West Gate Tunnel – Environmental Effects Assessment

Expert Report of Dr. John Heilig

1. Introduction

As a Director of Heilig & Partners, I have prepared the technical report titled "*West Gate Tunnel Project –Vibration and Regenerated Nosie from Tunnel Construction Assessment*" which is presented as Technical Report I to the Environmental Effects Statement (EES) for the West Gate Tunnel Project.

The role that I had in preparing the EES was to identify the Environmental Performance Requirements (EPRs) that would preserve amenity and be protective of building integrity. I have also assessed the vibration and regenerated noise impacts from the tunnelling activities with respect to the EPRs.

I have reviewed the preliminary matters and request for further information relevant to my area of expertise that were prepared by the Inquiry and Advisory Committee and have prepared a response to the matters raised.

I have also reviewed the submissions and where necessary provided additional information to clarify the position of the EES.

I have adopted the Technical Report I of the EES as the basis of my written expert evidence for the purposes of the West Gate Tunnel Project Inquiry and Advisory Committee's review of the EES, draft planning scheme amendment and works approval application.

2. Qualifications and experience

Appendix A contains a statement setting out my qualifications and experience, and the other matters raised by Planning Panels Victoria 'Guide to Expert Evidence'.

I confirm that I have read the Code of Conduct for expert witnesses and that I agree to comply with it. I confirm that I have considered all the material facts that I am aware of that might alter or detract from the opinions I express. In particular, unless I state otherwise, this evidence is within my sphere of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

I hold the qualifications of Bachelor of Engineering (BE) with Honours and a Doctor of Philosophy (PhD), both from the University of Queensland in Australia with the latter awarded in 1988.

I have worked in the industry for more than 30 years and have extensive domestic and international experience in the measurement, assessment and impact of vibration/regenerated noise from mechanical equipment as well as blasting from civil construction projects. I have been associated extensively with design, vibration analysis and prediction at more than 800 sites throughout the world. I have also consulted to government agencies on acceptable vibration criteria. I have provided, or am continuing to provide, advice and extensive design input into many of the tunnels developed or presently being constructed, including the three major tunnels in Brisbane, the four current significant tunnelling projects in Sydney as well as the Melbourne Metro Tunnel which presently under construction for Melbourne. I have been involved with the review of two other tunnels in Auckland.

A copy of my curriculum vitae is provided in Appendix B.

3. Statement of scoping requirements

Scoping Requirements have been set down for the preparation of an Environment Effects Statement (EES) for the West Gate Tunnel. These include Scoping Requirements for Ground Vibration and Regenerated Noise.

The evaluation objectives for Ground Vibration and Regenerated Noise are as follows:

> *To minimise adverse air quality, noise and vibration effects on the health and amenity of nearby residents, local communities and road users during both construction and operation of the project.*

As relevant to ground vibration and regenerated noise, the scoping requirements include an assessment of ground borne vibrations and regenerated noise from construction and operation that could adversely affect residential amenity or other property assets or infrastructure.

The assessment necessitates that the design considers management measures to control vibrations resulting from construction works and road tunnel operations to acceptable levels. It also requires an analysis of the potential for vibration to cause disturbance to occupants of residential buildings or other sensitive land uses or cause adverse effects on property and infrastructure.

4. The West Gate tunnelling in perspective

In simple terms, tunnelling in environments where there is minimal surface development is unusual. The complexity, challenges and economics generally preclude tunnelling in all but urbanised areas. Tunnelling therefore often occurs near to populated areas and other high density, potentially sensitive locations. Tunnelling activities similar to the proposed West Gate Tunnel, that is, an alignment at a similar depth and as near to residential properties have been successfully completed. Many of these tunnels have been developed in Australia.

In addition to tunnels, other large scale construction and building projects that have used similar construction equipment to that planned for the West Gate Tunnel Project and have been successfully developed.

EPRs that protect personal amenity, ensure building integrity and allow commercial entities to operate contemporaneously with the construction activities, are therefore a necessary component of the environmental specifications. Projects that have specified EPRs, assessed the construction activities against these criteria, identified any necessary mitigation measures, incorporated an extensive community program and compiled the information into a Construction Noise and Vibration Management Plan (CNVMP) have been effective and delivered positive benefits to the community. The West Gate Tunnel project will be similarly constructed, but within guidelines which are more restrictive than several of these other projects which have all been successfully completed.

5. Key Aspects of the EES

In developing the EES for the project, I have considered four key components. These include:

- The effects
- The Environmental Performance Requirements (EPRs)
- The predicted impacts
- The mitigation options

5.1 The Effects

Vibration effects will necessarily occur as a result of the mechanical excavation with a Tunnel Boring Machine (TBM). Vibration produced by the TBM is described by periods of activity, which can persist for tens of minutes, followed by periods of minimum impact as the equipment re-sets, re-grips or advances. Despite the nature of the vibration, these sources of vibration are generally considered continuous in their assessment.

Relationships that describe the decay of vibration with distance for each equipment type have been applied to determine the impacts at varying distances from the construction activities.

Vibration, if sufficiently high, can cause superficial damage to adjacent buildings. The results of well documented 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 limits virtually ensures the project can be free of vibration related damage. These same standards form part of the EPRs for the West Gate Tunnel project.

Low levels of vibration, much lower than those that can result in damage, are readily perceived by persons and sometimes considered as 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 within vibration industry that vibration will be personally intolerable to building occupants well before any damage to the building or its contents may occur.

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 difficult given that it requires firstly an estimate of the level of vibration plus additional estimates detailing how the vibration pulse manifests as audible noise effects. Influences such as the geological conditions and the soft soil profile, construction of the property 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. Regenerated noise is only applicable to persons within a building. 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 can be variable.

5.2 The Environmental Performance Requirements

EPR's are proposed for different equipment types, operational times, building types and occupancies. The EPRs for the West Gate Tunnel project are considered complete and adequately cover the range of potentially sensitive receivers. The criteria address personal amenity and infrastructure damage.

Unlike the recently assessed Melbourne Metro Tunnel, the West Gate Tunnel project is not near to highly sensitive medical and scientific equipment or bioresources such as that within the Parkville Precinct. From this perspective, the EPRs for the West Gate Tunnel project with respect to vibration are limited to amenity and infrastructure damage and are therefore more clearly defined.

The EPRs are drawn from the Australian Standard AS2436-2010 as an over-arching qualitative guide to noise and vibration control on construction, demolition and maintenance sites. In terms of vibration, the standard does not directly propose permissible levels of vibration but rather references other Australian Standards such AS2187.2, the British Standards such as BS6472-2, BS7385-2 and BS5228-2 and guidelines such as the NSW Assessing Vibration technical guide.

The human comfort criteria for continuous vibration are drawn from the British Standard BS6472[1] recommendations. The vibration criteria in the British Standard are given as vibration dosage values (VDV) and covers both daytime (7am to 10pm) and evening (10pm to 7am) activities. The standard lists the "*preferred*" and "*maximum*" values to limit different likelihoods of "*adverse comment*".

In the simplest terms, 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 measurement and analysis of dosage levels is however complex and EPRs in some other metric, such as the velocity or root mean square velocity (RMS), are often preferable as they are more easily measured, modelled and administered.

The British Standard BS5528[2] also recognises the merits of the dosage concept as being appropriate, but proposes an alternative metric and in particular the Standard indicates "*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*".

It is my recommendation that the dosage criteria remain the basis of the amenity based EPRs, but with the guideline value expressed as the peak particle velocity (PPV).

5.3 Predicted Impacts

The predicted impacts are determined using standard and supportable formed models. The vibration/distance relationships are based upon existing data sets and adjusted for the geology along the alignment. The distance at which the vibration impacts correspond to an "*adverse effect*" is well aligned with values typical of other projects.

Establishing whether compliance with the vibration and regenerated noise values in the EPR's has been undertaken using these equations.

5.4 Mitigation

Mitigation measures that are commonly implemented on construction projects are less applicable for tunnelling projects. Commonly thought of mitigation measures for construction projects will, for

[1] BS6472-1:2008 British Standard Guide to evaluation of human exposure to vibration in buildings Part 1: Vibration sources other than blasting

[2] BS5528-2:2009 British Standard Code of practice for noise and vibration control on construction and open sites Part2: Vibration

tunnelling projects, generally equate to a longer project duration and therefore possibly a greater overall impact on persons. For tunnelling, mitigation measures such as:

- Substitution of a high energy source with a lower energy source are of limited practicality;
- Increasing the separation distance is 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 project 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.

Mitigation options for tunnelling projects are few, particularly with TBM constructed tunnels. 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. The focus should be on the education and monitoring. My experience at other projects is that the majority of residents are accepting of slightly elevated levels providing they are informed of the potential impacts. Establishing EPR's that are protective of both amenity and assets are always a key element.

Limiting the effects of vibration and regenerated noise from a TBM are effectively limited to reduced operational hours, or temporary relocation of affected persons. Whilst options such as reduced thrust or cutter head rotation speed for the TBM are possible options, the equipment is designed to operate within a range of particular machine variables and departure from these optimum values will necessarily lead to increased construction periods. A significant departure could lead to very inefficient and ineffective cutting. Unlike an hydraulic hammer where the hydraulic hammer can be replaced with a smaller unit should any non-compliances occur, this is not possible with the TBM. Therefore a significant reduction in the vibration level from the TBM is generally unlikely with mitigation restricted to limiting the hours of operation, or relocation of affected tenants.

It has been previously observed on other projects that early discussions with the affected residents typically lead to a resolution that allows both the construction activities and the residents to cooperate contemporaneously. Relocation of between a few days to a week generally only occurs as a result of evening based activities which lead to sleep deprivation. Where relocation is an option considered by the resident, the relocation is only short term as the impact of TBM reduces as the TBM continues to advance away from the property.

6. Further work since preparation of the EES

Since the EES for the project has been finalised, I have not requested that further assessments or analyses be completed.

The analyses presented in my initial assessment are considered appropriate. Nothing has caused me to materially change my opinions as expressed in the EES.

7. Response to Inquiry and Advisory Committee

I have read the report prepared by the Inquiry and Advisory Committee report for the West Gate Tunnel Project entitled "Preliminary Matters and Further Information Request" dated 18 July 2017.

A Request for Information referred to as DM1-F indicates:

Environment Performance Requirement NVP6 for construction vibration targets for amenity protection provides "*preferred values*" and "*maximum values*". The proponent is asked to:

- *Nominate which it proposes as the single target*
- *Provide these vibration dose values as the equivalent peak particle velocities (PPV's) to facilitate managing this effect.*

Table 8 of the Technical Report I lists the Vibration Dose Values (VDV) which could result in various likelihoods of adverse comment in residential buildings from either daytime or evening construction activities. As an example, for a residential property subjected to vibration effects during the daytime designated period, the identified dosage values vary from $0.2ms^{-1.75}$ to $1.6ms^{-1.75}$ and cover effects classed as "*low probability of adverse comment*", "*adverse comment possible*" and "*adverse comment probable*". Given the variability in human reaction to vibration, each class of response is described by two levels of vibration, a "*preferred value*" and a "*maximum value*". As an example, the "*preferred value*" and "*maximum value*" to achieve a "*low probability of adverse comment*" are $0.2ms^{-1.75}$ and $0.4ms^{-1.75}$ respectively.

Given the significance of the project, the community benefit and the high level of contractor based community liaison and involvement, an acceptable level of disturbance is considered to lie at the upper end of "*low probability of adverse comment*", that is the "*maximum value*" of $0.4ms^{-1.75}$ and $0.2ms^{-1.75}$ for daytime and evening activities respectively. I consider these values an acceptable compromise between minimising the construction impact and ensuring that the works can continue at an acceptable rate of progress.

The dosage values identified in Table 9 of the same technical report for different locations and periods of activity (daytime/evening). Table 10 of my technical report has calculated the equivalent peak particle velocities (PPV's) expressed in velocity (mm/s) for each of the location categories (residential, commercial and industrial) values given in Table 9 and the maximum value that is classed as a "*low probability of adverse comment*". The vibration velocity values in Table 10 for each of the various building usages correspond to the maximum vibration value for a "*low probability of adverse comment*". The values in Table 10 are provided for reference only and should be confirmed by the contractor based upon the equipment type, usage, schedule and so on.

8. Response to Written Submissions

I have read the submissions to the project. A number of these submissions contain comments that are relevant to the EES and my area of expertise. These amounted to fifteen submissions and included eleven from local residents. A combined submission from a community group within Yarraville as well as a combined submission from the Yarraville Community Centre have also been prepared. Two additional submissions from the Maribyrnong and Melbourne City Councils were submitted.

These submissions raise few concerns with all matters having been addressed in the EES. The submissions therefore do not affect my findings or those opinions expressed in the documents. The issues raised in these submissions do not require a reworked comprehensive response, however given the few concerns, it may be beneficial to the hearing committee to understand my views on these common areas of concern.

The concerns in the submissions that I have reviewed include:

1. Concern regarding structural damage to buildings that would occur from the vibration produced by the construction activities or settlement associated with the reactive soils;

2. Concern regarding the condition surveys and confirmation that and defects attributable to the construction activities will be repaired;

3. Concern regarding the relocation policy, how this would be implemented and how would be responsible for supporting and arranging this action by the contractor;

4. Concerns regarding the transparent and appropriate monitoring and reporting of impacts.

An appropriate set of EPRs coupled with a workable Construction Noise Environmental Management Plan (CNVMP) are key to the project. When both of these are effectively developed and administered, the vibration and regenerated noise related impacts associated with the project can be addressed to a standard that ensure the amenity for the adjacent residents and the integrity of any assets are appropriately protected.

The EPR's for vibration presented in the EES address these matters (NVP3, NVP4, NVP5, NVP6, NVP7, NVP8, NVP9, NVP12 and NVP13). In particular the two key issues of ensuring the vibration produced by the works prevent structural damage to the adjacent properties and ensure the amenity of residents around the works is not unduly affected are addressed. The EPRs are based upon Australian or other International Standards and can be further justified by comparison with other peer reviewed international papers.

It is not uncommon for residents adjacent to a significant construction project to be concerned that vibrations could damage the surrounding properties. The possibility of damage to properties arising from the vibration generated by the tunnelling is however extremely low. I am unaware of damage to properties from vibration occurring as a result of the tunnelling activities on any of the other projects I have been involved with. Other naturally occurring environmental effects induce stresses that far exceed those produced by vibration. As an example, a humidity change of around 20% induces a level of stress equivalent to that generated by a vibration pulse with an amplitude of around 60mm/s. Routine daily weather phenomena produce far greater stresses than the equivalent stress level induced by a level of vibration compliant with the EPR's.

Whilst there will likely be noticeable cracks to some properties during the tunnel construction period, these changes will however be no different or occur at any increased rate when compared to properties that lie well beyond the construction envelope. The vibration EPRs are very heavily biased towards human comfort criteria and therefore effectively prevent any opportunity for structural or superficial damage to infrastructure around or above the tunnel alignment.

The EPR's are consistent, but more stringent, than the permissible levels imposed on other recently completed tunnelling projects, such as the North South Bypass, the Airport Link, Inner Northern Busways and Legacy Way in Brisbane, and the NorthConnex, WestConnex and WestConnex Stage 2 in Sydney and the CityLink, Melbourne Metro Tunnel and the previously proposed EastLink tunnels in Melbourne.

A few submitters are unclear on the condition surveys and how any defects will be subsequently addressed. The objective of a condition survey report is to provide an indicative representation of the condition of the infrastructure prior to the commencement of any earthworks/construction activities. This provides a baseline in the event that damage to the property is caused by the construction activities encouraging the contractor to minimise the risk of property damage. Should a resident raise concern about potential damage to their property, and the property is within a reasonable distance of the works, it is not uncommon for the contractor to err on the side of conservatism and undertake a condition survey.

Where condition surveys are undertaken, it is accepted practice for the results of the survey to be made available to the property owners. The surveys should be undertaken by an appropriately qualified person.

In the event that a resident believes that their property has been damaged by the construction process, the preferred approach is to review the condition survey report, assess the measurements data, identify the potential effects and in the event the damage is determined to be associated with the project works, prepare a plan for repair.

A submitter has concerns about the possibility that the construction effects could impact on the reactive soils beneath their property. It is known that vibrations can affect soils, although any densification depends upon the soil type and the level of vibration. Only certain ground conditions are however susceptible to vibratory densification and the vibrations have to be high. The British Standard BS7385-2 reports on laboratory tests that identified for soils that would be far more susceptible to impact from vibration than those around the West Gate Tunnel, the soil became vulnerable to impact only at vibration levels above 10mm/s, and even then, the effect is dependent up the duration of the vibration. The EPRs for the West Gate Tunnel project restrict continuous vibration levels to values less than 20% of the BS7385 reported minimum vibration value.

Some submitters have concerns regarding the temporary relocation arrangements during the construction phase. There are existing examples of a how relocation options could be implemented, such as the Cross Rail project in the UK, where a measured exceedance of a threshold value for a set numbers of days enables the option of relocation. I am also aware of other projects where the contractor has assessed the anticipated level of vibration and offered temporary relocation to residents prior to confirming the measured levels of impact. The mitigation options for the West Gate Tunnel Project will be detailed in the CNVMP as part of the EPR NVP3. It should be noted that EPR NVP6 is based around amenity and there are many instances where vibration and regenerated noise values in excess of the EPRs occur without an unacceptable impact on the receiver's amenity.

The mitigation process may therefore encompass a range of options that will be determined by the contractor. Irrespective of the approach, my experience on all other projects is that the range of options are tailored according to the individual resident's requirements. It would be expected that all residents that could be affected by the construction activities would be consulted in advance to ensure any impact on amenity is minimised.

The Yarraville Community Centre have questioned the method of monitoring and reporting in general, although focussed on air quality rather than vibration and regenerated noise related effects. To ensure the EPRs are met, vibration and regenerated noise levels will be monitored in accordance with the relevant standard and compared against the EPRs that have been proposed. A selection of representative monitoring properties will be chosen based upon:

- The proximity to the works area, ensuring that the monitoring sites are located as close as practically possible to the sensitive infrastructure;
- Monitoring locations that offer a secure area that minimise the possibility of interference from the public;
- Monitoring locations that provide an accurate indication of the vibration level.

Monitoring locations will be continually revised as the source of the vibration changes according to the construction schedule. Based upon other successfully completed large scale construction projects that have been undertaken near to sensitive areas, it is expected that the monitoring will be proactive with a system that analyses the measured levels continuously and alerts the contractor if vibration levels

approach specified vibration limits. This pro-active approach permits a change in practices, methods or equipment sizes prior to any extended exceedances of the prescribed limits.

In summary, I consider that all the issues raised by the submitters have been appropriately addressed in the EES and further clarified by my comments above.

9. Conclusions

I conclude that the assessment of the vibration impacts, including the regenerated noise effects, from the tunnelling aspect of the West Gate Tunnel project comply with the scoping requirements to the full extent. The assessment includes the information necessary to allow the impacts to be quantified. In particular, I confirm the following:

- The EES applies internationally accepted standards to derive the EPR's that are stringent, ensure quality of life for persons around the project boundary as well as ensuring they are protective of building integrity.

- As best as can be determined, the estimate of the induced vibration and regenerated noise impacts from the different sources uses relationships are reasonable and the calculated levels are typical of that expected from the equipment selection, separation distances and rock types appropriate to the West Gate Tunnel project.

- A comparison of the EPR's with the predicted levels has identified that compliance in some areas will be challenging, even with application of best practices. These areas may necessitate a change in the construction methods, the operating times, an alternative and mutually agreeable criteria with the affected parties, and in some locations, the possibility of temporary respite during the periods may be required.

Other large scale tunnelling projects have been successfully completed by implementing an approach consistent with that proposed for the West Gate Tunnel project. A set of EPR's for the project consistent with internationally recognised stringent standards that are protective of amenity and building integrity will ensure world's best construction practices are followed. Producing a detailed CNVMP that specifically addresses the vibration and regenerated noise matters along the alignment is key to the successful project delivery. A detailed monitoring and mitigation plan will ensure transparency of the activities. A strong community team conveying the potential impacts to persons along the alignment in advance of the construction activities will be a necessary component of project group.

Whilst it is accepted that the project will in some areas produce perceptible levels of vibration and/or audible levels of regenerated noise, the EPR's and CNVMP will ensure the project is completed using techniques consistent with world's best practices that produces the minimum possible impact on amenity and ensures infrastructure is appropriately protected.

10. Declaration

I have made all the inquiries that I believe are desirable and appropriate and that no matters of significance which I regard as relevant have to my knowledge been withheld from the Inquiry and Advisory Committee.

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Signed

John Heilig

Date: 1st August, 2017

Appendix A Matters Raised in Relation to Guide to Expert Evidence

I hold the qualifications of Bachelor of Engineering (BE) Honours in Mining and a Doctor of Philosophy (PhD), both from the University of Queensland in Australia. I have held these qualifications for more than 25 years.

I have worked in the construction industry and have extensive domestic and international experience in the measurement and analysis of vibration from mechanical equipment as well as the design, analysis, and performance of controlled rock blasting in civil construction projects. I have been associated extensively with vibration analysis and prediction at sites throughout the world.

My experience specifically in the vibration assessment from mechanical equipment or drilling and blasting practices includes large scale tunnelling projects throughout Australia and other countries. My preparation of the West Gate Tunnel Environmental Effects Statement (EES) and this evidence draws on experience gained at more than eight hundred sites worldwide in the areas of both equipment vibration and small scale controlled blasting.

I have been retained to advise on vibration and regenerated noise related aspects associated with the tunnelling component of the project. The following statement pertains to the effects of construction vibration on personal amenity and potential damage to infrastructure. I have walked the alignment on multiple occasions. My evidence is based on these site visits and an analysis of the expected vibration levels from different construction methods. Where appropriate, my comments draw on experience from these other sites.

The predicted vibration and regenerated noise impacts from the tunnelling construction process have been based upon other the information provided in the EES. It states the types of construction equipment that would commonly be used to develop a large diameter tunnel. Whilst the assumptions are based upon best practices and available data, the accuracy of all modelling should be confirmed during the initial stages of each construction process. The results presented in the EES should therefore be considered preliminary.

My assessment and evidence addresses the vibration and regenerated noise from the tunnelling. My analyses have not considered surface works that may generate vibration in other areas of the project corridors. My analyses have also not addressed vibration from the operation of the tunnel or other traffic related vibration that may occur during the construction process.

In assessing the submissions for the project, it has been assumed that all submissions relevant to my area of expertise have been provided.

Appendix B Heilig CV

HEILIG PARTNERS
Engineered Excellence

Condensed Curriculum Vitae for Dr. John Heilig

Dr John Heilig is an engineer with in excess of 25 years of extensive specialised international experience in blasting and vibration related engineering. John has a special skills in optimisation of hard rock excavation using drilling and blasting, application of specialised mining techniques and the measurement and analyses of vibration from mechanical excavation equipment. John has consulted to more than 500 projects in over ten countries. Specialised skills include:

- Optimisation of drilling and blast design for both underground and open-pit activities to maximise cost effectiveness, productivity and/or fragmentation;
- Auditing of drilling and blasting activities at mining, quarrying and civil operations, including preparation of technical reports discussing comparison of the operation's activities with respect to world's best practices;
- Structural and vibration monitoring from blasting or other mechanical construction activities with a comparison of measured vibration levels with Australian Standards or other criteria set to avoid structural damage and minimise human annoyance;
- Detailing of specialised excavation methods in areas where restrictive vibration criterion is applied or close proximity of infrastructure necessitates controlled techniques;
- Control and minimisation of ground and air borne vibrations from blasting activities linked with quarrying, mining or construction activities;
- Analysis, prediction and measurement of vibration produced from mechanical equipment such as tunnel boring machines (TBM), road headers, hydraulic hammers, pile driving, vibratory rollers etc;
- Measurement and analysis of regenerated noise from mechanised tunnelling equipment such as TBM's and roadheaders.
- Dilapidation surveys of infrastructure, including identifying the extent of the surveys and the area where dilapidation surveys should be undertaken.
- Application of computer based data acquisition instrumentation for monitoring and control purposes related to mining, quarrying and construction activities. Development of the flexible datatrap
- suite of software for analysis and presentation of monitoring results
- Preparation of technical documents and training seminars assessing the appropriateness of various excavation methods.
- Preparation of technical documents for submission to regulatory authorities for approving drill and blasting methods in built up areas. Reports discuss necessary control measures;
- Expert witness in field of vibration analyses from mechanical activities. Assessment of expected impacts from blasting, including vibration, air overpressure and flyrock

Surface Mining and Quarrying

Extensive experience including assessment of drilling and blasting designs. Outcomes for multiple projects have focussed on revising mining methods to reflect the site specific objectives (environmental, fragmentation, diggability, etc.). Optimised excavation methods near final walls to minimize the extent of damage to the slopes, crest and berms. Assessed new "green field" projects preparing documents submitted as part of the Environmental Effects Statement or Material Change of Use (MCU). Assessment of blast designs with respect to controlling vibration, air overpressure and flyrock.

Underground Mining

Consulted to projects at underground operations in Australia and overseas countries investigating the effect of explosive loading conditions on underground stability, production rates and fragmentation. Optimised drilling patterns to improve similar parameters. Presented seminars to mining industries on methods of optimising and assessing underground drill and blast practices. Extensive knowledge of methods of assessing drill and blast performance using high end vibration monitoring methods. Understanding of the influence of blast design parameters on raise performance.

Tunnelling

Analyses, predictions and application of detailed 3D models for the assessment of vibration and regenerated noise from TBM and road headers. Assessed drill and blast patterns to minimise drill and blast cycles times by way of optimising advance. Developed working procedures on tunnelling practices. Guided mining operations and research groups on instrumentation and techniques to monitor, analyse and optimise the performance of tunnelling patterns. Key recent local projects have included the North South Bypass (Clem 7), Airport Link Northern Busway, Legacy Way, East West Link, North West Rail Link, and the Eastern Busway.

QUALIFICATIONS
B.E. Mining (Hons), University of Queensland
PhD. Mining Engineering, University of Queensland
Registered Professional Engineer (RPEQ 6304)
Certificate IV in Training
Unrestricted Shotfirer's License - Queensland

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Condensed Curriculum Vitae for Dr. John Heilig

Civil

Widespread experience in multi-billion dollar civil projects, particularly those requiring excavation in near proximity to vibration sensitive equipment structures, slopes, services (water, gas, telecommunications). Assessed excavation requirements for portals, road cuttings, foundations and trenches with respect to adjacent sensitive equipment. Completed studies that have assessed the effectiveness of alternative methods in those areas where environmental criteria remains prohibits conventional excavation methods. Specification of appropriate of vibration criterion and monitoring procedures for the protection of structures and equipment, including heritage and cultural monuments. Developed models for the analysis and prediction of vibration from hydraulic hammers, pile driving, vibratory rollers and dozers.

Training

Training seminars to industry related professionals in the areas of surface and underground drilling and blasting methods and the measurement and analyses of the environmental effects of vibration and air overpressure. Training in the use and equipment required for the measurement of vibration from mechanical equipment

Legal Representation

Expert witness for presentation in the Environmental Courts, both nationally and internationally. Detailed knowledge of the processes involved with use of explosives, new quarry developments, extensions or Material Change of Use (MCU) applications. Knowledge of the relevant Australian and International standards referencing impulsive or continuous vibration and its effect on structural integrity and human perception.

Monitoring Equipment

Procurement of specialised monitoring equipment for the measurement of vibration and air overpressure from drilling and blasting activities. Specification of equipment for detailed assessment of vibration impacts related to construction activities with mechanical equipment. Configuration of automated data retrieval and management system for analysing data collected from blasting or mechanical equipment, such as TBM and road headers, in particular using the datatrap suite of software

Publications

In excess of 15 publications listed in national and international journals and conferences

Clients

Provided expertise in the areas of drilling and blasting, monitoring and the assessment of vibration from mechanical equipment and legal representation for both existing or planned activities. A selection of contracts have included:

- **Civil**: Leighton, Thiess, Baulderstone Hornibrook, John Holland, Abigroup, MacConnell Dowell, Watpac, EROC, MacMahon, BMD, Downer, Transfield, Walter, Lend Lease, Golding, L&D Contracting, Rosenlund, Seymour Whyte, Ghella, Acciona, Delta, Australand, Clough, Mainland Civil, Wagners, McNab, Australand, Laing O'Rourke, Multiplex, Matrix, Amalgamated Constructions, Dragage et Traveaux, Gammon, Roche, JJ MacDonald, Covecorp, Vecchio, MTRC, Queensland Rail
- **Dams:** Wyaralong Dam, Wivenhoe Upgrade, Borumba Dam, Burrinjuck Dam, Pindari Dam, Burnett River Dam, Burdekin Dam, Lake Manchester, Binga Dam, Linkwater
- **Key Local Projects**: North South Bypass (Clem 7), Airport Link Northern Busway, Legacy Way, Eastern Busway., East West Link, EBus2, C2C, Transcity, North West Rail Link, T2E, Citylink
- **Mining**: Newmont, BHP Billiton, BMA, AngloCoal, RioTinto, INCO, Falconbridge, Brunswick, Aquarius Platinum, Couer Gold, Olympic Dam, Noranda, Barrick, Adamus Resources, Solid Energy, Northern Gold Mining, Placer Dome, Newcrest, Keegan Resources, , PanAust, New Hope
- **Quarry**: Hanson, Boral, CSR, Stonemaster, Karreman, Brisbane City Council., Mansell, Wagners, Sunshine Coast, Hardrock, Gympie Regional, Suncoast
- **Drilling & Blasting**: Orica, Dyno Nobel, Maxam, CBS, Canex, Sequel Drill & Blast, Suncon Drill & Blast, AVKO, Roche Blasting Services, Pacific Drilling and Blasting, RJW Drilling
- **Legal**: Corrs Chambers Westgarth, Deacons, Connor O'Meara, Minter Ellison, Clayton Utz, Simpson Grierson, Robert Milne, Brisbane City Legal, p&e Law, Results Legal
- **Consultants**: Parson Brinckerhoff, Arup, Maunsell, Connell Wagner, SKM, Golder Associates, Fugro, Snowden, Sinclair Knight Merz, Cardno, GHD, Hyder, Itasca, Metso, Simmonds Bristow, Aecom, Coffey, AVKO, KBR, Noise Measurement, Noise Mapping, WBM, Ecoroc
- **Countries**: Australia, New Zealand, Papua New Guinea, United Kingdom, Singapore, Hong Kong, Philippines, China, Canada, United States, Alaska, Chile, Slovakia, South Africa, Ghana, Chile.

QUALIFICATIONS
B.E. Mining (Hons), University of Queensland
PhD. Mining Engineering, University of Queensland
Registered Professional Engineer (RPEQ 6304)
Certificate IV in Training
Unrestricted Shotfirer's License - Queensland

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