27 November 2015

HAZELWOOD MINE FIRE SECOND INQUIRY

REVIEW OF JACOBS' REPORT

Submitted to:
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Level 50, Bourke Place
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REPORT

Report Number. 1542819-001-R-Rev0

Distribution:

1 Copy - King & Wood Mallesons
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Golder Associates

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1.0 INTRODUCTION

1.1 Engagement

1) I, Dr Chris Haberfield of Golder Associates Pty Ltd (**Golde**r) have prepared this report in response to letters dated 12 October 2015 and18 November 2015 from King & Wood Mallesons (**KWM**) with regard to providing expert geotechnical advice on matters arising from the Hazelwood Mine Fire Inquiry, second Board of Inquiry. KWM act for Hazelwood Power Corporation Pty Ltd, Hazelwood Power Partnership, International Power (Australia) Pty Ltd and GDF SUEZ Australia Energy and its related entities (together **GDFSAE**). A copy of the KWM letters are included in Appendix A.

2) The second Board of Inquiry commissioned Jacobs Australia Pty Ltd (**Jacobs**) to provide a review of future mine rehabilitation options for the Latrobe Valley coal mines and addressing Terms of Reference Eight and Nine (**TOR**) dated 26 May 2015. The outcomes of Jacobs' assessment are set out in a Final Report entitled "*Review of Future Rehabilitation Options for Loy Yang, Hazelwood and Yallourn Coal Mines in the Latrobe Valley*" dated 16 November 2015 (**Jacobs Report**).

3) I had previously been instructed by KWM to review an earlier draft of the Jacobs Report dated 12 October 2015 (**Jacobs Draft Report**) and to attend a "technical experts review conference" which was held on 27 and 28 October 2015. A copy of the KWM letter of engagement dated 17 October 2015 is also included in Appendix A. The technical experts review conference provided a forum to discuss the Jacobs Draft Report and provide feedback to Jacobs on that report. I attended the technical experts review conference.

4) I have now been instructed to review the Jacobs Final Report and to provide my opinion on specific questions which are set out in a KWM letter dated 18 November 2015 (see Appendix A).

5) This report sets out my answers to the questions asked in respect to the Jacobs l Report. Given the short time-frame available for review, only a high level review of the Jacobs Report was possible, and this is reflected in my opinions as set out in this report.

1.2 Summary of qualifications and experience

6) I am a Principal Geotechnical Engineer and a Principal of Golder based in the Melbourne office. Golder is an international engineering consulting company specialising in geotechnical and environmental engineering and earth sciences. I concurrently hold the position of Research Associate with the Department of Civil Engineering, Monash University.

7) I have a BSc degree (1979) in Mathematics and a BE (H1) (1981) degree in Civil Engineering, both from the University of Sydney, and a PhD in Geotechnical Engineering (1988) from Monash University. I have 34 years of experience in researching, teaching and practising in geotechnical engineering.

8) I am a Fellow of Engineers Australia. I am a Chartered Professional Engineer (CP Eng), a Registered Professional Engineer in Queensland (RPEQ), a past Australasian and First Vice President of the International Society for Rock Mechanics, and a Past Chairman of both the Victoria Chapter and the National Committee of the Australian Geomechanics Society. I am the recipient of the 2007 EH Davis Award which recognises outstanding recent achievements in the science and engineering of geomechanics in Australia. I am currently a member of Technical Committee 207 – Soil Structure Interaction of the International Society for Soil Mechanics and Geotechnical Engineering.

9) My areas of expertise and experience include foundation design and analyses, numerical and analytical modelling, testing and behaviour of soil and rock, design and performance of ground anchors and piles, stress analysis and fracture mechanics, ground structure interaction including retaining walls and underground openings, slope stability assessment and analyses and influence of construction techniques in geotechnical engineering.

10) I have published in excess of 140 refereed papers in my areas of expertise.

11) I have wide ranging experience in geotechnical engineering projects and have provided geotechnical engineering advice both in Australia and overseas for large building projects, mines, reclamations, ports and infrastructure projects. These projects have involved foundations, deep excavations, retention systems, ground improvement, earthworks, tunnels, shafts and slopes. I have also provided expert advice with respect to geotechnical issues in coronial, dispute and arbitration cases.

12) I am familiar with the geotechnical related mining issues in the Latrobe Valley and have previously provided design and expert advice in relation to such matters.

13) My qualifications and experience are set out in the curriculum vitae in Appendix B.

1.3 Questions

14) I have been asked by KWM to prepare a report for the purposes of the Hazelwood Mine Fire Inquiry in which I set out my expert opinion on the following matters:

15) *"1. Is the approved model for the final rehabilitation of Hazelwood Mine detailed in the Work Plan Variation (of a partial lake within a lowered landform) (***Approved Final Rehabilitation Model***), a feasible and appropriate model for final rehabilitation from the perspective of:*

(a) achieving a safe and stable final landform; and

(b) returning the Mine site to a condition which will enable future beneficial land use and which will complement the surrounding environment?";

16) *"2. Given the progression of the mining operations at the Hazelwood Mine, and the extent of progressive rehabilitation and in-pit dumping of materials to date, are there any reasonably practicable final rehabilitation models for the Hazelwood Mine other than the Approved Final Rehabilitation Model?" (***Other Practical Alternatives***);*

17) *"3. From a geotechnical perspective, and considering hydrogeological risk, do you agree that the following landform options identified in the Jacobs report:*

(a) Pit Lake; and

(b) Partial Backfill of the Mine Void to Below the Water Table (BWT)

*are the only two potentially viable rehabilitation options for the final rehabilitation of the Hazelwood Mine?" (***Landform Options***)*;

18) *"4. Do you agree with the approach taken by Jacobs, to assessing geotechnical and hydrogeological risk with respect to the rehabilitation options for the Hazelwood Mine referred to in 3(a) and (b) above?"* (**Risk Approach Adopted by Jacobs**);

19) *"5. Subject to your opinion in relation to 4 above – do you agree that the Partial Backfill BWT Landform option represents the lowest risk landform for the Hazelwood Mine?"* (**Lowest Risk Landform**);

20) *"6. Do you agree that the Partial Backfill BWT Landform option is the option referred to in the Jacobs Report which most closely aligns with the Approved Final Rehabilitation model?"* (**Alignment with Approved Final Rehabilitation Model**);

21) *"7. Do you agree with the assumptions made in the Jacobs Report (including within the Risk Assessments (appendix D) and Cost Estimates (Appendix E) with respect to suitable techniques for:*

(a) managing floor and batter stability; and

(b) managing fire risk,

in relation to the Pit Lake Landform and Partial Backfill BWT Landform options?" (**Assumptions re Managing Stability and Fire Risk**);

22) *"8. Further to 7 above, do you consider that a clay or overburden cover of 2 metre thickness is required as proposed in the Jacobs Report for all exposed coal above the water body in rehabilitated batters? If not, why not, and would a clay or overburden cover of a lesser thickness constitute a sufficient fire risk control measure?"* (**Overburden Thickness to Mitigate Fire Risk**)*;*

23) *"9. Do you have any other comments on:*

(a) the assessment by Jacobs of the Pit Lake Landform and Partial Backfill BWT landform options in relation to the Hazelwood Mine contained in the Jacobs Report?

(b) the Cost estimates in the Jacobs Report insofar as they relate to Hazelwood Mine;

(c) the Jacobs Report generally?" (**Other Comments**).

1.4 Relied Upon Information

24) In providing my opinion below I have relied upon the following:

i) Witness Statement of James Anthony Faithful, Hazelwood Power Corporation, dated 13 November 2015 at its annexures (**Witness Statement of James Faithful**) provided by email on 17 November 2015;

ii) Documents listed in KWM letter dated 12 October 2015 (see Appendix A) and additional background documents provided on 22 October 2015;

iii) 2015 Hazelwood Ground Water Modelling Report dated September 2015 provided electronically on 22 October 2015;

iv) My knowledge gained during a previous engagement and a site visit to Hazelwood Mine on 22 July 2013 during which I observed the batters of the mine, the HARE and HARA (refer paragraph 37 below), the Morwell Main Drain and batter rehabilitation works as they were at that time;

v) My knowledge gained through previous work I have completed in respect to mining and related works in the Latrobe Valley.

2.0 ANSWERS TO QUESTIONS

2.1 Question 1 – Approved Final Rehabilitation Model

25) *Is the approved model for the final rehabilitation of Hazelwood Mine detailed in the Work Plan Variation (of a partial lake within a lowered landform) a feasible and appropriate model for final rehabilitation from the perspective of:*

(a) achieving a safe and stable final landform; and

(b) returning the Mine site to a condition which will enable future beneficial land use and which will complement the surrounding environment?

26) Yes.

27) The landform present prior to commencement of mining generally comprised rolling hills and pasture. This landform was generally safe and stable and sustained beneficial land uses (e.g. farming). With commencement of mining, the stability of the landform was reduced. In fact, mining activities at Hazelwood Mine have been and continue to be only possible because of the significant and on-going pumping of groundwater from (and hence depressurisation of) the aquifers[1] which are located at depth below the floor of the mine (referred to as the M1 and M2 aquifers). Prior to commencement of mining,

[1] Water bearing, relatively permeable soil or rock from which water can be readily extracted

the piezometric levels[2] within the M1 and M2 aquifers were at levels significantly above the current floor of the mine pit (at about RL -60 m) and have since been drawn down by pumping. If pumping from the aquifers ceased and the pit was left to degrade naturally, the groundwater pressure in the aquifers would quickly increase towards pre-mining levels leading to failure of the mine pit floor, collapse of the batters of the mine and uncontrolled entry of groundwater (through cracks in the floor and batters of the mine pit) into the mine pit to form a lake. The water level in the mine pit would then continue to rise until it reached equilibrium with the surrounding groundwater level and other environmental influences (surface water inflows, evaporation etc). Other environmental processes (e.g. erosion and landslip) would gradually reshape and flatten batters until they were stable (with batter slopes likely to be steeper than 2.5H:1V). After many years, the resulting landform (a lake and wetlands in a low lying landscape) would once again be stable. The groundwater level and lake water level would be self-equilibrating, rising and falling in response to each other. Such a stable landform would once again be able to sustain beneficial land use.

28) The Approved Final Rehabilitation Model set out in the Work Plan Variation (approved on 11 May 2009) for Hazelwood Mine aims to achieve a similar stable pit lake, low lying landform as described above, but in a reasonable time period and in a controlled and safe manner (rather than the uncontrolled and potentially unsafe manner described above). That is, the Approved Final Rehabilitation Model provides a managed progression from end of mining to a landform consistent with that which would be achieved if left to nature. The end result is a landform that is in equilibrium with and reflects natural processes, as was the landform that was present prior to mining commenced.

29) The Hazelwood Mine Approved Final Rehabilitation Model has the following main features:

- Ash and overburden (unsuitable for use on the batters) is placed in the floor of the mine.
- The mine pit batters will be flattened and reshaped to form stable slopes as follows:
    - batters within the overburden material[3] will be reshaped to be no steeper than 3H:1V with safety berms installed where the vertical height of the batter is greater than 20 m;
    - permanent coal batter faces reshaped to no steeper than 2.5H:1V and preferably 3H:1V;
    - exposed coal (above equilibrium lake level) will be covered with overburden (which provides a barrier to fire entering the coal and a medium for plant growth) and revegetated;
- Mining infrastructure will be removed.
- *"The pit will be allowed to fill with water creating a lake."* It is currently proposed that lake filling will initially take place by continuing aquifer depressurisation pumping and placing the pumped water into the mine pit. Pumping will continue until the water level in the pit[4] reaches an elevation at which "weight balance"[5] is achieved. Achieving weight balance will mitigate base heave and assist with batter stability. The pit lake will then slowly fill until equilibrium (as described above) is attained. Current estimates put the equilibrium lake level at about RL 8 m. The time taken to reach weight balance and equilibrium level depend on the availability of water. Current estimate is that weight balance is likely to be achieved with a lake water level at about RL -22 m (or a depth of water of about 38 m)[6] which under agreed water allocations could take as little as 7 years to achieve[7]. The current estimate of equilibrium lake level is RL 8 m resulting in a water depth of about 68 m which corresponds to slightly more than half the depth of the mine pit.

[2] In simplistic terms the level to which water would rise to in a well installed into the aquifer

[3] The near surface soil overlying the coal – the overburden is typically 9 m to 16 m thick at Hazelwood Mine

[4] Water could be potentially obtained from a number of sources including groundwater, rainfall and runoff captured by the Hazelwood Pondage 5)

[5] Weight balance is when the weight of water and overburden placed in the base of the pit is estimated to be sufficient to counteract the uplift pressure from the underlying aquifers.

[6] refer paragraph 105 of Witness Statement of James Faithful

[7] GHD report entitled Hazelwood Groundwater Modelling Report, dated September 2015

- The intention is to provide a site that provides for safe access for the public and enables beneficial land use.

30) Whilst I consider the Approved Final Rehabilitation Model for Hazelwood to be a feasible and appropriate model for final rehabilitation (from a geotechnical perspective), further studies are required to better understand the details of how this is to be achieved. Such studies include:

    a. Depth of overburden cover on exposed coal batters that is required to reduce fire risk to an acceptable level;

    b. Available water sources and rate at which filling can be reasonably achieved considering interaction with other mines and water users;

    c. Groundwater and surface water quality and their impact on lake water quality and how to maintain lake water quality within acceptable levels;

    d. Long term batter stability particularly for the northern batters of the mine which are adjacent to high value public infrastructure (e.g. freeway and Morwell Main Drain and the Morwell township). Experience has shown that the stability of these batters is sensitive to the depth of water in the coal seams within the batters. The depth of water in the coal seams in some areas around the mine can rise and fall quickly and if not mitigated can cause movement of the batters. Whilst such movements have occurred because of the availability of a concentrated source of water (e.g. within the Morwell Main Drain), they have been limited to areas close to the mine (generally within 300 m of the batter crest). Identification of areas where there is potential for rapid increases in water level in the coal need to be identified and suitable mitigation measures implemented. The risk that such movements pose to life and property also requires further study.

31) I am aware that Hazelwood Mine is being proactive in addressing at least some of the knowledge gaps identified above by commissioning independent investigations into pit slope stability and groundwater (e.g. GHD groundwater modelling report[8] and GHD's ongoing assessment of long term batter stability). The need to carry out the above studies is realised by the mine operator as confirmed at paragraph 165 of the Witness Statement of James Faithful.

2.2 Question 2 – Other Practical Alternatives

32) *Given the progression of the mining operations at the Hazelwood Mine, and the extent of progressive rehabilitation and in-pit dumping of materials to date, are there any reasonably practicable final rehabilitation models for the Hazelwood Mine other than the Approved Final Rehabilitation Model?*

33) No. Whilst other alternatives are possible, they are currently not feasible due to their impracticality, insufficient available material and/or high cost.

34) The progression of mining operations and the planned progressive rehabilitation are described in the Initial Work Plan and the Work Plan Variation.

35) As described in the Work Plan Variation, Phase 2 of the West Field Development has been underway since about 2010 and involves mining westward from the existing batters of the mine (see Figure 1).

[8] GHD report entitled Hazelwood Groundwater Modelling Report, dated September 2015

Figure 1: General Location Plan (Ref Figure 2.1 of Work Plan Variation)

36) Mining operations and presence of mine infrastructure (which is required for ongoing mining operations) limits the areas in which progressive rehabilitation can occur. Nevertheless significant rehabilitation works have been undertaken to date comprising approximately 557 hectares within the Mining Licence Area[9]. These rehabilitated areas are shown in Figure 2 and include the eastern and western overburden dumps and various batters around the mine.

37) In addition, significant in-pit placement of materials has occurred. These include:

- the Hazelwood Ash Retention Area (HARA)
- The Hazelwood Ash Retention Embankment (HARE)
- Internal overburden dump

38) The rehabilitation and in-pit dumping that has occurred is generally consistent with the Work Plan Variation. Material that is not suited to the rehabilitation of the batters has been placed in-pit. This includes the ash from the power station and saturated overburden material that is currently being mined from Block 1C in the West Field[10].

39) The overburden at Hazelwood Mine is typically 9 m to 16 m thick and is variable in nature. The overburden to date has either been stockpiled (in overburden dumps) or used to rehabilitate batters as set out in the approved Work Plan. The Eastern and Western Overburden Dumps have already been rehabilitated, but if deemed necessary, the overburden in these dumps could theoretically be utilised on mine batters (for fire protection or buttressing) or within the pit to assist weight balance. However, the cost associated with relocating this material would be high and would probably exclude this as a source.

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[9] Paragraph 121 of Witness Statement of James Faithful

[10] Paragraph 99 (e) Witness Statement of James Faithful

The need or otherwise for such work needs to be established. The studies identified in my reply to Question 1 above should assist in answering this question.

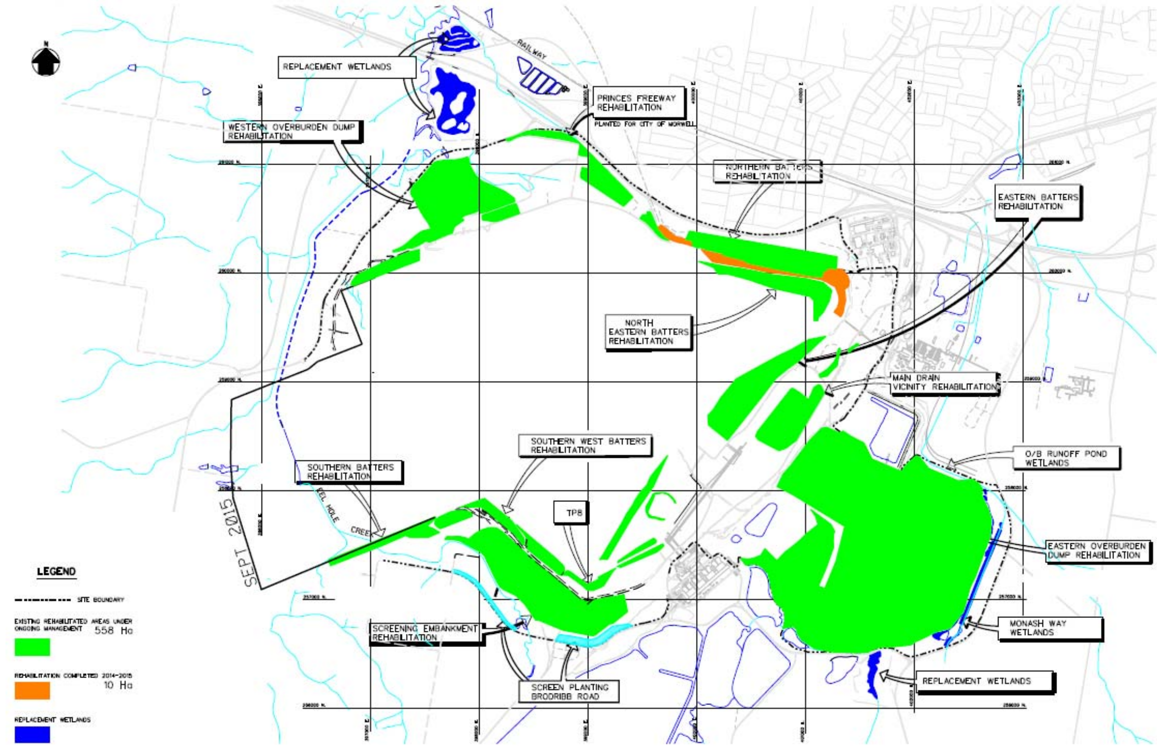

Figure 2: Existing rehabilitated areas at September 2015 (Ref Witness Statement of James Faithful)

40) There is insufficient overburden available at Hazelwood Mine to back fill the mine and achieve weight balance (which is required for a stable landform). The only options for obtaining weight balance (and a stable final landform) are to either use material sourced from outside of the Mine Licence (e.g. overburden from other mines or excavations or waste) at considerable cost, continue to depressurise the underlying aquifers for ever, or form a lake in the bottom of the pit. Of these options, the lake option is the only reasonably practical option.

41) Given the likely significant cost associated with moving material from already rehabilitated areas and the lake option being the only practical option, I currently see no geotechnical based reason to disturb already rehabilitated areas or to depart from the Approved Final Rehabilitation Model.

2.3 Question 3 – Landform Options

42) *From a geotechnical perspective, and considering hydrogeological risk, do you agree that the following landform options identified in the Jacobs report:*

(a) Pit Lake; and

(b) Partial Backfill of the Mine Void to Below the Water Table (BWT)

are the only two potentially viable rehabilitation options for the final rehabilitation of the Hazelwood Mine?

43) Yes, although I have difficulty in distinguishing between the Pit Lake and BWT options. In my view, they are one and the same option with the only difference being in the depth of water in the lake and the

amount of backfill placed within the mine void. The Jacobs' Pit Lake Option has less backfill placed in the mine pit void and a greater depth of water than the Jacobs' BWT option. Both options require sufficient backfill/water to be placed in the mine pit void to achieve weight balance and a stable landform.

44) This is also indicated in the Jacobs cost estimates which show only one item that is different between the Pit Lake and BWT options (refer Appendices E5 and E6 of the Jacobs Report).

45) In The BWT option (Jacobs Report Appendix E6) there is an a "*Design Control*" item described as *"Placement of overburden (mine waste material), interseam materials and fill over batters to contribute to weight balance"* and an activity described as "*Differential backfilling across floor and batters to create multi-level in-pit landform with some AWT and some BWT areas such that AWT batters are sloped as shallow as possible*". This activity is subdivided into *"Reshaping – Pit wall / Short term / Assumed total BWT pit wall area outside the scope of operations / 94 ha"* for cost of $302,321.47 and *"Reshaping – Pit floor / Short term / Assumed outside the scope of operations / 836 ha"* for cost of $2,675,200.00.

46) In the Pit Lake Option (Jacobs Report Appendix E5) the corresponding *"Design Control"* item is described as *"Design and construction of slopes to suitable gradient"* and an activity described as *"Reshaping of selected batters for a safe and stable outcome".* This activity has a single cost line item of *"Reshaping – Pit wall / Short term / Assumes whole area of AWT final sloped pit walls / 288 ha" for a cost of $922,746.*

47) Both the Pit Lake and BWT options are consistent with the Approved Final Rehabilitation Model.

48) As stated above in my reply to Question 2, there is insufficient overburden available at Hazelwood Mine to back fill the mine or to achieve weight balance (which is required for a stable landform). A substantial portion of the available overburden is required for batter rehabilitation, leaving a smaller volume for use in achieving weight balance.

49) The only options for obtaining weight balance (and a stable final landform) are to either use material sourced from outside of the Mine Licence (e.g. overburden from other mines or excavations or waste), continue to depressurise the underlying aquifers forever (or until such time as backfilling becomes viable; e.g. using pit as a landfill), or form a lake in the bottom of the pit.

50) Sourcing additional overburden material from off site is not practical due to the significant costs involved and potential environmental issues associated with borrowing material from somewhere else, presumably by excavation of a large amount of material.

51) Backfilling the pit with waste is not currently feasible due to the high cost associated with lining the pit (to meet EPA and environmental regulations etc) and providing the infrastructure to transport the waste. In addition, depressurisation would need to continue until such time as there was sufficient waste in the pit to obtain weight balance.

52) Permanent depressurisation requires continued maintenance of pumps and wells, and carries a significantly higher risk of instability (should pumps fail or become ineffective). It is also not a sustainable solution.

53) The only practical way to achieve weight balance within current (and likely near future constraints) is through use of water, and hence it is inevitable that there will be a lake in the base of the pit.

2.4 Question 4 – Risk Approach Adopted by Jacobs

54) *Do you agree with the approach taken by Jacobs, to assessing geotechnical and hydrogeological risk with respect to the rehabilitation options for the Hazelwood Mine referred to in 3(a) and (b) above?*

55) Yes and No.

56) I agree that a risk assessment approach is a reasonable method to assess the geotechnical and hydrogeological risks associated with the Pit Lake and BWT options. However, in my view the Failure Mode Analysis risk assessments presented in the Jacobs Report are too generic to be meaningful and

are not consistent from one landform option to another. In addition, in respect to geotechnical risk, the risk assessments carried out by Jacobs are not consistent with established industry practice for assessing risk of landslip. My reasons for this are set out below.

57) It should have been reasonably obvious to Jacobs from the very start that given the characteristics of the mine pit, the rehabilitation and in-pit dumping that has already occurred and the present and future likely constraints regarding future landforms, a lowered landform with a lake was the only practical or feasible option for rehabilitation of Hazelwood Mine. The depth of water in the lake (i.e. differentiating between a Pit Lake and BWT landform options) was largely irrelevant in respect to geotechnical and hydrogeological risk because to achieve a stable landform in the long term, the lake water level must be in equilibrium with the environment and groundwater conditions and appropriate engineering measures (or controls) will have been installed to mitigate the identified risks.

58) The Failure Mode Analysis (FMA) approach documented in the Jacobs Report is a method of justifying the reasonably obvious conclusion that the only potential viable options for Hazelwood Mine are a Pit Lake or BWT landform. From a generic viewpoint, the Jacobs' FMA risk assessments also identify, in a very general sense, potential hazards and mitigation measures (design controls). However, the FMA risk assessments are too general and non-specific to be used to assess risk levels or as a basis to estimate costs of rehabilitation.

59) The Jacobs' FMA risk assessment identifies a hazard (e.g. multi-batter collapse) and controls to mitigate the hazard (e.g. design of slopes to suitable gradient). It then identifies how these controls could potentially fail and identifies additional controls (referred to as Secondary Design Control) to mitigate failure of the primary controls. The risk is then assessed assuming that the primary and secondary controls are adopted (referred to as residual risk). The residual risk is assessed using a risk matrix (referred to as a Risk Judgement Matrix – see Jacobs Report page 38 of Appendix D) based on an assessment of consequence and likelihood associated with the hazard.

60) There is insufficient information in the Jacobs Report to understand the decision processes involved in assessing likelihood and consequence, and therefore risk. In particular, it is unclear to me how likelihood could be reasonably assessed without reference to specific batter slopes and locations and without identifying the specific events that could contribute to multi-batter failure (e.g. rise in groundwater level in the coal due to inundation from the Morwell Main Drain). In addition, how can consequence be reasonably assessed without specific reference to the items at risk from each hazard at each location and the likelihood that that they will be impacted by the hazard?

61) Jacobs do not provide the basis of the risk matrix they adopted to assess risk from consequence and likelihood, nor do they explain the implications of Low, Moderate, High or Critical risk. The risk matrix adopted by Jacobs is significantly different (and results in a higher assessed qualitative risk) to that which is commonly used in Australia for assessing landslide risk (see below in reference to AGS 2007 Guidelines). This is illustrated below in respect of Jacobs' assessment of risk from multi batter collapse. For this hazard, the Jacobs' risk assessment indicates high and low risks respectively for Pit Lake and BWT options. As set out below, this inconsistency in assessed risk levels for what is essentially the same landform option is a result of the non-specific approach adopted by Jacobs and calls into question the validity of the Jacobs' approach.

62) Consider the Jacobs risk scenario for landform Stability (Collapse) for Hazelwood Mine set out in Appendices D3 (Pit Lake) and D4 (BWT). For a potential risk issue (hazard) of multi-batter collapse Jacobs identify the following potential causes for both the Pit Lake and BWT options:

i) *"Not achieving weight balance.."*

ii) *"Incorrect geotechnical design including slope angles (and fracture planes)"*

iii) *"Changes in material competency, due to water ingress"*

iv) *"Timing between mining cessation and water filling"*

v) *"Heave…of pit floor"*

63) The primary design controls identified by Jacobs for the Pit Lake option are:

   i) *"Placement of overburden and fill over batters to achieve weight balance"*

   ii) *"Design of slopes to suitable gradient"*

   iii) *"Water management, establish drainage, especially for the upper batters where infiltration is a threat"*

   iv) "*Aquifer depressurisation of Morwell and Traralgon aquifer systems to help achieve weight balance and to prevent floor heave. This needs to be balanced with the rate of filling of the pit lake"*

   v) *"Installation of pressure relief wells in high risk areas of pit cut back"*

64) In comparison, the primary design controls identified by Jacobs for the BWT option are the same as for the Pit Lake option but in addition include :

   vi) *"Restrict access to areas immediately below the high batters (may constrain land uses)"*

   vii) *"Differential backfilling across floor and batters to create multi-level in-pit landform with some AWT and some BWT areas such that AWT batters are sloped as shallow as possible"*

   viii) "*Buttressing of slopes during pit filling*"

   ix) *"Progressive coverage of batters following completion of mining on batters"*

   x) *"Restrict access to area on the northern and eastern batters which are more exposed"*

65) It is not clear to me why the same or similar additional primary design controls listed in paragraph 64 for the BWT option cannot also be applied for the Lake Option. In addition I do not understand how *"Differential backfilling across floor and batters to create multi-level in-pit landform with some AWT and some BWT areas such that AWT batters are sloped as shallow as possible"* assists with landform stability or why it is required as a control measure.

66) The potential failure modes of the primary Design Controls for the Pit Lake Option are assessed by Jacobs to be:

   i) *"Incorrect calculation of weight balance"*

   ii) *"Pressure build up behind individual batters as a result of intermediate aquifer pressure pushes walls out and results in slip failure"*

   iii) *"Poor water management on surface benches or aquifer pressures"*

   iv) *"Insufficient compaction of benches resulting in differential settlement"*

   v) *"Poor stormwater management on upper batters allowing infiltration"*

   vi) "*Seismic event above design criteria"*

   vii) *"Insufficient volume of suitable overburden, interseam and fill materials available on site to achieve required weight balance when combined with water load"*

67) The potential failure modes for the Primary design Controls for the BWT option assessed by Jacobs are similar to those for the Pit Lake option set out in paragraph 66) above (although different words are used) but also includes an additional failure mode:

   viii) *"The regional groundwater pressure recovers higher or faster than expected"*

I do not understand why this failure mode does not apply to the Pit Lake option.

68) The secondary design controls identified by Jacobs for the Pit Lake option are:

i) *"Conservative management of water during transition state. Buttressing could be implemented during the transition state"*

ii) *"Dewatering of pit"*

iii) *"Increase FoS, especially near rivers, townships and other infrastructure"*

iv) *"Avoid water level being at the toe of batter. Aim water level around mid- to upper batters"*

v) *"Quality control of fill placement and slope construction within specified tolerance limits"*

vi) *Source additional overburden, interseam and fill materials off site from other mine sites"*

vii) *"Ongoing dewatering of aquifers immediately adjacent to pit"*

69) I provide my view on the design controls identified in the Jacobs Report in my answer to Question 7 below.

70) The secondary design controls identified by Jacobs for the BWT option are the same or similar to those identified for the Pit Lake option with control vii) above being reworded as *"Manage groundwater pressure surface by pumping to follow the material placement schedule".*

71) With respect to landform stability, the residual landform stability risk rating for the Lake Pit and BWT landform options assumes the following controls can or have been effectively implemented by the mine operator (ref Table 8.3 of the Jacobs Report)

i) *"Placement of overburden (mine waste material), inter-seam materials and/or other fill over the floor of the pit and the lower batters and benches to contribute to achieving a weight balance between the pit and the underlying and surrounding groundwater (aquifer) pressure";*

ii) *"Design and execution of the overall slope angle on batters and benches so that long term slope stability is achieved in keeping with the geology of each face. The angle and design of each face in each pit will likely be different because of the different geology and risk profile for each face (this practice is used now)";*

iii) *"Controlled re-pressurisation of the aquifer recovery of water level following the cessation or reduction of pumping) to achieve weight balance. A balance between the aquifer pressure and material (or water) in the pit is needed";*

iv) "*Design and construction of both the overall slopes and the slope of individual batters to a suitable (long term) gradient in keeping with the risk profile of the wall in questions (geology and setting)";*

v) *"Water management (water addition) to maintain (or achieve) weight balance";*

vi) *"Buttressing of selected high risk faces prior to pit filling";*

vii) *"Installation of pressure relief wells / horizontal drains to control shallow water pressure in upper batters";*

viii) *"Source additional overburden, interseam and/or backfill materials off lease to reach the final long term slope profile required for each wall";*

ix) *"Design of drainage diversion and control on above water level batters to avoid water seeping into upper slope areas that reduce stability";* and

x) *"Infiltration control in critical upper slope areas for faces/walls that are close to important features (rivers, roads or other infrastructure) outside mine boundary".*

72) Not all of the design controls set out in Appendices D3 and D4 appear to be included in the above list. It is not clear from the Jacobs Report whether or not the Jacobs' risk assessment has assumed all the

controls set out in Appendix D3 and D4 have been or can been effectively implemented by the mine operator.

73) The outcomes of the above considerations result in Jacobs assessing a consequence level of 4 (Major – Single fatality, severe irreversible damage to one or more persons) and a likelihood level of E (Rare – Event is very unlikely to occur during the closure phase and unlikely to occur post relinquishment) for a High risk level for the Pit Lake option. For the BWT option, risk is assessed as Low based on a consequence level of 2 (Medium – Reversible injury or health effects of concern that would typically result in medical treatment of one or more persons) and a likelihood of E (Rare). Given the similarities between the inputs (and design controls) into the risk assessments for the Pit Lake and BWT landform options, it would seem reasonable that they should result in a similar risk level.

74) Jacobs would appear to assume the same design controls are used for the Lake and BWT options (refer Table 8.3 of the Jacobs Report). However, this appears to contradict the design controls set out in Appendices D3 and D4. Perhaps the difference in assessed High risk for the Lake Option and Low risk for the BWT option is due to the extra control measures that are identified for the BWT option (see paragraph 64) above and Appendix D4 of the Jacobs Report). However, similar controls could also be implemented for the Pit Lake Option which would reduce the assessed risk to Low.

75) The assessed risk is entirely dependent on the Risk Judgement Matrix adopted by Jacobs. By using the same qualitative descriptors for consequence and likelihood as assessed by Jacobs for the Pit Lake and BWT landform options in the risk matrix provided for risk to property[11] in the Landslip Risk Management guidelines [**AGS Guidelines**] published by the Australian Geomechanics Society (2007)[12] results in Low risk for both Pit Lake and BWT landform options. The AGS Guidelines describes Low risk as *"Usually accepted to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required".*

76) Similar conclusions can also be drawn regarding the Jacobs' assessment of single batter collapse.

77) As is set out in my response to Questions 7 and 9 below, it is not clear to me how the Jacobs' costings have been assessed from its risk assessments. The costings appear to include items that are not identified in the risk assessments.

78) A meaningful risk assessment process needs to consider each domain of the mine in turn (e.g. north eastern batter), and for each domain identify the hazards that are present (e.g. landslip), the probability that these hazards will occur, the items at risk (e.g. people, public infrastructure, urban development etc) and their susceptibility. For domains where the risk is considered to be unacceptable, mitigation measures (or controls) that reduce the risk to tolerable or acceptable levels (see reply to Question 5 below) can then be identified and costed.

2.5 Question 5 – Lowest Risk Landform Option

79) *Subject to your opinion in relation to 4 above – do you agree that the Partial Backfill BWT Landform option represents the lowest risk landform for the Hazelwood Mine?*

80) In the context of geotechnical and hydrogeological risk, the landform with the lowest risk would be to completely backfill the mine pit with overburden. However, this option is not practical. Whilst the geotechnical and hydrogeological risks associated with the Partial Backfill BWT Landform option are higher than for the complete backfill option, the risks can be mitigated through appropriate engineering to achieve tolerable or acceptable risk levels (see below). The same is true for the other landform options. However the engineering measures required to achieve tolerable or acceptable risk levels differ significantly in magnitude, practicality, environmental impact and cost from one landform option to another.

[11] See page 93 of the AGS 2007 Guidelines. These Guidelines recommend a quantitative (rather than qualitative) risk assessment be carried out for risk to life. The risk matrix provided in AGS 2007 Guidelines is intended for a qualitative assessment of risk to property but can also be used to provide an indication of qualitative risk to life.

[12] Practice note guidelines for landslide risk management 2007". Australian Geomechanics, Vol 42, No 1, March 2007.

81) With respect to batter stability, an appropriate method for assessing risk would be as set out in the AGS Guidelines. The AGS Guidelines are incorporated into the erosion management overlays for a number of Councils around Australia (including Colac Otway, Yarra Ranges, Frankston, Mornington Peninsular and Pittwater) for development of areas with susceptibility to landslip.

82) As set out in the AGS Guidelines, the risks arising from geotechnical related hazards are usually assessed on the basis of either being "tolerable" or "unacceptable" risk in respect to both risk to life and risk to property. The AGS Guidelines (page 78) define tolerable risks as *"risks within a range that society can live with so as to secure certain benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if practicable."*

83) "Acceptable" risks provide a lower risk level (typically an order of magnitude lower) than Tolerable Risks. Acceptable Risks are *"risks which everyone affected is prepared to accept. Action to further reduce such risks is usually not required unless reasonably practicable measures are available at low cost in terms of money, time and effort* (Refer AGS Guidelines pg 78). The AGS Guidelines suggest that *"for most development in existing urban areas criteria based on Tolerable Risk levels are applicable because of the trade-off between the risks, the benefits of development and the cost of risk mitigation*."

84) At a high level (and without having undertaken risk assessment according to the procedures set out in the AGS Guidelines), my view is that the most practical solution of achieving a stable landform also offers the lowest cost solution (in terms of dollars, environmental impact, sustainability etc.) in respect to achieving similar Tolerable or Acceptable Risk levels. In my view the Partial Backfill BWT Landform option is the most practical option, and will achieve a stable landform for the lowest cost.

85) However in my view there is also very little difference in the mitigation measures that would be required to achieve Tolerable (or acceptable) Risk levels for the Pit Lake and BWT options, noting that in my view both options are variations of the same theme and are consistent with the Approved Final Rehabilitation Model.

2.6 Question 6 – Alignment with Approved Final Rehabilitation Model

86) *Do you agree that the Partial Backfill BWT Landform option is the option referred to in the Jacobs Report which most closely aligns with the Approved Final Rehabilitation model?*

87) Yes. Noting my comment above relating to the Pit Lake and BWT options being variations on the same theme of a lake in a low level landscape.

2.7 Question 7 – Assumptions re Managing Stability and Fire Risk

88) *"Do you agree with the assumptions made in the Jacobs Report (including within the Risk Assessments (appendix D) and Cost Estimates (Appendix E) with respect to suitable techniques for:*

(a) managing floor and batter stability; and

(b) managing fire risk,

in relation to the Pit Lake Landform and Partial Backfill BWT Landform options?"

2.7.1 Floor and Batter Stability

89) Table 8.3 and Appendices D3 and D4 set out control measures that Jacobs assume or suggest are implemented to manage floor and batter stability. These include (from Table 8.3 of the Jacobs Report):

i) "*Placement of overburden (mine waste material), inter-seam materials and/or other fill over the floor of the pit and the lower batters and benches to contribute to achieving a weight balance between the pit and the underlying and surrounding groundwater (aquifer) pressure";*

ii) *"Design and execution of the overall slope angle on batters and benches so that long term slope stability is achieved in keeping with the geology of each face. The angle and design of each face in* *each pit will likely be different because of the different geology and risk profile for each face (this practice is used now)";*

iii) *"Controlled re-pressurisation of the aquifer recovery of water level following the cessation or reduction of pumping) to achieve weight balance. A balance between the aquifer pressure and material (or water) in the pit is needed";*

iv) *"Design and construction of both the overall slopes and the slope of individual batters to a suitable (long term) gradient in keeping with the risk profile of the wall in question (geology and setting)";*

v) *"Water management (water addition) to maintain (or achieve) weight balance";*

vi) *"Buttressing of selected high risk faces prior to pit filling";*

vii) *"Installation of pressure relief wells / horizontal drains to control shallow water pressure in upper batters";*

viii) *"Source additional overburden, interseam and/or backfill materials off lease to reach the final long term slope profile required for each wall";*

ix) *"Design of drainage diversion and control on above water level batters to avoid water seeping into upper slope areas that reduce stability"; and*

x) *"Infiltration control in critical upper slope areas for faces/walls that are close to important features (rivers, roads or other infrastructure) outside mine boundary*".

Additional control measures from Appendices D3 and D4 of the Jacobs Report that appear to be additional to those above include:

xi) *"Conservative management of water during transition state. Buttressing could be implemented during the transition state"*

xii) *"Dewatering of pit"*

xiii) *"Increase FoS, especially near rivers, townships and other infrastructure"*

xiv) *"Avoid water level being at the toe of batter. Aim water level around mid- to upper batters"*

xv) *"Quality control of fill placement and slope construction within specified tolerance limits"*

90) In broad terms, in my view the control measures identified in the Jacobs Report provide a "shopping" list of general options that could be used to mitigate risks of potential instability associated with the Pit Lake and BWT landforms. However, the requirement or otherwise to implement one or a number of control measures and the type of control measures that are effective will need to be assessed for each domain (e.g. batter) of the mine. The control measures which are applicable will likely vary from one location to another within the mine. The control measures that are adopted will depend on the results of detailed assessments that are or will be undertaken and on the results of monitoring that will be undertaken during transition from operating mine to final landform.

91) I do not understand how xii) *"Dewatering of pit"* mitigates batter slope failure. The presence of a lake improves stability of the batters. Perhaps this was meant to be the same as xvii) *"Ongoing dewatering of aquifers immediately adjacent to pit".*

92) Stipulating an increase in FoS (factor of safety) near rivers, townships and other infrastructure is too simplistic. The concept of factor of safety (FoS) is commonly used to assess the stability of a slope. However, a calculated FoS depends on many assumptions including the strength of the materials making up the slope, the batter geometry and most importantly the groundwater level in the slope. In general as groundwater levels rise within a slope, the FoS of the slope reduces. The question arises, what groundwater level is to be assumed in the assessment of FoS. A high groundwater level may be a very unlikely event, and as a result a lower FoS than adopted for ambient conditions may be applicable. Linking the FoS of a slope to annual probability of failure (as required for a risk assessment) is not

straight forward. It is the risk level that is important, not some arbitrary FoS calculated for assumed conditions.

93) With respect to xiv) "*Avoid water level being at the toe of batter".* I don't see how this can be practically implemented. In my view it will do very little to improve stability if other control measures such as v) and vii) above are successfully implemented.

2.7.2 Fire risk

94) Table 8.2 and Appendices D3 and D4 set out control measures that Jacobs assume or suggest are implemented to manage fire risk. These include:

i) "*Coal faces will be covered or capped to prevent exposure";*

ii) *"Programmed maintenance of the cover/ capping, including monitoring, top up of the cover will be undertaken";*

iii) *"Use of shallow rooted species for vegetation to prevent breach of cover in critical areas";*

iv) *"Erosion prevention to avoid cover breach in the long term";*

v) *"Control of activities within the landform (e.g. vehicle use in areas where there are coal seams or restrict public access to rehabilitated (high risk) areas)";*

vi) *"Include (and maintain) fire breaks in re-vegetation design";*

vii) *"Cover with water (e.g. fill pit to maximum extent). Consideration should be given transition period prior to filling. Fill pit as fast as possible with surface water if cover is not used in the transition phase. Filling rate can be slower if cover is used on areas eventually below the water level";*

viii) *"Limiting the amount of coal exposure at any point in time";*

ix) *"Maintenance of water level using controlled surface water to ensure that uncovered areas are not exposed by water level fluctuations".*

95) As with control measures to mitigate risk of instability, in broad terms, the above control measures set out in the Jacobs Report provide a "shopping" list of general options that could be used to mitigate fire risk associated with the Pit Lake and BWT landforms. However, the requirement or otherwise to implement one or a number of control measures and the type of control measures that are effective will need to be assessed for each domain (e.g. batter, vegetation type etc) of the mine. The control measures which are applicable will likely vary from one location to another within the mine. The control measures that are adopted will depend on the results of detailed assessment.

2.8 Question 8 – Overburden Thickness to Mitigate Fire Risk

96) *"Further to 7 above, do you consider that a clay or overburden cover of 2 metre thickness is required as proposed in the Jacobs Report for all exposed coal above the water body in rehabilitated batters? If not, why not, and would a clay or overburden cover of a lesser thickness constitute a sufficient fire risk control measure?"*

97) I have no specific knowledge regarding the minimum thickness of overburden that is required to protect coal from surface fire. I have not been able to find any technical publications that deal specifically with this topic or provide guidance on a minimum thickness of overburden.

98) I have been in contact with Dr Justin Leonard, Research Leader, Bushfire Urban Design, CSIRO. Dr Leonard informed me that CSIRO had not researched this specific topic but had carried out research into the measurement of soil temperature profiles in bushfires experiments, which concluded that soil type and moisture profiles are key factors. CSIRO had also held preliminary discussions and a site visit regarding open cut coal mine micro climates that relate to exposed coal ignition risk in bushfires. Dr Leonard expressed an interest in undertaking further research in this area.

99) I do know the basis on which Jacobs assumes a minimum thickness of 2 m. I can find no justification of this value in the Jacobs Report.

100) From a geotechnical view point, if it is assumed that only a relatively thin covering of overburden (<<1 m) provides sufficient insulation to prevent coal ignition and combustion during bushfire, then it would seem reasonable to assume that surface fire can only ignite coal through direct contact (i.e. through a crack or significant tree roots which penetrate through the full thickness of the overburden). If this assumption is valid, then an overburden thickness of significantly less than 2 m may be adequate fire protection provided cracking does not penetrate through the overburden, vegetation is limited to species that have relatively shallow root systems and the thickness of overburden does not diminish significantly with time as a result of surface erosion or similar.

101) Cracking of the overburden material could potentially occur through desiccation of reactive clay overburden or opening up of cracks due to block movement in the underlying coal. Block movement of the underlying coal (usually associated with instability caused by a rise in groundwater level), should it occur, is likely to generate cracks through the full thickness of the overburden, irrespective of the thickness of the overburden (within reasonable values), and may, depending on the stability of the final batter slopes, need to be addressed through inspection and maintenance.

102) The depth of desiccation cracking depends on the properties of the clay overburden and climate. Australian Standard AS2870-2011 “Residential slabs and footings” provides guidance on the depth of cracked zones for use in the design of footings in reactive clay soils. Whilst not directly applicable to fire, it would seem reasonable that the guidance provided in this document could be used to provide an estimate of crack depth in overburden materials used for fire protection.

103) Clause 2.3.2 of AS2870-2011 indicates a design crack depth of 0.5 Hs for areas outside Melbourne, where Hs is the depth of design soil suction change. Figure D2 of AS2870-2011 indicates a climatic zone of 2 for Hazelwood Mine and Table 2.5 of AS2970-2011 indicates for climatic zone 2 a Hs = 1.8 m. That is, a crack depth of 0.5 * 1.8 m = 0.9 m is indicated.

104) That is, cracking due to drying and shrinkage of a reactive clay overburden placed on the coal batters at Hazelwood Mine is unlikely to penetrate more than 0.9 m depth. It would therefore appear that a minimum overburden cover depth using reactive clay of about 1 m would be reasonable for Hazelwood Mine provided this cover thickness is maintained. If the overburden is low reactivity and non-dispersive then a thickness less than 1 m may be applicable, depending on the insulating properties of the soil and the type of vegetation.

2.9 Question 9 – Other Comments

105) *Do you have any other comments on:*

   (a) the assessment by Jacobs of the Pit Lake Landform and Partial Backfill BWT landform options in relation to the Hazelwood Mine contained in the Jacobs Report?

   (b) the Cost estimates in the Jacobs Report insofar as they relate to Hazelwood Mine;

   (c) the Jacobs Report generally?”

106) In respect to (a), I have no further high level comments to make on the assessment of the Pit Lake Landform and Partial Backfill BWT landform options in relation to the Hazelwood Mine contained in the Jacobs Report. However, my further review and more detailed analysis of the Jacobs Report may identify other aspects of the report which require clarification or comment.

107) In respect to (b), I make the following high level comments on the cost estimates set out in the Jacobs Report as they relate to Hazelwood Mine.

108) A reasonable estimate of costs is impossible to achieve without detailed knowledge of the treatment required at every location which requires rehabilitation. For example, design costs associated with developing detailed rehabilitation plans, the volume of earthworks required and method of placement to

achieve design batter profile, extent of surface and subsurface drainage works (e.g. number of horizontal drains), monitoring and maintenance costs etc. It is unlikely that Jacobs has this knowledge.

109) The Jacobs' cost estimates exclude a wide range of activities[13] such as *"bulk civil works associated with overburden placement and slope battering activities"* and assume that these costs can be accommodated within the current Work Plans. This may or may not be the case.

110) I do not have the expertise to review the Jacobs' unit costs used in its cost estimates. However, I provide the following comments on the assumptions that have been made by Jacobs in formulating its estimates of costs to address landform stability issues.

111) The cost estimates for the Pit Lake and BWT landform options at Hazelwood Mine set out in Appendix E5 and E6 are subdivided in terms of risk issues. Presumably those risk issues considered in the Jacobs' cost estimates require design controls (as identified in the Jacobs' risk assessment) to be implemented. The design controls, activity, assumptions and costing of controls to be implemented in order to mitigate the risks associated with landform instability as assessed by Jacobs are summarised in Tables 1 and 2 for Pit Lake and Partial backfill BWT landform options respectively. Only those items with a non-zero cost are included.

112) Comparison of Table 1 and Table 2 indicate that the Jacobs' assessed costs for the Pit Lake and Partial Backfill BWT landform options are identical except for an additional allowance for *"Differential backfilling across floor and batters to create multi-levels in-pit landform with some AWT and some BWT areas such that AWT batters are sloped as shallow as possible".* As noted above in my reply to Question 4, I do not understand why this item is required or how it helps with landform stability. If this item is removed, the Jacobs' assumed costs for the Pit Lake and BWT landform options are identical.

113) The major cost item in the Jacobs' costing addressing landform stability is an allowance for *"Design of drainage diversion and control on above water level batters".* This item accounts for 75 % of the total estimated cost to address landform stability issues. This item does not appear as a control measure in the Jacobs' risk assessment and I do not understand why a 5 m wide x 2 m deep drainage channel and a 5 m high x 25 m wide levee is required to be constructed around the entire perimeter of the mine.

114) Table 8-40 of the Jacobs Report compares estimated costs for each risk issue identified for the Pit Lake and BWT landforms. Other than the difference identified above for landform stability, the cost estimates are identical for both the Pit Lake and BWT options. Considering the different volumes of water and backfill indicated by the Pit Lake and BWT landform options, I cannot see how this can be the case.

115) In conclusion, it is my view that the cost estimates developed by Jacobs are likely to be significantly in error and cannot be relied upon. In fairness to Jacobs, it was not possible for Jacobs to develop a reasonable estimate of costings for the landform options at Hazelwood Mine, because they could not possibly reasonably scope the rehabilitation works required in the time frame and with the information available to Jacobs.

116) In respect to (c), in my view the emphasis of the Jacobs Report is misplaced. Jacobs identify the *"key finding of this study is that in light of a comprehensive review of landform options we have not identified a markedly different landform option from those currently envisaged. This finding is important and should inform future assessments of the management of these sites"* (page 124 of the Jacobs Report).

117) In my view there is too much emphasis in the Jacobs Report on identifying the only practical option (lake in a lowered landform) and too little emphasis on a detailed assessment of the risks and costs associated with implementation of this landform at each mine, given the approved Work Plans that are in place and the rehabilitation works undertaken to date. The Jacobs' assessment is too generic to provide reasonable responses to the TOR.

[13] Jacobs report pages 148 and 149

Table 1: Pit Lake: Landform Stability - Design controls, activity and costing

Design Control	Activity	Assumption	Total cost
Design and construction of slopes to a suitable gradient	Reshaping of selected batters for a safe and stable outcome	Assumes whole area of AWT final sloped pit walls	$922,746
Water management to achieve weight balance	Surface water injection from flooding	Pumps, pipe network and maintenance	$2,170,000
	Surface water injection from water entitlement		$2,170,000
	Water injection from dewatering		$2,170,000
Installation of pressure relief wells / horizontal drains in high risk areas of pit cut back	Pressure relief well installation	16,400 m	$574,000
Design of drainage diversion and control on above water level batters	Drainage diversion	5m wide, 2 m deep, length 1.5 x perimeter of pit crest with a 20 m set back	$1,596,315
	Levee construction	5 m high 25 m at base, set back 150 m from pit (crest)	$22,486,942
	Compaction	Compaction of pit edge	$3,960,600
	Slope battering	Battering of levee only from angle of repose to 20^{o}, height 5 m	$80,878
	Ripping and seeding	Pit edge only	$1,553,485
Total			**$39,393,715**

Table 2: Partial Backfill BWT: Landform Stability - Design controls, activity and costing

Design Control	Activity	Assumption	Total cost
Differential backfilling across floor and batters to create multi-levels in-pit landform with some AWT and some BWT areas such that AWT batters are sloped as shallow as possible	Reshaping – Pit wall	Assumed total BWT pit wall area. Assumed outside the scope of operations	$302,321
	Reshaping – Pit Floor	Assumed outside the scope of operations (836 hectares)	$2,675,200
Design and construction of slopes to a suitable gradient	Reshaping of selected batters for a safe and stable outcome	Assumes whole area of AWT final sloped pit walls	$922,746
Water management to achieve weight balance	Surface water injection from flooding	Pumps, pipe network and maintenance	$2,170,000
	Surface water injection from water entitlement		$2,170,000
	Water injection from dewatering		$2,170,000
Installation of pressure relief wells / horizontal drains in high risk areas of pit cut back	Pressure relief well installation	16,400 m	$574,000
Design of drainage diversion and control on above water level batters	Drainage diversion	5m wide, 2 m deep, length 1.5 x perimeter of pit crest, 20m setback	$1,596,315
	Levee construction	5 m high 25 m at base, set back 150 m from pit (crest)	$22,486,942
	Compaction	Compaction of pit edge	$3,960,600
	Slope battering	Battering of levee only from angle of repose to 20^{o}, height 5 m	$80,878
	Ripping and seeding	Pit edge only	$1,553,485
Total			**$42,520,117**

Report Signature Page

GOLDER ASSOCIATES PTY LTD

Chris Haberfield

Chris Haberfield
Principal

CMH/AJR/cmh

A.B.N. 64 006 107 857

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APPENDIX A

King & Wood Mallesons Letters

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12 October 2015

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By courier

Dear Sir,

Hazelwood Mine Fire Inquiry

We act for Hazelwood Power Corporation, Hazelwood Power Partnership, International Power (Australia) Pty Ltd and GDF SUEZ Australian Energy and its related entities (together, **GDFSAE**) in relation to the Board of Inquiry appointed to inquire into and report on certain matters relating to the Hazelwood Coal Mine Fire in 2014 specified in the Terms of Reference dated 26 May 2015 (**TOR**).

GDF SUEZ Australian Energy is the owner and operator of the Hazelwood Coal Mine and Power Station.

This is the second Board of Inquiry process in relation to the Hazelwood Coal Mine Fire. The first Inquiry was completed in 2014, and a report was published by that Board.

The TOR for the present Inquiry are enclosed.

Our client wishes to retain you as an expert for the purposes of the process which the Board wishes to follow in relation to paragraphs 8 and 9 of the TOR. Paragraphs 8 and 9 of the TOR concern short, medium and long term options for the rehabilitation of the Latrobe Valley mines.

The process the Board is following in relation to TOR 8, 9 and 10 is set out in the attached letter from the Board dated 8 October 2015.

As relevantly detailed in that letter, it is envisaged that:

1. a draft report prepared by the expert appointed by the Board (Jacobs) in relation to TOR 8 and 9 will be circulated to all parties who have been granted leave to appear (namely our client, the State of Victoria, Energy Australia Yallourn Pty Ltd, AGL Loy Yang Pty Ltd and Environment Victoria Inc) today;

KWM

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2. there will be a "technical experts review conference" with Jacobs to discuss the Jacobs draft report on 27 and 28 October 2015 at which the parties are invited to have 1-2 representatives attend (including any expert);

3. Jacobs will finalise its report by 13 November 2015;

4. any expert reports obtained by the parties (including our client) in relation to TOR 8 and 9 (and 10) are to be filed by 23 November 2015;

5. hearings in relation to TOR 8 and 9 (and 10) will be conducted on 8-11 December 2015 in Morwell.

As is apparent from this summary, our client wishes to retain you to attend the technical experts review conference on 28/28 October 2015, prepare a report in relation to the Jacobs report, and attend the hearings on 8-11 December 2015. In relation to the hearings in December, it is unlikely that you will be required to attend all four days – however the precise days on which attendance will be required are not known at this stage.

Please find enclosed the following background materials for your assistance:

Hazelwood Mine Fire Inquiry

1. The TOR;
2. Practice Direction for Terms of Reference 8, 9, 10 (Mine Rehabilitation);
3. Letter from Principal Legal Adviser, Hazelwood Mine Fire Inquiry, dated 8 October 2015 concerning the Board's intended process in relation to TOR 8 – 10;
4. Summary of Community Consultations on Rehabilitation Terms of Reference;
5. Summary of public submissions to the Board on matters the subject of TOR 8 and 9;
6. Victorian Government submission on Rehabilitation Terms of Reference;
7. AGL (Loy Yang) submission on Rehabilitation Terms of Reference;
8. Energy Australia (Yallourn) submission on Rehabilitation Terms of Reference;
9. Environment Victoria submission on Rehabilitation Terms of Reference;
10. GDF SUEZ Australian Energy submission on Rehabilitation Terms of Reference;
11. Statement of James Faithful of GDFSAE filed in the first Hazelwood Mine Fire Inquiry; and
12. 2014 Hazelwood Mine Fire Inquiry Report – Chapter 3.

Licence materials

13. Mining Licence 5004 together with Approved Work Plan – September 1996;
14. Instrument of Amalgamation of additional mining licences into MIN5004 – July 1996;

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15. Instrument of Variation and Addition of Licence Conditions – January 2015;
16. Approved Work Plan Variation dated May 2009;
17. EPA Licence 46436;
18. Ground Control Management Plan.

We will forward to you a copy of the draft Jacobs report as soon as it is available.

Thanks for your assistance.

Yours faithfully,

King & Wood Mallesons

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By email

Dear Sir,

Hazelwood Mine Fire Inquiry

We refer to our previous correspondence, and to the Final Report of Jacobs Australia Pty Limited (**Jacobs**) dated 16 November 2015 (**the Jacobs Report**) which has been provided by Jacobs to the Hazelwood Mine Fire Board of Inquiry for the purposes of Terms of Reference 8 and 9 (**TOR 8 and 9**).

Expert report

We write to request that you prepare a report for the purposes of the Hazelwood Mine Fire Inquiry in which you set out your expert opinion on the following matters:

1 Is the approved model for the final rehabilitation of Hazelwood Mine detailed in the Work Plan Variation (of a partial pit lake within a lowered landform) (**the Approved Final Rehabilitation Model**), a feasible and appropriate model for final rehabilitation from the perspective of:

(a) achieving a safe and stable final landform; and

(b) returning the Mine site to a condition which will enable future beneficial land use and which will compliment the surrounding environment?

2. Given the progression of the mining operations at the Hazelwood Mine, and the extent of progressive rehabilitation and in-pit dumping of materials to date, are there any reasonably practicable final rehabilitation models for the Hazelwood Mine, other than the Approved Final Rehabilitation Model?

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3. Has a final rehabilitation model similar to the Approved Final Rehabilitation Model been implemented elsewhere:

   (a) in Australia, or

   (b) Internationally?

4. What further work is required at the Hazelwood Mine in order to successfully implement to the Approved Final Rehabilitation Model? Are you able to identify short, medium and long term work priorities in this regard, having regard to the planned Mine closure date (2033)?

In preparing your expert report in relation to the matters set out above, please:

1. Set out the matters, facts and circumstances on which you rely, and any relevant assumptions which you have made, for the purposes of your opinion;
2. Enclose as annexures a copy of our letter dated 17 October 2015 and subsequent correspondence (including this letter): Attachment A; and
3. Attach a current CV: Attachment B.

Timing of report

The Board has determined that any expert reports obtained by the parties (including our client) in relation to TOR 8 and 9 are to be filed by 27 November 2015.

On this basis, we request that you finalise your report by this date if at all possible.

Hearings

As noted in our letter dated 17 October 2015, it is likely that you will be required to give evidence at the hearings in relation to TOR 8 and 9 which have been set down for 8 - 11 December 2015 in Traralgon. It is unlikely that you will be required to attend for more than one day. However at this stage we do not know the dates on which your attendance will be necessary. We will keep you informed in this regard.

Thank you for your assistance.

Yours faithfully,

King & Wood Mallesons

APPENDIX B

Curriculum Vitae of Chris Haberfield

Chris M Haberfield

Education
BSc University of Sydney, 1979
BE (Civil) First Class Honours, University of Sydney, 1981
PhD, Monash University, 1988

Affiliations
Research Associate, Department of Civil Engineering, Monash University
Teaching Fellow, Department of Civil Engineering, Monash University
Fellow, Chartered Professional Engineer, Engineers Australia (FIE Aust, CPEng)
Registered Professional Engineer Queensland (RPEQ)
Past National Chairman, Past Victorian Chapter Chairman, Australian Geomechanics Society
Past Australasian and First Vice-President, International Society for Rock Mechanics
Member Australian Geomechanics Society
Member, International Society for Soil Mechanics and Geotechnical Engineering
Member International Society for Rock Mechanics
Associate Editor, Canadian Geotechnical Journal
Member, ISSMGE Technical Committee TC207
Sub Committee Chairman, TC207 Foundation Structure Interaction
Associate PhD supervision, University of Queensland, Indian Institute of Technology (Bombay)
Member, working group for a "Joint Submission from the Institute Public Works Engineering Australia (Vic) and Engineers Australia to the Victorian Building Authority on Slab Heave".

Awards
EH Davis Memorial Lecture 2007, Australian Geomechanics Society
Victor Milligan Award 2005, Golder Associates Pty Ltd
Jack Morgan Award for Technical Excellence, 2009, Golder Associates Pty Ltd

Experience

2001 to date

Golder Associates Pty. Ltd. **Melbourne, Australia**
Principal Geotechnical Engineer, then Associate, now Principal
(0.8 time 2001 to 2004, then full-time)
Responsible for geotechnical investigation, analysis and design for a wide range of projects including bridges, high rise buildings, tunnels, wharf developments, major excavations, mines, roads, railways, earthworks and reclamation and industrial developments. Consulted extensively on landslip issues, piled foundations and retention structures. Provided high level analysis and acted as expert witness in various litigation matters. Areas of expertise include: soil and rock engineering with emphasis on soft, weak and weathered rock; pile and rock anchor analysis, design and performance in on-shore and off-shore deposits, with particular emphases on piles and anchors in rock, including the influence of construction techniques on performance; rock mass and rock joint behaviour; slope stability analysis and design; stability of well bores in the oil and gas industry; use of expansive concretes for geotechnical applications; fracture mechanics; stress analysis; numerical and analytical modelling - non-linear finite element (includes Phase 2 and PLAXIS) & FLAC analyses; advanced laboratory testing; including triaxial and constant normal stiffness direct shear testing; insitu testing techniques – especially pressuremeter and field pile and anchor testing. Developer of GARSP – a system for analysis and design of rock socketed piles which has resulted in significant savings on numerous piling projects.

1983-2004

Monash University (Clayton) **Melbourne, Australia**
Senior Tutor, Lecturer, Senior Lecturer, then Associate Professor, now Research Associate
Department of Civil Engineering (full time 1983-2001, then 0.2 time)
Responsibilities included research, teaching at undergraduate and post-graduate levels, supervision of research students, consulting to industry, administration, leadership and governance. Main research interests lie in the performance of soft, weak and weathered rock with particular emphasis on the analysis, design, construction and response of engineering works (eg foundations, retaining walls, slopes etc) in these materials. Research contributions include >100 refereed research papers, numerous invited and key note lectures, the commercial software program ROCKET, theoretical models for rock mass and joint behaviour, patented equipment for measurement of the roughness of rock sockets, new interpretation method for pressuremeter tests in rock and development of specialist specialist laboratory and field testing equipment. 21 years of teaching experience with major responsibilities for undergraduate courses in soil mechanics and engineering, rock mechanics and engineering, engineering geology, geomechanics design and construction, solid mechanics and stress analysis, finite element analysis. Presentation of numerous post graduate courses and seminars

covering in-situ testing, rock engineering, foundation engineering, soil mechanics, plasticity theory, experimental soil mechanics, finite elements in geomechanics, seepage analyses. Consulting to industry covered a wide range of projects involving stress analysis and geotechnical problems and included analysis, design, review, testing, mediation and expert witness activities. Senior level administrative and leadership roles including the positions of Head of Geomechanics Group, Director of Research, Deputy Head of Department and numerous Departmental, Faculty and University committees.

1981-1983 **Coffey Partners Pty Ltd** **Sydney, Australia**

Geotechnical Engineer

Undertook geotechnical investigation, analysis and design for a range of projects, including high rise buildings, roads, bridges, excavations, dams, mines and industrial developments. Developed finite element, slope stability and other geotechnical analysis packages which at that time were not commercially available.

Chris M Haberfield

PROJECT RELATED EXPERIENCE – INFRASTRUCTURE PROJECTS

New Royal Adelaide Hospital **Adelaide, Australia**
Lead of geotechnical design team responsible for analysis and design of retention systems and foundations for the new hospital. Unusual aspects of the design required serviceability design for earthquake, unsaturated, reactive, hard soils and 10 m deep basement excavation with no support to be provided by the building. Retention system comprised large diameter CFA soldier pile wall supported by permanent anchors.

Diesel Tank **Adelaide**
New diesel tank founded on soft ground. Provided peer review of ground improvement works and foundation design.

Port Botany Expansion **Sydney**
New container terminal, including almost 2 km of extra berth length, 60 hectares of reclamation, 7 million cubic metres of dredging, blockwork and counterfort retaining walls up to 21.5m high, extensive revetment edge structures, bridges, structures and pavements. Project geotechnical engineers. Responsible for high level review.

Bored Pile Specification **NSW**
Provision of recommendations to update bored piling specification for Road and Maritime Services, NSW

Caltex Tank Upgrade **Gladstone**
Control of the staged hydro-testing of a new large oil tank built on soft clay. The foundation required monitoring or pore water pressures during loading to avoid a tank foundation failure. Pore pressures were calculated using the finite element methods to model the foundations and compare with measured pore pressure and settlement data.

Peninsular Link **Melbourne**
Provided geotechnical consulting services for construction of freeway project. Responsible for review and analysis of major road interchanges.

Nurana Reclamation **Bahrain**
Review of 500 hectare reclamation for compliance and settlement issues.

Regional Rail Link, Package B **Melbourne**
Provided geotechnical consulting services for winning tender and geotechnical engineering design and construction services during final design and construction. Responsible for foundations and ground improvement for package B. Included embankments over soft ground and bridge over the Maribyrnong River.

M80 Upgrade **Melbourne**
Provided geotechnical consulting services for winning tender for upgrade of M80 freeway including retrofitting piled foundations to 5 bridge abutments and bridge widening.

Diyar Reclamation Project **Bahrain**
Stage 1A comprised 320 hectares of reclamation (dredged fill (sand) material to 5 m depth). 25 hectares of reclamation did not meet Contract Specification requirements. Responsible for analysis of settlement of non-conforming areas, and provision of recommendations to improve settlement performance of the fill.

North South Bypass Tunnels **Brisbane**
Internal reviewer for detailed design for temporary tunnel support for the conventional road tunnels.

The Bluff Windfarm **South Australia**
Geotechnical consulting services and analysis and design of footings for wind generator turbines

Middleborough Road/Rail Separation **Melbourne**

Chris M Haberfield

Independent reviewer for soldier pile walls and other geotechnical aspects of 1 km long excavation and support works required to take a main suburban rail line beneath a main arterial road.

Musselroe Windfarm **Tasmania**
High level review of footings for wind generator turbines

Collgar Windfarm, Merredin **Western Australia**
Review of rotational stiffness of turbine footings

Fisherman's Landing LNG Plant **Gladstone**
Geotechnical Engineer for detailed design of a cutter soil mixed ground improvement for a 200,000 m3 LNG membrane storage tank. Design of wick drains and instrumentation and surcharging of plant area. Monitoring of hydro testing.

Mt Gellibrand Wind Farm **Victoria**
Geotechnical consulting services and analysis and design of footings for wind generator turbines

Wiggins Island **Gladstone**
Review of pile design for new elevated trestle structures for wharf development. Provision of advice with respect to latent conditions claim.

Kicking Horse Canyon Road Bridge **British Columbia, Canada**
Review of bored pile foundation design and provision of advice during construction of new road bridge through deep canyon with steep valley walls.

Brown Hills Windfarm **South Australia**
Geotechnical consulting services and analysis and design of footings for wind generator turbines

Gateway Bridge **Brisbane, Australia**
Geotechnical design leader for the Gateway Bridge duplication tender submission responsible for geotechnical works associated with footings and construction of the bridges. Responsible for aspects of the analysis of pile performance for tender submission for duplication of the Gateway Bridge. The existing Gateway Bridge is a 6 lane pre-stressed concrete box girder bridge with an overall length of 1.6 km, and a navigation span across the Brisbane River of 260 m. At the time of construction, it was the largest concrete girder span in the world.

Oaklands Hill Windfarm **Victoria**
Preliminary design of wind turbine footings

Mount Hotham Redevelopment **Mount Hotham, Victoria**
Independent peer review of geotechnical works (rock slope stability, retention systems and foundations) associated with realignment of the Alpine Highway through Hotham.

Bald Hills Windfarm **South Australia**
Geotechnical consulting services and analysis and design of footings for wind generator turbines

NEG-Micon Wind Farm **Edithburgh, South Australia**
Geotechnical consulting services and design of footings for 50 plus wind turbines in variably cemented calcareous soils over cavernous limestone.

Phu Mt Bridge **Vietnam**
Pile foundation design for the 800 m long approach spans on either side of the cable stayed bridge, design of staged embankment construction with wick drains for 7 m high approach embankment over 15 m of soft clays, review of monitoring data and advice during construction of the embankment.

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Eastern Freeway Extension Tunnels **Donvale, Victoria**
Review and advice on geotechnical/ground conditions for the twin 1.5 km highway tunnels as part of study assessing programming implications for the Department of Infrastructure.

Melbourne City Link - Southern Link **Melbourne, Australia**
Design input and construction support for remedial measures associated with structural failure of the permanent cast insitu concrete lining of the 16 m wide (3 lane) 3.5 km Burnley Tunnel including geotechnical design and construction advice for rock anchors.

Waubura Windfarm **Victoria**
Geotechnical consulting services and analysis and design of footings for wind generator turbines

Saigon II Bridge **Vietnam**
Geotechnical investigation and pile foundation design for a new 960 m long bridge over Saigon River adjacent to the existing bridge, assessment of the effect of bridge construction activities on the existing bridge.

Lal Lal Creek Bridge **Victoria, Australia**
Long span elevated rail bridge with columns up to 35 m high. Responsible for analysis, design and assessment of foundations (CFA and driven piles and pad footings) for bridge columns and advice during construction. Significant lateral, tension and compression loads.

Swan Street Bridge **Melbourne, Australia**
Prior to the construction of City Link, Swan Street Bridge was one of the main traffic corridors from east to west and carried very high vehicle loads and volumes. The bridge was built in about 1950, with the east abutment founded on rock and the west founded on piles through 20 m of soft clay. Over the past 50 years the ground surface at the east abutment has settled in excess of 1.2m resulting in lateral loading of the piles and damage to the west abutment. Dewatering during the construction of the City Link tunnels resulted in accelerated settlement of the ground surface. Extensive monitoring and analyses were carried out over a period of about 5 years to assess the impact of the tunnelling works on the bridge. Responsible for the analysis of the monitoring data (including piezometers, inclinometers, settlement points and extensometers) and analysis of the impact on the bridge foundations.

Goongoongup Railway Bridge **Perth, Australia**
Review of analysis of impact of fill embankments on bridge movements due to consolidation of underlying soft clay.

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PROJECT RELATED EXPERIENCE – LARGE BUILDINGS AND BASEMENTS

Nodia Development **Delhi**
Developments comprising 5 tower buildings to 300 m height (38 to 80 levels), 5 level podium structure and extensive three level basement (approx 350 m x 350 m in plan) in permeable alluvial deposits below water table. Responsible for pile raft design and geotechnical consulting services.

Prima Pearl Tower **Melbourne**
Geotechnical investigation and consulting services for a sixty level tower. Challenges included variable founding conditions for bored piles and a 10 m deep excavation in soft clays for construction of the core.

151 Collins Street **Melbourne**
Geotechnical consulting services for tower and multi level basement development.

JW Marriott Hotel **Bahrain**
Review of pile design and pile test results for 50 level tower.

Mirvac Tower 6, Docklands **Melbourne**
Geotechnical consulting services for tower development.

Abode 318 **Melbourne**
Multi-level residential development located near the Melbourne Underground Rail Loop tunnels beneath La Trobe Street. Services provided included geotechnical investigation, pile design and modelling of potential impact of the development on the nearby railway tunnels.

171 Collins Street **Melbourne**
Multi-level residential apartment building with a five level basement. Services provided included geotechnical investigation and site assessment services. Design of the basement incorporated passive rock bolting of the basement excavation faces with soldier piles terminated well above the design excavation level.

Burj Al Alam Development **Dubai**
Very tall tower of 500 m height and multi level podium, 20 m deep basement excavation. Ground conditions comprise sand over soft calcareous siltstone/sandstone. Responsible for value engineering of the piled foundations for the tower and podium comprising analysis and design.

Nakheel Tower **Dubai**
Very tall tower (in excess of 1000 m) and multi-level podium structure with 25 m deep basement excavation. Ground conditions comprise sand over soft calcareous siltstone/sandstone/gypsum to at least 200 m depth. Responsible for ground investigation, factual and interpretive ground investigation reports, analysis and design of excavation support and deep foundations, pile testing, analysis of pile load and integrity test results, and construction advice.

Melbourne Convention Centre **Melbourne**
This development included the construction of a twenty level hotel and a two level basement with a permanent perimeter cut off wall. The subsurface geology was highly complex and variable. Responsibilities included the geotechnical investigation, hydrogeological modelling and footing design and assessment.

Gate of Kuwait **Kuwait**
Provision of geotechnical advice and analysis for piled raft foundations for an 84 storey building. Geotechnical advice included review of available geotechnical information, input to additional geotechnical investigation involving pressuremeter and downhole seismic testing, initial supervision of geotechnical investigation, input to pile construction specification, recommendations for test piles and assessment of test pile results.

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Mirvac Tower 8, Docklands **Melbourne**
Geotechnical consulting services for tower development.

Southern Cross Wheel **Melbourne**
Provision of geotechnical advice and foundation design for ferris wheel

Era Project **Bahrain**
Assessment of pile group foundation settlement for 50 storey building. Assessment includes review of pile footing design and pile load test results.

Media House **Melbourne**
Multi-level building constructed on a deck built over the rail corridor at Southern Cross Station. Responsibilities included management of the investigation within the rail corridor, provision of a geotechnical report presenting design recommendations for the footings to support the crash walls supporting the concrete deck. Site assessment services during construction of the footings were also provided.

Barwa Business Centre **Doha, Qatar**
Development comprises nine towers from 40 to 60 levels and large podium structure. Responsible for pile raft analysis and design for towers and pile design for podium, analysis of pile load tests, and advice during construction.

Kuwait Business Town **Kuwait**
Provision of geotechnical advice and analysis for piled raft foundations for two high rise (36 and 40 storey) buildings. Geotechnical advice included review of geotechnical information, input to additional geotechnical investigation involving pressuremeter and downhole seismic testing, input to pile construction specification, recommendations for test piles and assessment of test pile results.

Deli Grand City Medan **Medan North Samatra**
Development comprises several towers and large podium shoppong area. Ground conditions comprise 20 m of soft alluvial deposits grading to stiff to very stiff clay and very dense sands at 60 m depth. Responsible for review of laboratory test data to assess engineering properties and of proposed foundation solution.

Oracle Project **Broadbeach Australia**
Development comprises two towers at 40 levels and 50 levels with deep basement. Ground conditions comprise dense sands and very stiff clays over hard rock at depth. Responsible for value engineering of the piled foundations comprising analysis and design. Final solution comprised piled raft with piles floating in the sand.

Soul Project **Gold Coast Australia**
Development comprises 300 m tall tower and deep basement. Ground conditions comprise dense sand over hard rock at depth. Responsible for value engineering of the piled foundations comprising analysis and design.

Chinatown Stage 2 **Darwin Australia**
Development comprises 22 level tower with 9m deep basement. Ground conditions comprise thin hard rock capping over deeply weathered extremely weak phyllite to in excess of 50 m depth. Responsible for ground investigation, geotechnical analysis and design of the basement retention and foundation systems.

Esplanade Development **Darwin Australia**
Development comprises 21 level tower with 9m deep basement. Ground conditions comprise thin hard rock capping over deeply weathered extremely weak phyllite to in excess of 50 m depth. Responsible for ground investigation, geotechnical analysis and design of the basement retention and foundation systems.

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Vision Project **Brisbane Australia**
Development comprises 80 level tower with podium and 25 m deep basement in Brisbane CBD. Ground conditions comprised 15 m of soft clay over hard fractured rock. Adjacent stuctures (including 35 storey tower supported on concrete precast piles) posed special problems with respect to support of the excavation for the basement. Responsible for geotechnical analysis and design of the basement retention and foundation systems.

Bahrain Bay **Bahrain**
Development comprising two towers of up to 50 storeys with multi-level podium. Ground conditions comprise loose sand over weak calcareous siltstone and limestone. Provided advice to piling contractors with respect to pile performance, analysis of pile load tests and pile group settlement performance.

Villamar at the Harbour **Bahrain**
Development comprising three towers of up to 40 storeys with multi-level podium. Ground conditions comprise loose sand over weak calcareous siltstone and limestone. Responsible for analysis and design of excavation support and deep foundations, analysis of pile load and integrity test results, and construction advice.

HWT Development **Melbourne**
A residential and commercial development of approximately 30 levels behind a retained heritage listed façade. A double level basement was also constructed with the tower supported on spread footings. Increased allowable bearing pressures were adopted following detailed site investigation including the use of high pressure insitu pressuremeter testing.

Royal Domain Towers **Melbourne**
Geotechnical consulting services and footing design for forty level residential development with one basement located on St Kilda Road, Melbourne. The subsurface conditions comprised deeply weathered siltstone with dykes.

Village Docklands **Melbourne**
Geotechnical investigation, reporting and provision of design advice for the proposed development of a 13 000 square metre site in Docklands. The proposed development included a single level basement and four towers with piled footings in varying ground conditions.

Freshwater Place **Melbourne**
Four towers ranging between about 40 and 60 levels with an eight level podium structure and a single level basement. The subsurface conditions were highly variable with a layer of soft clay over a layer of discontinuous and variable basalt underlain by Yarra Delta sediments and weathered siltstone. Responsibilities included geotechnical investigation, basement and foundation analysis and design and supervision of footing installation. The footing solution included a combination of spread footings, CFA piles founding on both basalt and siltstone and bored piles socketed into the weathered siltstone

City Centre Project **Bahrain**
Large commercial/retail/hotel development comprisng two Hotel towers and multilevel podium structure. Ground conditions comprised hydraulic fill over soft clay over calcareous sandstone, siltstone, mudstone and limestone. Development supported on 4000 bored piles up to 1.05 m diamter socketed between 9 m and 15 m into rock. Assisted piling contractor with assessment of ground conditions, pile design, assessment of static and dynamic load tests, pile installation and integrity issues and testing and group settlement assessment.

Pearl Towers Project **Bahrain**
Hotel development comprisng three Hotel towers and multi storey podium. Ground conditions comprised hydraulic fill over soft clay over calcareous sandstone, siltstone, mudstone and limestone. Development supported on bored piles up to 1.2 m diamter and 29 m in length. Piling contractor required assistance with pile design, assessment of static and dynamic load tests and group settlement assessment.

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Financial Harbour **Bahrain**
Review of ground conditions and pile design for 80 level plus tower development.

Yarra's Edge, Towers 2 and 3 **Melbourne, Australia**
Twenty and thirty-one level residential towers constructed on banks of the Yarra River, Melbourne. Difficult ground conditions comprising 25 m of soft clay over stiff clay and gravel with rock at 40 m depth. Responsible for assessment of as-constructed driven pile foundations, formulation and analyses of remedial solutions due to unsatisfactory performance of as-constructed foundations, advice during remediation works and assessment of monitoring and performance of remediated foundations.

Yarra's Edge, Towers 4 and 5 **Melbourne, Australia**
Thirty plus level residential towers constructed on banks of Yarra River, Melbourne. Difficult ground conditions comprising 25 m of soft clay over gravel with rock at +40 m depth. Responsible for ground investigation, excavation and foundation design (driven and bored piles), assessment of alternative foundation options (CFA and driven piles) and advice during construction.

MCG, Northerns Stand **Melbourne, Australia**
Responsible for analysis and design of cantilevered and anchored soldier pile walls and pile foundations (bored and CFA piles) and advice during construction. Assessment of displacements and pile actions. Significant lateral and compression loads.

Spencer Street Station Redevelopment **Melbourne, Australia**
Redevelopment of main rail station in Melbourne comprising large span roof, tower structures and railway platforms in difficult and variable ground comprising soft clay to hard rock. Responsible for analysis and design of piles (driven, CFA and bored) and pad footings, temporary support for large mobile cranes, and advice during construction. Significant lateral, tension and compression loading.

Concept Blue Development **Melbourne, Australia**
Residential and commercial tower development with six basements adjacent to railway tunnels. Responsible for analysis and design of excavation works, soldier pile wall, bored piled foundations, assessment of impact of works on railway tunnels, advice prior to and during construction.

Meriton Apartments, Residential Tower **Gold Coast**
Responsible for analysis and geotechnical design of piled raft foundation and its impact on underlying peat layer and assessment of settlement, raft and pile actions and raft performance.

Monash Caulfield, Stage 1 **Melbourne**
Project manager for alternative footing design solution (piled raft) for multi-storey office and carpark building and construction phase advice. Developed pile raft design solution which resulted in significant savings to the contractor and developer.

Concept Blue **Melbourne**
Project manager for redesign, investigation and analysis works for footing solution and impact assessment of new twenty-six level tower and 5 basements development adjacent to four tunnels of Melbourne underground rail loop.

Watergate Place **Melbourne**
Geotechnical investigation and reporting for 18 storey residential towers and commercial complex located in difficult ground conditions. Construction phase advice on piles and general earthworks.

University Square Project **Melbourne**
Geotechnical investigation, design advice on footings and deep basement construction (15-17 m). Footing inspection and assessment.

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KENS Centre **Sydney**
Development comprises twin 33 level office towers with up to 6 basements adjacent to underground railway tunnels of the Inner City Loop. Presence of weaker shale layer within otherwise high strength sandstone rock required detailed settlement analysis and modification of footing sizes and founding levels. Responsible for the analysis of the impact of earthquake on development and railway tunnels.

Crown Second Hotel **Melbourne**
New tower hotel in area with difficult foundation conditions. Responsible for analysis and design of piled foundations, and geotechnical advice during construction.

Eureka Tower **Melbourne**
Eighty eight level residential tower with a single level basement. The subsurface conditions included two layers of discontinuous basalt separated by sediments of the Yarra Delta all underlain by high strength weathered siltstone. Responsibilities included geotechnical investigation and foundation analysis and design.

Swinburne University **Melbourne**
New tower development founded on bored piles in siltstone. Responsible for additional site investigation and pile design and analyses and geotechnical advice during construction which resulted in reduced pile lengths and significant savings to the client.

Melbourne Sports and Aquatic Centre, **Melbourne**
Responsible for design and analysis of bored pile design and review of piling options by contractors and provision of geotechnical advice during construction..

Quay West Apartments **Melbourne**
Tower residential development founded on bored piles in fresh siltstone. Provided review of bored pile design.

Skyline Towers **Goldcoast**
Assessment of settlement issues.

Cyclatron **Melbourne**
Assessment of foundation solutions for vibration isolation.

Various
Internal review of foundation design, analysis factual and interpretative reports and provision of internal advice for numerous buildings and other major structures within Australia and the Middle East but also in asia and North America.
Pile joint testing and assessment, Frankipile Australia
Assessment of observed settlements, Crown Casino Promenade, Melbourne
CNS direct shear testing of pile rock interfaces for assessment of bored pile performance, new hotel development, Dubai
Assessment of performance and movements of soldier pile retention system for deep basement, Port Melbourne

Research and Development **Melbourne**
Research into the behaviour of soft, weak and weathered rock with particular emphasis on the analysis, design, laboratory and field testing, construction techniques and response of engineering works in these materials. Development of pile and foundation analysis programs, non-linear finite element programs, advanced slope stability programs and laboratory and field testing equipment and systems.

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PROJECT RELATED EXPERIENCE – SLOPE STABILITY

Marandoo **Pilbara**
Assessment of stability of 250 m high high wall is saturated, fissured clay below the water table for mining of iron ore.

Landslide **New Guinea**
Assessment and analysis of large landslide in New Guinea highland impacting on mining project.

Sebuku Coal Mine **Indonesia**
Review and design of retention system to support soft mud in vicinity of mine high wall.

Holcim Quarries **South East Victoria**
Geotechnical consulting services for stability of quarry pits and over burden dumps, including assessment of instability.

Jembayan Coal Mine **Indonesia**
Assessment of coal loadout facility affected by landslide. Review of design and redesign.

Fairhaven Surf Lifesaving Club **Fairhaven**
Geotechnical advice relating to coastal erosion, dune instability and proposed redevelopment of club facilities

Landslip Risk Assessment Review **Melbourne**
From 2002 provision of specialist advice to the Planning Department to review planning applications with respect to land stability issues for development on areas covered by the Erosion Management Overlay.

Landslip Risk Assessment **Melbourne**
Investigation, reporting and stability assessment for various sites where development is covered by planning restrictions. Representative for a number of private clients at Planning Tribunal hearings on land stability issues.

Doncaster Quarry **Melbourne**
Stability assessment of quarry rock slopes for future development of landfill for Maningham City Council.

Minerva Gas Field Development **Port Campbell**
Geotechnical investigations, desktop studies, stability review for shoreline crossing and onshore pipeline route. Assessment of horizontal directional drilling options. Provision of specialist advice for EIS-EES Panel hearing.

Dartmouth Dam Crest Road **North East Victoria**
Review of existing reports, risk assessment and remedial works proposed for batter slopes above public access road for VicRoads.

Coastal Cliff **Mornington Peninsula**
Stability and finite element analysis to assess potential causes of landslip.

Thredbo Landslip **Thredbo**
Review of circumstances leading to Thredbo Landslip in July 1997, in which 18 people were killed. Expert witness for in the Civil case heard in the Supreme Court of NSW. Responsible for assessing the evidence pertaining to geotechnical engineering issues, carrying out analyses and physical experiments to assess the reasons for the tragedy and the cause, or trigger, which led to the landslip at that time. Extensive site assessment, analysis of facts and competing hypothesis, testing, review and reporting.

Coastal Cliff **Portsea**
Review of remedial works and reports on coastal cliff failure which destroyed part of a residential development.

Chris M Haberfield

Road Batter Failures **Melbourne**

Provision of specialist advice to Asset Management and Civil Departments of the Shire of Yarra Ranges with respect to repair and prevenbion of road batter failures and design of drainage works. Batter failures at Perrins Creek Road, Kallista Emerald Road, Old Coach Road, Churchill Road, Mt Dandenong Tourist Road all required significant stabilisation works.

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PROJECT RELATED EXPERIENCE – DISPUTE AND ARBITRATION

Seawall failure — Koolan Island

Assessment of failure of seawall that led to mine inundation, Koolan Island, WA. Review of design, analysis of monitoring data and provision of expert report for insurance claim.

Pile installation - wharf — Geraldton

Assessment of hard driving of steel tube piles during construction of a new wharf at Geraldton.

Failure of jet grouting – port facility — Geraldton

The construction of an underground vault in calcareous sand fill required a jet grout floor and wall seals (between contiguous CFA piles) to allow a vault to be safely constructed in the dry. Significant leakage and blow-ins occurred during construction requiring significant remedial works. Provided an assessment of the jet grout and piling works and the reasons for the leakage and blow-ins.

Pile installation for transmission towers — NSW

Assessment of latent condition claim for additional works related to the installation of bored piles in hard ground.

Mine pit slope instability — Morwell

Review of data and historical report and provision of expert report as to cause of movements of pit wall in open cut coal mine following sink hole formation in nearby drain. VCAT – settled during proceedings

Hard dredging — Darwin

Assessment of claim for hard dredging conditions at East Arm Port related to presence of very strong quartzite bands. Involved in three separate claims from different areas within East Arm Port and involving different parties.

Damage to large span culvert — Sydney

A pair of large span culverts buried beneath 30 m of fill exhibited cracking and significant displacements about 1 year after the completion of the backfill. Provided an expert report on likely cause of damage to the culverts. Heard in Supreme Court of NSW – settled during proceedings.

4 Level Basement in Sand — Dee Why

A four level basement in alluvial sands with high water table constructed using secant pile CFA pile wall showed significant out-of-alignment of piles as the basement was constructed. Construction was delayed due to water ingress and other ground related issues, resulting in deletion of the fourth basement level. Extensive analysis, review of other expert reports and provision of advice to Counsel. Heard in the Supreme Court of NSW – settled during proceedings.

2 Level Basement in Sand — Sydney

A two level basement in alluvial sands with high water table constructed using secant pile CFA pile wall moved laterally following failure of a water main in the adjacent main road. Concern was raised over the stability of the wall and resulted in closure of the road for weeks and installation of temporary support. Construction was significantly delayed. Extensive analysis, review of other expert reports and provision of advice to Counsel. Heard in the Supreme Court of NSW.

Failure of jet grout floor — Newcastle

A jet grout floor was installed in sand between two diaphragm walls to act as a ground water cut-off. The jet grout was not successful in providing sufficient water cut-off and alternate measures were required to be implemented. Provided an expert report with respect to the design and construction of the jet grout floor.

Chris M Haberfield

Erosion issues **Flinders**

Recent clearing of land on the foreshore provided higher potential for erosion and slope instability. Provided an expert report of assessment of erosion and landslip risk and recommendations for their minimization. Heard in VCAT.

Cracked house **Melton**

Assessment of site classification for a cracked house in Melton.

Wharf Construction Problems **Darwin**

East Arm Wharf – Stage 2 comprised an 110 m extension to the existing wharf facilities which included constructrion of a 25 metre high piled retaining wall supporting granular backfill. Piles comprised 1,500 mm diameter steel tube piles driven up to 10 m in weathered phyllite. Difficulties during construction led to large claim by contractor. Responsible for analysis of geotechnical problems experienced during construction and assessment of their impact on the measured performance of the wall and the validity of the claim. Claim was settled prior to formal legal proceedings. Extensive review, analysis, reporting and briefing of legal counsel.

Planning Appeals – Landslip **Various**

Provision of advice on landslip and stability issues for appeals to VCAT on Planning Applications. Includes projects in the Shire of Yarra Ranges, Mornington Peninsula and Ottway/Colac Shire. Review, analysis, reporting, briefing of legal council and expert witness.

Pool on Cliff top **Mt Eliza**

A pool, constructed on a coastal cliff top was issued with an emergency order for demolition due to concern from the local council that it posed a risk to the public and environment. Provided advice to Counsel regarding landslip stability issues and associated matters. Heard in Building Commission of Victoria.

Subsidence at Bridge **Melbourne**

The area around the west abutment of a major bridge has settled more than 1.2m since 1950 causing visible distress to the bridge. The settlement was due to consolidation of underlying soft clays and to dewatering associated with the construction of Burnley Tunnel. Responsible for analysis, review, reporting and briefing of legal council for Expert Assisted Mediation.

Landslip **Thredbo**

Review of circumstances leading to Thredbo Landslip in July 1997, in which 18 people were killed. Expert witness in the Civil case heard in the Supreme Court of NSW. Responsible for assessing the evidence pertaining to geotechnical engineering issues, carrying out analyses and physical experiments to assess the reasons for the tragedy and the cause, or trigger, which led to the landslip at that time. Extensive site assessment, analysis of facts and competing hypothesis, testing, review and reporting.

Craking of Granite Façade **Melbourne**

Assessment of reasons for cracking of granite facade of a commercial tower building. Cracking of the granite façade after installation resulted in the entire facade being replaced. Responsible for testing and assessment of fracture resistance of the granite and the mechanism that led to the failure. Extensive testing, analysis, review and reporting. Expert witness for Arbitration Hearing.

Lift Failure **Melbourne**

Failure of a false lift during construction of a commercial tower building resulted in the death of one person. Responsible for testing and analysis of lift components, review and reporting. Expert witness for Coronial Inquiry.

Vehicle Accident **Winton**

Racing car crashed into embankment during race meeting, causing serious injury to driver. Responsible for assessment of energy absorbed by an earth embankment when impacted by the car so that an assessment of the speed of the car at impact could be made. Testing, analysis, review and reporting. Expert witness in Supreme Court of NSW.

Cracked House **Melbourne**
A recently constructed house suffered settlement and severe cracking localised to one corner of the house. The cause was initially thought by others to be ground movements due to reactive clays. Subsequent investigation indicated this was not the case, and movements were likely due to a previously undetected area of poorly compacted deep fill underlying the front corner of the house. Responsible for subsequent ground investigation, review of reports and provision of advice to Counsel.

Flood Damage to House **Cairns**
Flash flooding resulted in structural damage to a house. Responsible for review of reports and provision of expert opinion to Mediator acting for the Insurance Council of Victoria.

Cracked House **Grafton**
A recently constructed house suffered settlement and severe cracking. The cause was attributable to compression of underlying soft natural deposits which went undetected during the geotechnical investigation. Responsible for review of reports and provision of advice to Counsel. Heard in the District Court of NSW at Sydney.

Ground Movements **Melbourne**
Provision of advice with respect to the ground movements expected from a proposed deep excavation next to existing commercial building. Responsible for review, analysis, reporting and briefing of legal counsel.

Damage to Wharf **Darwin**
During construction of Stage 1 of East Arm Wharf, concerns with the design of the 25m high sheet pile wall were raised and could not be reconciled. Responsible for mediating between contractor and owners engineers to assess the likely performance of the as designed wall. During this process the wall moved laterally a significant distance, requiring design of remedial measures. Extensive analysis, review, reporting, remedial design and mediation. Issues settled without legal proceedings.

Thickner Instability **Murrin Murrin**
Part of the mineral processing system involves thickening of tailings before sedimentation in a tailings pond. The so-called thickeners which were used for this purpose experienced instability in the base of the thickener which had been formed from process solids. This caused disruption and down-time to be experienced, resulting in a claim against the designers and installers of the thickner equipment. Responsible for assessing the possible reasons for the instability. Extensive review, analysis and reporting. Expert witness at formal Arbitration hearing.

Assessment of Rock Properties **Melbourne**
A three lane, 3.2 km long road tunnel up to 60 m below ground surface experienced problems during and post-construction. The legal proceeding that followed required a report which set-out the knowledge of the engineering properties of the rock through which the tunnel was constructed. Responsible for compiling this report.

Coastal Cliff Failure **Sorrento**
A cliff failure resulted in damage to residential property. Remedial works were carried out and repairs made. Concerns were raised with respect to the stability of the remediated works. Responsible for the assessment of the current stability of the cliff and the effectiveness or otherwise of the remedial works. Review, analysis and reporting. Currently subject to legal proceedings.

Severe Distress to House **Melbourne**
Severe cracking and settlement of a 100 year old house occurred over a period of 20 years. Leakage of water from a road storm water pit was identified as the cause. Responsible for assessing the cause of the damage. Review, analysis, reporting and briefing of legal counsel. Matter settled prior to formal legal proceedings.

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Failed Retaining Wall Hobart

Retaining wall along boundary between two private residences failed due to addition of some 5 m of fill on the uphill side of the wall. Responsible for assessment of cause of failure and review of remedial works. Review, analysis, reporting and briefing of legal counsel. Currently subject to legal proceedings.

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