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Monday, April 11, 2016

Ref:jhh:High level review V2

Mt. Tim Power  
Partner – Herbert Freehills Smith  
101 Collins Street,  
Melbourne VIC 3000

**RE: High level review of vibration and regenerated noise assessment**

Dear Tim,

The high level review addresses the key areas as per the structure of the Impact Assessment Report. The review also includes an additional section covering the general adequacy of the report, its structure and overall content.

The key areas are as follows:

- 1) Summary
- 2) Impacts of
- 3) Other comparative projects
- 4) Appropriate performance criteria/guideline targets
- 5) Predictions and determining if the targets/guidelines can be met
- 6) Implications of the predicted values
- 7) Identifying appropriate mitigation options
- 8) Evaluating residual risks

**Summary**

*The technical assessment of the vibration impacts, including the regenerated noise effects, are very well presented, easy to follow and includes the information necessary to allow the impacts to be quantified. Dividing the project into precincts and highlighting the impacts in each precinct using a combination of text, drawings and tables allow for straight forward review. All relevant construction areas are adequately addressed with the exception of the cross passages between tunnels which appears to have been omitted from any analyses. The assessment applies internationally accepted standards to derive the performance criteria that are stringent and will ensure quality of life for persons around the project boundary. The proposed performance criteria are however complex and may be difficult to administer. As best as can be determined from the information supplied, the estimate of the induced vibration impacts from the different sources uses relationships that are generic and not as site specific as potentially could have been applied. The calculated levels are however typical of that expected from the equipment selection, separation distances and rock types and are therefore acceptable as measure of the likely impacts. A comparison with the performance criteria has identified that compliance with proposed conditions will be challenging, even with application of best practices. An overall assessment of the impacts could be improved by identifying the number of "affected property days" over the total alignment rather than for only the closest property in each precinct. This would further allow an indication of the level of mitigation and risk encumbered of the project. There are precincts within the project, and activities within these areas, where compliance cannot be guaranteed and mitigation options are few. Mitigation options are scantily addressed in the assessment, particularly given the sections of the project where compliance with the performance limits cannot be achieved. The risk in completing the project on time and on budget lies in how these sections of the project will be managed and mitigated. Ensuring all potentially sensitive receivers are identified and appropriate vibration constraints determined is equally important.*



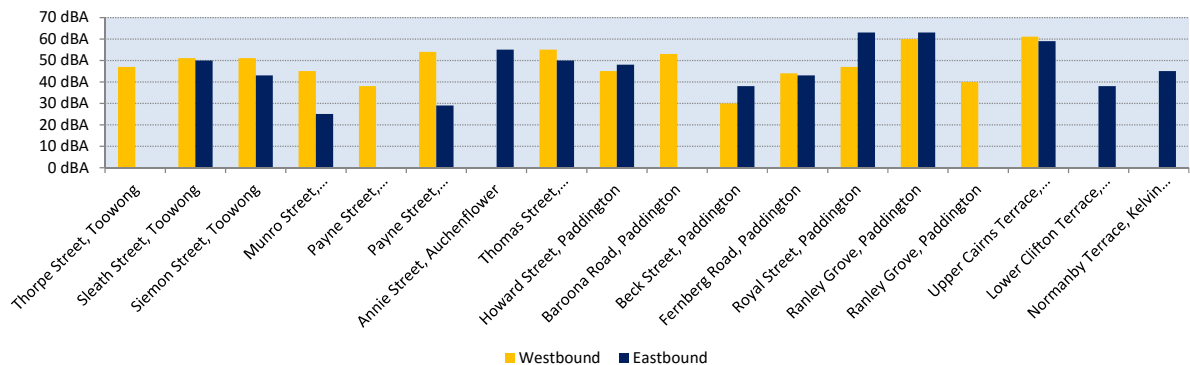
### **Understanding the impacts**

- 1) Vibration effects will necessarily occur as a result of the mechanical excavation of the rock mass using TBM, road headers or hydraulic hammers mounted to excavators. Vibration produced by these sources is described as periods of activity, which can persist for up to 15 minutes, followed by periods of nil impact as the equipment re-sets, re-grips or relocates to other areas. These sources of vibration are generally considered continuous in their assessment. Other sources such as piling can be described as either intermittent or continuous, although the latter is a more conservative descriptor in terms of personal amenity assessment. Blasting produces impulsive vibration which is short term persisting for not more than 10 seconds at most once per day.
- 2) Relationships that describe the decay of vibration with distance for each equipment type are applied to determine the impacts at varying distances from the construction activities. Blast vibration relationships also include a third parameter that includes the quantity of explosive contributing to the vibration.
- 3) Vibration, if sufficiently high, can cause superficial damage to adjacent buildings. The results of well documented blasting studies linking vibration levels and observed building damage have been published in the international journals and have subsequently been incorporated into vibration standards that are universally applied. Compliance with these suggested limits virtually ensures the project can be free of vibration related damage.
- 4) Low levels of vibration, much lower than those that can result in damage, are readily perceived by persons and often considered annoying and impacting upon their personal amenity. The human body is very capable of detecting levels of vibration well less than a few percent of those values that are linked with the onset of superficial building damage. Vibration impacts for construction projects are therefore assessed against personal amenity criteria with the knowledge that compliance with these limits virtually ensures no impact in terms of building integrity. It is commonly accepted that vibration will be personally intolerable to building occupants well before any damage to the building or its contents may occur. Understandably, some highly calibrated and specialised scientific or medical apparatus may necessitate lower levels of vibration that falls outside of the comments above.
- 5) Regenerated noise, or what can be referred to as ground-borne noise, occurs as a result of vibration inducing momentary deflections, generally less than a few microns, into the floors, walls, ceilings and other hard surfaces of buildings. An estimate of the level of regenerated noise is particularly challenging given that it requires initially an estimate of the level of vibration plus additional calculations detailing how the vibration pulse manifests as audible noise effects. Influences such as the geological conditions and the soft soil profile, construction of the house and whether it is slab on ground, strip footings or piered foundations, number of levels and whether single or multi story, the type of floor or wall coverings and whether carpet, timber or tiles are a few of the many factors affecting the level of regenerated noise. Typically the different effects are grouped together as knowledge of the individual impacts without an inspection of every property coupled with an extensive geotechnical investigation is not possible. The outcome is that the accuracy of regenerated noise predictions is poor, yet it remains the impact that will prompt essentially all mitigation measures. Any measures to better understand and estimate with a greater degree of accuracy regenerated noise predictions will reduce the risk to the project.

### **Comparison with other projects**

- 6) The impacts of tunnelling and construction activities on equipment and personal amenity have been assessed at multiple other large scale tunnelling projects completed through Australia.
- 7) In terms of likely impacts and mitigation options, the *Legacy Way* project in Brisbane involved developing twin 12 metre diameter tunnels in hard rock formation beneath residential properties. The tunnel length was approximately 4.6 kilometres. The tunnel depth varied between 25 metres to more than 50 metres below surface level. The portals were located in areas of minimum residential impact. No significant underground excavations were required. Vibration levels from the construction process, including TBM and hydraulic hammers, varied up to 2mm/s. Blasting produced vibration levels up to 25mm/s. Regenerated noise values were measured up to 60dBA. Tenants (occupiers) from a total of 328 households were relocated through the project. Residents from 42 properties were relocated as a result of the TBM activities with the remaining 238 households affected by cross passage

developments. The report did indicate the average number of nights each household were relocated for. The following graph shows the measured levels of regenerated noise at sections along the tunnel alignment.



- 8) The *North South Bypass Tunnel (Clem 7)* is a 4.8 kilometre twin tunnel that passes beneath the Brisbane River as well as both commercial and residential properties. The depth of the tunnel was of similar depth to the Legacy Way project although with more than half of the tunnel passing beneath commercial properties where vibration and regenerated noise was less imposing. No adjustments to the TBM operating schedule, other than planning regular maintenance during evening hours, or the TBM operating parameters (thrust and cutter head rotation) were implemented. Exceedances of regenerated noise limits occurred and were mitigated through relocations and monetary compensation. Sections of the tunnel accesses were developed using road headers that were associated with similar regenerated noise measurements and mitigation options to the TBM.
- 9) The *Airport Link* project was a significant construction project and involved the construction of tunnels with an overall length in excess of 7 kilometres. Large caverns and intersections with on and off ramps resulted in extended periods of construction that focused in key sections of the project. The extensive surface works impacted upon a large catchment area and resulted in relocation as a key mitigation measure. Commercial properties were affected to an extent greater than initially expected.
- 10) A report prepared on the M5 East project indicated that regenerated noise levels associated with the night-time road header tunnelling operations were expected to be acceptable to most building occupants (i.e. below 40dBA) at offset distances of about 37 metres or more. At 30 metres, there was expected to be adverse comment from affected residents.
- 11) A report prepared for the Epping to Chatswood rail link in Sydney that involved the construction of two 7.2 metre diameter tunnels provided comment on the impacts of regenerated noise levels. The level of tolerable noise within the homes was set at 40dBA. Noise levels that measured more than 40dBA were identified as the point at which residents and families would be offered alternative accommodation until the machines had passed. The report indicated that along the first half of the alignment, some 130 homes were identified as being within the field of TBM noise and vibration. The report also indicated that the noise from the TBM starts being heard and felt at about 100 metres off and remains evident for another 100 metres or so once they have passed. There were no data within the document to support or verify the conclusions.

### Performance Criteria

- 12) The performance criteria for vibration are clear, although they are perhaps more complicated than other appropriate performance criteria that could have been proposed. While the concept of dosage criteria for assessing personal amenity is sound, there is a general dislike of dosage limits amongst contractors, regulators and community groups due to its complexity. However this is perhaps not sufficient to suggest that it should not be applied.
- 13) Limits are proposed for different vibration sources, operational times, building types, occupancies and equipment characteristics. The performance criteria are considered complete and adequately cover the



range of equipment usage and potentially sensitive receivers. The criteria address personal amenity, building damage and equipment sensitivity.

- 14) The vibration criteria are expressed as “*Guideline Targets*” rather than “*Limits*” which potentially allows opportunity for the contractor to motivate for alternative, possibly elevated, criteria. It also removes the definitive step between compliance and non-compliance and could result in challenges in terms of administering the performance criteria. It may also, with the submission of a detailed technical document, provide the opportunity to substitute alternative criteria, such as the replacement of a vibration dosage criteria with an RMS equivalent.
- 15) “*Guideline Targets*” could also be considered advantageous for contractors as they allow opportunities for alternative construction techniques. However, “*Guideline Targets*” are less rigid in terms of clearly identifying permissible values and therefore offer less certainty for affected property owners.
- 16) Building damage are assessed against the German Standard DIN4150 using the peak particle velocity domain, human comfort are assessed against the British Standard BS6472 using a vibration dosage and sensitive equipment assessment requires one-third octave analyses. Multiple types of monitoring equipment will be required to assess compliance. Without significant development, automated transparent reporting via modems capable of displaying of information via web pages is unlikely.
- 17) Criteria to protect against building damage are drawn from the German Standard DIN4150. The standard has international acceptance and addresses different building types and occupancies as well as the frequencies of vibration. The proposed values also consider long and short term vibration effects, differentiated according to whether fatigue effects are possible. There is commonly conjecture as to whether fatigue can occur and it would be prudent to specify which table of values apply for the different equipment types.
- 18) The German Standard DIN4150 has been adopted over the existing Australian Standard AS2187.2. The Australian Standard draws values from the British Standard which is equally regarded as being protective of building integrity. It could be considered unusual to adopt standards other than the applicable Australian Standard when the latter is considered to adequately address building related damage.
- 19) Vibration performance criterion for tunnelling activities are however almost inconsequential in terms of limiting impact to affected persons around the tunnel alignment. Complaint as a consequence regenerated noise sources will occur well in advance of non-compliance from vibration, possibly with the exception of buildings that house very sensitive equipment, such as scientific or medical imaging equipment. Compliance with the noise performance criteria virtually ensures compliance with the vibration performance criteria. However, note that vibration compliance may still be achieved in instances where the noise performance are exceeded.
- 20) The human comfort criteria for continuous vibration are drawn from the NSW Guidelines which essentially replicates the British Standard BS6472 recommendations. The vibration criteria are referenced against dosage limits for both daytime (7am to 10pm) and evening (10pm to 7am) in terms of preferred and maximum values to limit “*adverse comment*”. The dosage criteria severely penalises elevated values and attempts to restrict the overall exposure of affected persons by ensuring that any instances of elevated vibration are accompanied by extended periods of lower vibration values. The calculations are complex and provide a true measure of compliance only at the end of the assessment period, which is 10pm and 7am each day. A prediction of the dosage value can however be estimated by undertaking a lesser period of measurement and calculating the estimated value over the full monitoring period. By applying these criteria, there will be a loss of immediacy in responding to any complaints with only persons only having an estimate of whether compliance will be achieved. Performance criteria in the peak or RMS velocity domain are often preferable as they allow for an immediate review as to whether any adjustments to practices are required.
- 21) The performance criteria for the effects of vibration on sensitive scientific, electrical and medical equipment are sound and will be protective of their continued operation. However, it may be onerous in terms of both monitoring requirements and the ability to comply with vibration levels that are expected

to be exceeded through normal day to day activities. A significant risk to the project is ensuring that all potentially sensitive equipment has been identified and the possible impacts identified.

- 22) The vibration limits for sensitive medical equipment are commonly provided by the equipment manufacturer and will identify criteria amongst other values for, continued operation and transport. These values will define as nil impact (the equipment can continue to be used with no effect on its calibration) or the transport criteria referring to damage levels. Where the limits are particularly onerous, the equipment is commonly vibration isolated to prevent exceedances by activities such as foot falls or doors slamming and so on. It is suggested that liaison with asset owners that could be affected is undertaken as soon as practically possible to better define the permissible limits, as well as defining possible impacts.
- 23) The proposed ASHRAE limits are considered onerous. The VC-B criterion for microsurgery, eye surgery, neurosurgery and so on, is  $25\mu\text{m/s}$  per one-third octave which will equate to peak values around  $0.2\text{mm/s}$  for a combined frequency sweep. A similar vibration value would however be necessary to ensure that the regenerated noise levels are compliant with the evening performance criteria and overall the equipment limits may not be the limiting control. Other more sensitive equipment has been identified in the assessment with limits half the surgery values.
- 24) Vibration produced by operators that is required for the routine of sensitive equipment such as walking, opening cupboards, closing doors and so on, can generate peak values upwards of  $0.3\text{mm/s}$  but typically less than  $1\text{mm/s}$ .
- 25) The “*Guideline Targets*” for human comfort are based on a values related to “*adverse comment*”. In terms of calculated values and “*adverse comment*”, the following statements apply:
  - a. Adverse comments are not expected at dosage values less than the preferred value
  - b. There is a low probability of adverse at dosage values between the preferred and maximum value
  - c. Adverse comments are possible at dosage values between the maximum value and twice the maximum value
  - d. Adverse comments are probable at dosage values between twice the maximum value and four times the maximum value
  - e. Adverse comments are very likely at dosage values more than four times the maximum value
- 26) The “*Guideline Targets*” are said to based on trigger methods for Management Actions. It is further suggested Management Actions require consultation be undertaken to provide information to the community. This appears to relate to the tunnelling activities rather than the “other construction areas” where equipment other than a TBM or road header would be used. For the TBM or road header activities, there is no indication that other measures would be employed to reduce the level of impact. It is noted that if the impact remains unacceptable, temporary relocation may be appropriate. It is also noted that triggering Management Actions does not necessarily correlate with levels of vibration or regenerated noise would be classed as disturbing. For tunnelling, there is no suggestion that other mitigation measures will be necessary when vibration levels or regenerated noise values approach the “*Guideline Targets*”.
- 27) For the “*other construction areas*”, that is not tunnelling, exceeding the “*Guideline Targets*” does however initiate a requirement to change practices to reduce vibration or regenerated noise impacts. The option of relocation is also considered one of the possible options.
- 28) The British Standard BS5528 recognises the dosage concept provided in BS6472-1 although suggests “*whilst the assessment of the response to vibration in BS6472-1 is based on the VDV and weighted acceleration, for construction it is considered more appropriate to provide guidance in terms of the PPV, since this parameter is likely to be more routinely measured based upon the more usual concern over potential building damage, Furthermore, since many of the empirical vibration predictors yield results in terms of PPV, it is necessary to understand what the consequences might be of any predicted levels in terms of human perception and disturbance*”. The guidance values are as follows:



RMS Vibration Level	Effect of vibration
0.14 mm/s	Vibration might be just perceptible in the most sensitive situations for most vibration frequencies associated with construction. At lower frequencies, people are less sensitive to vibration
0.3 mm/s	Vibration might just be perceptible in residential environments
1.0 mm/s	It is likely that vibration of this level in residential environments will cause complaint, but can be tolerated if prior warning and explanation has been given to residents
10 mm/s	Vibration is likely to be intolerable for any more than a very brief exposure to this level.

29) The vibration values (RMS) can be estimated from the dosage criteria using an approximate relationship. The estimated values are as follows. The comments in the final two columns are based upon experience at other tunnelling projects.

Daytime / Evening	Dosage Criteria	Dosage Criteria Description	BS6472 Description	Equivalent RMS vibration level	Equivalent peak level of vibration	Likelihood of complaint	Probability of Relocation
Daytime	0.4 ms <sup>-1.75</sup>	Preferred maximum residential dosage	Low probability of adverse comments	0.22mm/s	0.66mm/s	Unlikely	5%
	0.8 ms <sup>-1.75</sup>	Twice maximum residential dosage	Adverse comments are probable	0.44mm/s	1.32mm/s	Reasonable likelihood	20%
	1.6 ms <sup>-1.75</sup>	Four times the maximum residential dosage	Adverse comments are very likely	0.87mm/s	2.61mm/s	Very likely	75%
Evening	0.2 ms <sup>-1.75</sup>	Preferred maximum residential dosage	Low probability of adverse comments	0.12mm/s	0.36mm/s	Unlikely except for dwellings with slab on ground, hard finishes	10%
	0.4 ms <sup>-1.75</sup>	Twice maximum residential dosage	Adverse comments are probable	0.25mm/s	0.75mm/s	High	40%
	0.8 ms <sup>-1.75</sup>	Four times the maximum residential dosage	Adverse comments are very likely	0.49mm/s	1.47mm/s	Very high	60%

30) The appropriateness of the noise performance criteria are not considered in this document. It is expected that noise criteria should not distinguish between air borne and ground borne noise sources in proposing performance criteria.

**Predictions**

31) The expected effects are calculated using standard and supportable formed equations. The relationships appear to be based upon generic data sets rather than information more appropriate to the moderately weathered siltstone (Melbourne Formation) where the works will be undertaken. An increase in the variability between the predicted and measured values could occur. A comparison of the offset distances corresponding to an “adverse effect” are well aligned with values typical of other projects.

32) The predicted vibration levels from the different size hydraulic hammers are based around a single vibration level measured at 25 feet and subsequently extrapolated to different distances. The measurements were most taken from information collected in the USA (given the 25 feet standard measurement). A comparison of the offset distances and values generated by the different sources of vibration produces reasonable numbers when compared with other information, although the degree of variability between predicted and measured may again be greater than preferred.

- 33) Determining whether compliance can be achieved is based around these equations, plus an estimate of the percentage utilisation of the equipment. The duty cycle is key to assessing compliance with the vibration dosage and regenerated noise performance criterion. The duty cycle for the road header is taken as 60%, that is, the road operates for 6 minutes in every 10 minute period. The duty cycle for the TBM is conservatively placed at 100% which will lead to slightly elevated vibration dosage criterion. The TBM would typically operate for periods of up to 10 minutes followed by a delay of typically five minutes during which time it re-positions. The duty cycle calculations are therefore reasonable, if not conservative.
- 34) An estimate of the vibration impacts from blasting is based upon equations given in the Australian Standard AS2187.2 for average blasting conditions. These equations have their origins in the early blasting assessments (>40 years) completed in the USA and are generally be considered to have limited applicability for blasting in the Melbourne Formation. The proposed blasting vibration relationship has however been adjusted to reflect the percentile conditions given in the blasting performance criteria. While the relationship is not considered specific to Melbourne Formation rock type, the calculated vibration levels at given distances for a particular explosive weight are reasonable and not dissimilar from the vibration levels predicted using more site specific vibration relationships.
- 35) Best practices would include a controlled trial blast prior to the larger scale production blasts. It is expected that the project conditions would address the requirements for a trial blast.
- 36) The duration of the impacts is calculated by assuming production rates for the TBM and road header equipment. The proposed rates of advance for both items of plant are reasonable and consistent with other projects. Advance levels of 11.5 metres per day for the TBM and 5 metres per day for the road header are proposed.
- 37) The greatest chance for “*adverse comment*” will occur from areas where extended construction activities are required, such as establishment of caverns, stations, boxes, cross passages and so on. Based upon other projects, in terms of relocation, more than two-thirds could be expected to result from these other forms of construction, rather than the main line tunnels which can be completed with generally minimum impact, at least in terms of duration.
- 38) The effects from the construction of the cross passages have been considered in the documents. Experience at other projects indicates that this aspect can result in adverse comment given the extended duration over which it is normally completed. In addition, the other larger construction areas are usually better positioned with respect to minimising impacts whereas the cross passages are limited in their position to comply with tunnelling standards. Tunnel development also occurs with a TBM at relatively quick advance rates and the impact on properties is short duration. Developing the cross passages is normally a slower process. In the event that the cross passages are developed with a road header, the impact time would be reduced.

### **Implications**

- 39) The analyses have provided information on the modelled impacts for approximately 3000 properties around the project alignment. In each precinct, the impact is expressed as the number of days (duration) that the closest affected receiver would be impacted for. These data are most useful to determining the project impacts. In Precinct 1, the tunnelling activities are modelled to induce levels at the closest property that exceed the “*Guideline Targets*” that would trigger Management Actions for two periods of 10 days plus a second period of 32 days for the road header activity.
- 40) It would be preferable to understand the number of properties affected, and for how long each property is impacted by levels exceeding the “*Guideline Target*” values. A table that identifies the number of properties as well as the duration that vibration is modelled to be perceptible, the noise audible, or relocation possibly required would better summarise the project impacts. For regenerated noise, the table could also calculate the number of “*affected property days*” based upon noise values either side of the “*Guideline Target*” values, such as 40dBA, 45dBA and 50dBA.

- 41) As an example, Precinct 6 at the CBD South Station is modelled to have impacts that could trigger Management Actions for up to six weeks up to three times at a number of sensitive receivers during the project duration. A similar table highlighting the number of “*affected property days*” for all affected properties, rather than the most affected, would be a useful indicator for the impact.

### **Mitigation**

- 42) M Mitigation measures commonly promoted for construction project are less applicable for tunnelling projects and will necessarily involve a longer project duration, and possibly greater overall personal impact. Measures such as:
- Substitution of a high energy source with a lower energy source have been included in the assessment, although are of limited practicality
  - Dampening of vibration is impractical for hard rock excavation projects
  - Increasing the separation distance remains a high level control measure and requires adjustments to the project alignment, such as increasing the depth of the tunnel. This measure forms part of best practice in the iterative design process, however, is generally not feasible as a mitigation measure;
  - Receiver control measures, such as vibration isolation, are limited to items of equipment rather than property wide. While airborne sound isolation is possible through practices such as double glazing, options for the reduction of regenerated noise on a large scale are impractical.
- 43) Mitigation options for tunnelling projects are few, particularly with TBM and road header construction. Community education that provides information in advance to potentially affected asset owners and residents detailing the impacts, the duration and how these will be perceived is the most effective mitigation measure. There will necessarily be a number of affected residents who will challenge the project, irrespective of the information made available. The focus should be on the education of vast majority. Residents are often accepting of elevated levels providing they are informed of the impacts.
- 44) Early discussion with asset owners where sensitive equipment is located will be necessary. It will assist in better defining the performance criteria as well as identifying the full extent of the impacts.
- 45) Appropriate mitigation will depend upon the source of the vibration. Limiting the effects of vibration and regenerated noise from a TBM are effectively limited to reduced operational hours, or relocation. Whilst options such as reduced thrust or cutter head rotation speed for the TBM are reasonable sounding options, they are rarely, if ever, implemented. Unlike the example of a hydraulic hammer where the hydraulic hammer can be replaced with a smaller unit should complaints be received, this is not possible with the TBM. Therefore a reduction in the vibration level from the TBM is not possible with mitigation restricted to limiting the hours of operation, or relocation of affected tenants. For the more significant levels of impact, property acquisition may be required. The accuracy of the vibration and regenerated noise modelling is critical in establishing the zone of impacts and number of potentially affected persons.
- 46) Like the TBM, mitigating the impacts of the road header are very limited. Whilst the efficiency of the road header operator and their ability to control the pressure of the rotating drum on the rock face can lead to lower peak levels of vibration, these practices are better aligned with best equipment practices rather than vibration mitigation options. As with the TBM, the options are limited to reduced hours of operation, relocation or property acquisition.
- 47) Smaller size excavators and hydraulic hammers necessarily induce lower levels of vibration and regenerated noise. Options for reducing vibration levels by using smaller hammers are possibilities, but of limited practicality. Smaller hammers are of limited use for bulk excavation works with most of these works using equipment of 30 tonne or greater. The greatest possibility of adverse comment will occur from these types of works. Hydraulic hammers generate perceptible levels vibration, are commonly associated with extended works and are the phase of works leading to greatest complaint. It would be reasonable to expect that more than ½ of any relocations for the project would be associated with work in precincts where hydraulic hammering activities dominate.



- 48) The most commonly identified mitigation option is the reduction in the size of the hydraulic hammer with effects assessed for 7, 12, 15, 20, 30 tonne excavators. The construction areas where these extended activities will occur will necessarily lead to complaint and adverse comment.
- 49) Controlling vibration from piling is achievable through changes to the hammer drop weight or height, or where absolute control is required, the use of bored rather driven piles. Piling is only expected during daylight hours and any impacts are expected to be well controlled.
- 50) Control of vibration from blasting can be achieved through changes to the explosive weight, although below some explosive quantity blasting becomes ineffective and uneconomic as an excavation method. In such cases, blasting is normally replaced by hydraulic hammering which ultimately leads to a reduced level of personal amenity.
- 51) Relocation of commercial tenants is commonly cost prohibitive. Relocation generally occurs as a result of evening based activities leading to sleep deprivation which is eliminated with most commercial properties aside from motels, hostels or hospitals.
- 52) Experience at other tunnelling projects indicates that construction of the cross passages between tunnels can result in increased adverse comment and complaint. The development of the portals, boxes and stations are identified as key construction areas and generally positioned in areas to have minimum impact. The cross passages between tunnels are positioned according to regulatory separation distances, typically 120 metres, and may therefore be located under sensitive receivers. Depending upon the method of construction, residents can be subjected to elevated levels of vibration and regenerated noise for extended periods.
- 53) Relocation should be expected for a small number of properties where the regenerated noise levels that exceed 40dBA. Where the regenerated noise level exceeds 50dBA, a large percentage of relocations should be expected. Other projects have considered offering relocation where the noise level exceeds 40 to 45dBA during the evening period.

### **Risk**

- 54) The risk to the project with respect to vibration and regenerated noise centres on the methods of excavation not being able to comply with the performance criterion. In addition, excavation durations that exceed the expected or acceptable terms will increase adverse comment. The limited mitigation measures that can be effectively implemented for tunnelling projects are few. If vibration levels are underestimated for part of the project, it is very probable that they will be underestimated for the entire project.
- 55) A risk to the project is that the correlation between the peak level of vibration, the RMS level of vibration and regenerated noise has underestimated the regenerated noise levels. The impacts will be greater than expected.
- 56) A risk to the project is that advance rates for the TBM and road header are less than proposed. A decrease in the advance rates of 11.5 metres and 5 metres per day will result in longer exposure times for persons around the alignment. The advance rates are reasonable and the risk is therefore considered small.
- 57) A significant risk to the project is any commercial buildings that involve tasks that necessitate highly controlled environments, such as recording or broadcast studios, medical suites or electronic test laboratories. These may also necessitate significant adjustments to the tunnelling schedule.
- 58) A significant risk to the project are those buildings or commercial premises that may house sensitive equipment that have not been identified during the assessment phase. The proposed performance criteria for sensitive equipment is restrictive and could impact upon the scale of construction excavation for distances of up to 100 metres from the equipment location.

59) All key commercial buildings where the possibility of relocation as a mitigation option cannot be implemented should be considered as a risk to the project deliverables. Motels where quiet evening environments are expected should be identified and the impacts assessed.

60) The risk of building related damage from vibration effects alone are consider minor.

As always, you are most welcome to contact me at your convenience to discuss in further detail any of the issues raised in this letter.

Yours truly,

*John Heilig*

Dr. John Heilig  
*Principal - Heilig & Partners Pty Ltd*

