-west of the North Pit.

The impact of the generated airblast levels from the source of the blast is generally guided by the sonic decay law recommended in the Australian Standard (AS 2187.2-2006). It is highlighted that for the airblast impact assessment, the cube-root scaled distance is more appropriate (than the square root used for ground vibration) as detailed in the Australian Standard (AS 2187.2-2006). This assessment has utilised the cube-root scaled distance.

The sonic decay formula is specified as follows:

$$\boldsymbol{P} = \boldsymbol{k}\left(\frac{D}{\sqrt[3]{m}}\right)^{a}$$

Where:	***P***	=	Peak Pressure (kPa)
	D	=	Distance between charge and point of measurement (m)
	m	=	Maximum Instantaneous Charge (MIC), effective charge Mass per delay (kg)
	a	=	Site exponent
	k	=	Site constant

It should be noted that there are some limitations to this type of assessment as air vibrations are affected by a number of factors. The major limitation is the exclusion of stemming column height in the analysis. Other factors not included in the model are topographical features, blast confinement and weather conditions. These limitations can be addressed through operational controls, such as an appropriate pre-blast check procedure (e.g. BMP, Section 3.1 Meteorological Assessment), which can, as an example, postpone blasting in adverse weather conditions.

The airblast monitoring measurements were analysed with the results presented in **Figure 5.** The airblast graph features two lines corresponding to the median of the measured data set marked as Sound Pressure Level (SPL) 50%, and SPL 95% (corresponding to 95% of the total data). As previously noted, the 5% criteria is utilised following ANZECC guidelines, which allow for the inherent variation in emission levels, by allowing a 5% exceedance of general criterion.

The recommended attenuation rate (rate at which sound decreases in intensity) is specified in Australian Standard, Explosives – Storage and use, Part 2 – Use of explosives (AS 2187 - 2006). The rate is specified as an 8.6 dBL decrease with a doubling of distance. To facilitate the recommended attenuation rate the forced exponent has been set to -1.45.

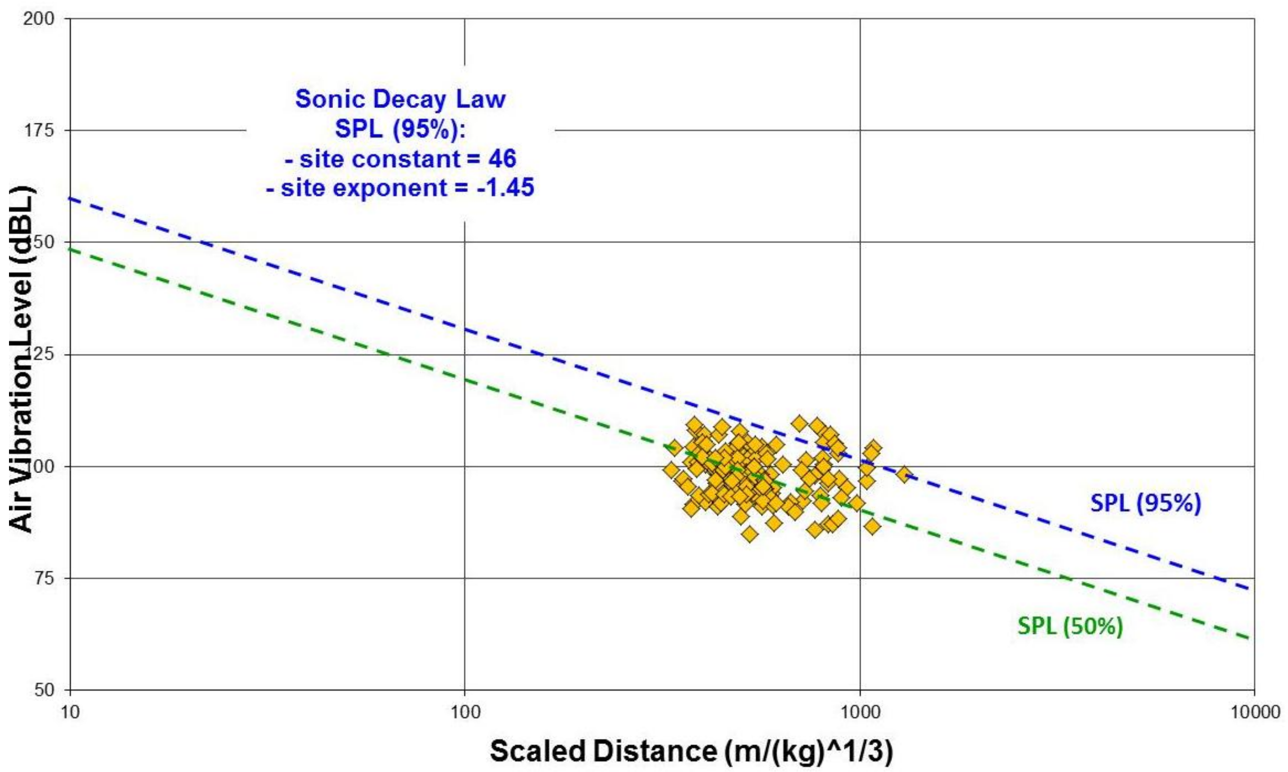

Figure 5 – Sonic Decay Law for Mount Owen Complex Conditions

The results were plotted and used to generate a sonic decay law analysis. Based on the assessment, the estimated sonic decay parameters are as follows:

- site exponent a = -1.45
- site constant k = 46

The formula used for modelling purposes is therefore:

$$P = 46\left(\frac{D}{\sqrt[3]{m}}\right)^{-1.45}$$

Where:	***P***	=	Peak Pressure (kPa)
	D	=	Distance between charge and point of measurement (m)
	m	=	Maximum Instantaneous Charge (MIC), effective charge Mass per delay (kg)

4.2 BLAST EMISSION CRITERIA

4.2.1 Criteria for Private Residences

Blast Emission Criteria for Human Comfort

To minimise the impact on residential receivers, the Environment Protection Authority (EPA) adopts the ANZECC (1990) guidelines "Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration". The guidelines indicate the following:

- The general criterion for ground vibration is 5 mm/s (PPV).
- The PPV of 5 mm/s may be exceeded on up to 5% of the total number of blasts over a period of 12 months. The upper PPV level of 10 mm/s should not be exceeded at any time.
- The general airblast criterion is 115 dBL (decibel Linear).
- The level of 115 dBL may be exceeded on up to 5% of the total number of blasts over a period of 12 months. The airblast level should not exceed 120 dBL at any time.

Mount Owen Complex currently apply these criteria to private residential locations, as specified in the Mount Owen Complex BMP (2012).

Blast Damage Criteria – Ground Vibration

In regards to blast damage criteria for residential structures, the Australian Standard AS 2187-2:2006, part entitled "Explosives – Storage and Use – Part 2: Use of Explosives" refers to other available standards, such as British Standard BS 7385-2:1993 and American (USBM) RI8507. The British Standard BS7385-2, document entitled "Evaluation and

Measurement for Vibration in Buildings – Part 2: Guide to Damage Levels from Ground Borne Vibration" and USBM RI8507 employ frequency-dependent limits, see **Appendix 2A.**

The blast damage criteria are frequency dependant; based on the British Standard BS 7385-2:1993 these range from 15 mm/s for low frequencies up to 50 mm/s for high frequencies, see **Appendix 2B.** The cited range is well above the blast emission criteria for human comfort (i.e. 5 mm/s and 10 mm/s) as discussed above. It therefore follows that when vibration limits for human comfort are imposed, compliance with blast damage criteria for residential structures will be achieved. Note that the British Standard indicates the lowest transient vibration value for cosmetic damage to be 15 mm/s at 4Hz (similar to typical blast frequency). Therefore by applying lower vibration limits of 5 and 10 mm/s negligible damage (if any) is to be expected.

Blast Damage Criteria – Airblast

The Australian Standard AS 2187-2:2006, specifies a conservative limit of 133 dBL as a safe level, implying no damage to the structure. AS 2187-2:2006 also specifies that the damage to windows (regarded as the most fragile/sensitive material) is considered improbable for airblast level exposures below 140 dBL.

In summary, it is inferred that for the Project, when vibration limits for human comfort are imposed (as specified above), by default, the possibility of structural damage for the surrounding residential structures is eliminated as the criteria for human comfort is more stringent.

4.2.2 Criteria for Infrastructure

The existing ground vibration and airblast emission criteria for various infrastructure subject to this assessment, including relevant heritage items are presented below.

St Clements Anglican Church, Camberwell

The applicable ground vibration limit criteria for St Clements Anglican Church, located in Camberwell village (approximately 4,760 metres - from the RERR Mining Area, the closest section of the Project), are specified in the Mount Owen Complex BMP (2012). These include 2 and 5 mm/s vibration limits with the following conditions attached:

- The PPV of 2 mm/s may be exceeded on up to 5% of the total number of blasts over a period of 12 months.
- The upper PPV level of 5 mm/s should not be exceeded at any time.

To address community concerns regarding protection of the church, Mount Owen have committed to designing blasts to achieve vibration levels to comply with the requirements of the BMP as outlined above.

St Clements Anglican Church is located in Camberwell village; therefore the same airblast limits of 115 / 120 dBL as for private residences apply.

Ravensworth Homestead

The Ravensworth Homestead is located 1,660 metres to the south-west of the BNP boundary; the closest section of the Project. The Ravensworth Homestead is a historic complex comprising of a farmhouse and several associated out-buildings. The recommended vibration limits specified in the Ravensworth East Mine conditions of consent (DA 52-03-99) are as follows:

- 126 dBL - for airblast; and
- 5 mm/s - for ground vibration

These vibration limits are used as assessment criteria for the Project.

Chain of Ponds Inn

The Chain of Ponds Inn is located 4,290 metres to the west of the BNP boundary; the closest section of the Project. The applicable vibration limits (based on the Liddell Coal Operation consent DA 305-11-01) are:

- 133 dBL - for airblast; and
- 10 mm/s - for ground vibration

These vibration limits are used as assessment criteria for the Project.

Former Dulwich Homestead (Kangory Homestead)

The Dulwich Homestead is located 5,150 metres to the south of the proposed North Pit Continuation boundary; the closest section of the Project. No specific applicable vibration limit criteria for Dulwich Homestead exist. For the purpose of this assessment, the criteria outlined above for Ravensworth Homestead has been adopted.

Hebden Public School (former)

The former Hebden Public School is located 1,030 metres to the north-west of the BNP boundary; the closest mining area of the Project. The condition of the site of the former Hebden Public School was assessed in detail and the vibration limit for the school building was estimated to be 16 mm/s. The details of the assessment are presented in an ESC report (Report No. UM-1411-040914, see **Appendix 4**).

This vibration limit is used as an assessment criterion for the Project.

John Winter Memorial

The John Winter Memorial is located 1,020 metres to the north-west of the BNP boundary; the closest mining area of the Project. The condition of the site was assessed in detail and the vibration limit was estimated to be 250 mm/s. The details of the assessment are presented in an ESC report (Report No. UM-1411-040914, see **Appendix 4**).

This vibration limit is used as an assessment criterion for the Project.

Power Transmission Lines

A ground vibration limit criterion of 50 mm/s (applicable to transmission power poles) is specified in the Mount Owen Complex BMP (2012).

The powerlines and transmission towers (i.e. free standing and tension towers) are owned by Ausgrid (NSW electricity grid operator).

More recently, Ausgrid generally uses a vibration limit of 100 mm/s for free standing towers. However, for tension towers (generally located at the corners/bends), lower vibration limits such as the 50 mm/s still apply.

It is proposed that the criteria of 50mm/s, as outlined in the BMP will be maintained for the Project. If further studies indicate that increased vibration limits can be achieved, an application to modify the approved limits will be made in consultation with the relevant authority.

Prescribed Dams

Tailings Pit 1 (TP1) is located approximately 650 metres at its closest point to the south-east of the BNP boundary; the closest section of the Project in modelled Year 1. The ground vibration limit applicable to the dam wall is 50 mm/s, as stated in the conditions imposed by Dam Safety Committee (DSC) (Annexure "D" Standard Mining Conditions, 2011). In addition, a minimum requirement requested by the DSC is that monitoring of blast vibration be undertaken at the closest point to the blast on the TP1 embankment crest. The TP1 dam is enclosed by two prescribed embankments; one on the southern and one on the eastern side. Mount Owen currently operates four (4) vibration monitoring stations located along the TP1 dam crest and toe on the southern and eastern sides; the locations are marked in Figure 7C. The 50 mm/s vibration limit is used as an assessment criterion for TP1.

The TP1 dam vibration limit is however applicable for a limited time only. This is due to the fact that the TP1 dam is scheduled to commence capping in 2016 and capping completed in approximately 2017. It has been indicated by the DSC that when capping is completed the TP1 dam can then be de-prescribed. Therefore, the limit would only be applicable for the period of 2016 to 2017 (i.e. 2016 is the Project commencement date). As such it is only applicable to blasting in the North Pit Continuation and BNP areas. The limit is not applicable to the RERR Mining Area as commencement of blasting activities is scheduled for 2022 (i.e. after the dam capping).

North Void Stage 2 water dam (NVS2) is located approximately 550 metres to the north-west of the BNP boundary, the closest section of the Project. NVS2 is bounded by two prescribed embankments, the southern embankment, adjacent to Hebden Rd, and the central embankment at the northern end of the dam. Emplacement in NVS2 has ceased due to being full. Capping of the tailings will commence from the Southern Embankment and is scheduled to begin in 2015.

BNP is within the Notification Area for NVS2 imposed by the DSC. Therefore the same requirements as for TP1 are relevant for NVS2. The 50 mm/s vibration limit is used as an assessment criterion for TP1.

Ashton Coal Proposed Clean Water Dam 1 is yet to be constructed. It is proposed to be located a substantial distance away from the RERR Mining Area boundary (the Project's closest location), approximately 3,810 metres. For the purpose of this assessment, the criterion outlined above for TP1 has been adopted for Dam 1.

Railway Lines - Main Northern Rail Line

The Main Northern Rail line is located approximately 3,060 metres from the RERR Mining Area (the Project's closest location). The applicable vibration limit as specified in the Mount Owen Complex BMP (2012) is:

- 25 mm/s - for ground vibration

This vibration limit is used as the assessment criterion for the Project. If further studies indicate that increased vibration limits can be achieved, an application to modify the approved limits will be made in consultation with the relevant authority.

Public Roads

A comprehensive overview of the existing allowable vibration limits for various infrastructure (including public roads and related facilities) was presented in ACARP Report No. C14057, "Effect of Blasting on Infrastructure". Following a wide-ranging review of various mines' experiences, conservative blasting levels for infrastructure were recommended. Ground vibration levels for roadways were specified as follows:

- Public Roads – 100 mm/s
- Concrete bridges – 100 mm/s (also referenced in Australian Standard AS2187.2-2006)

These vibration limits are used as assessment criteria for the Project. If further studies indicate that increased vibration limits can be achieved, an application to modify the approved limits will be made in consultation with the relevant authority.

Surface Mine Infrastructure

Guidelines in regards to ground vibration limits for mine infrastructure are provided in Australian Standard AS 2187.2-2006 "Explosives - Storage and Use - Part 2: Use of Explosives". These include:

- 25 mm/s for occupied non-sensitive sites, such as factories and commercial premises
- 100 mm/s for unoccupied structures of reinforced concrete or steel construction
- Frequency-dependent damage limit criteria for other structures or architectural elements that include masonry, plaster and plasterboard in their construction

The closest, non Glencore mine infrastructure is the Integra Underground Mine (IUM) surface infrastructure. It is located 2,880 to 4,260 metres from the closest blasting area, i.e. the North Pit Continuation boundary.

4.2.3 Criteria for Underground Workings

Blast emission criteria for underground mines are generally specified by two different measures, that is, Safe Vibration Limit and Vibration Limit for Personnel Withdrawal (Lewandowski et al. 2006).

"Safe Vibration Limit" for an Underground Mine:

This is a unique number mainly dependent upon rock strength characteristics. The safe vibration limit is specified as "the level at which there is a high probability of rock strata damage". To avoid any potential damage issues, blasting should be designed below the safe vibration limit using a target vibration level (that is, specified below the safe vibration limit).

The "safe vibration limit" is a site specific limit and varies for each underground mine. The limit is mainly dependent upon geological/geotechnical conditions of the rock strata, mainly related to the immediate roof/rib conditions. Generally this limit should be established for each particular mine when blasting is undertaken in close proximity to an underground mine, that is, generally within less than 1 km distance.

The previous study associated with blasting in the ERP, undertaken in 2005/2006 between Mount Owen and IUM revealed that the safe vibration limit for IUM conditions is in the order of 250 mm/s (Terrock, 2005). Prior to the commencement of blasting within 1 km of the IUM, it is recommended to review the specified limit for IUM conditions as underground conditions could have changed from those that the limit was based on.

"Vibration Limit for Personnel Withdrawal":

Based on extensive previous studies (Lewandowski et al 2006 and 2007), a 10 mm/s vibration level is recommended and used across a number of underground mines for personnel withdrawal and is specified as a human comfort level, and not as a safe vibration limit (which is higher). The same 10 mm/s vibration limit is recommended for the Integra underground mine. Note that the mine sections exposed to predicted vibration levels of less than 10 mm/s can be manned if notification to all personnel of the predicted vibration levels is given. Personnel must also be informed of excluded sections (that is, where vibrations exceed 10 mm/s).

This limit has been used across different mines with similar issues including IUM and Mount Owen.

The risks associated with two different operations acting simultaneously can be effectively managed via the implementation of a Blast Management System between the open cut and underground mines (Lewandowski et al 2007).

The system has been developed and implemented successfully in a number of different mines in the Hunter Valley with similar issues. Also, the same system has previously been implemented between Mount Owen and IUM for mining within the ERP. The assessment of blasting within the ERP (a small box cut) was undertaken in 2005/2006 and involved interaction between Mount Owen and IUM management.

A summary of blast emission criteria used in the assessment is presented in **Table 7.**

Table 7: Summary of Blast Emission Criteria

Location	Vibration Criteria (mm/s)	Airblast Criteria (dBL)
Private residences	5 / 10	115 / 120
St Clements Church, Camberwell	2 / 5	115 / 120
Ravensworth Homestead	5	126
Chain of Ponds Inn	10	133
Former Dulwich Homestead	5 (1)	126 (1)
Hebden Public School (former)	16	n/a
John Winter Memorial	250	n/a
Power Transmission Line	50	n/a
Tailings Pit 1	50	n/a
NVS2 Dam	50	n/a
Ashton Coal Clean Water Dam 1	50 (2)	n/a
Surface Mine Infrastructure occupied	25	n/a
Surface Mine Infrastructure unoccupied	100	n/a
Railway Lines	25	n/a
Public Roads	100	n/a
Concrete Bridges	100	n/a
Underground Workings	250 / 10 (3)	n/a

1 – adopted from Ravensworth Homestead

2 – adopted from Tailings Pit 1

3 – used for underground personnel withdrawal only

5.0 BLAST IMPACT ASSESSMENT

5.1 COMMUNITY

5.1.1 Introduction

This section addresses the potential impact of the Project on the residential receivers and surrounding area. The assessment is designed to address the potential airblast and ground vibration exposure which will be generated when undertaking blasting within the North Pit Continuation, BNP and the RERR Mining Area.

The Project includes the continuation of the current mining operations within the North Pit to the south of the currently approved North Pit mining limit and in two adjacent sections located to the west of the North Pit Continuation, i.e. the BNP and RERR Mining Area. As mining progresses within the North Pit Continuation, mining operations will move south and south east, closer to the localities of Falbrook and Middle Falbrook. The proposed mining activities in the BNP and RERR pits will be located a substantial distance from these local communities and from the private residences to the north west of the Project Area.

This assessment aims to address the air and ground vibration exposure levels that may potentially impact on the existing residences.

5.1.2 Location of Residential Receivers

The boundaries of the three mining areas of the Project and the location of the adjacent residences are highlighted in **Figure 6**. The residences shown in the figure are all privately owned (excludes mine owned residences).

The main points to note are as follows:

- The closest private residences representing the Falbrook and Middle Falbrook areas (i.e. located to the south-east of the North Pit Continuation) are predominately widely spread and as such, substantial variation in air and ground vibration levels can be expected. This will provide a large range of vibration exposures as the North Pit Continuation progresses south and the distances vary.
- Camberwell village represents the densest cluster of residences and is located approximately 4.1 km and 4.6 km to the south of the RERR and North Pit Continuation boundaries respectively.
- There is an area of widely spread residences in the north-east direction approximately 4.1 km from the North Pit Continuation pit shell.
- There is a relatively sparse group of residences in the north-west direction approximately 5.7 km from the BNP mining limit.

Mount Owen Complex operates thirteen (13) vibration monitoring stations designated to monitor blasting activities. For the locations of the existing monitoring stations refer to **Figure 6**. Mount Owen proposes to utilise the same monitoring stations for blast impact monitoring for the Project.

The stations are as follows:

- Residence ID 29 – mine owned
- Residence ID 123 – mine owned
- Residence ID 112 - private
- Green Acres (Residence ID 122 – private (with Glencore acquisition rights))
- Camberwell Village
- St Clements Church (Camberwell)
- Ravensworth Homestead
- TP1 Monitors (x 4)
- Railway
- Powerlines

The first five above-listed monitoring stations apply to monitoring blast impacts on residential receivers as per the existing development consent. These monitoring stations are placed in strategic locations and are considered representative for the local community.

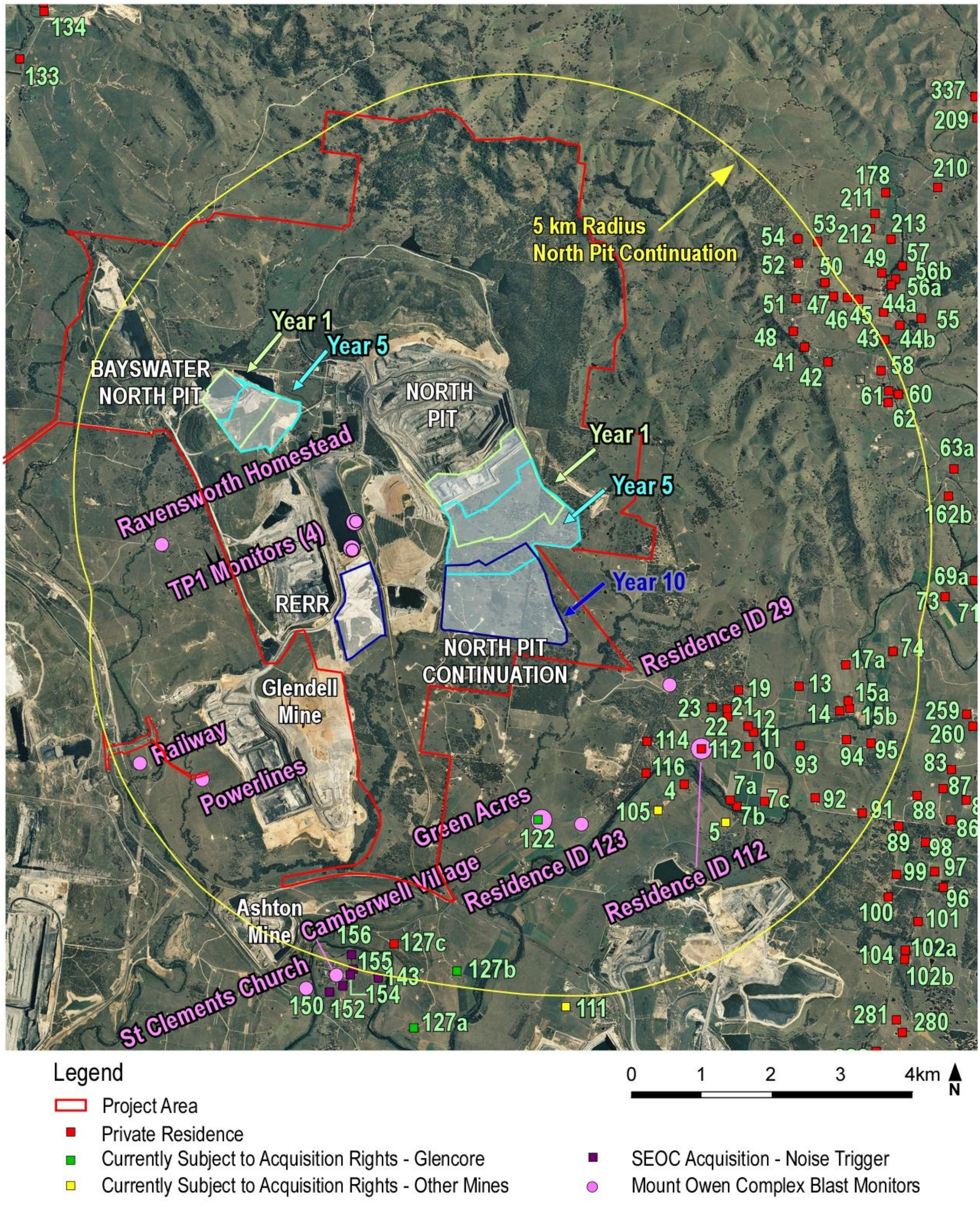

Figure 6 - Locations of Privately Owned Residences in relation to the proposed North Pit Continuation, BNP and RERR Mining Areas

As shown in **Figure 6** the closest monitoring station is represented by Res ID 29 (a Glencore-owned residence). This station is currently located at approximately 3 km from the existing and approved North Pit boundary and will be located approximately 1.6 km from the North Pit Continuation final mining limit.

5.1.3 Assessment Results

5.1.3.1 Ground vibration

To assess the potential impact of ground vibrations on residential receivers vibration modelling was undertaken. The modelling included an assessment of the ground vibration impacts utilising the site law formula specific for Mount Owen Complex conditions as explained in Section 4.1.1.

North Pit Continuation

The ground vibration modelling provides ground vibration estimates for private residences located within a 5 kilometre radius of the North Pit Continuation. The impact of blasting on private residences located beyond the 5 km radius is considered negligible (refer to **Figure 6**) and well below the applicable criteria.

The modelling undertaken included three different years of extraction, Year 1, 5 and 10. The results indicated that as mining progresses closer to the residential receivers, the impact will be gradual and steadily increase. The results were examined and collated into a table of results, presenting the worst case scenario, i.e. the highest impact irrespective of the modelled year. In other words, the table highlights the maximum vibrations that will be generated during the lifetime of the Project. These results are presented in **Table 8A**.

There were seven different simulations performed for each modelled year involving charge masses ranging from 33 to 791 kg.

The modelling included two different sections of the pit shell where blasting will involve different maximum charge masses. Blasting activities in the eastern section will use lower charge masses with a simulated potential maximum of 544 kg, while blasting in the western section was simulated with a potential maximum of 791 kg.

The modelling accounts for the worst case scenario, i.e. blasting from the eastern or southern boundary of the proposed mining limit corresponding to the minimum distance between the blast site and residential receivers.

Table 8A below shows the distances for each potentially affected residence within a 5 km radius and estimated vibrations using variable charge masses.

Table 8A: Results of Ground Vibration Modelling for privately owned Residences (within the 5 km radius) – Maximum Vibration Estimates; North Pit Continuation

Residential ID	Min. Distance (North Pit Cont.) (m)	Estimated Max Ground Vibration (mm/s)						
		MIC (kg)						
		ANFO 33	Heavy ANFO 49.4	ANFO 250	ANFO 363	Heavy ANFO 544	ANFO 527 (1)	Heavy ANFO 791 (1)
41	4,010	0.1	0.1	0.4	0.5	0.7	0.7	1.0
42	4,180	0.1	0.1	0.4	0.5	0.7	0.7	0.9
46	5,000	0.1	0.1	0.3	0.4	0.5	0.5	0.7
47	4,790	0.1	0.1	0.3	0.4	0.5	0.5	0.7
48	4,030	0.1	0.1	0.4	0.5	0.7	0.7	1.0
50	4,800	0.1	0.1	0.3	0.4	0.5	0.5	0.7
51	4,360	0.1	0.1	0.3	0.5	0.6	0.6	0.8
52	4,650	0.1	0.1	0.3	0.4	0.6	0.5	0.8
54	4,830	0.1	0.1	0.3	0.4	0.5	0.5	0.7
58	4,780	0.1	0.1	0.3	0.4	0.5	0.5	0.7
59	4,460	0.1	0.1	0.3	0.4	0.6	0.6	0.8
60	4,870	0.1	0.1	0.3	0.4	0.5	0.5	0.7
61	4,760	0.1	0.1	0.3	0.4	0.5	0.5	0.7
62	4,700	0.1	0.1	0.3	0.4	0.6	0.5	0.7
74	4,640	0.1	0.1	0.3	0.4	0.6	0.6	0.8
91	4,860	0.1	0.1	0.3	0.4	0.5	0.5	0.7
92	4,170	0.1	0.1	0.4	0.5	0.7	0.7	0.9
93	3,630	0.1	0.1	0.4	0.6	0.8	0.8	1.1
94	4,210	0.1	0.1	0.4	0.5	0.7	0.6	0.9
95	4,560	0.1	0.1	0.3	0.4	0.6	0.6	0.8
17A	3,980	0.1	0.1	0.4	0.5	0.7	0.7	1.0
10	2,990	0.1	0.2	0.6	0.8	1.1	n/a	n/a
	3,900 (2)	-	-	-	-	-	0.7	1.0
11	2,950	0.1	0.2	0.6	0.8	1.2	n/a	n/a
	3,890 (2)	-	-	-	-	-	0.7	1.0
12	2,840	0.1	0.2	0.7	0.9	1.2	n/a	n/a
	3,790 (2)	-	-	-	-	-	0.8	1.1
13	3,360	0.1	0.1	0.5	0.7	0.9	n/a	n/a
	4,350 (2)	-	-	-	-	-	0.6	0.8
14	4,000	0.1	0.1	0.4	0.5	0.7	0.7	1.0
15A	4,090	0.1	0.1	0.4	0.5	0.7	0.7	0.9
15B	4,130	0.1	0.1	0.4	0.5	0.7	0.7	0.9
19	2,540	0.2	0.2	0.8	1.1	1.5	n/a	n/a
	3,520 (2)	-	-	-	-	-	0.9	1.2
21	2,470	0.2	0.2	0.8	1.1	1.6	n/a	n/a
	3,420 (2)	-	-	-	-	-	0.9	1.2

Residential ID	Min. Distance (North Pit Cont.) (m)	Estimated Max Ground Vibration (mm/s)						
		MIC (kg)						
		ANFO 33	Heavy ANFO 49.4	ANFO 250	ANFO 363	Heavy ANFO 544	ANFO 527(1)	Heavy ANFO 791(1)
22	2,530	0.2	0.2	0.8	1.1	1.5	n/a	n/a
	3,470(2)	-	-	-	-	-	0.9	1.2
23	2,270	0.2	0.3	1.0	1.3	1.8	n/a	n/a
	3,220(2)	-	-	-	-	-	1.0	1.4
112	2,450	0.2	0.2	0.8	1.1	1.6	n/a	n/a
	3,310(2)	-	-	-	-	-	0.9	1.3
114	1,820	0.3	0.4	1.4	1.8	2.5	n/a	n/a
	2,600(2)	-	-	-	-	-	1.4	1.9
7	3,370	0.1	0.1	0.5	0.7	0.9	n/a	n/a
	4,174(2)	-	-	-	-	-	0.7	0.9
4	2,630	0.1	0.2	0.8	1.0	1.4	n/a	n/a
	3,390(2)	-	-	-	-	-	0.9	1.3
5	3,430	0.1	0.1	0.5	0.7	0.9	n/a	n/a
	4,190(2)	-	-	-	-	-	0.6	0.9
116	2,190	0.2	0.3	1.0	1.4	1.9	n/a	n/a
	2,870(2)	-	-	-	-	-	1.2	1.6
105	2,730	0.1	0.2	0.7	1.0	1.3	n/a	n/a
	3,370(2)	-	-	-	-	-	0.9	1.3
122	2,520	0.2	0.2	0.8	1.1	1.5	n/a	n/a
	2,670(2)	-	-	-	-	-	1.3	1.8
127B	4,790	0.1	0.1	0.3	0.4	0.5	0.5	0.7
127C	4,530	0.1	0.1	0.3	0.4	0.6	0.6	0.8
155	4,990	0.1	0.1	0.3	0.4	0.5	0.5	0.7
156	4,800	0.1	0.1	0.3	0.4	0.5	0.5	0.7

(1) – charge mass applicable only to the western section of the pit shell

(2) – minimum distance to the western section of the pit shell

The results of the ground vibration modelling for the private residential receivers due to blasting in the North Pit Continuation are summarised as follows:

- The potential ground vibration levels experienced by the nearest private residences will be gradual and steadily increase as mining progresses southward. Generally for the majority of residences, the least impact is expected for modelled Year 1 while the highest impact was identified for modelled Year 10.
- The impact of vibration will be highly variable dependent upon charge mass; with negligible impact for low charge masses, i.e. 33 to 150 kg and increasing for higher charge masses.
- The estimated vibration exposure for all residences using variable charge masses of 33 to 544 kg (in the eastern section of the North Pit Continuation pit shell) is in the

order of 0.1 to 2.5 mm/s. This is below the applicable vibration limits specified as 5 mm/s (for 95% of blasts) and 10 mm/s (not to be exceeded).

- The estimated vibration exposure for all residences using variable charge masses of 33 to 791 kg (applicable to the western section of the pit shell) is in the order of 0.1 to 1.9 mm/s. This is also below the applicable vibration limits specified as 5 mm/s (for 95% of blasts) and 10 mm/s (not to be exceeded).

Bayswater North Pit

The BNP is located a substantial distance from the nearest private residences, in excess of 5 km. As indicated above, considering the proposed blasting parameters, the expected ground vibration impact will be either low or negligible. To demonstrate the accuracy of this assumption a sample of the closest residences in various directions was selected to obtain vibration estimations and therefore provide indicative vibration exposures for each area of concern.

The results were examined and collated into a table of results, presenting the worst case scenario for the closest representative residences, i.e. the highest impact irrespective of the modelled year. In other words, the table highlights the maximum vibrations that will be generated during the lifetime of the Project. These results are presented in **Table 8B**.

There were five different simulations performed for the final pit boundary involving charge masses ranging from 33 to 544 kg. The modelling accounts for the worst case scenario, i.e. blasting from the boundary of the BNP mining limit corresponding to the minimum distance between the blast site and the residential receivers.

Table 8B: Results of Ground Vibration Modelling for Privately Owned Residences – Maximum Vibration Estimates; Closest Residences around BNP

Residential ID	Min. Distance (m)	Direction from BNP	Estimated Max Ground Vibration (mm/s)				
			MIC (kg)				
			ANFO 33	Heavy ANFO 49.4	ANFO 250	ANFO 363	Heavy ANFO 544
133	5,280	NWN	< 0.1	0.1	0.2	0.3	0.5
134	5,700	NWN	< 0.1	0.1	0.2	0.3	0.4
41	7,210	E	< 0.1	< 0.1	0.1	0.2	0.3
48	7,100	E	< 0.1	< 0.1	0.2	0.2	0.3
51	7,210	E	< 0.1	< 0.1	0.1	0.2	0.3
23	7,170	SE	< 0.1	< 0.1	0.2	0.2	0.3
114	6,750	SE	< 0.1	< 0.1	0.2	0.2	0.3
127C	7,210	SES	< 0.1	< 0.1	0.1	0.2	0.3
156	7,240	SES	< 0.1	< 0.1	0.1	0.2	0.3

The results of the ground vibration modelling for the private residential receivers due to blasting in the BNP are summarised as follows:

- The estimated vibration exposure for all residences using variable charge masses of 33 to 544 kg is no higher than 0.5 mm/s and is considered low / negligible. This is well below the applicable vibration limits specified as 5 mm/s (for 95% of blasts) and 10 mm/s (not to be exceeded) in the licence conditions.

RERR Mining Area

The ground vibration modelling provides ground vibration estimates for private residences located within a 5 kilometre radius of the RERR Mining Area. The impact of blasting on private residences located beyond the 5 km radius is considered negligible for the considered blasting parameters, as discussed above.

This assessment for the RERR Mining Area included six different vibration simulations involving charge masses ranging from 33 to 1,038 kg based on 4, 16 and 26 metre benches.

The estimated maximum vibration levels for the closest residential receivers of concern are summarised in **Table 8C.**

The projected ground vibrations due to blasting with low charge masses of 33 and 49.4 kg showed low vibration levels of approximately 0.1 mm/s for all assessed residences. The impact is considered as low / negligible.

The projected ground vibration levels when blasting charge masses of 396 and 593 kg indicated that vibration levels for all residences should be in the order of 1 mm/s or less. However, the predicted vibration exposure for the majority of the residences is expected to be less than 0.7 mm/s**.**

The ground vibration modelling revealed that the impact of blasting charge masses of 692 and 1,038 kg on the analysed private residences is also low. The indicative ground vibration levels for the closest residences (under 4,230 metres from the blast) are generally in the order of 1.1 to 1.6 mm/s.

Table 8C: Results of Ground Vibration Modelling for privately owned Residences (within the 5 km radius) – Maximum Vibration Estimates; RERR Mining Area

Residential ID	Min. Distance (RERR) (m)	Estimated Max Ground Vibration (mm/s)					
		MIC (kg)					
		ANFO 33	Heavy ANFO 49.4	ANFO 396	Heavy ANFO 593	ANFO 692	Heavy ANFO 1,038
21	4,970	0.1	0.1	0.4	0.5	0.6	0.8
22	5,000	0.1	0.1	0.4	0.5	0.6	0.8
23	4,770	0.1	0.1	0.4	0.6	0.7	0.9
112	4,790	0.1	0.1	0.4	0.6	0.7	0.9
114	4,020	0.1	0.1	0.6	0.8	0.9	1.2
105	4,620	0.1	0.1	0.4	0.6	0.7	1.0
4	4,760	0.1	0.1	0.4	0.6	0.7	0.9
116	4,210	0.1	0.1	0.5	0.7	0.8	1.1
122	3,400	0.1	0.1	0.7	1.0	1.1	1.6
127 b	4,700	0.1	0.1	0.4	0.6	0.7	0.9
127c	4,100	0.1	0.1	0.5	0.7	0.8	1.2
143	4,550	0.1	0.1	0.5	0.6	0.7	1.0
150	4,740	0.1	0.1	0.4	0.6	0.7	0.9
152	4,630	0.1	0.1	0.4	0.6	0.7	1.0
154	4,480	0.1	0.1	0.5	0.6	0.7	1.0
155	4,390	0.1	0.1	0.5	0.7	0.7	1.0
156	4,230	0.1	0.1	0.5	0.7	0.8	1.1

The results of the ground vibration modelling for the RERR Mining Area for the private residential receivers are summarised as follows:

- The predicted vibration levels for blasting in the RERR Mining Area for the anticipated charge masses of 33 to 1,038 kg revealed either low or negligible vibration impact on the surrounding private residences. The expected vibration levels for the majority of blasting should be below 0.7 mm/s. The vibration levels should not exceed 1.6 mm/s for the closest residence even when considering the worst case scenario, i.e. the deepest bench and blasting from the edge of the proposed RERR Mining Area.
- These predictions are substantially below the blast emission criteria applicable for private residences including the 5 mm/s (allowed for 95% of blasts) and the 10 mm/s (not to be exceeded) as applicable to the proposed RERR Mining Area.

5.1.3.2 Airblast

To perform the airblast overpressure modelling the sonic decay formula specified in Section 4.1.3 was utilised. The modelling was performed for each of the mining areas (i.e. North Pit Continuation, BNP and RERR) and applicable modelled years of extraction. The results were examined and collated into three separate tables representing the worst case scenario, i.e. the highest impact irrespective of the modelled year. In addition, the analysis reflects the potential highest impact scenario, that is, initiation of the charge mass from the edge of the modelled area / pit. In other words, the tables highlight the maximum vibrations that will be generated during the lifetime of the Project.

North Pit Continuation

The impact of blasting is highly variable as it depends on the actual distance to the blast. The distance between the residences and the blasting zone depends on the year of mining extraction. The modelling undertaken included three different years of extraction, i.e. Years 1, 5 and 10. As mining progresses from Year 1, through Year 5 to Year 10, increasing airblast emissions are predicted. The results of the airblast modelling for private residences located within a 5 km radius are presented in **Table 9A.**

Table 9A: Results of Airblast Modelling for Privately Owned Residences (within the 5 km radius) – Maximum Airblast Estimates; North Pit Continuation

Residential ID	Min. Distance (North Pit Cont.) (m)	Estimated Max Airblast Overpressure (dBL)						
		MIC (kg)						
		ANFO 33	Heavy ANFO 49.4	ANFO 250	ANFO 363	Heavy ANFO 544	ANFO 527(1)	Heavy ANFO 791(1)
41	4,010	97	99	106	107	109	109	111
42	4,180	97	99	105	107	109	109	110
46	5,000	95	96	103	105	106	106	108
47	4,790	95	97	104	105	107	107	109
48	4,030	97	99	106	107	109	109	111
50	4,800	95	97	104	105	107	107	108
51	4,360	96	98	105	106	108	108	110
52	4,650	96	97	104	106	107	107	109
54	4,830	95	97	104	105	107	107	108
58	4,780	95	97	104	105	107	107	109
59	4,460	96	98	105	106	108	108	109
60	4,870	95	97	104	105	107	107	108
61	4,760	95	97	104	105	107	107	109
62	4,700	95	97	104	105	107	107	109
74	4,640	96	97	104	106	107	107	109
91	4,860	95	97	104	105	107	107	108
92	4,170	97	99	105	107	109	109	110
93	3,630	99	100	107	109	110	110	112

Residential ID	Min. Distance (North Pit Cont.) (m)	Estimated Max Airblast Overpressure (dBL)						
		MIC (kg)						
		ANFO 33	Heavy ANFO 49.4	ANFO 250	ANFO 363	Heavy ANFO 544	ANFO 527(1)	Heavy ANFO 791(1)
94	4,210	97	99	105	107	109	108	110
95	4,560	96	97	104	106	108	107	109
17A	3,980	98	99	106	108	109	109	111
10	2,990	101	103	110	111	113	n/a	n/a
	3,900(2)	-	-	-	108	-	109	111
11	2,950	101	103	110	111	113	n/a	n/a
	3,890(2)	-	-	-	108	-	109	111
12	2,840	102	103	110	112	114	n/a	n/a
	3,790(2)	-	-	-	108	-	110	111
13	3,360	100	101	108	110	111	n/a	n/a
	4,350(2)	-	-	-	106	-	108	110
14	4,000	97	99	106	108	109	109	111
15A	4,090	97	99	106	107	109	109	111
15B	4,130	97	99	106	107	109	109	110
19	2,540	103	105	112	113	115	n/a	n/a
	3,520(2)	-	-	-	109	-	111	112
21	2,470	104	105	112	114	115	n/a	n/a
	3,420(2)	-	-	-	109	-	111	113
22	2,530	103	105	112	113	115	n/a	n/a
	3,470(2)	-	-	-	109	-	111	113
23	2,270	105	106	113	115	116	n/a	n/a
	3,220(2)	-	-	-	110	-	112	114
112	2,450	104	105	112	114	115	n/a	n/a
	3,310(2)	-	-	-	110	-	111	113
114	1,820	107	109	116	117	119	n/a	n/a
	2,600(2)	-	-	-	113	-	115	116
7	3,370	100	101	108	110	111	n/a	n/a
	4,174(2)	97	99	105	107	-	109	110
4	2,630	103	104	111	113	114	n/a	n/a
	3,390(2)	-	-	-	110	-	111	113
5	3,430	99	101	108	109	111	n/a	n/a
	4,190(2)	-	-	-	107	-	109	110
116	2,190	105	107	114	115	117	n/a	n/a
	2,870(2)	-	-	-	112	-	113	115
105	2,730	102	104	111	112	114	n/a	n/a
	3,370(2)	-	-	-	110	-	111	113
122	2,520	103	105	112	113	115	n/a	n/a
	2,670(2)	-	-	-	113	-	114	116
127B	4,790	95	97	104	105	107	107	109
127C	4,530	96	98	104	106	108	108	109

Residential ID	Min. Distance (North Pit Cont.) (m)	Estimated Max Airblast Overpressure (dBL)						
		MIC (kg)						
		ANFO 33	Heavy ANFO 49.4	ANFO 250	ANFO 363	Heavy ANFO 544	ANFO 527[(1)]	Heavy ANFO 791[(1)]
155	4,990	95	96	103	105	106	106	108
156	4,800	95	97	104	105	107	107	108

(1) – charge mass applicable only to the western section of the pit shell

(2) – minimum distance to the western section of the pit shell

– shaded cells show values exceeding a 115 dBL level

The results of the overpressure modelling for the private residential receivers due to blasting in the North Pit Continuation are summarised as follows:

- The airblast levels experienced by the residences will be gradual and steadily increase as the mine progresses south. Generally, for the majority of residences, the least impact is expected for modelled Year 1 while the highest impact was identified for modelled Year 10.
- The impact of airblast will be highly variable dependent upon charge mass; with low/negligible impact for low charge masses, i.e. 33 to 49.4 kg ranging between 95 and 109 dBL.
- As detailed in **Table 9A**, the applicable criteria of 115 dBL can be achieved at the residential receivers under a range of operational scenarios.
- The estimated airblast exposure for residences using variable charge masses of 33 to 544 kg (applicable to the eastern section of the North Pit Continuation) is in the order of 95 to 119 dBL. The model indicates that by decreasing the charge mass, the airblast emission can be effectively managed reducing the predicted emissions to below the required limit of 115 dBL (for 95% of blasts). For example, based on the table above, the predicted airblast level for the property ID 23 is 116 dBL at 2,270 m to the blast (this distance corresponds to blasting in modelled Year 10 and the edge of the North Pit Continuation). The airblast level can be managed by decreasing the charge mass to achieve a predicted airblast value of 113 dBL which is below the 115 dBL airblast limit.
- The projected airblast levels due to blasting in the western section of the North Pit Continuation present lower airblast levels in comparison to the eastern section. Potential airblast levels are in the order of 95 to 116 dBL. The model indicates that by decreasing the charge mass the airblast emission can be effectively managed with predicted emissions being below the required limit of 115 dBL (for 95% of blasts). For example, based on the table above, when blasting with a higher charge mass of 791 kg the predicted airblast level for the property ID 122 is 116 dBL at 2,670 m to the blast (this distance corresponds to the final year of blasting and the edge of the North Pit Continuation). The airblast level can then be managed by decreasing the charge mass to enable the blast to be below the 115 dBL airblast limit.

- The results of the modelling for the eastern and western sections show that the impact on the surrounding residences can be managed effectively (to remain below the imposed airblast criteria) by using appropriate charge masses. This can be achieved either by blasting smaller benches or by the application of deck charges, together with the application of precise initiation timing.
- As the Project reaches greater depths, some topographical shielding will emerge due to a change in the contours of the area. This will assist with impacts associated with airblast and lessen the impact on the surrounding community.
- The proposed Management Measures for the Project are discussed further in Section 6.0.

Bayswater North Pit

The impacts of blasting and the generated airblast emissions on the surrounding community have been addressed by airblast vibration modelling. The modelling included two different stages of extraction, i.e. Year 1 and 5. The results of the airblast modelling are presented in **Table 9B.** The table highlights the maximum airblast that will be generated during the life of the BNP.

As shown in **Table 9B**, the closest residence is located approximately 5,280 metres from the BNP. As stated in the previous section, considering the proposed blasting parameters, the expected airblast exposure for residences which are located in excess of 5 km will be low to negligible. To demonstrate the accuracy of this assumption a sample of the closest residences in various directions of increased residential density was selected. Vibration estimations for these receivers were generated, therefore providing indicative vibration exposures for each area of concern.

Table 9B: Results of Airblast Modelling for Privately Owned Residences – Maximum Airblast Estimates; Closest Residences around BNP

Residential ID	Min. Distance (m)	Direction from BNP	Estimated Max Airblast Overpressure (dBL)				
			MIC (kg)				
			ANFO	Heavy ANFO	ANFO	ANFO	Heavy ANFO
			33	49.4	250	363	544
133	5,280	NWN	94	96	102	104	106
134	5,700	NWN	93	95	101	103	105
41	7,210	E	90	92	99	100	102
48	7,100	E	90	92	99	100	102
51	7,210	E	90	92	99	100	102
23	7,170	SE	90	92	99	100	102
114	6,750	SE	91	93	99	101	103
127C	7,210	SES	90	92	99	100	102
156	7,240	SES	90	92	98	100	102

The results of the overpressure modelling for the private residential receivers due to blasting in the BNP are summarised as follows:

- The impact of airblast will be highly variable dependent upon charge mass; with low/negligible impact ranging between 90 and 106 dBL for all blasting scenarios within the BNP. The model indicates that airblast emission can be effectively managed with predicted emissions being below the required limit of 115 dBL (for 95% of blasts).
- It is envisaged that as the BNP reaches greater depths, some topographical shielding will emerge due to a change in the topographical features of the area. This will further assist with impacts associated with airblast and lessen the impact on the surrounding community.

RERR Mining Area

As extraction in the RERR Mining Area does not start until 2022, the modelling is based on the modelled Year 10 of the Project. The analysis includes assessment for the final RERR extent. The analysis provides estimates for the potential highest impact scenario, that is, initiation of the charge mass from the edge of the proposed RERR Mining Area.

The air vibration modelling provides airblast estimates for private residences located within a 5 kilometre radius of the RERR Mining Area. The residences within this distance are located mainly to the south with some to the south-east and east. Accounting for the charge masses to be used, the impact of blasting on private residences located beyond the 5 km radius is considered negligible and therefore there is no need for detailed analysis. The results of the airblast modelling are presented in **Table 9C.**

The projected overpressure levels for the residential receivers due to blasting using charge masses of 33 to 49.4 kg are in the order of 95 to 101 dBL. The blast impact generated is classified as negligible.

The predicted airblast levels when blasting charge masses of 396 to 593 kg are in the order of 106 to 112 dBL.

The projected airblast levels for the deepest bench using charge masses of 692 to 1,038 kg revealed that the impact on the analysed residences is acceptable (below the airblast criteria of 115 dBL). The indicative air blast level for the closest residence is in the order of 112 to 114 dBL. The far distance residential receivers (i.e. more than 5 km) will be exposed to airblast levels of less than 106 dBL.

Table 9C: Results of Airblast Modelling for Privately Owned Residences (within the 5 km radius) – Maximum Airblast Estimates; RERR Mining Area

Residential ID	Min. Distance (RERR) (m)	Estimated Max Airblast Overpressure (dBL)					
		MIC (kg)					
		ANFO 33	Heavy ANFO 49.4	ANFO 396	Heavy ANFO 593	ANFO 692	Heavy ANFO 1,038
21	4,970	95	96	105	107	108	109
22	5,000	95	96	105	107	107	109
23	4,770	95	97	106	107	108	110
112	4,790	95	97	106	107	108	110
114	4,020	97	99	108	110	110	112
105	4,620	96	97	106	108	108	110
4	4,760	95	97	106	107	108	110
116	4,210	97	99	107	109	110	111
122	3,400	100	101	110	112	112	114
127 b	4,700	95	97	106	108	108	110
127c	4,100	97	99	108	109	110	112
143	4,550	96	98	106	108	109	110
150	4,740	95	97	106	107	108	110
152	4,630	96	97	106	108	108	110
154	4,480	96	98	106	108	109	111
155	4,390	96	98	107	108	109	111
156	4,230	97	98	107	109	110	111

The results of the overpressure modelling for the private residential receivers due to blasting in the RERR Mining Area are summarised as follows:

- The impact of airblast is highly dependent upon charge mass; with low/negligible impact ranging between 95 and 114 dBL for all blasting scenarios within the RERR Mining Area. The model indicates that the airblast emissions can be effectively managed with predicted emissions being below the required limit of 115 dBL.
- As the RERR Mining Area reaches greater depths, some topographical shielding will emerge due to a change in the topographical features of the area. This will further assist with impacts associated with airblast and lessen the impact on the surrounding community.

5.1.3.3 Flyrock and Other Issues

Mount Owen operates using a standard 500 metre exclusion zone (all land within a 500 metre radius of the North Pit Continuation, BNP and RERR Mining Area is owned by Mount Owen, with the exception of the public road, i.e. Hebden Road, in the vicinity of the BNP). The 500 metre distance is considered appropriate for managing the risk of flyrock, and it is used widely across the mining industry. More details in regards to each mining area and the associated impacts are provided below.

The blasting activities related to mining in the North Pit Continuation will overlap with mining operations within the BNP, and the RERR Mining Area. Notwithstanding, Mount Owen will not blast simultaneously at the North Pit Continuation, BNP or RERR Mining Area.

The potential impacts of blast fume are assessed separately in the Air Quality Impact Assessment for the Project.

North Pit Continuation

The issue of flyrock impact on adjacent residences is considered negligible. The closest private residence (residence 114) will be located in excess of 1.8 km from the North Pit Continuation boundary.

Similarly, there is no risk of flyrock to infrastructure (including all items assessed in this report) as they will be located a substantial distance from the North Pit Continuation boundary (all in excess of a 500 metre radius).

Bayswater North Pit

The issue of flyrock impact on residences adjacent to the BNP is considered negligible. The closest private residence (residence 133) will be located in excess of 5.2 km from the pit shell of the BNP boundary.

The only infrastructure located within the 500 metre radius is a public road, i.e. Hebden Road, located at 450 metres from the proposed pit boundary. This will require additional management of the potential flyrock issue, as indicated in the Blast Mitigation Measures.

There are no other infrastructure facilities located within the 500 metre radius. Therefore, with the exception of Hebden Road, there is no risk of flyrock to infrastructure (including all items assessed in this report).

RERR Mining Area

For the RERR Mining Area the issue of flyrock impact on adjacent residences is considered negligible. The closest private residence (residence 122) will be located approximately 3.4 km from the RERR Pit mining limit and has existing Glencore acquisition rights.

The only infrastructure located within the 500 metre radius is the existing TP1 Tailings Dam. However, this dam is scheduled for capping, with capping to be completed in approximately 2020. This is prior to the commencement of mining in the RERR Mining Area, therefore, there are no potential risks related to the TP1 infrastructure facility.

There is no risk of flyrock for the other infrastructure facilities (including all items assessed in this report) as they will be located a substantial distance from the RERR Mining Area (all in excess of a 500 metre radius).

5.2 INFRASTRUCTURE

5.2.1 Location of Infrastructure

This section addresses the potential vibration exposure of the Project on the adjacent infrastructure and identified listed and potential heritage items. The analysis is based on vibration modelling and appropriate studies and experiences in the area of blast vibration impacts on infrastructure facilities. The vibration modelling results have been analysed in the context of the impact of the North Pit Continuation, BNP and RERR Mining Area on the existing infrastructure facilities, including references to relevant vibration limits.

The infrastructure specified below was identified and assessed in this report (refer to **Figures 7A** and **7B**): **Figure 7A** highlights the location of the infrastructure, while **Figure 7B** shows the locations of the identified significant heritage items. The infrastructure and significant heritage items covered in this report include:

- Listed and potential Heritage Items:
    - Ravensworth Homestead,
    - Ravensworth Public School (former),
    - St Clements Anglican Church, Camberwell,
    - Community Hall, Camberwell,
    - Camberwell Glennies Creek Underbridge,
    - Chain of Ponds Inn,
    - Middle Falbrook Bridge over Glennies Creek,
    - Greylands and Outbuildings,
    - Former Dulwich Homestead (Kangory Homestead);
    - Hebden Public School (former)
    - John Winter Memorial Site
- 330 kV and 132 kV Powerlines, including Tension Towers and Substation;
- Prescribed dams:
    - TP1 Dam (Year 1 and 5 only),
    - NVS2 Dam
    - Ashton Coal Clean Water Dam 1;
- Main Northern Rail line;
- Local roadways including Hebden Road, Falbrook Road, Glennies Creek Road and New England Highway; and
- Proposed Hebden Road infrastructure including rail overpass and Bowmans Creek Bridge.

General inspections of the surrounding infrastructure were carried out by an ESC engineer and Mount Owen representatives on the 11th of February 2011, 19th of June 2012 and the 22nd of August 2014. The inspections included identification of the individual infrastructure points and the state of each structure's foundations and overall structural condition. The inspections also included the heritage items of St Clements Church in Camberwell, Ravensworth Homestead, former Hebden Public School and John Winter Memorial site. In addition, the inspection included a review and inspection of the relevant monitoring stations.

Mount Owen Complex undertakes an extensive vibration monitoring program covering a number of infrastructure and heritage items. The vibration monitoring stations relevant to the monitoring of these infrastructure items are presented in **Figure 7C** and include:

- St Clements Church, Camberwell;
- Ravensworth Homestead;
- TP1 monitors (four monitors);
- Railway; and
- Powerlines.

Operational blasting processes usually include certain inherent risks when undertaken in the proximity of existing infrastructure. Generally, these risks diminish with an increased distance from the blasting area. This assessment includes an overview of these risks via a detailed review of the proposed mine plans (in view of the distance from the blast area) and their potential impact on the surrounding infrastructure.

The distances between the blasting areas and infrastructure points were estimated for each proposed blasting area including North Pit Continuation, BNP and RERR Mining Area and are listed in **Tables 10A** to **10C** respectively.

The distance estimations are based on the proposed mine plan extraction area. The simulations undertaken are therefore considered to be fully representative of the actual blast impacts.

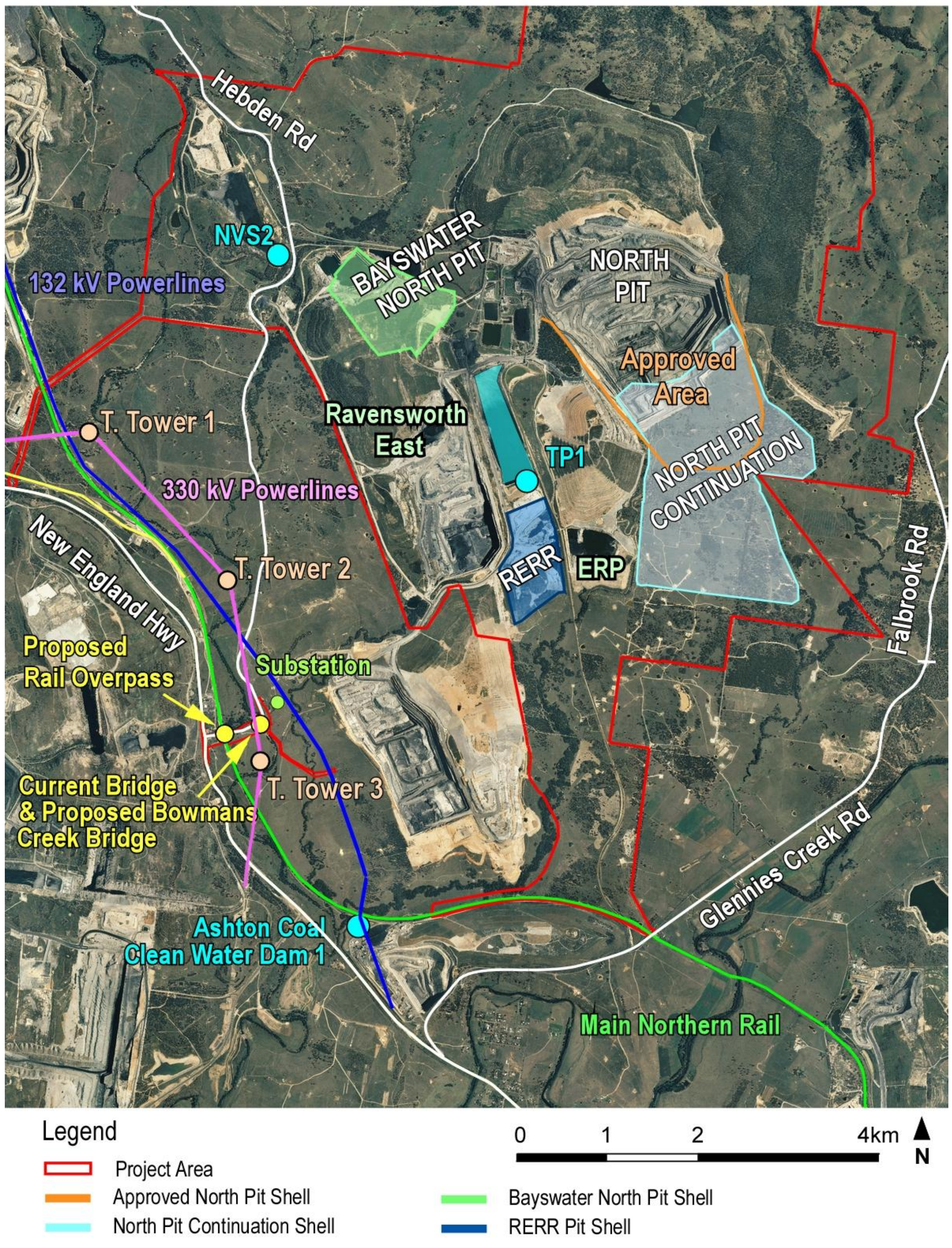

Figure 7A – Locations of the Infrastructure with respect to the North Pit Continuation, BNP and RERR Mining Area

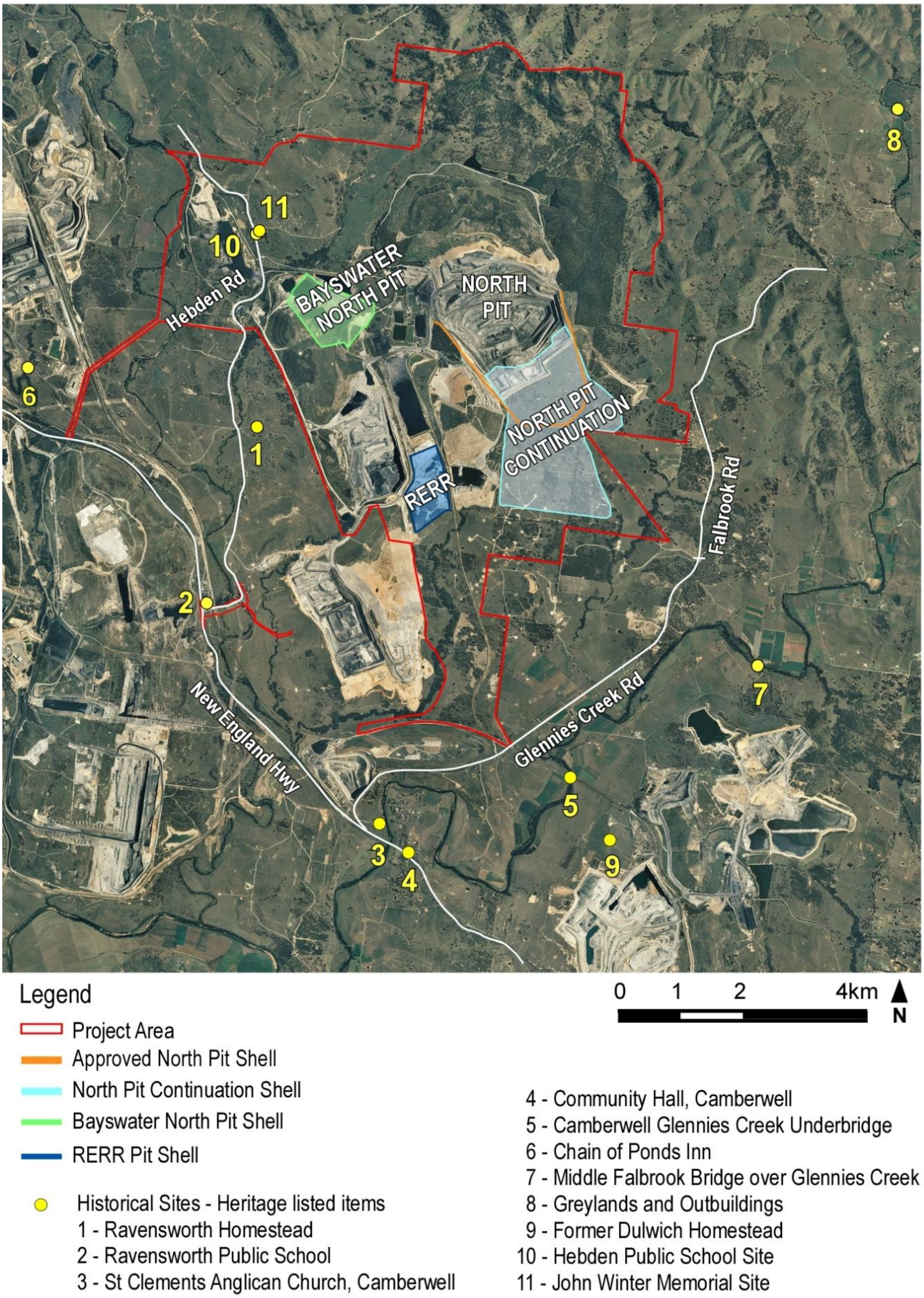

Figure 7B – Locations of Listed and potential Heritage Items in the Vicinity of the North Pit Continuation, BNP and RERR Mining Area

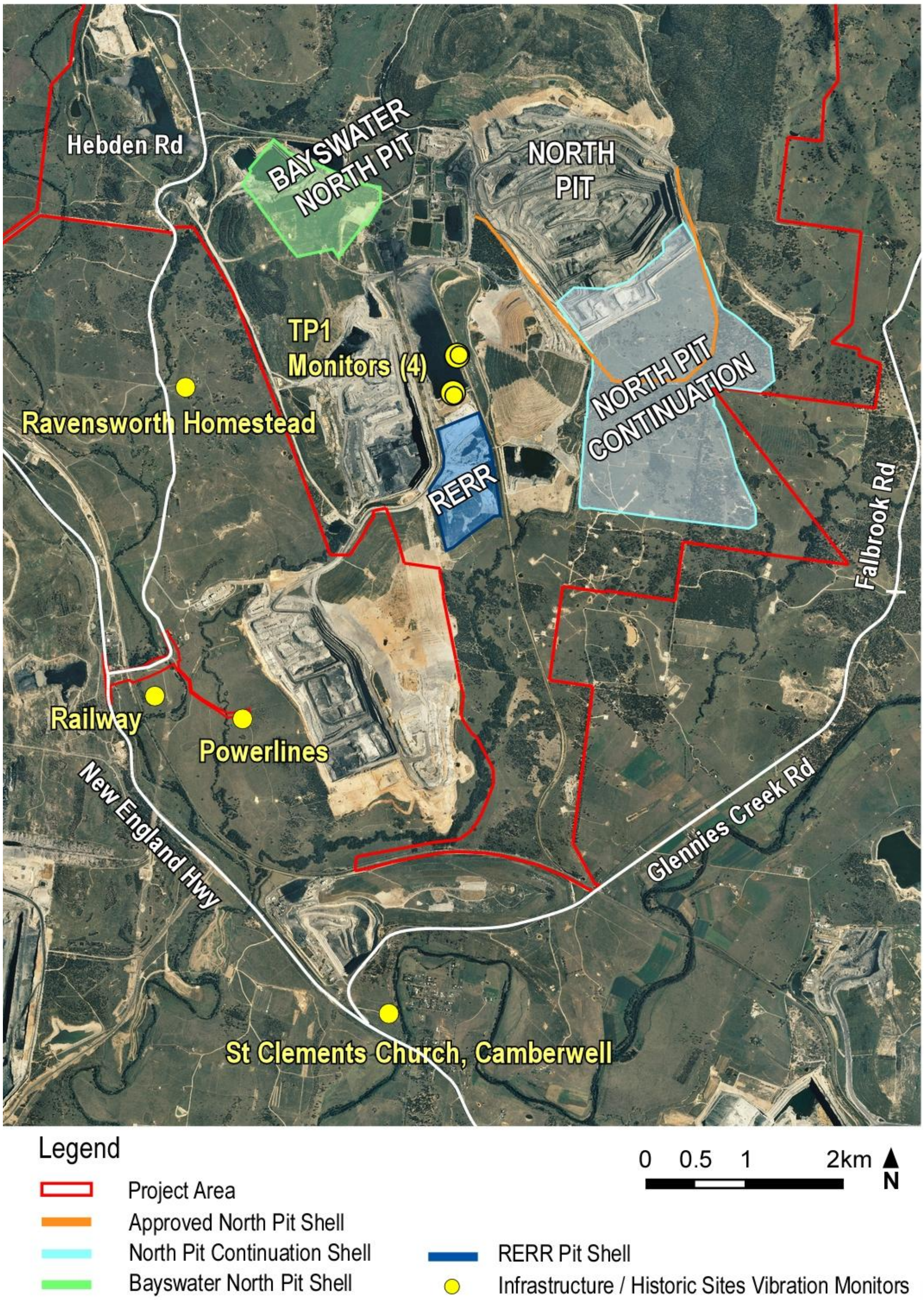

Figure 7C – Locations of the Monitoring Stations for monitoring of Infrastructure and Significant Heritage Items for Mount Owen Complex

5.2.2 Assessments Results

5.2.2.1 Ground Vibration

The vibration modelling undertaken in this section has been performed according to the formula specified in Section 4.1.1 for surface conditions.

North Pit Continuation

The assessment undertaken included seven different simulations involving various charge masses, which can potentially be used at the North Pit Continuation. Vibration estimates for three different years of extraction, Year 1, 5 and 10 were generated, examined and collated into a table of results, presenting the worst case scenario, i.e. the highest impact irrespective of the modelled year. The vibration estimates for each item of infrastructure are summarised in **Table 10A**.

The results of the ground vibration modelling for the infrastructure due to blasting in the North Pit Continuation are summarised as follows:

- The closest infrastructure, TP1 dam (located 1,110 metres from the blasting area), will be exposed to vibration levels no higher than 8 mm/s. This is well below the vibration criteria of 50 mm/s.
- The NVS2 dam (located 3,930 metres from the blasting area) will be exposed to vibration levels no higher than 1 mm/s. This is well below the vibration criteria of 50 mm/s.
- Glennies Creek Road and Falbrook Road (located at 1,160 and 1,540 metres respectively) will be exposed to vibrations no higher than 7 mm/s. This is well below the vibration criteria for roadways of 100 mm/s.
- The vibration exposures for other infrastructure and significant heritage items (considering the highest modelled charge mass) are below 1.5 mm/s, which is below any of the applicable criteria.
- None of the infrastructure or significant heritage items is located within the 500 metre exclusion zone (i.e. used as a standard exclusion zone for flyrock control) of the North Pit Continuation. Therefore the issue of flyrock does not apply.

Table 10A: Results of Ground Vibration Modelling for Infrastructure – Maximum Vibration Estimates; North Pit Continuation

Infrastructure	Min. Distance (North Pit Cont.) (m)	Estimated Max Ground Vibration (mm/s) MIC (kg) ANFO 33	Heavy ANFO 49.4	ANFO 250	ANFO 363	Heavy ANFO 544	ANFO 527	Heavy ANFO 791
Significant Historical Items								
Ravensworth Homestead	3,700	0.1	0.1	0.4	0.6	0.8	0.8	1.1
Ravensworth Public School (former)	4,990	0.1	0.1	0.3	0.4	0.5	0.5	0.7
St Clements Church, Camberwell	5,460	<0.1	0.1	0.2	0.3	0.4	0.4	0.6
Community Hall, Camberwell	5,760	<0.1	0.1	0.2	0.3	0.4	0.4	0.5
Camberwell Glennies Creek Underbridge	4,190	0.1	0.1	0.4	0.5	0.7	0.6	0.9
Chain of Ponds Inn	7,340	<0.1	<0.1	0.1	0.2	0.3	0.3	0.4
Middle Falbrook Bridge, Glennies Ck	3,370	0.1	0.1	0.5	0.7	0.9	0.9	1.3
Greylands and Outbuilding	6,370	<0.1	<0.1	0.2	0.2	0.3	0.3	0.5
Former Dulwich Homestead (Kangory)	5,150	0.1	0.1	0.3	0.3	0.5	0.5	0.6
Hebden Public School (former)	4,320	0.1	0.1	0.3	0.5	0.6	0.6	0.9
John Winter Memorial	4,310	0.1	0.1	0.3	0.5	0.6	0.6	0.9
Powerlines								
132kV Powerlines	3,950	0.1	0.1	0.4	0.5	0.7	0.7	1.0
330kV Powerlines	4,420	0.1	0.1	0.3	0.4	0.6	0.6	0.8
Tension Tower 1	5,820	<0.1	0.1	0.2	0.3	0.4	0.4	0.5
Tension Tower 2	4,510	0.1	0.1	0.3	0.4	0.6	0.6	0.8
Tension Tower 3	4,590	0.1	0.1	0.3	0.4	0.6	0.6	0.8
Substation	4,170	0.1	0.1	0.4	0.5	0.7	0.7	0.9
Prescribed Dams								
TP1 Dam (southern embankment)	1,210	0.5	0.7	2.6	3.5	4.9	4.7	6.6
TP1 Dam (eastern embankment)	1,110	0.6	0.8	3.0	4.0	5.6	5.4	7.5
NVS2 (southern embankment)	3,930	0.1	0.1	0.4	0.5	0.7	0.7	1.0
NVS2 (central embankment)	4,860	0.1	0.1	0.3	0.4	0.5	0.5	0.7

Infrastructure	Min. Distance (North Pit Cont.) (m)	Estimated Max Ground Vibration (mm/s)						
		MIC (kg)						
		ANFO 33	Heavy ANFO 49.4	ANFO 250	ANFO 363	Heavy ANFO 544	ANFO 527	Heavy ANFO 791
Ashton Coal Clean Water Dam 1	4,870	0.1	0.1	0.3	0.4	0.5	0.5	0.7
Railway								
Main Northern Rail Line	3,560	0.1	0.1	0.5	0.6	0.9	0.8	1.2
Local Roads, Bridge								
Falbrook Road	1,160	0.6	0.8	2.8	3.8	5.2	5.1	7.0
Glennies Creek Road	1,540	0.4	0.5	1.8	2.4	3.3	3.2	4.5
Hebden Road	3,830	0.1	0.1	0.4	0.6	0.8	0.7	1.0
Current Bridge, Hebden Road	4,440	0.1	0.1	0.3	0.4	0.6	0.6	0.8
Proposed Hebden Road Infrastructure								
Proposed Bowmans Creek Bridge	4,430	0.1	0.1	0.3	0.4	0.6	0.6	0.8
Proposed Rail Overpass	4,850	0.1	0.1	0.3	0.4	0.5	0.5	0.7

Bayswater North Pit

Assessing the impact of blasting for the BNP involved five different simulations including various charge masses which can potentially be used at the BNP. The vibration estimates for each item of the infrastructure are presented in **Table 10B**. The results present the worst case scenario, i.e. the highest impact irrespective of the modelled year.

The results of the ground vibration modelling for the infrastructure due to blasting in the BNP are summarised as follows:

- The closest infrastructure, Hebden Road (located 450 metres from the blasting area), will be exposed to vibration levels no higher than 24 mm/s. This is well below the vibration limit criteria for roadways of 100 mm/s. As indicated in Section 5.1.3.3 the mine operates using a 500 metre exclusion zone for flyrock control. Appropriate mitigation measures, will be necessary to control the flyrock risk when blasting less than 500 metres from the road. In the past, the mine used the same mitigation measures on Hebden Road, when blasting in Ravensworth East until 2008. For more details refer to the mitigation measures section, presented in Section 6 of this report.
- TP1 dam (located within 650 metres of the BNP) will be exposed to vibration levels no higher than 14 mm/s. This is well below the vibration limit criteria of 50 mm/s imposed by the Dam Safety Committee.
- NVS2 dam (located 550 metres from the blasting area) will be exposed to vibration levels no higher than 18 mm/s. This is well below the vibration criteria of 50 mm/s.

- The closest significant heritage items are the John Winter Memorial together with the former Hebden Public School (located 1,020 and 1,030 metres from the pit boundary respectively). The maximum predicted vibration exposure for both of the structures is under 7 mm/s. This is well below the respective vibration limit criteria of 250 and 16 mm/s.
- The Ravensworth Homestead is located 1,660 metres from the pit boundary. The predicted vibration exposure is in the order of 0.3 to 2.9 mm/s. This is below the applicable vibration limit criteria of 5 mm/s for this infrastructure.
- Vibration exposures for other infrastructure and significant historical items (considering the highest modelled charge mass) are below 1.5 mm/s, which is below any of the applicable vibration limit criteria.

Table 10B: Results of Ground Vibration Modelling for Infrastructure – Maximum Vibration Estimates; BNP

Infrastructure	Min. Distance (BNP) (m)	Estimated Max Ground Vibration (mm/s)				
		MIC (kg)				
		ANFO 33	Heavy ANFO 49.4	ANFO 250	ANFO 363	Heavy ANFO 544
Significant Historical Items						
Ravensworth Homestead	1,660	0.3	0.4	1.6	2.1	2.9
Ravensworth Public School (former)	4,500	0.1	0.1	0.3	0.4	0.6
St Clements Church, Camberwell	7,670	<0.1	<0.1	0.1	0.2	0.3
Community Hall, Camberwell	8,160	<0.1	<0.1	0.1	0.2	0.2
Camberwell Glennies Creek Underbridge	7,770	<0.1	<0.1	0.1	0.2	0.2
Chain of Ponds Inn	4,290	0.1	0.1	0.3	0.5	0.6
Middle Falbrook Bridge, Glennies Ck	8,320	<0.1	<0.1	0.1	0.2	0.2
Greylands and Outbuilding	8,950	<0.1	<0.1	0.1	0.1	0.2
Former Dulwich Homestead (Kangory)	8,950	<0.1	<0.1	0.1	0.1	0.2
Hebden Public School (former)	1,030	0.7	0.9	3.4	4.5	6.3
John Winter Memorial	1,020	0.7	0.9	3.4	4.6	6.4
Powerlines						
132kV Powerlines	3,100	0.1	0.2	0.6	0.8	1.1
330kV Powerlines	2,900	0.1	0.2	0.6	0.9	1.2
Tension Tower 1	3,080	0.1	0.2	0.6	0.8	1.1
Tension Tower 2	2,980	0.1	0.2	0.6	0.8	1.1
Tension Tower 3	4,670	0.1	0.1	0.3	0.4	0.6
Substation	4,000	0.1	0.1	0.4	0.5	0.7
Prescribed Dams						
TP1 Dam (southern embankment)	1,710	0.3	0.4	1.5	2.0	2.8

Infrastructure	Min. Distance (BNP) (m)	Estimated Max Ground Vibration (mm/s)				
		MIC (kg)				
		ANFO 33	Heavy ANFO 49.4	ANFO 250	ANFO 363	Heavy ANFO 544
TP1 Dam (eastern embankment)	650	1.4	1.9	7.0	9.5	13.1
NVS2 (southern embankment)	550	1.8	2.5	9.2	12	17
NVS2 (central embankment)	1,540	0.4	0.5	1.8	2.4	3.3
Ashton Coal Clean Water Dam 1	6,310	<0.1	0.1	0.2	0.3	0.3
Railway						
Main Northern Rail Line	3,170	0.1	0.2	0.6	0.8	1.0
Local Roads, Bridge						
Falbrook Road	5,240	<0.1	0.1	0.2	0.3	0.5
Glennies Creek Road	6,490	<0.1	<0.1	0.2	0.2	0.3
Hebden Road	450	2.5	3.5	12	17	24
Current Bridge, Hebden Road	4,250	0.1	0.1	0.3	0.5	0.7
Proposed Hebden Road Infrastructure						
Proposed Bowmans Creek Bridge	4,250	0.1	0.1	0.3	0.5	0.7
Proposed Rail Overpass	4,510	0.1	0.1	0.3	0.4	0.6

RERR Mining Area

Assessing the impact of blasting for the RERR Mining Area included six different simulations including various charge masses which can potentially be used. The vibration estimates for each item of infrastructure are presented in **Table 10C**.

The results of the ground vibration modelling for the infrastructure due to blasting in the RERR Mining Area are summarised as follows:

- The closest infrastructure, TP1 dam (located at 300 metres) will not be functional by the time blasting at the RERR Mining Area commences. The TP1 dam is scheduled to be fully capped in approximately 2017, six years prior to the commencement of blasting at the RERR Mining Area, currently scheduled for approximately 2023. Since it is highly likely that the TP1 dam will be de-prescribed by then, it follows that the current vibration limit criteria for this infrastructure will not apply. The TP1 dam will be exposed to vibration levels no higher than 76 mm/s when blasting the maximum charge mass of 1,038 kg from the northern edge of the pit. A charge mass of 593 kg yields vibration of 48 mm/s; this is below the vibration criteria of 50 mm/s. This shows that the impact can be managed effectively (to remain below the imposed vibration criteria) by using appropriate charge masses. Reduction in charge masses can be accomplished by blasting smaller benches or by the application of deck charges, together with the application of precise initiation timing. In the event that the TP1 dam still retains its prescribed status when blasting commences, the area of increased blast management will be limited to a relatively narrow strip (i.e. approximately 100 m) along the northern section of the RERR Mining Area.

- NVS2 dam (located 3,690 metres from the blasting area) will be exposed to vibration levels no higher than 2 mm/s. This is well below the vibration criteria of 50 mm/s.
- The second closest infrastructure is Ravensworth Homestead (located at 2,490 metres). The predicted vibration exposure is in the order of 0.2 to 2.6 mm/s. This is below the applicable vibration limit criteria of 5 mm/s for this infrastructure.
- The vibration exposures for other significant historical items (considering the highest modelled charge mass) will be in the order of 0.1 to 1.5 mm/s, which is below any of the applicable vibration limit criteria.
- The vibration exposures for other infrastructure (considering the highest modelled charge mass) are below 2.5 mm/s, which is below any of the applicable vibration limit criteria.
- None of the infrastructure or significant historical items are located within the 500 metre exclusion zone (i.e. a standard exclusion zone for flyrock control) of the RERR Mining Area. Therefore the issue of flyrock does not apply.

Table 10C: Results of Ground Vibration Modelling for Infrastructure – Maximum Vibration Estimates; RERR

Infrastructure	Min. Distance (RERR) (m)	Estimated Max Ground Vibration (mm/s)					
		MIC (kg)					
		ANFO 33	Heavy ANFO 49.4	ANFO 396	Heavy ANFO 593	ANFO 692	Heavy ANFO 1,038
Significant Historical Items							
Ravensworth Homestead	2,490	0.2	0.2	1.2	1.6	1.9	2.6
Ravensworth Public School (former)	3,550	0.1	0.1	0.7	0.9	1.1	1.5
St Clements Church, Camberwell	4,760	0.1	0.1	0.4	0.6	0.7	0.9
Community Hall, Camberwell	5,150	0.1	0.1	0.4	0.5	0.6	0.8
Camberwell Glennies Creek Underbridge	4,640	0.1	0.1	0.4	0.6	0.7	0.9
Chain of Ponds Inn	6,320	< 0.1	0.1	0.3	0.4	0.4	0.6
Middle Falbrook Bridge, Glennies Ck	5,580	< 0.1	0.1	0.3	0.5	0.5	0.7
Greylands and Outbuilding	9,170	< 0.1	< 0.1	0.1	0.2	0.2	0.3
Former Dulwich Homestead (Kangory)	5,840	< 0.1	0.1	0.3	0.4	0.5	0.7
Hebden Public School (former)	4,390	0.1	0.1	0.5	0.7	0.7	1.0
John Winter Memorial	4,380	0.1	0.1	0.5	0.7	0.8	1.0
Powerlines							
132kV Powerlines	2,600	0.2	0.2	1.1	1.5	1.7	2.4

Infrastructure	Min. Distance (RERR) (m)	Estimated Max Ground Vibration (mm/s)					
		MIC (kg)					
		ANFO 33	Heavy ANFO 49.4	ANFO 396	Heavy ANFO 593	ANFO 692	Heavy ANFO 1,038
330kV Powerlines	2,990	0.1	0.2	0.9	1.2	1.4	1.9
Tension Tower 1	4,710	0.1	0.1	0.4	0.6	0.7	0.9
Tension Tower 2	3,020	0.1	0.2	0.9	1.2	1.4	1.9
Tension Tower 3	3,210	0.1	0.1	0.8	1.1	1.2	1.7
Substation	2,790	0.1	0.2	1.0	1.4	1.5	2.1
Prescribed Dams							
TP1 Dam (southern embankment)(1)	300	5	7	35	48	55	76
TP1 Dam (eastern embankment) (1)	300	5	7	35	48	55	76
NVS2 (southern embankment)	3,690	0.1	0.1	0.6	0.9	1.0	1.4
NVS2 (central embankment)	4,900	0.1	0.1	0.4	0.6	0.6	0.9
Ashton Coal Clean Water Dam 1	3,810	0.1	0.1	0.6	0.8	0.9	1.3
Railway							
Main Northern Rail Line	3,060	0.1	0.2	0.9	1.2	1.3	1.8
Local Roads, Bridge							
Falbrook Road	4,070	0.1	0.1	0.5	0.7	0.8	1.2
Glennies Creek Road	3,660	0.1	0.1	0.6	0.9	1.0	1.4
New England Highway	3,740	0.1	0.1	0.6	0.9	1.0	1.3
Hebden Road	2,610	0.2	0.2	1.1	1.5	1.7	2.4
Current Bridge, Hebden Road	3,020	0.1	0.2	0.9	1.2	1.4	1.9
Proposed Hebden Road Infrastructure							
Proposed Bowmans Creek Bridge	3,020	0.1	0.2	0.9	1.2	1.4	1.9
Proposed Rail Overpass	3,420	0.1	0.1	0.7	1.0	1.1	1.5

(1) – most likely not applicable due to TP1 Dam capped prior to commencement of blasting in the RERR area

5.2.2.2 Airblast

Generally, infrastructure items are not assessed in terms of airblast exposure as levels required to inflict damage are not applicable and/or not reached. Amongst the items assessed there were only two items that have applicable airblast limits. These infrastructure items are the Chain of Ponds Inn and Ravensworth Homestead; both represent listed heritage items of state significance. To perform the airblast overpressure modelling the formula specified in Section 4.1.3 was utilised.

North Pit Continuation

The estimated airblast impact for infrastructure due to blasting in the North Pit Continuation is summarised as follows:

- The calculated airblast exposure for the Chain of Ponds Inn (located at 7,340 metres distance) using the range of potential charge masses of 33 to 791 kg is predicted to be in the order of 90 to 104 dBL. This is below the imposed airblast criteria limit of 133 dBL.
- The calculated airblast exposure for the Ravensworth Homestead (located at 3,700 metres distance) using the range of potential charge masses of 33 to 791 kg is predicted to be in the order of 98 to 112 dBL. This is below the imposed airblast criteria of 126 dBL.
- The impact of airblast on other analysed infrastructure and listed and potential heritage items is low or negligible.

Bayswater North Pit

The estimated airblast impact for infrastructure due to blasting in the BNP is summarised as follows:

- The calculated airblast exposure for the Chain of Ponds Inn (located at 4,290 metres distance) using the range of potential charge masses of 33 to 544 kg is predicted to be in the order of 100 to 108 dBL. This is below the imposed airblast criteria limit of 133 dBL.
- The calculated airblast exposure for the Ravensworth Homestead (located at 1,660 metres distance) using the range of potential charge masses of 33 to 544 kg is predicted to be in the order of 109 to 120 dBL. This is below the imposed airblast criteria of 126 dBL.
- The impact of airblast on other analysed infrastructure and listed and potential heritage items is low or negligible.

RERR Mining Area

The estimated airblast impact for infrastructure due to blasting in the RERR Mining Area is summarised as follows:

- The calculated airblast exposure for the Chain of Ponds Inn (located at 6,320 metres distance) using the range of potential charge masses of 33 to 1,038 kg is predicted to be in the order of 92 to 106 dBL. This is below the imposed airblast criteria limit of 133 dBL.

- The calculated airblast exposure for the Ravensworth Homestead (located at 2,490 metres distance) using the range of potential charge masses of 33 to 1,038 kg is predicted to be in the order of 103 to 118 dBL. This is below the imposed airblast criteria of 126 dBL.
- The impact of airblast on other analysed infrastructure and listed and potential heritage items is low or negligible.

5.3 INTEGRA UNDERGROUND MINE

5.3.1 Interactions with Integra Underground

This section addresses the impact of the Project on the adjacent IUM and related surface infrastructure.

The IUM is located immediately adjacent to the Mount Owen Mine, with a small section where both Mount Owen and Integra's mining leases and mine plans overlap each other. Based on the conceptual mine plans for the Project, the North Pit Continuation and the RERR Mining Area are to be located approximately 250 metres above the IUM underground workings in the section where the mine plans overlap (refer to **Figure 8**).

Based on the anticipated production schedules for the Project and IUM, it is unlikely that direct interaction of operational activities would occur. However, it is important to note that IUM announced in mid 2014 that it is entering a period of care and maintenance, so this could impact the anticipated production schedule. Notwithstanding the potential issue of direct interaction has been addressed below.

The proposed mine plans for the Project and the adjacent IUM are presented in **Figure 8**. The Mount Owen mining lease and the IUM mining lease overlap in the southern section of the North Pit Continuation area and the RERR Mining Area. In this section, Mount Owen has the extraction rights to the upper seams down to the Bayswater seam (approximately 215 metres below ground level), while IUM has the extraction rights to the lower mining seams, extending from the currently mined Middle Liddell seam to the lower Barrett and Hebden seams. The Middle Liddell seam and already extracted underground longwall blocks are shown in **Figure 8**. In addition **Figure 8** depicts the location of Integra surface facilities as well as the previously mined ERP. ERP is currently being used for tailings storage purposes only and is scheduled to be capped and rehabilitated prior to Year 1 of the Project.

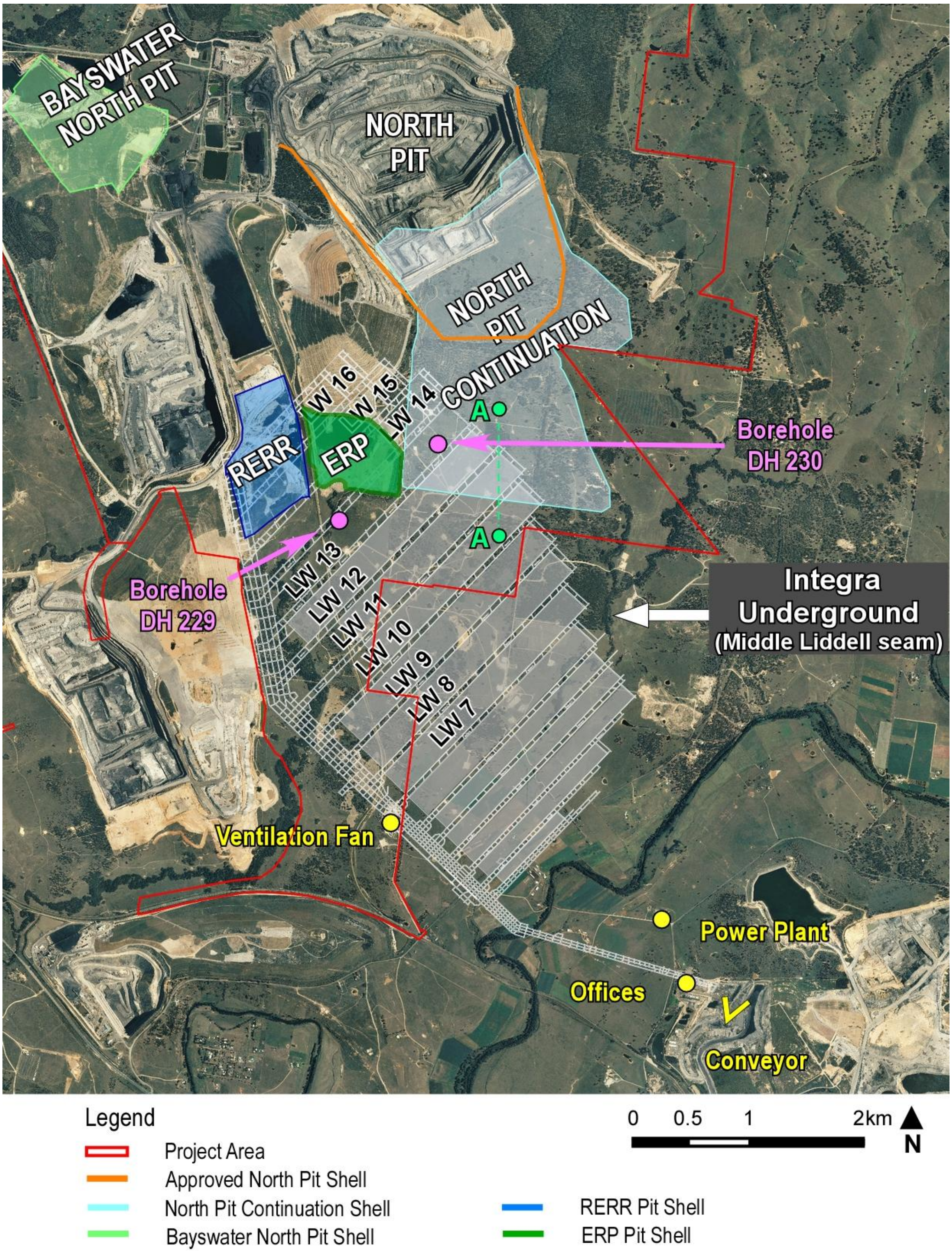

Figure 8 – Locations of the ERP, North Pit Continuation, the BNP and RERR Mining Areas versus Integra Underground Mine

Mining within the North Pit Continuation will advance from the northern end south towards the IUM workings. The RERR Mining Area is to be located above the north-western section of the IUM. Based on the current IUM mine plans, the IUM main headings extend from the southern end and progress to the north, which is also the case for the longwall operations. The potential for operational overlap between the Project and IUM is expected to occur in the latter years of the Project. It is highlighted that this overlapping stage is unlikely as the IUM workings (of the Middle Liddell seam) are scheduled to be completed by that time. It should be noted that the extraction plans for IUM might be altered due to IUM entering a care and maintenance phase.

Where mining operations could overlap, representative borehole logs were obtained and inspected for vertical separation between the Bayswater seam (representing the bottom of the North Pit Continuation in the southern portion and the RERR pit floor) and Middle Liddell Seam (representing the current IUM workings). Two representative boreholes, DH229 and DH230 from the area have been examined; see **Figure 8** for borehole locations. The estimated vertical separation for these boreholes was 254 and 257 metres respectively; see **Appendices 3A** and **3B**.

The schematic cross section showing the applicable North Pit Continuation and underground mine (IUM) is presented in **Figure 9**. The same schematic representation applies to the RERR Mining Area. The figure shows the Middle Liddell seam, the shallowest seam Integra has approval to mine. However, it should be noted that with time, as the current Middle Liddell seam is fully extracted, IUM mining operations will most likely commence to mine the lower Hebden seam. Therefore, the vertical distance between the two operations will subsequently increase by the additional depth. Due to the increased distance the impact of blasting will be reduced.

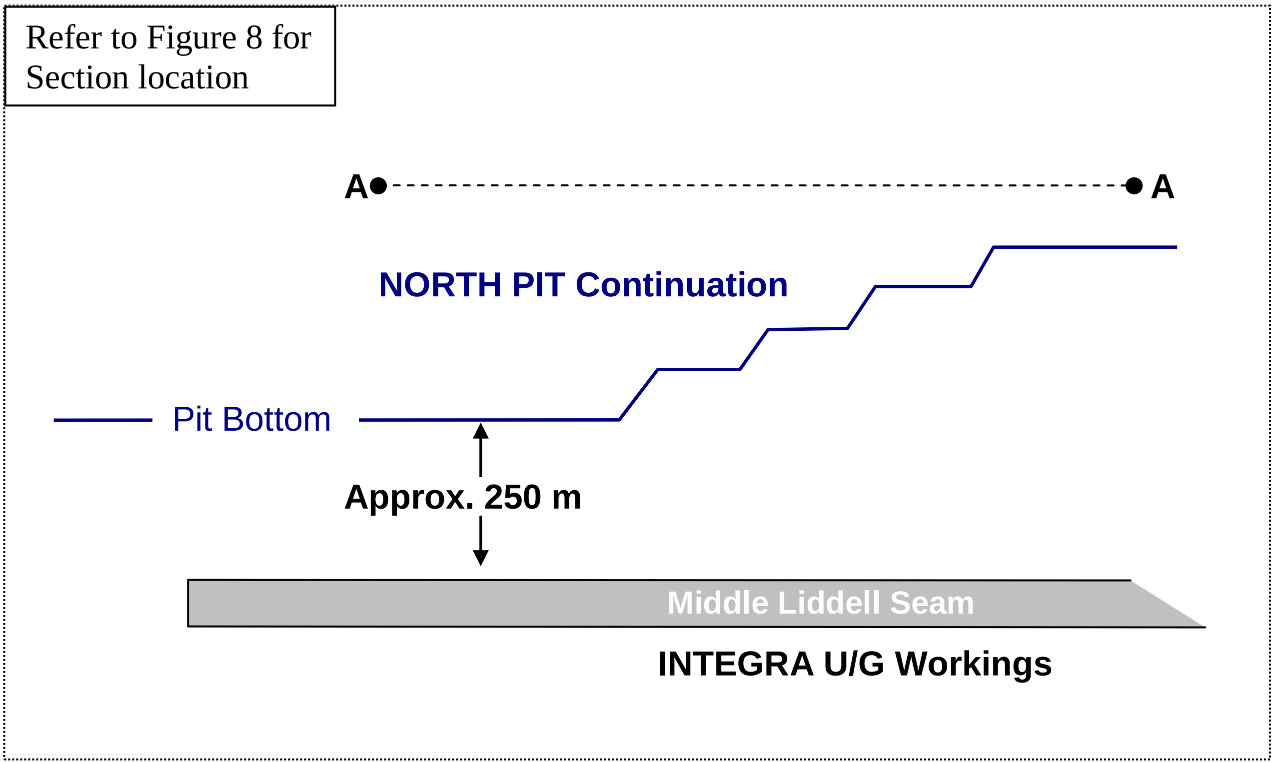

Figure 9 – Schematic Cross-section showing the North Pit Continuation Area and Integra Underground Mine (IUM) Separation Distance; a similar schematic representation applies to the RERR

To account for the most conservative scenario (disregarding both mines extraction schedules) and for the purpose of this assessment, a hypothetical scenario is assumed, i.e. IUM will still be operating or that some facilities will still be in use at the current seam level, which is the Middle Liddell seam, when blasting is undertaken within the Project mining areas. Such considerations will assume that the underground workforce will be present during surface blasting activities.

It is important to highlight that both mines interacted successfully in the past when a mining operation, similar to that proposed, was undertaken. This previous mining operation included blasting in the ERP that resulted in full interaction with the adjacent IUM in 2005 and 2006. For that purpose a comprehensive system between Mount Owen and Integra was introduced including vibration prediction, blast notification and underground personnel management on a blast by blast basis. A similar interaction system will be developed, in consultation with Integra, for blast management in the North Pit Continuation and RERR Mining Area.

5.3.2 Assessment Results

5.3.2.1 Ground Vibration

5.3.2.1.1 IUM - Underground Workings

The vibration predictive model used in the assessment was previously developed from monitoring data associated with blasting in the ERP in 2005/06 (Terrock, 2006). Refer to **Section 4.1.2** for the formula used in this assessment.

The modelling provides an indication in regards to the potential blast impacts from the Project on the IUM workings. The modelling is based on the Middle Liddell seam, the nearest seam to the Project, which therefore represents the worst cases scenario.

North Pit Continuation

The assessment undertaken was based on seven different simulations involving various charge masses ranging from 33 to 791 kg. Most of the overlap between the North Pit Continuation and the IUM occurs over the western section of the North Pit Continuation where a higher maximum charge mass (i.e. 791 kg) is anticipated. The modelling accounts for the worst case scenario, i.e. blasting from the edge of the base of the North Pit Continuation pit shell.

The vibration estimates for IUM workings are summarised in **Table 11A**.

Table 11A: Vibration Modelling Summary – Impact of North Pit Continuation on IUM (Middle Liddell Seam)

Infrastructure	Min. Distance (North Pit Cont.) (m)	Estimated Max Ground Vibration (mm/s)						
		MIC (kg)						
		ANFO 33	Heavy ANFO 49.4	ANFO 250	ANFO 363	Heavy ANFO 544	ANFO 527	Heavy ANFO 791
Below Blast Area (sections of LW 10-14)	250	2	3	10	14	19	18	26
Affected longwalls*: LW 9-15	300	1.5	2	8	10	14	14	19
Affected longwalls*: LW 8-16	500	0.7	0.9	3	5	6	6	8
Affected longwalls*: LW 7-16	800	0.3	0.4	1.6	2	3	3	4
Main Headings	1,300	0.1	0.2	0.7	1.0	1.4	1.3	1.8

** Affected longwalls when blasting from the edge of the base of the North Pit Continuation boundary (or directly above the IUM workings)*

NOTE: - applicable vibration criteria are:

- *indicative 250 mm/s vibration limit for underground workings (from the previous study Terrock (2006)) - this limit will need to be confirmed via a geotechnical assessment prior to the commencement of blasting within 1 km of IUM;*

- *10 mm/s vibration limit for underground personnel withdrawal*

The results of the ground vibration modelling for the IUM workings due to blasting in the North Pit Continuation are summarised as follows:

- For the area immediately underneath the blasting zone (i.e. 250 metres separation comprising of sections of longwalls 10 to 14) the predicted vibration is in the range of 2 to 26 mm/s. This only applies to the end sections of the longwalls. Due to the predicted vibration levels being in excess of 10 mm/s, personnel withdrawal for the affected longwall areas will be required during blasting.
- For the area 300 m away from the blasting zone, the ground vibration is expected to range between 1.5 and 19 mm/s. These vibration predictions apply to longwall panels 9 to 15. Due to the predicted vibration levels being in excess of 10 mm/s, personnel withdrawal for the affected longwall areas will be required during blasting.
- The other sections of the underground mine at distances in excess of 500 m from the blast (involving longwalls 8 to 16) will be exposed to vibration levels of 8 mm/s or less. As vibration levels are predicted to be below 10 mm/s personnel management during blasting is not considered to be required.
- Modelling for the main headings area, which is used as a transport road and is located a substantial distance away (1,300 metres or more), identified a markedly lower vibration impact in the order of 2 mm/s or less. As vibration levels are predicted to be below 10 mm/s there is no need for personnel management during blasting.
- It can be expected that lower seams (i.e. below the Middle Liddell seam) being further away from the base of the North Pit Continuation will be exposed to lower ground vibration.

The modelling revealed that there is a high degree of variability in the potential vibration exposures for various sections of the underground mine and it is very much dependent upon the distance between the blasting area and the actual section of the underground mine.

<u>Bayswater North Pit</u>

There is no overlap between the BNP Mining Area and IUM, see **Figure 8**. Due to the substantial distance of more than 2,000 metres between the BNP and IUM workings there is no interaction between the open cut and underground workings. The maximum predicted ground vibration exposure for the IUM due to blasting in the BNP is 0.5 mm/s, resulting in negligible impact. As such detailed assessment is not applicable.

<u>RERR Mining Area</u>

The assessment undertaken was based on six different simulations involving various charge masses ranging from 33 to 1,038 kg. The overlap with the IUM occurs almost over the entire RERR Mining Area, see **Figure 8**. The modelling accounts for the worst case scenario, i.e. blasting from the edge of the base of the RERR Mining Area.

The vibration estimates for IUM workings are summarised in **Table 11B**.

Table 11B: Vibration Modelling Summary – Impact of the RERR Mining Area on IUM (Middle Liddell Seam)

Infrastructure	Min. Distance (RERR) (m)	Estimated Max Ground Vibration (mm/s)					
		MIC (kg)					
		ANFO 33	Heavy ANFO 49.4	ANFO 396	Heavy ANFO 593	ANFO 692	Heavy ANFO 1,038
Below Blast Area (sections of LW 15-16, northern section of Main Headings)	250	2	2.8	15	20	23	32
Affected longwalls*: LW 14-16, Main Headings	300	1.5	2	11	15	17	24
Affected longwalls*: LW 13-16, Main Headings	500	0.7	0.9	5	7	8	11
Affected longwalls*: LW 12-16, Main Headings	800	0.3	0.4	2	3	4	5
Affected longwalls*: LW 11-16, Main Headings	1,000	0.2	0.3	2	2	3	4

The results of the ground vibration modelling for the IUM workings due to blasting in RERR are summarised as follows:

- For the area immediately underneath the blasting zone (i.e. 250 metres separation comprising sections of longwalls 15 to 16 and a section of the Main Headings) the predicted vibration is in the range of 2 to 32 mm/s. Due to the predicted vibration levels being in excess of 10 mm/s, personnel withdrawal for the affected longwall areas will be required during blasting.
- For the area 300 m from the blasting zone, the ground vibration is expected to range between 1.5 and 24 mm/s. These vibration predictions apply to longwall panels 14 to 16 as well as a section of the Main Headings. Due to the predicted vibration levels being in excess of 10 mm/s, personnel withdrawal for the affected longwall areas will be required during blasting.
- Other sections of the underground mine at distances in excess of 500 m from the blast (involving longwalls 13 to 16 and a section of the Main Headings) will be exposed to vibration levels of 11 mm/s or less. For sections with vibration predictions in excess of 10 mm/s personnel withdrawal will be necessary.
- The other sections of the mine, located a substantial distance away (800 metres or more), identified a markedly lower vibration impact in the order of 5 mm/s or less. As vibration levels are predicted to be below 10 mm/s there is no need for personnel management during blasting.
- It can be expected that lower seams (i.e. below the Middle Liddell seam) being further away from the base of the RERR Mining Area will be exposed to lower ground vibration.

5.3.2.1.2 IUM – Surface Facilities

The surface infrastructure of IUM includes standard surface facilities, utilised by the underground mine, such as a ventilation fan, conveyors, office buildings, etc. All of these facilities are located a substantial distance from the North Pit Continuation, BNP and RERR Mining Area boundaries.

To assess the potential blast impacts vibration modelling was undertaken for each of the proposed mining areas. This involved the estimation of expected vibrations using the formula for surface conditions introduced earlier in this report, see – Section 4.1.1.

North Pit Continuation

The results of the ground vibration modelling for the IUM surface facilities due to blasting in the North Pit Continuation are presented in **Table 12A** and are summarised as follows:

- The predicted vibration exposures for the surface facilities are no higher than 2 mm/s, which are considered low/negligible and provide a negligible risk to the IUM surface infrastructure facilities. These exposures are well below the applicable vibration limits (i.e. 25 and 100 mm/s) for the considered industrial infrastructure.

Table 12A: Vibration Modelling Summary for the North Pit Continuation on Integra Surface Facilities

Infrastructure	Min. Distance (North Pit Cont.) (m)	Estimated Max Ground Vibration (mm/s)						
		MIC (kg)						
		ANFO 33	Heavy ANFO 49.4	ANFO 250	ANFO 363	Heavy ANFO 544	ANFO 527	Heavy ANFO 791
Conveyor*	4,260	0.1	0.1	0.3	0.5	0.6	0.6	0.9
Power Plant*	3,450	0.1	0.1	0.5	0.7	0.9	0.9	1.2
Integra Surface Facilities**	4,020	0.1	0.1	0.4	0.5	0.7	0.7	1.0
Integra Ventilation Fan*	2,880	0.1	0.2	0.7	0.9	1.2	1.2	1.6

* - *applicable vibration criteria of 100 mm/s*

**- *applicable vibration criteria of 25 mm/s*

Bayswater North Pit

The results of the ground vibration modelling for the IUM surface facilities due to blasting in the BNP are presented in **Table 12B** and are summarised as follows:

- The predicted vibration exposures for the surface facilities are no higher than 1 mm/s, which are considered low/negligible and provide a negligible risk to the IUM surface infrastructure facilities. These exposures are well below the applicable vibration limits (i.e. 25 and 100 mm/s) for the considered industrial infrastructure.

Table 12B: Vibration Modelling Summary for the BNP on Integra Surface Facilities

Infrastructure	Min. Distance (BNP) (m)	Estimated Max Ground Vibration (mm/s)				
		MIC (kg)				
		ANFO 33	Heavy ANFO 49.4	ANFO 250	ANFO 363	Heavy ANFO 544
Conveyor*	7,810	< 0.1	< 0.1	0.1	0.2	0.2
Power Plant*	6,940	< 0.1	< 0.1	0.2	0.2	0.3
Integra Surface Facilities**	7,500	< 0.1	< 0.1	0.1	0.2	0.3
Integra Ventilation Fan*	5,030	0.1	0.1	0.3	0.4	0.5

* *- applicable vibration criteria of 100 mm/s*

**\- *applicable vibration criteria of 25 mm/s*

RERR Mining Area

The results of the ground vibration modelling for the IUM surface facilities due to blasting in the RERR Mining Area are presented in **Table 12C** and are summarised as follows:

- The predicted vibration exposures for the surface facilities are no higher than 3 mm/s, which are considered low/negligible and provide a negligible risk to the IUM surface infrastructure facilities. These exposures are well below the applicable vibration limits (i.e. 25 and 100 mm/s) for the considered industrial infrastructure.

Table 12C: Vibration Modelling Summary for the RERR Mining Area on Integra Surface Facilities

Infrastructure	Min. Distance (RERR) (m)	Estimated Max Ground Vibration (mm/s)					
		MIC (kg)					
		ANFO 33	Heavy ANFO 49.4	ANFO 396	Heavy ANFO 593	ANFO 692	Heavy ANFO 1,038
Conveyor*	5,610	< 0.1	0.1	0.3	0.4	0.5	0.7
Power Plant*	4,680	0.1	0.1	0.4	0.6	0.7	0.9
Integra Surface Facilities**	5,280	< 0.1	0.1	0.4	0.5	0.6	0.8
Integra Ventilation Fan*	2,710	0.1	0.2	1.0	1.4	1.6	2.2

* *- applicable vibration criteria of 100 mm/s*

**\- *applicable vibration criteria of 25 mm/s*

5.3.2.2 Airblast

The estimated airblast formula used in the assessment for the infrastructure was specified in Section 4.1.3.

North Pit Continuation

Analysis for the North Pit Continuation revealed that the estimated airblast level for the closest surface infrastructure, i.e. the ventilation fan (located at 2,880 m), is in the range of 102 to 115 dBL (for an MIC of 33 to 791 kg). This is below the recommended Australian Standard safe level that will prevent structural/architectural damage specified as 133 dBL (AS 2187.2-2006).

Bayswater North Pit

Analysis for the BNP revealed that the estimated airblast level for the closest surface infrastructure, i.e. the ventilation fan (located at 5,030 m), is in the range of 95 to 106 dBL (for an MIC of 33 to 544 kg). This is below the recommended Australian Standard safe level that will prevent structural/architectural damage specified as 133 dBL (AS 2187.2-2006).

RERR Mining Area

Analysis for the RERR Mining Area revealed that the estimated airblast level for the closest surface infrastructure, i.e. the ventilation fan (located at 2,710 m), is in the range of 102 to 117 dBL (for an MIC of 33 to 1,038 kg). This is below the recommended Australian Standard safe level that will prevent structural/architectural damage specified as 133 dBL (AS 2187.2-2006).

6.0 MANAGEMENT AND MITIGATION MEASURES

Mount Owen currently utilises a number of blast control measures and technologies (as detailed in the current BMP (2012)), which minimise blast impacts and enable blasts to be designed not to exceed the relevant criteria.

The blast emission control measures proposed for the Project are specified below:

Control measures for ground vibration:

- Control ground vibration levels will be managed to not exceed relevant criteria by using appropriate charge mass design. It is recommended to include either the application of deck charges, together with the application of precise firing times (using electronic detonators), or the application of lower charge masses by blasting smaller benches;
- Use of an appropriate initiation sequence to minimise the possibility of hole interaction;

- Use of a ground vibration predictive model (based on collated monitoring data) to estimate potential vibration levels to aide with the design of future blasts.

Control measures for airblast:

Management of overpressure impacts to ensure that the blast impact assessment criteria are met for all private residences will be achieved by implementing the procedures listed below.

- Control airblast emission by using appropriate charge mass design. It is recommended to include either the application of deck charges together, with the application of precise firing times (using electronic detonators), or the application of lower charge masses by blasting smaller benches;
- Use of an appropriate initiation sequence to minimise the possibility of hole interaction;
- Continued refinement of the understanding of the geology of the blast area and adjustment to the blast design where necessary for geological conditions that may be conducive to higher air blast impacts;
- Application of appropriate quality stemming material and stemming height to enable appropriate confinement of explosive charges and therefore minimise airblast emission;
- Maintain appropriate burden specification for the front row holes (to avoid face burst);
- Use of an airblast predictive model (based on collated monitoring data) to estimate potential overpressure levels to aide with the design of future blasts;
- Use of an appropriate pre-blast meteorological condition review to avoid blasting in unfavourable weather conditions.

Based on the modelling undertaken all blasts will be managed to meet the specified criteria.

The assessment also identified the following mitigation and management measures which are recommended for the Project.

Blast Monitoring System for North Pit Continuation and RERR Mining Area

The assessment identified the exact locations of various private residences. These are positioned mainly to the north-east, east, south, south-east and north-west of the North Pit Continuation boundary. The residences are considered to be widely spread. Based on the detailed assessment it is considered that the current blast monitoring system, including air and ground vibration monitoring stations, is relatively limited in the context of the North Pit Continuation footprint. The monitoring associated with the private residences is mainly concentrated in the south and south-east.

With respect to the current mine location and existing mine footprint, the currently operating blast monitoring system is adequate. However, the North Pit Continuation boundary is advancing to the south closer to the residences of Falbrook and Middle Falbrook. It is therefore recommended that the current blast monitoring system be modified as the Project advances. In addition, the substantial spread in private residence locations needs to be considered from a blast monitoring point of view.

It is recommended additional monitoring stations be installed to the east (to cover the eastern residences) and the south-east. Considering the North Pit Continuation footprint and the wide spread of residences, at least two additional monitoring stations (or a relocation of the existing stations) will be required to provide an adequate and representative coverage for the area. The recommended locations for the monitors for the eastern area is any of the residences 41, 42 or 48 and for the south-east any of the residences 13, 17a or 14.

The RERR Mining Area will be located relatively close to the Year 10 pit boundary of the North Pit Continuation. Implementation of the above recommendations for the North Pit Continuation will assist with monitoring efficiency for the RERR mining Area. Therefore no specific recommendations for the RERR are required.

Blast Monitoring System for Bayswater North Pit

Considering the location of the BNP and surrounding infrastructure facilities there will be an additional requirement for monitoring of these facilities. This would include monitoring of the NVS2 dam while the dam retains its prescribed status. The NVS2 dam is scheduled for capping commencing in approximately 2015. The recommended placement of a monitoring unit is on the crest of the southern embankment at the closest point to the blasting area. Another facility that would require monitoring is the transmission power lines located to the West of the BNP. The recommended location is the closest transmission tower to the south-west of the BNP; it would provide representative coverage for the considered infrastructure facilities for the relevant area.

Pre-Blast Check Protocol

The Project will result in ongoing movement of the blasting operations in relation to the adjacent residences. The shortest distance between a private residence and the active mining boundary of the Project will occur in Year 10 of the Project. The North Pit Continuation boundary will be 1,820 m from the residence ID 114. In view of the ongoing progression of the North Pit Continuation, the pre-blast check protocol will be reviewed once a year.

Weather Monitoring System

The assessment of environmental conditions prior to blasting plays a vital role in the pre-blast assessment protocol. The weather conditions can affect the blast impact outcome (especially noise distribution and intensity), as well as dust distribution. The current Mount Owen BMP highlights the need for the assessment of environmental conditions prior to blasting. One of the tools utilised is the use of Mount Owen weather monitoring stations.

The Project includes geographical progression of mining operations within the Mount Owen Mine. Should the Project be approved, the BMP would be updated to include a review of the weather monitoring system.

Interaction with Integra Underground Mine (IUM)

The IUM is located immediately adjacent to the Mount Owen lease boundary, with a small section where both Mount Owen and IUM's mining leases overlap. Based on the Project and IUM extraction schedules, it is highly unlikely that blasting activities will be undertaken in the proximity of active underground workings at IUM. This is due to the fact that the IUM extraction phase is scheduled to be finalised well before the Project advancement stage. It is important to note that this analysis has been based on publically available information from IUM's most recent environmental assessment. IUM announced in mid 2014 that the IUM was entering a period of care and maintenance, which will affect the extraction plan for IUM. At the time, late in the Project when this interaction is anticipated, Mount Owen will liaise with IUM to clarify the extent of the mining.

Blast impacts can be managed effectively involving an agreement between both mines (i.e. Mount Owen and IUM) through the implementation of a Blast Management Protocol. It is proposed that the protocol will be developed and agreed with IUM prior to any blasting within 500 metres of the currently approved active underground workings. A similar protocol was introduced between the two mines in 2005 and 2006 when blasting in the ERP at Mount Owen Mine. Due to the existence of this previous protocol, both operations are familiar with the concept of blast management and the need for appropriate interaction between mine managements. The same system is currently used in various mines across the Hunter Valley which experience similar issues.

Interaction between North Pit Continuation, Bayswater North Pit and RERR Mining Area

Mining operations within the proposed North Pit Continuation and BNP and subsequently the North Pit Continuation and RERR Mining Area are scheduled to overlap. To avoid any potential issues due to blast impact interaction different blasting times for each proposed mining area are to be allocated and Mount Owen will not undertake simultaneous blasts.

Blasting within 500 metre of Roads - Bayswater North Pit

Some operational activities in the BNP will be undertaken within 500 metres of Hebden Road as well as the Mount Owen Mine access road. This will require the formulation of appropriate management measures and consultation with relevant stakeholders. Mount Owen will implement an appropriate protocol, including preventative measures to ensure that the 500 metre exclusion zone is maintained during blasting. The 500 metre exclusion zone is highlighted in **Figure 10**.

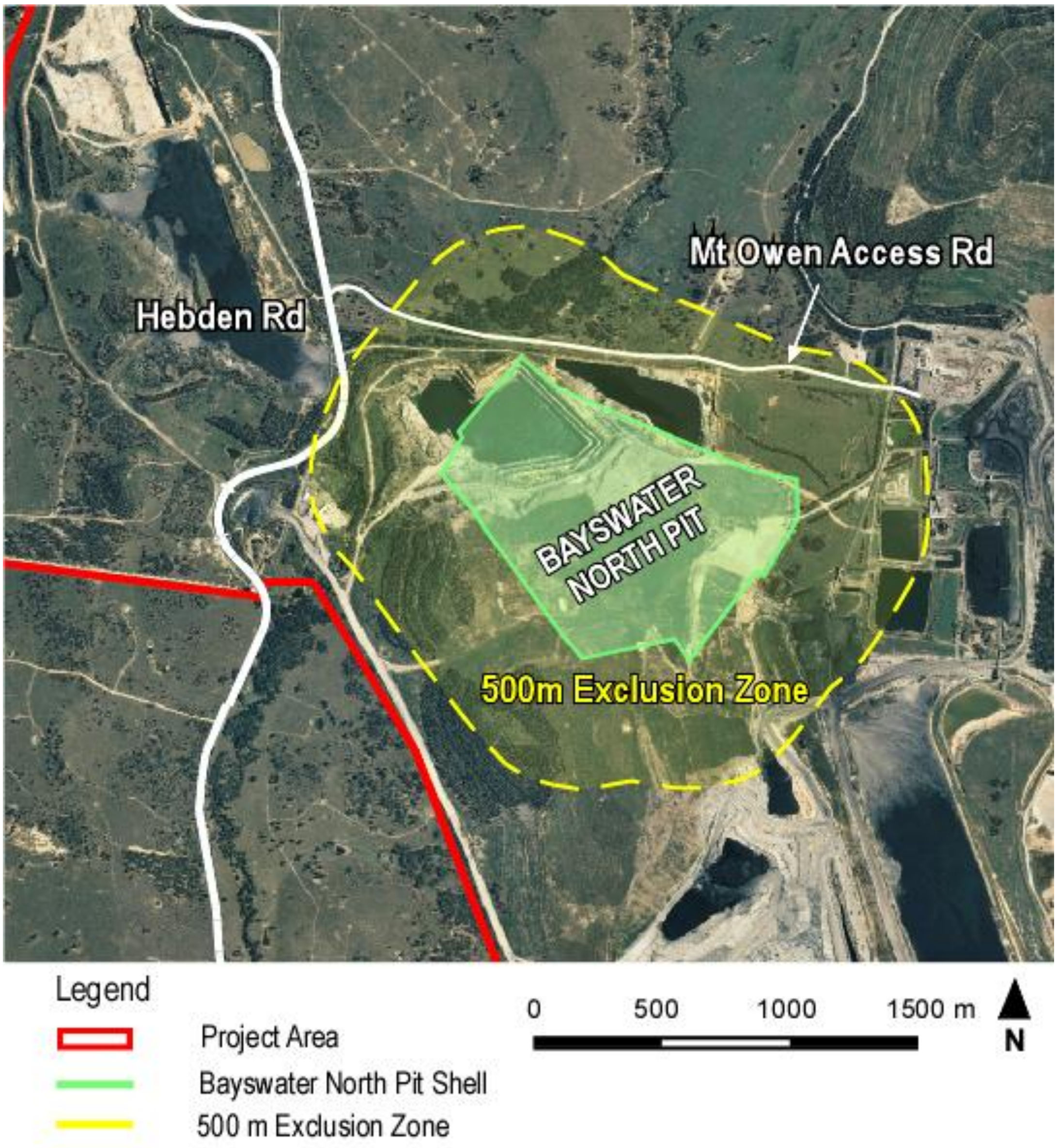

Figure 10 – Locations of the 500 m BNP Exclusion Zone and affected Hebden Road

7.0 CONCLUSIONS

The report presents an assessment of the impact of blasting activities associated with the Mount Owen Continued Operations Project on private residences, infrastructure and IUM. The Project proposes a continuation of the existing mining activities beyond the current North Pit mining limit and mining operations within the BNP and RERR Mining Area.

The site laws for ground vibration and overpressure used in the assessment are based on historical data sourced from the Mount Owen Complex monitoring stations.

The impact of expected blasting activities was modelled and quantified to determine the anticipated ground and airblast vibration levels.

The results of the analyses were assessed against the current operational limits and other applicable limit criteria for the assessed items (see **Table 7**). The current operational vibration limits at Mount Owen are specified as 5 mm/s allowed for 95% of blasts, and 10 mm/s not to be exceeded. The operational airblast limits are 115 dBL allowed for 95% of blasts and 120 dBL not to be exceeded.

The results of the assessment indicate that all impacts on private residences, infrastructure and IUM interactions can be managed effectively (complying with the respective vibration and airblast criteria) with the adoption of the management measures identified in this report (see Section 6).

8.0 REFERENCES

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15. Terrock 2006 Report No. MOM-0618-301106 "Assessment of the Vibration Predictive Model for Integra Underground Mine". Internal Report for Mount Owen.
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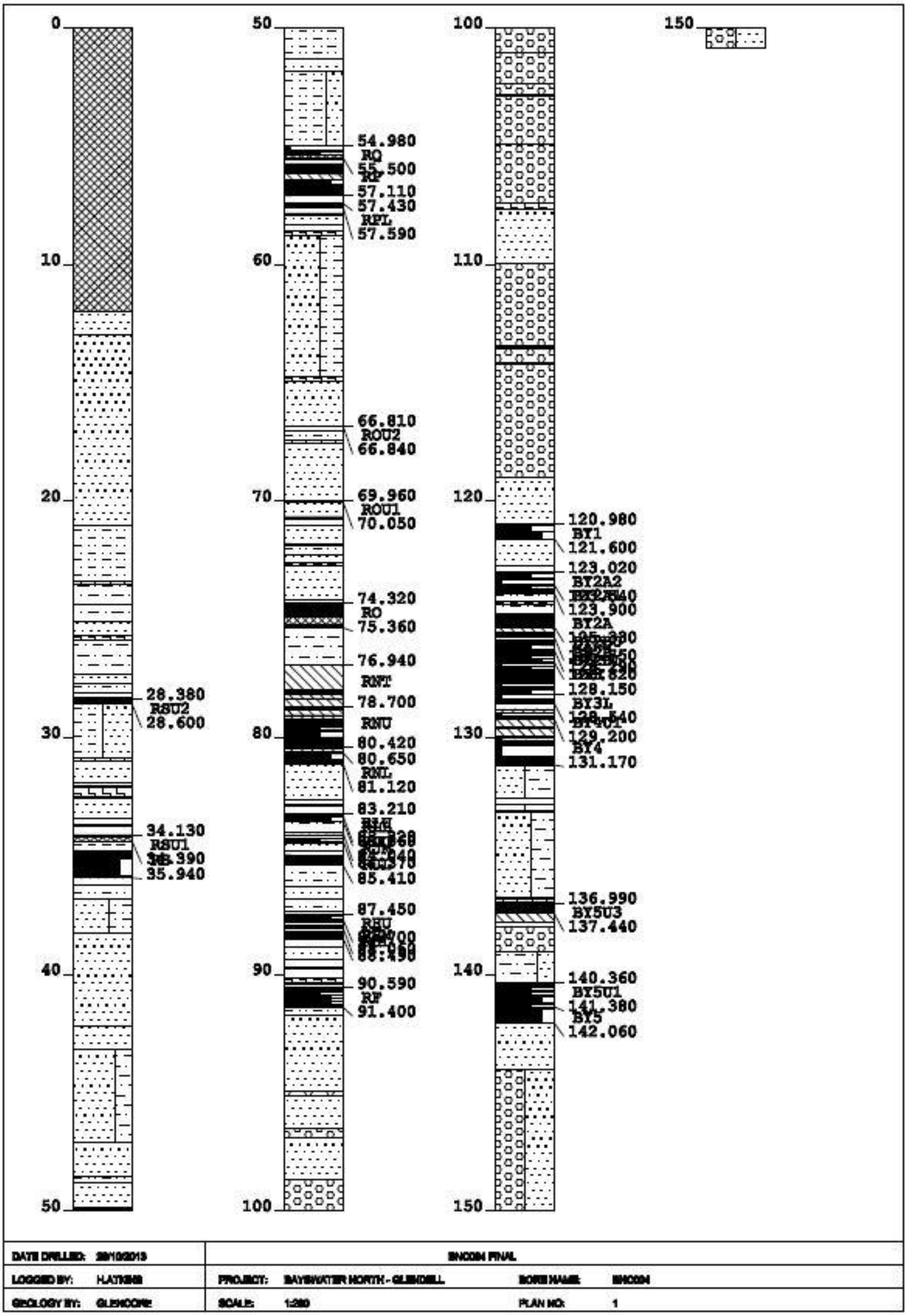
17. US Bureau of Mines, USBM RI8507.

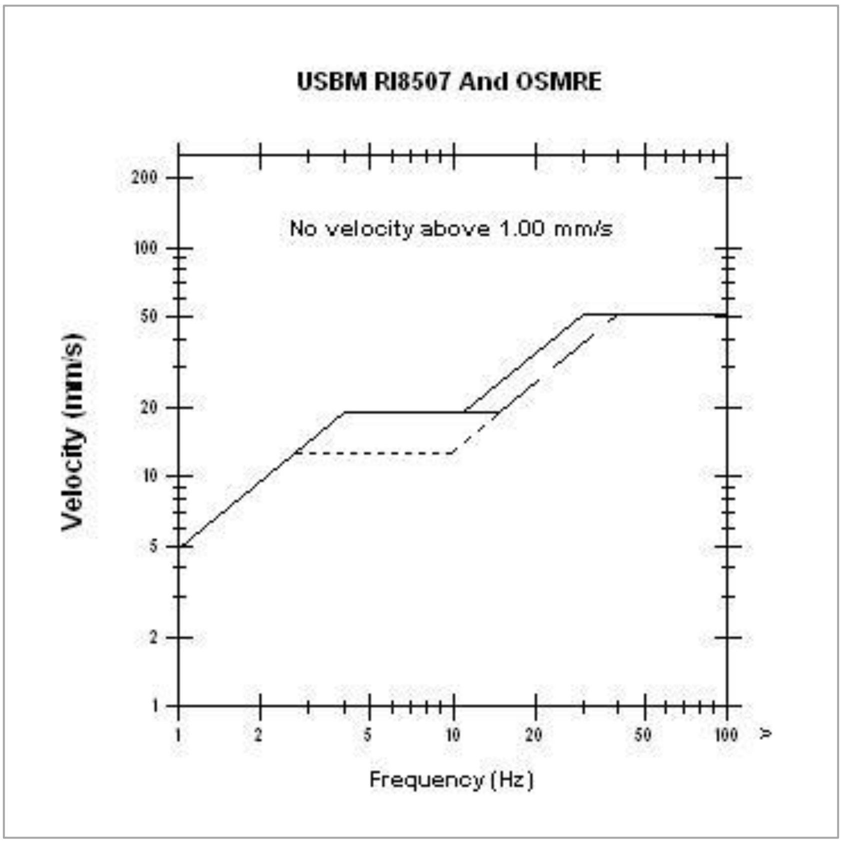
Thomas Lewandowski
8th October 2014
Enviro Strata Consulting

9.0 APPENDICES

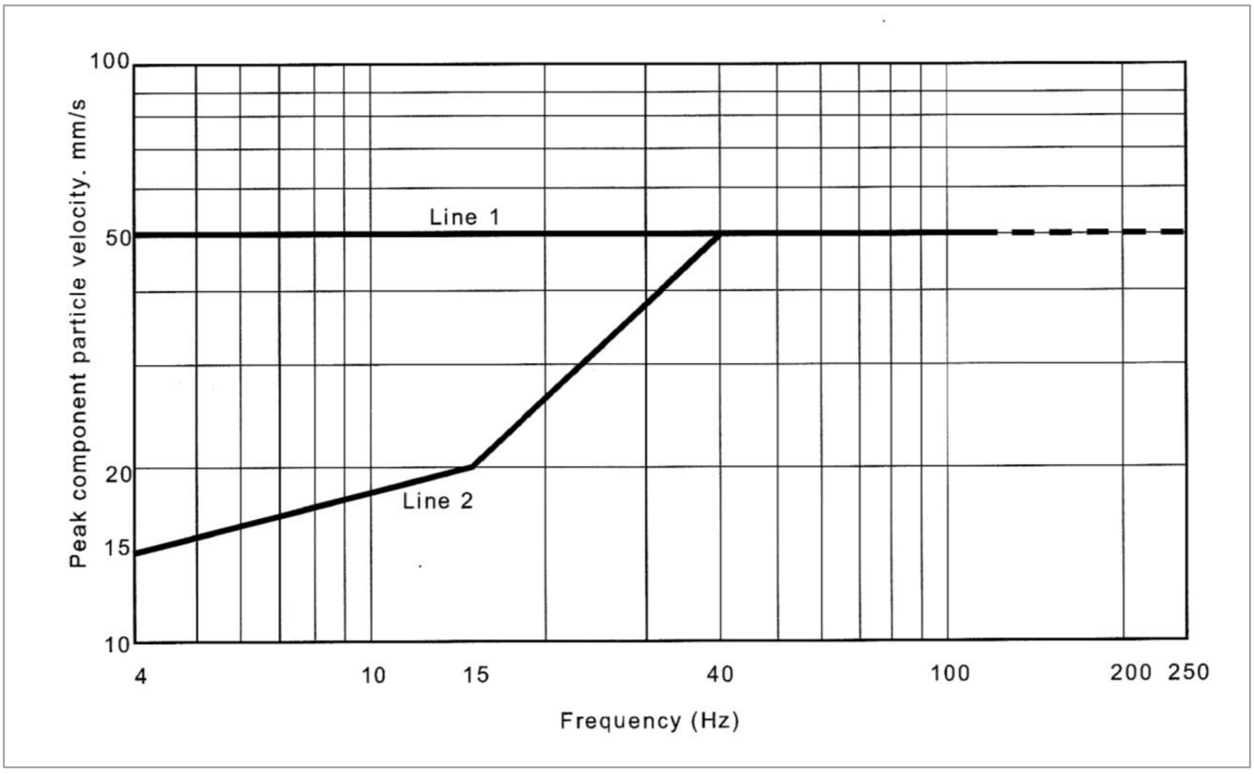
Appendix 1 – Borehole Log – BNC004



Appendix 2A – Safe Level Ground Vibration Blasting Criteria from USBM RI8507



Appendix 2B – Transient Vibration Guide Values for Cosmetic Damage - British Standard (BS 7385-2:1993)



Appendix 3A – Summary of Borehole Log – DH 229

INTEGRA COAL

VALE

BOREHOLE No. **DH229**

BOREHOLE SUMMARY SHEET

PROJECT AND SURVEY:

PROJECT:	Integra Underground
AREA:	INTEGRA UNDERGROUND
GEOLOGIST:	Luke Johnson
COMMENCED:	15/03/2010
COMPLETED:	4/1/2010
TOTAL DEPTH:	523.18
NORTHING:	6,410,426.04
EASTING:	321,397.44
RL:	98.96
TARGET SEAM:	Lower Hebden
PURPOSE:	Resource delineation

COAL SEAMS:

CODE	TOP	BASE	INTERVAL
BAY	155.00	158.55	3.55
PG	361.99	363.61	1.62
PG	368.88	369.83	0.95
AR	406.83	409.45	2.62
AR	411.65	413.71	2.06
UL	415.31	416.29	0.98
UML	424.84	425.45	0.61
UML	426.08	426.81	0.73
ML	442.19	444.57	2.38
LL	460.49	462.77	2.28
BR	482.22	485.34	3.12
HD	500.67	503.28	2.61
LHD	514.00	515.27	1.27

REHABILITATION:

DATE CEMENTED:	14/04/2010
DATE REHABILITATED:	17/05/2010

Appendix 3B – Summary of Borehole Log – DH 230

INTEGRA COAL

VALE

BOREHOLE No. **DH230**

BOREHOLE SUMMARY SHEET

PROJECT AND SURVEY:

PROJECT:	Integra Underground
AREA:	INTEGRA UNDERGROUND
GEOLOGIST:	Luke Johnson
COMMENCED:	29/01/2010
COMPLETED:	29/01/2010
TOTAL DEPTH:	596.25
NORTHING:	6,411,069.43
EASTING:	322,225.84
RL:	118.32
TARGET SEAM:	Lower Hebden
PURPOSE:	Resource delineation

COAL SEAMS:

CODE	TOP	BASE	INTERVAL
BAY	206.45	207.60	1.15
AR	448.39	450.59	2.20
AR	459.84	461.08	1.24
UL	461.25	462.23	0.98
UML	482.23	482.66	0.43
UML	484.37	485.16	0.79
ML	498.76	501.15	2.39
LL	521.25	523.23	1.98
BR	538.39	541.12	2.73
HD	557.55	560.21	2.66
LHD	579.12	580.45	1.33

REHABILITATION:

DATE CEMENTED:	28/04/2010
DATE REHABILITATED:	17/05/2010

Appendix 4 – ESC 2014 Report 'Vibration Limits for Former Hebden Public School and John Winter's Memorial Site', Report no. UM-1411-040914'

(see next page)

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UMWELT (AUSTRALIA) PTY LTD

VIBRATION LIMITS FOR FORMER HEBDEN PUBLIC SCHOOL AND JOHN WINTER'S MEMORIAL SITE

REPORT NO. UM1411-040914

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04th September 2014

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VIBRATION LIMITS FOR FORMER HEBDEN PUBLIC SCHOOL AND JOHN WINTER'S MEMORIAL SITE

REPORT NO. UM1411-040914

1. INTRODUCTION

Enviro Strata Consulting Pty Limited was engaged by Umwelt Australia Pty Limited on behalf of Mount Owen Pty Limited to undertake an estimation of allowable vibration limit criteria for two historically significant sites i.e. the former Hebden Public School and John Winter Memorial. The request was instigated by the mine's plans for the future development of the Mount Owen Continued Operations Project (the Project) in the vicinity of these structures.

The report presented below addresses the following points:

- Assessment of the conditions of the former Hebden Public School and the John Winter Memorial.
- Estimation of allowable vibration limits for the former Hebden Public School and the John Winter Memorial.
- Potential risks associated with structural damage due to blasting impacts.

2. PROJECT METHODOLOGY

The following project methodology has been used in the assessment:

- A site assessment undertaken on the 22.08.14 which included structural testing and a visual inspection of the structures and strata conditions;

- Review of available geotechnical information for the area;
- Revision of existing reports and available relevant information.

Also referenced are the author's experiences and overseas studies related to blast exposure of various structures and similar concerns associated with historical structures.

3. GENERAL SITE DESCRIPTION

Former Hebden Public School

The site of the former Hebden Public School is located in Hebden, approximately 22 kilometres to the north-west of Singleton. The former Hebden Public School opened in October 1912 and closed in December 1973 (NSW Department of Education).

School records, including the Register of Admission, Observation books, Punishment Book and Visitors Books are held in the Education Department's archives but are not available online.

According to the information extracted from the Visitors Book by the NSW State Records, the school was visited by Officers of the Public Works Department and the Furniture Branch in 1964, 1967-68 and 1970-73. The visits were related to various maintenance and improvement works being either projected or carried out on the building and grounds.

The school building is a small weatherboard construction with corrugated iron roof erected on timber piers. There is a timber floor and a fire place serviced by an external brick chimney. Other remnants of former structures exist in the surrounding area such as timber flooring, concrete pathways, slabs and piers.

The property was likely sold after the school's closure. The relatively new steel post and wire fence may have been constructed at that time.

The former Hebden Public School is located approximately 1,030 metres to the north-west of the proposed Bayswater North Pit, which is the closest mining area of the Project.

John Winter Memorial

The John Winter Memorial is located in Hebden, approximately 22 kilometres to the north-west of Singleton. The site is located approximately 70 metres from the former Hebden Public School. The site consists of a terrazzo headstone and monument. There is no evidence of other graves or memorial sites in the area. The following is a time-line sequence summarising John Winter's life.

- Born at Barnet, Buckinghamshire, England in 1832
- Arrived in NSW on the "Blenheim" in 1855
- Worked as a mower at Kentucky, in the New England district

- Arrived in Canberra and selected land at Red Hill, (now known as Gungaderra)
- Married Jemima McPherson on June 13, 1861 and had eight children – four boys and four girls
- Moved to live with his daughter (Shumack) at Ravensworth after the federal government resumed his property as part of the site of the proposed new federal capital, Canberra
- Died at Ravensworth in 1928 aged 96 years and was supposedly buried at the Church of England cemetery at Hebden.

The John Winter Memorial site is located approximately 1,020 metres to the north-west of the proposed Bayswater North Pit, which is the closest mining area of the Project.

Both the John Winter Memorial and the former Hebden Public School are considered to be of local significance, primarily in terms of their potential associative and social significance.

4. SITE ASSESSMENT AND VIBRATION LIMITS CRITERIA

A site inspection was undertaken on the 22.08.14 and involved ESC principal consultant Thomas Lewandowski and Mount Owen personnel Gary Bernasconi.

The visit included a site inspection, a detailed examination of the former Hebden Public School and John Winter grave site, a photo session and structural testing using non-destructive Schmidt Hammer Test. Test results are summarised in **Table 1**. The inspection included not only the two structures but also an inspection of the surrounding area including other structural elements of the school remains such as footpaths, an elevated platform, BBQ area, water tank and others.

4.1 TOPOGRAPHY OF THE AREA

The first observation is related to the topographical features of the area. The site is gently sloping with an estimated slope of 1.4 degrees. The gentle slope of the surface strata is in an easterly direction i.e. the surface strata is sloping down from Hebden Road to the east. In terms of potential damage for the existing structures this presents the optimal conditions as there is no opportunity for water pooling around the former Hebden Public School, nor around the John Winter grave site. The water runoff is directed away from these structures.

Water pooling can have a substantial impact on the structural integrity of manmade structures, particularly if it persists over an extended period of time.

The structural observations for both structures revealed the absence of any corner subsidence and related cracking, which could be caused by water pooling. The area is therefore considered to have an efficient drainage scenario, where water is drained away by the slope of the surrounding ground.

The installation of the water tank on the lower side of the school almost certainly helped over the years with any overflow directed away from the school building.

4.2 ASSESSMENT OF THE LOCAL GEOLOGY

The indirect damage mechanism is usually related to a failure of the underlying surface strata / soil, i.e. generally related to soil compaction / dislocation. This can subsequently impact the foundations and cause structural deterioration from the bottom of the structure upwards.

The indirect damage mechanism is very much dependent upon the underlying surface strata and level of ground vibration exposure.

To assess if the possibility of an indirect damage mechanism existed, an assessment of the surface strata conditions underlying the former Hebden Public School and John Winter Memorial was undertaken. For that purpose borehole logs from the adjacent area which are considered representative for the analysed region were obtained and inspected. The analysis revealed similarities between borehole logs, including presence of multi strata layers.

The two closest drilled boreholes to the former Hebden Public School included borehole No's **107** and **108A**.

Both boreholes are located within 400 metres of the former Hebden Public School. The geological cross-section based on the obtained drill log data is presented in **Appendices 1 - 2**. Based on the provided borehole logs the dominant rock type in this region is claystone and siltstone (i.e. up to 20 metres), with lesser amounts of sandstone, siderite and coal. It is concluded that the sequence is generally well bedded. Also, no sandy layers were detected in any of the borehole logs. Such rock strata are assessed to form a good base for the foundations of the former Hebden Public School and John Winter Memorial.

Based on these borehole logs there is no information provided on soil depth, this information was not logged. It is inferred that the top cover is approximately 0.5 metre of soil and 1 metre of clay in this area.

The additional testing undertaken on the 22.08.14 included digging of a small hole to confirm the quality of the soil in the top section of the strata. This test revealed the absence of sandy soil conditions, which could be affected during wet weather conditions and potentially when exposed to high vibration levels, i.e. the site inspection concluded the absence of sandy soil conditions, which could contribute to an indirect damage mechanism.

In summary, the geotechnical assessment of strata identified no poor quality soils (i.e. sandy soils) in the proximity of the analysed structures which could undergo the liquefaction process during blast vibration exposure. It should be noted that liquefaction is an exceptionally significant process in terms of possible damage. A visual inspection undertaken around the inspected structures confirmed the above conclusions.

4.3 SCHOOL BUILDING ASSESSMENT

School

The school assessment included a detailed assessment of the school building and surrounding structures. The school building represents a single, free standing building structure assembled of timber materials for both the floor and walls. There is a corrugated iron roof and the school also includes a fireplace with a brick chimney, see **Appendices 3A-E**.

The school building is a rectangular structure 8.7 x 6.1 metres, see **Figures 1A-E**. There is a single entry into the building foyer. The foyer is of limited dimensions and possibly served as a gathering place / information area (including information board). The building includes only one classroom 6 x 5.8 metres. The school entry has two concrete steps, which are of moderate strength of 32.3 MPa, see **Table 1**.

The state of the building is described as fair with only a couple of timber boards showing evidence of dry rot. There is paint peeling off the walls, but that is to be expected for a building of this age.

The internal observations indicated good conditions for the interior walls as well as for the floor (i.e. weatherboard used for the ceiling, floor and walls). There were no rotten timbers observed. There is some leakage through the roof indicated by two stains on the ceiling. This however is not extensive as there is no damage to the floor below. The school also has a ventilation fan, which helps in keeping damage to a minimum.

The classroom includes three windows on one side and one internal window to the foyer and one door entry. The conditions inside are described as above average for that age of structure.

The school building is elevated above ground on timber piers. The elevation ranges between 0.4 and 0.55 metres.

From a blasting point of view the school represents a relatively stiff structure with only a limited number of windows and doors. The closest comparison could be to a cubical block, which can take a significant amount of vibration before any damage occurrence (i.e. due to its rigidity).

From a material perspective as the whole structure is made out of timber, it provides a very flexible medium, which can take a substantial amount of vibrations before any damage or tilt occurrence.

To address the allowable vibration limit for this structure the most relevant and comparable study is presented below.

This includes the findings of the USBM (United States Bureau of Mines) study (**Siskind et. al. 1980**). The study is especially relevant as it is based on a large monitoring sample obtained from over 150 houses. The other important point is that the majority of the American houses include weatherboard construction similar to that of the former Hebden Public School.

The findings of the study are presented in a graphical format, see **Figure 2**. As shown, the presented curve is dependent not only on the vibration level but also on the generated frequency. It is important to note that the curve represents the levels of vibrations at which the potential onset of cosmetic damage starts to occur. It is stressed that the level at which cosmetic damage occurs is different from the onset of structural damage, which is substantially higher.

The typical frequencies generated by open cut blasting are generally above the 5 Hz range. Therefore, the inferred threshold level for the potential onset of cosmetic damage (using the USBM chart) and the inferred frequency is in the order of 12.7 mm/s (for gyprock) or 19 mm/s (for drywall). The quoted numbers represent an absolute minimum. Therefore, for the former Hebden Public School the 19 mm/s limit is used, as there is no gyprock material.

Similarly, the British Standard (BS 7385-2) provides vibration values for transient vibration relating to cosmetic damage, see **Figure 3**. Again, the damage level is dependent upon the frequency spectra. Similarly to the previous assessment, to induce any cosmetic damage high levels of vibrations (in excess of 16 mm/s for frequencies above 5 Hz) are required.

It should also be noted that the Australian Standard (AS 2187.2-2006) is not as prescriptive since no damage limit criteria are specified. However, the Australian Standard refers to the British and USBM standards for recommending ground vibration limits for control of damage to structures.

In the author's experience the above specified criteria are exceedingly conservative, when considering a weatherboard structure, as timber is a very flexible material (i.e. very forgiving material) when exposed to blast vibrations or earthquake effects. Nevertheless, the above discussed limits (i.e. 16 – 19 mm/s) can be used as a general guide when dealing with any potential cosmetic damage for the former Hebden Public School.

Chimney

The brick chimney is incorporated into the building structure and is 1.4 x 0.65 metres (outside width x depth dimensions). The estimated height of the chimney is in the order of 5.8 metres. The top part of the chimney is also locked by the timber frame of the top part of the roof. The estimated strength of the bricks is in the order of 28.5 MPa, see **Table 1**.

There is some cracking in one section of the chimney observed on both sides. The cracking is of limited depth and not extending through the whole chimney structure. Wire mesh netting has been installed at the back of the chimney structure for additional support.

The assessment concluded an almost vertical position of the chimney, without any significant tilt observed. From a damage perspective it should be recognized that there are a number of significant structural features, which prevent lateral movement of this structure, such as its incorporation into the wall of the building, the locking of the chimney by the timber elements in the top part of the roof, use of the mesh, etc.

The following are the steps undertaken in the process of identifying the ground vibration limit for the chimney.

To allow a 50 mm/s vibration level, the following calculations have been made:

The maximum deflection for the chimney in bending (using AS 3600-2001 Concrete Design) is L/125.

Therefore, for a 5.8 metre chimney, the maximum deflection is estimated as:

Maximum deflection = 5800 / 125 = 46.4 mm

Using a 50 mm/s vibration level the estimated vibration displacements are as follows:

- For a frequency of 5 Hz – estimated displacement – 1.6 mm;
- For a frequency of 15Hz – estimated displacement – 0.6 mm;
- For a frequency of 25 Hz – estimated displacement – 0.3 mm.

Allowing for a magnification of x3 for the top of the chimney the following estimations have been made:

- For a frequency of 5 Hz – estimated displacement – 4.8 mm;
- For a frequency of 15 Hz – estimated displacement - 1.8 mm;
- For a frequency of 25 Hz – estimated displacement - 0.9 mm.

Based on the above it is postulated that a vibration limit of 50 mm/s is permissible for the analysed chimney. It is stressed that the discussed 50 mm/s vibration limit is conservative as the estimated maximum displacement from vibrations presents approximately 1/10th of the maximum deflection allowed for this type of structure.

Table 1 – Summary of Strength Results Using Schmidt Hammer Test

Infrastructure / Tested Section	Measured UCS (MPa)			Estimated Average UCS (MPa)	Comments
School					
Concrete steps	48.6 34.5 18.3 43.1	43.1 29.0 22.1	30.3 25.5 29.0	**32.3**	Relatively good conditions – no major chipping observed
Patio in front of the school	18.3 22.1 18.3 25.5	25.5 22.1 16.2 23.8	29.0 23.8 18.3	**22.1**	A number of concrete slabs in front of the school. Relatively good condition.
Chimney – bricks	32.8 18.3 25.5 30.3	19.3 36.2 29.0	34.5 30.3 29.0	**28.5**	Good quality bricks, no breakage of bricks observed

Infrastructure / Tested Section	Measured UCS (MPa)	Estimated Average UCS (MPa)	Comments
Chimney – mortar joint	<10* <10* <10* <10* <10*	**<10***	Typical values for mortar detected. Usually less than 2 MPa (from other studies)
John Winter Grave			
Concrete footing	25.5 29.0 25.5 23.8 34.5 18.3 34.5	**27.3**	Good condition - no major cracking observed
Terrazzo – back side	57.9 57.9 58.6 46.5 50.3 43.1 39.6 57.9	**51.5**	Good condition – no major chipping observed
Terrazzo - sides	25.5 23.8 43.1 50.3 58.6 29.0 25.5 36.2 36.2 25.5 34.5	**35.3**	Good condition – no major chipping observed
Elevated Platform			
Concrete slab	25.5 29.0 10.3 23.8 25.5 30.3 16.2 43.1	**25.5**	Relatively good condition – no major chipping observed
Side wall – bricks	12.4 18.3 16.2 10.3 10.3 18.3 30.3 14.5 29.0 25.5	**18.5**	Good quality bricks, no breakage of bricks observed
Remains of Toilet Block			
Concrete	36.2 29.0 22.1 36.2 18.3 34.5 18.3 36.2 25.5	**28.5**	Variety of concrete elements tested
Footings of Old Building Section			
Concrete Piers	22.1 18.3 37.9 39.6 34.5 22.1 27.6 25.5 41.4	**29.9**	Various concrete elements
BBQ Area			
Bricks	29.0 36.2 25.5 18.3 36.2 32.8 12.4 32.8 32.8 22.1 14.5 22.1	**26.2**	No major structural damage detected

* Below instrumentation capability but still a valid estimation

4.4 GRAVE ASSESSMENT

The second structure assessed in detail from a damage point of view included a grave site, see **Appendix 4A-C**. The gravestone is dated 1928. The material used for the grave's construction includes a concrete plinth and a horizontal terrazzo slab and desk. There is also a granite material used for the tablet on the desk.

Due to the presence of the modern materials and their condition (such as terrazzo) it is inferred that the grave site has been updated at a later stage and is not as indicated by the date on the monument of 1928.

The state of the structure is described as very good. There is no tilt for any part of the grave**.** There are no signs of erosion or water pooling around the considered grave, which could contribute to localised subsidence and its deterioration and structural damage. The back side of the gravestone desk is of a limited height of 0.7 metres only without any signs of tilt.

To provide some indication about the structural strength a non-destructive Schmidt Hammer test was undertaken on the concrete plinth and terrazzo slab. The results of the testing are summarised in **Table 1**.

The assessment concluded moderately strong materials in the order of 27.3 MPa for the concrete plinth and 35.3 – 51.5 MPa for the terrazzo slab. Note that differences in the terrazzo material testing are potentially related to the instrumentation placement (i.e. either on stone or on concrete materials).

From a blasting perspective these are very strong and homogenous materials and therefore not easily susceptible to damage by ground vibration movement.

The structure itself is not very high above ground level and therefore is also not susceptible to damage by induced lateral ground motion. In addition it should be understood that the grave structure is not comparable to a free standing wall, which could be prone to exaggerated lateral movement due to induced vibrations. All sides of the grave are locked together, therefore representing a very stiff structure.

To provide some indication about the potential damage level for the structure the following comparative numbers are quoted.

Oriard (1998) believes vibration limits are not appropriate for mass concrete. No damage was observed on test blocks when subjected to 3 in/s (76.2 mm/s) of vibration twice a day from the time of pouring and 17 to 70 in/s (1778 mm/s) at three days and 100 in/s (2540 mm/s) at eight days.

Only some spalling of poorly bonded grout and a previously deteriorated surface were evident at 100 in/s (2540 mm/s).

For a free standing wall initial cracking appears to occur at 6 to 11 in/s (279.4mm/s) (RI 8507) and (RI8896). Cases of foundation cracks were likely caused by static failure.

Worldwide studies found driveways and slabs in contact with the ground did not crack, including those achieving vibrations of 5 to 10 in/s (254 mm/s).

Other studies indicated that there is the potential for spalling to occur in old concrete elements at approximately 280 - 300 mm/s or similar levels.

The author's experience includes exposure of concrete structural elements (including a concrete tunnel with a comparable strength of 25 - 30 MPa to the discussed grave), to high vibration levels in the order of 232 - 250 mm/s (Lewandowski and Cope 2009) without any negative impact or damage observed.

In summary from ESC's experience, vibrations in the order of 250 - 300 mm/s are generally insufficient to cause damage to structural elements in good condition, such as the considered John Winter Memorial of the estimated strength of 27 – 51 MPa. The inferred vibration damage level for the considered materials, considering the materials strength and current state of the structure, is estimated to be above the 300 mm/s level.

4.5 OTHER STRUCTURES

There are other structures present within the school grounds. These include:

An elevated platform - the platform is constructed of brick and mortar material, with a concrete slab on top (i.e. rectangle 7.35 x 1.85 metres). The elevation of the platform is 0.65 metres above ground level.

Footpaths – made out of concrete slab elements. Some of the footpaths are in good condition and some are damaged.

BBQ area – a brick and mortar structure of 1.3 x 1.5 metres. There are no major structural issues with the BBQ.

Concrete water tank – the tank is empty and shows a couple of 0.4 and 0.6 metre long cracks. The tank is approximately 4.1 metres in diameter and 3 metres high.

Remains of concrete piers for removed buildings - there are the remains of other structures such as other school buildings, toilet blocks, etc. The remains include only remnants of footings, such as concrete pier elements. There are no wall elements left. Generally these elements lie in disarray among the significant amount of rubbish, such as pumps, gutters and car parts. Based on the concrete footings the shape of the previous buildings can be inferred. With the exception of the footings the other elements are of no significant historical value as they were introduced later into the school grounds.

The vibration limit for the above discussed structures (due to their robustness) is similar to that proposed for the grave site.

5. CONCLUSIONS

At the request of Umwelt Australia a detailed assessment study for the former Hebden Public School and John Winter Memorial sites was undertaken. This included a review of relevant data and a site inspection undertaken by the ESC principal consultant in the presence of Mount Owen personnel on the 22.08.14. The investigation is summarised as follows:

- The state of the structures has been assessed in detail in Section 4 of the report. The school conditions include some cosmetic defects with some dry rot for a couple of the timber boards. The conditions are well above average for the age of the structure considering that it has been deprived of maintenance from the 70-ies. The John Winter Memorial condition is described as excellent. There are no major structural issues with the school and grave site which can be exacerbated by the proposed blasting in the vicinity of these structures.
- Geotechnical conditions and the topography of the area has been assessed in detail, and revealed the absence of any negative impacts on the analysed structures.
- The vibration limits for the former Hebden Public School were identified as 16 - 19 mm/s. As discussed in the report the specified levels are very conservative when considering weatherboard structures, as timber is very flexible material when exposed to blast vibrations or earthquake effects. The proposed limits are also well below the damage criteria for the chimney, which forms a part of the structure.
- The inferred safe vibration level for the John Winter Memorial was identified to be in the order of 250 mm/s. The inferred vibration damage level for the considered materials, considering materials strength and current state of the structure, is estimated to be above the 300 mm/s level. A similar level is applicable to the other miscellaneous structures located within the fenced boundary of the school.

Thomas Lewandowski
04th September 2014

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FIGURES

Figure 1A – Former Hebden Public School – Plan View

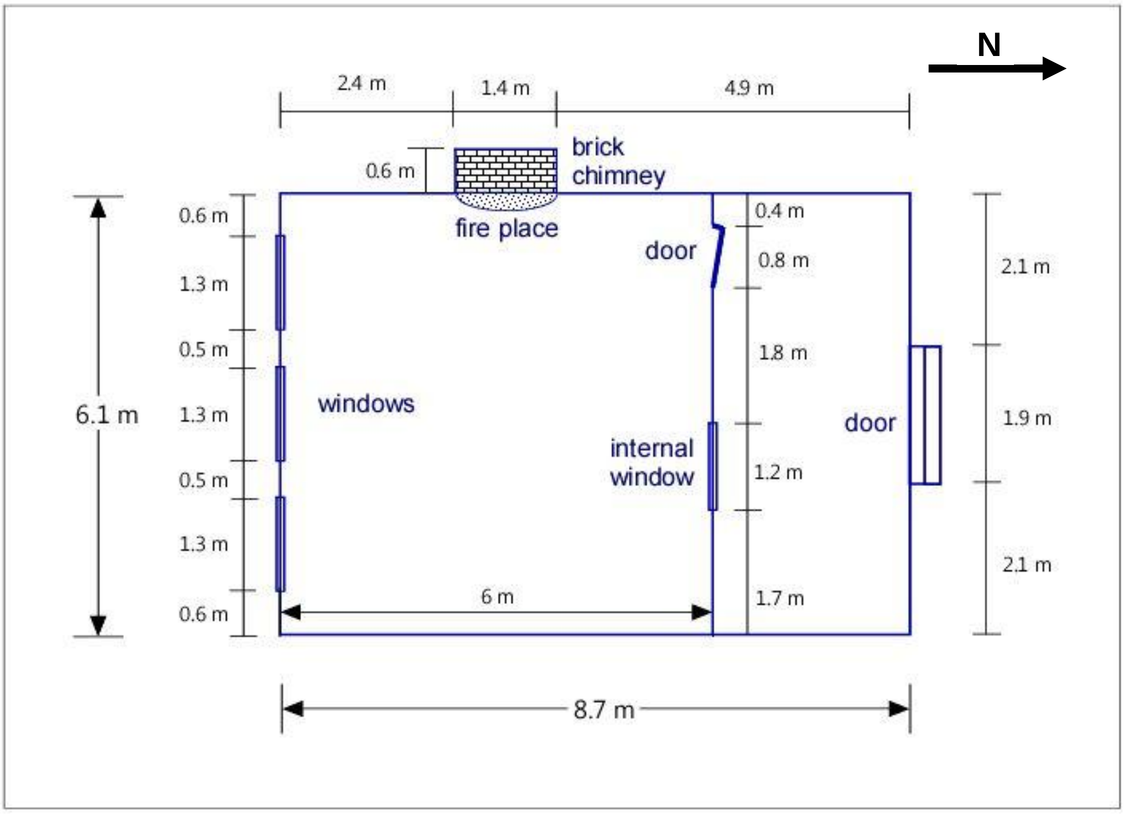


Figure 1B – Schematic of Former Hebden Public School – Northern Aspect

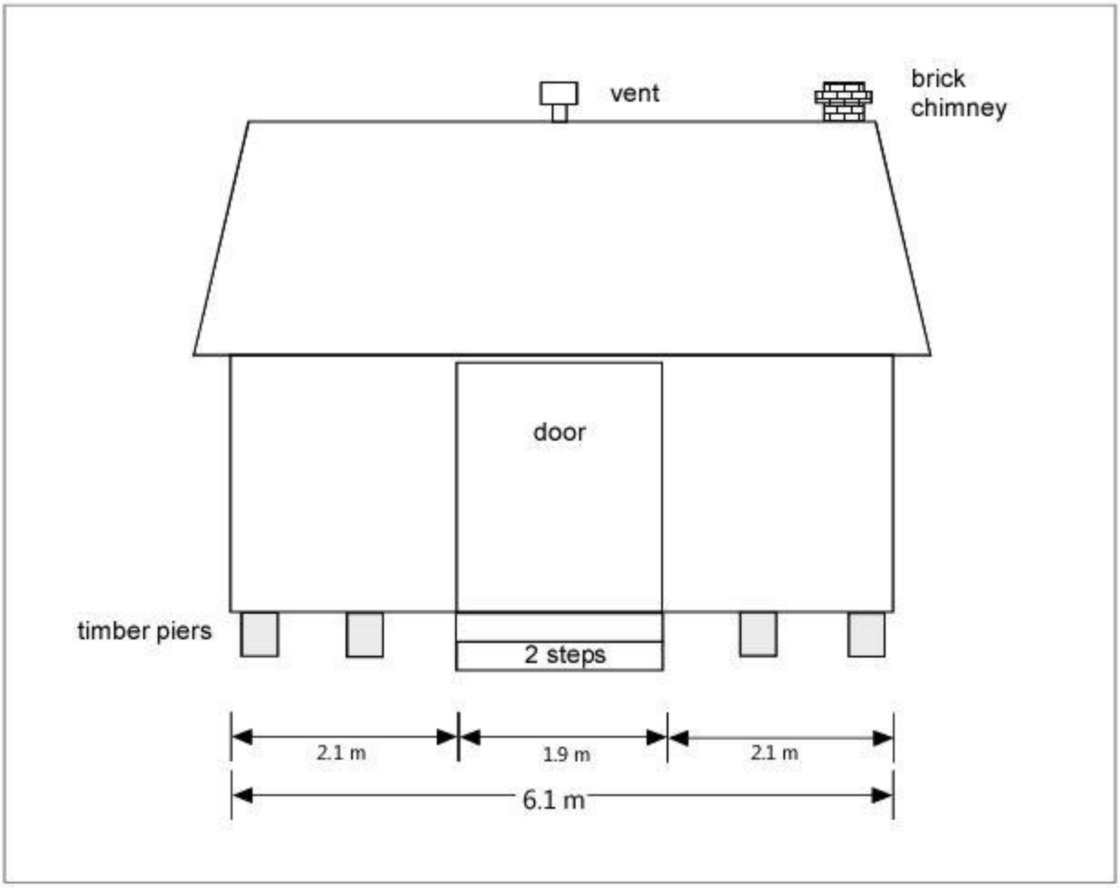


Figure 1C – Schematic of Former Hebden Public School – Eastern Aspect

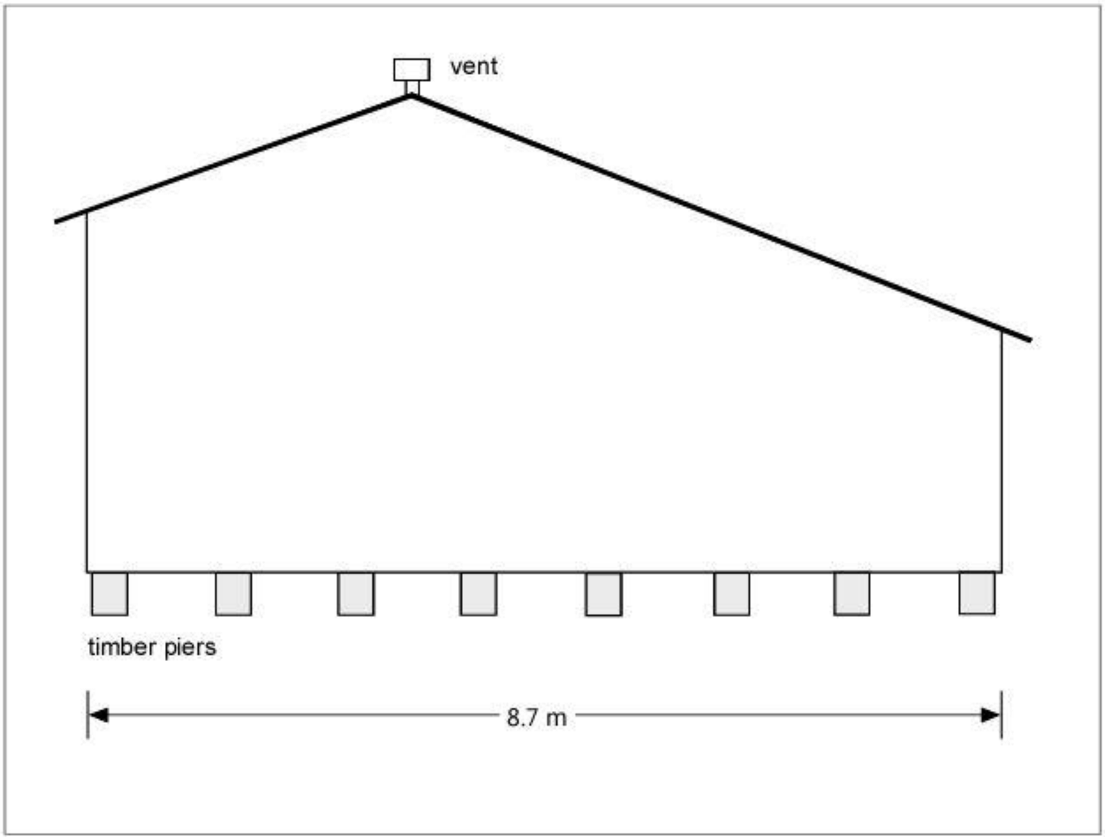


Figure 1D – Schematic of Former Hebden Public School – Southern Aspect

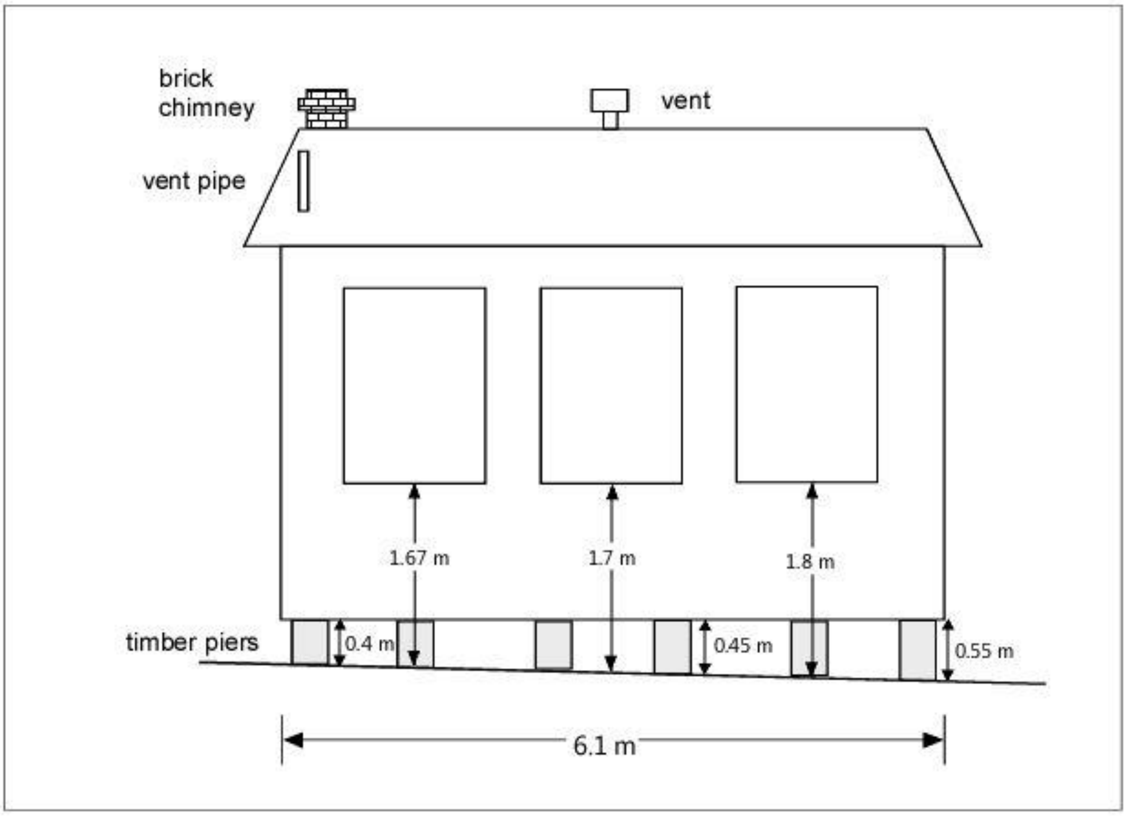


Figure 1E – Schematic of Former Hebden Public School – Western Aspect

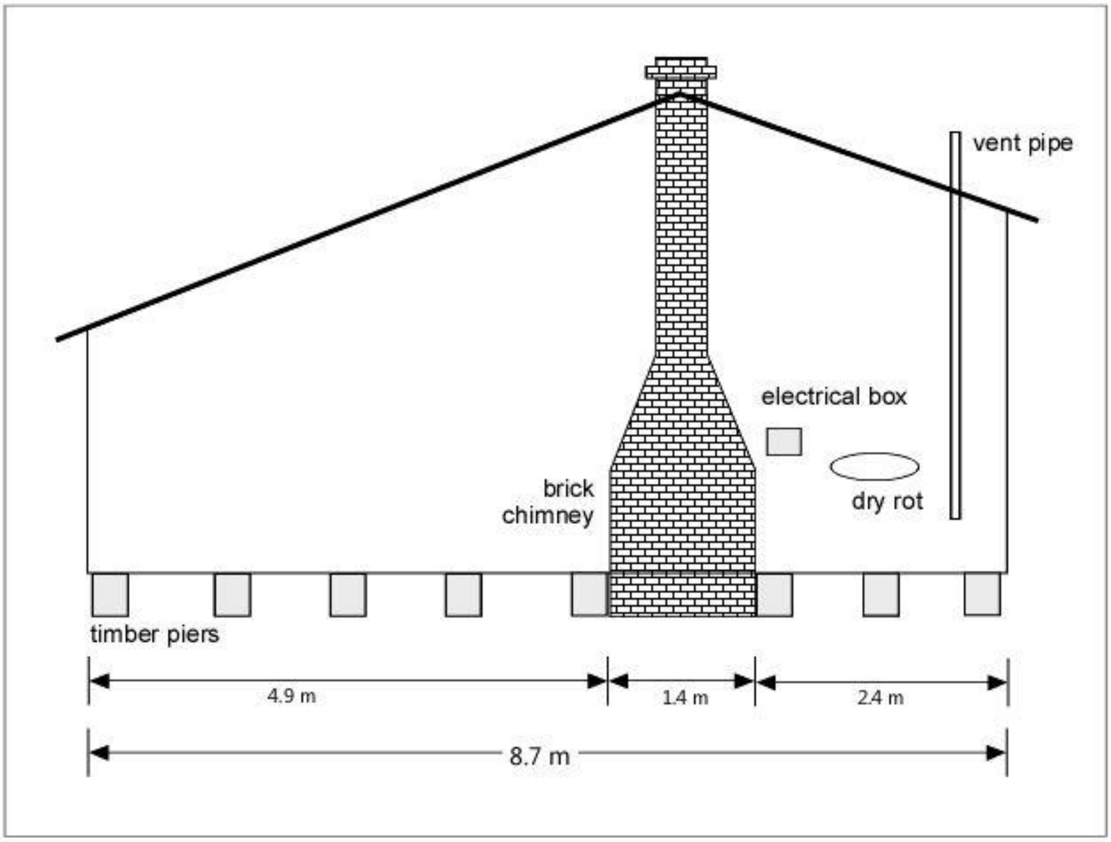


Figure 2 – USBM "Safe" Blasting Vibration Level Criteria (USBM RI 8507)

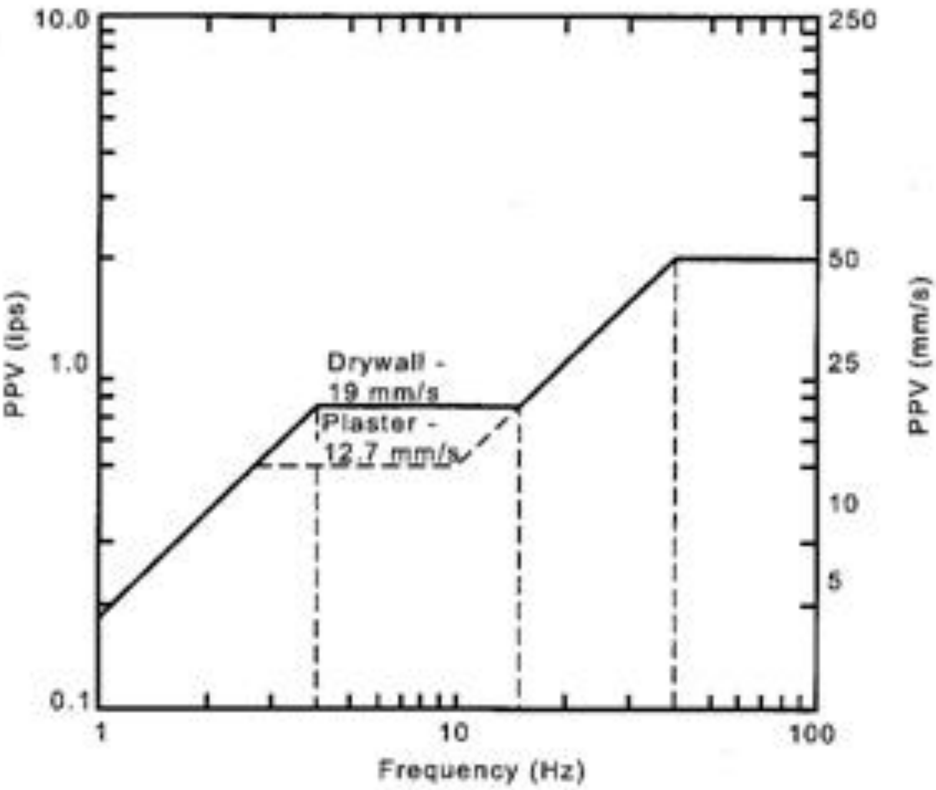
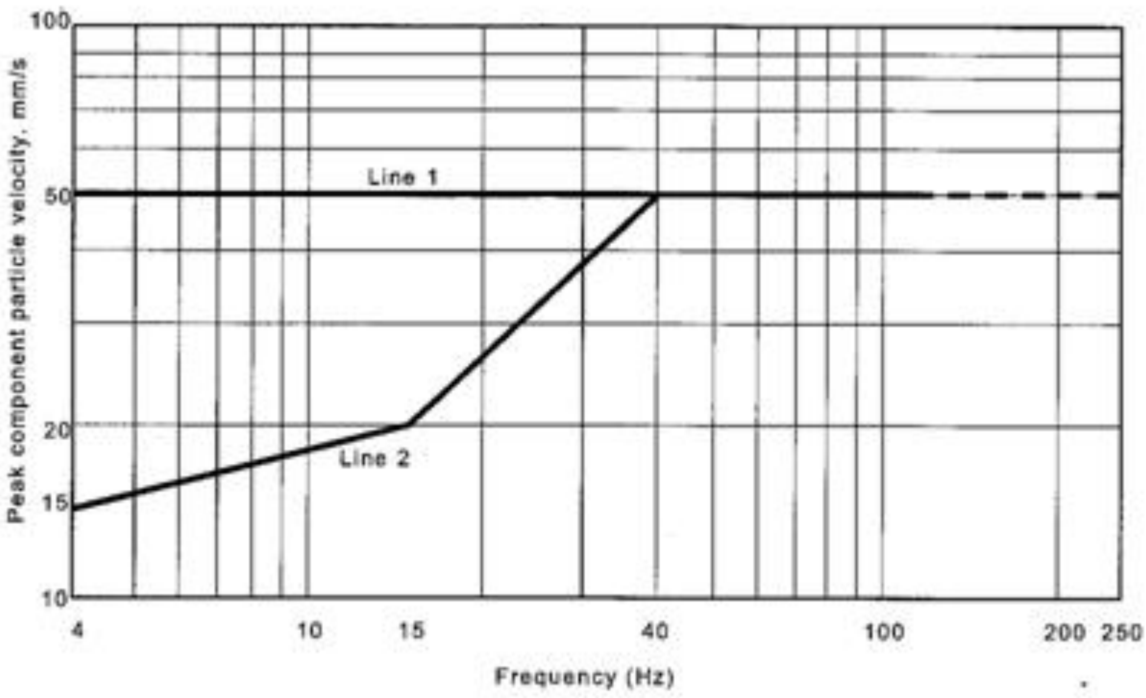
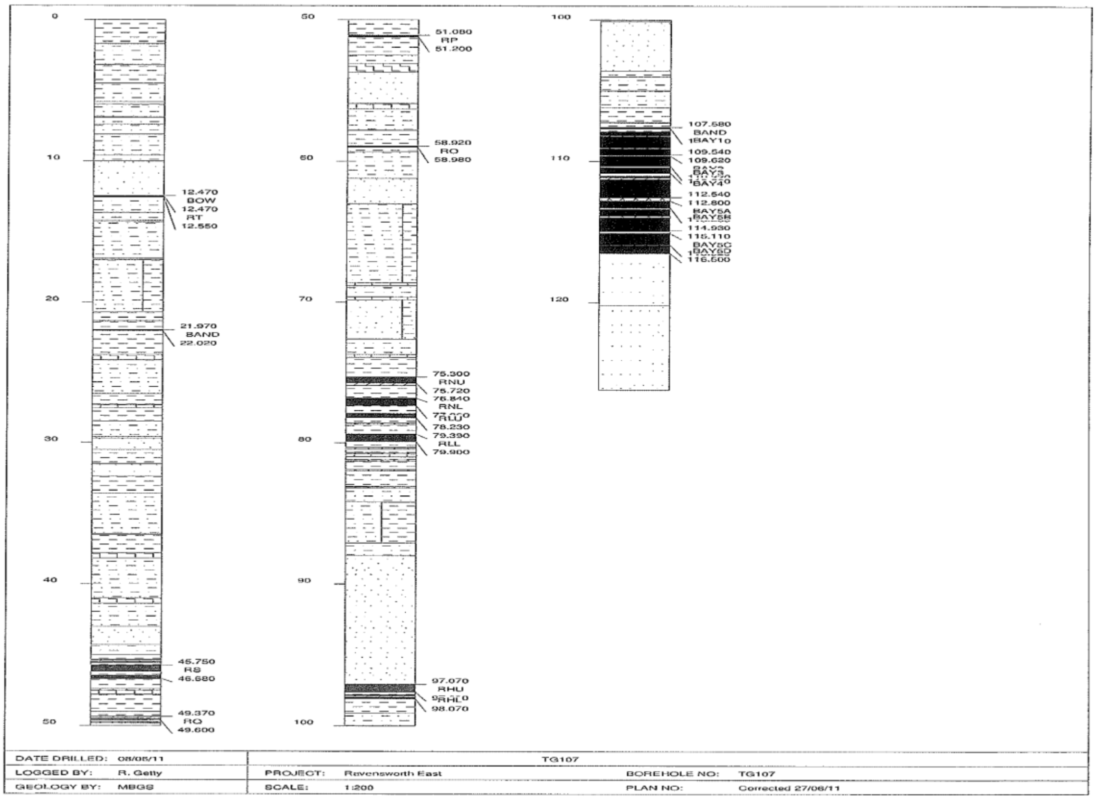


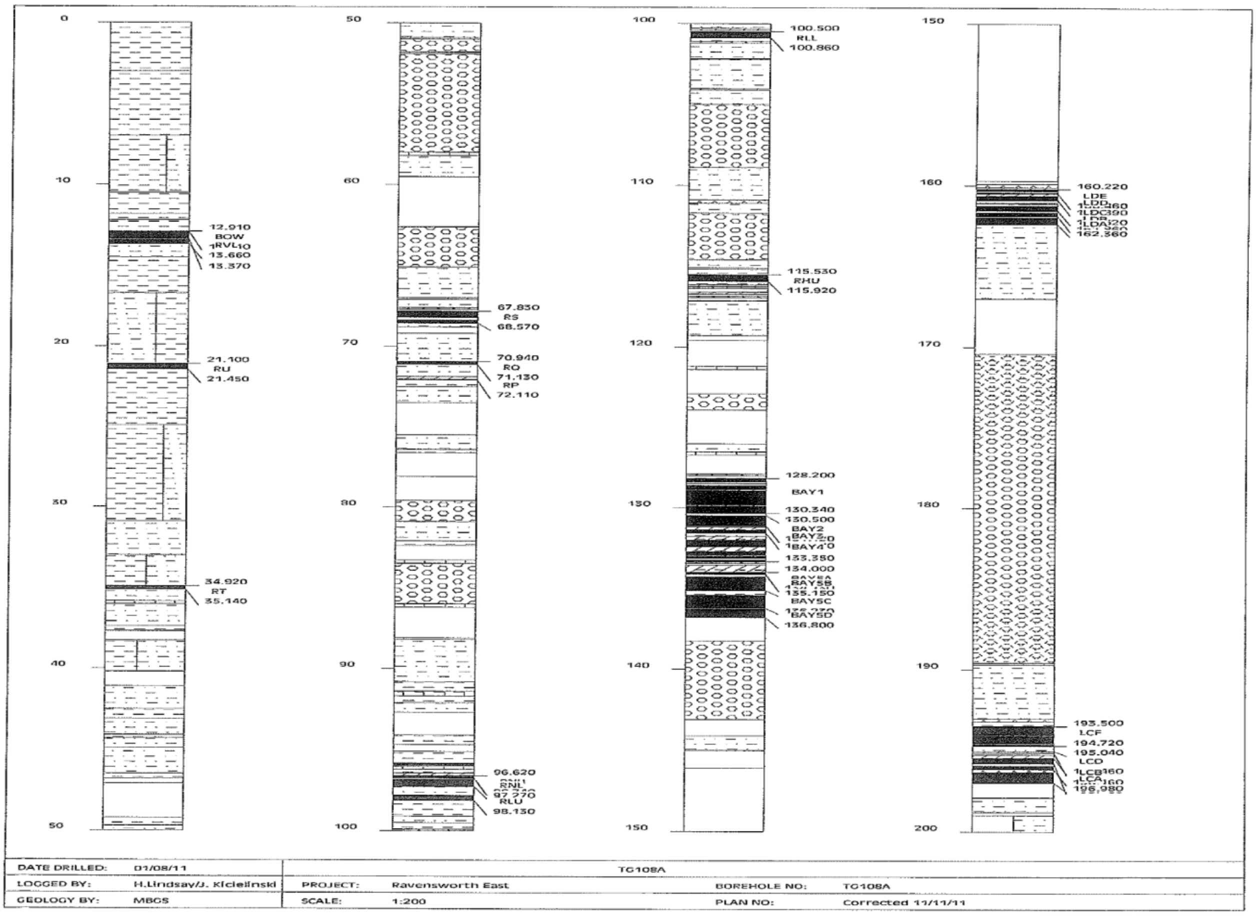
Figure 3 – Transient Vibration Guide Values for Cosmetic Damage (British Standard BS7385-2)



APPENDIX 1 – Borehole Log No. 107



APPENDIX 2 – Borehole Log No. 108A



APPENDIX 3A – View of Former Hebden Public School – Northern Aspect

APPENDIX 3B – View of Former Hebden Public School – Eastern Aspect

APPENDIX 3C – View of Former Hebden Public School – Southern Aspect

APPENDIX 3D – View of Former Hebden Public School – Western Aspect

APPENDIX 3E – View of Former Hebden Public School – Inside Conditions

APPENDIX 4A – View of John Winter Grave

APPENDIX 4B – View of John Winter Grave

APPENDIX 4C – View of John Winter Grave